

# Assessment of Biocontrol Agent Populations at 15 Release Sites in the Columbia River Estuary

Grant: W9127N-06-C-0023

February 2007

Submitted to  
U.S. Army Corps of Engineers

Submitted by  
Ralph J. Garono, Erin Thompson, and Lynda Moore  
*Earth Design Consultants, Inc.*

In Association with  
Fritzi Grevstad, *University of Washington*  
Peter McEvoy, *Oregon State University*



**Wetland & Watershed Assessment Group**  
**Earth Design Consultants, Inc.**

230 SW Third St., Suite 212

Corvallis, OR 97333

(541) 757-7896

(541) 757-7991 FAX

<http://www.earthdesign.com>

# Table of Contents

|  |    |
|--|----|
| A. Executive Summary .....   | 2  |
| B. Introduction.....   | 4  |
| 1. Purpose for this study.....   | 4  |
| 2. Biocontrol of <i>Lythrum salicaria</i> .....  | 4  |
| 3. Factors Affecting Successful Biocontrol of Purple Loosestrife .....                                       | 7  |
| C. Methods.....  | 9  |
| 1. Field Sampling.....   | 9  |
| 2. River Mile Calculations .....   | 11 |
| 3. RTK/ GPS and DEM Generation.....  | 11 |
| 4. Helicopter Video Transects.....   | 11 |
| 5. GIS and Data Analysis.....  | 19 |
| a. Site Maps.....  | 19 |
| b. Buffers and Data Summaries .....  | 20 |
| c. Tides.....  | 21 |
| d. Distance to High Ground .....   | 22 |
| e. Distance to Shrub/ Forested Vegetation.....   | 22 |
| 6. Statistical Summaries and Analysis .....  | 24 |
| D. Results.....  | 29 |
| 1. Evidence of Control to <i>Lythrum</i> .....   | 31 |
| 2. Factors that May Affect Establishment and Spread of Biocontrol Agents in the Columbia River Estuary ..... | 36 |
| a. Elevation .....   | 39 |
| b. Relationship between <i>Lythrum</i> Stem Densities and Elevation .....                                    | 40 |
| c. Relationship between <i>Galerucella</i> and Elevation .....   | 60 |
| d. Shrub and Forest Cover as Refugia .....   | 63 |
| e. Trends in <i>Lythrum</i> Damage.....  | 64 |
| f. Helicopter Videography of Transects.....  | 65 |
| E. Summary & Discussion.....   | 83 |
| 1. Summary of Results.....   | 83 |
| 2. Distinctions about Sites with Evidence of <i>Galerucella</i> .....  | 84 |
| a. Inundation/Elevation.....   | 84 |
| b. Distance to Shrub/Forest Cover .....  | 85 |
| c. Role of Other Releases.....   | 85 |
| F. Recommendations.....  | 87 |
| 1. The Match Between Control Organism Life Cycles and Environment.....                                       | 87 |
| 2. Helicopter Video.....   | 87 |
| 3. Change in Survey Schedule .....   | 88 |
| 4. Consider Additional Biocontrol Agents.....  | 88 |
| 5. Release Recommendations .....   | 89 |
| G. Literature Cited .....  | 90 |
| H. Acknowledgements .....  | 92 |
| I. Appendices .....  | 93 |

## A. Executive Summary

Strong evidence of biological control population establishment was observed at most of the 15 USACE biocontrol agent release sites during the summer of 2006. Although successful population establishment must typically be judged over a minimum of three years, we observed beetle adults, eggs, larvae, and/or plant damage presence 8 to 10 months after release. While the 2005 USACE biocontrol agent releases were of *Galerucella pusilla* only, all three species of *Galerucella* were observed and recorded including *G. pusilla*, *G. californiensis*, and native *G. nymphaeae*. We also observed *Nanophyes marmoratus* adults, which were not released by the USACE. We recommend that releases made by all groups be mapped so that the distribution of biocontrol agent populations can be better understood. Across all 15 USACE sites, the most prevalent life stage of *Galerucella* was eggs, comprising approximately 33% of all observations. Least frequently observed were adult beetles, accounting for approximately 5% of the total number observations. Possible explanations for the small number of adults observed include: 1) time of sampling, 2) disturbance while sampling, 3) time since original release, and 4) tidal flushing removing the beetles from the sites. Observations of *Galerucella* larvae were more common in June, but overall less common than *Galerucella* egg masses. The amount of damage present on *Lythrum* appears to be related to the number of biocontrol agents observed at the study site. We believe that the observed *G. pusilla* adults were most likely individuals released in 2005 that overwintered.

Although this initial study did not provide conclusive evidence, we believe proximity to shrub or forest cover, as well as the degree of tidal flushing may have a direct affect on biological control population establishment. We found that the distribution of *Lythrum* extended into the lowest elevations we sampled but evidence of *Galerucella* did not. Moreover, we observed beetles and/or plant damage only in quadrats with elevations greater than MSL. This suggests that tidal flushing may limit *Galerucella* distributions at lower elevations; however, we caution that we have only made a limited number of observations especially at elevations lower than MSL (only 0.5% of quadrats sampled were below MSL). Since quadrats in the 2006 study were not selected for elevation and randomization can not be assumed, we recommend that a more detailed study be initiated.

We did not find a strong relationship between the distance to or total amount of shrub and forest cover and the number of biocontrol agents. For example, Pillar Rock Downstream and Miller Island Downstream study sites have areas with elevations above the highest tides directly adjacent to the release point but show no indication of biocontrol agent establishment. We speculate, however, that shrubby or woody vegetation may act to decrease water velocities and thereby shelter biocontrol agents from tidal flushing. We recommend greenhouse studies be conducted before conclusions are drawn about the relationship between beetle survival and tidal inundation. We also recommend further exploration of patterns of establishment using detailed digital imagery and land cover data of the Lower Columbia River, as well as tidal gage data specific to each site.

## B. Introduction

### 1. Purpose for this study

The purpose of this study was to collect biocontrol agent population data and habitat information to address the degree to which purple loosestrife (*Lythrum salicaria*) biocontrol agent populations have become successfully established in Columbia River tidal wetlands and to judge the biocontrol agent effectiveness. We measured success by assessing biocontrol agent populations and measuring damage to *Lythrum* by the leaf-eating beetles. Although not the objective of this study, we also recorded presence of the root and seed weevils. Four biocontrol agents found to be effective in controlling *Lythrum* include two leaf-eating beetles: *Galerucella californiensis* (black-margined loosestrife beetle) and *Galerucella pusilla* (golden loosestrife beetle), a root-feeding weevil *Hylobius transversovittatus*, and a seed weevil *Nanophyes marmoratus*.

Purple loosestrife (**Figure 1**) is well-established and spreading within the Columbia River Estuary. *Lythrum* is deleterious to ecological communities in numerous ways evidenced by crowding out native plant species, reducing numbers of waterfowl, and reductions in shallow water habitats by increasing rates of sediment and debris accretion (Coombs et al. 2004). Our previous work has demonstrated that *Lythrum* can also affect litter decomposition rates and invertebrate communities (Garono and Schooler, unpublished data).



Figure 1. Flowers of *Lythrum salicaria* from Mott Island Study Site, July 2006.

### 2. Biocontrol of *Lythrum salicaria*

The use of biocontrol agents to control *Lythrum* populations started in the early 1990's. Four biological control organisms were introduced from Europe to North America to control

purple loosestrife: *Galerucella pusilla*, *G. californiensis*, *Hylobius transversovittatus* Goeze were first released in 1992, while *Nanophyes marmoratus* Goeze was first released in 1994 (Coombs et al. 2004). In subsequent years, all of these insects have been collected and redistributed to cover infestations of purple loosestrife across North America.

Once these insects were released and established in Oregon, the Oregon Department of Agriculture (ODA) staff and cooperators collected and redistributed biocontrol agents to other loosestrife-infested areas throughout the state. One of our objectives is to examine 15 *Galerucella* release sites in the Lower Columbia River (**Figure 2**) and to determine if biocontrol agent populations have successfully established. Biological control develops by stages and it is useful to evaluate progress step by step from releasing and establishing control organisms, to increasing and redistributing control organisms, to damaging and suppressing the target organism, and finally to managing plant succession. Releases in the Lower Columbia River are relatively recent, so the initial focus of evaluation is on the release and establishment phase as a function of the particular species released, their response to various habitat parameters, and the number of individuals released over time at each site.

Releases are usually made with a small number of individuals, and very small populations incur a higher risk of extinction than do larger populations. Grevstad (1999) investigated experimentally how the probability of establishment varies with the size of the release population (20, 60, 180, and 540 individuals) for *Galerucella pusilla* and *G. californiensis* in 36 sites scattered across New York state. She found that the probability of establishment increases with population size, reaching 100% for the largest population size investigated (540 individuals). If biocontrol populations in the Pacific Northwest (PNW) behave as populations in the eastern U.S., Grevstad's findings emphasize the importance of releasing populations of at least 540 individuals to maximize the probability of establishment. The relationship between release population size and probability of establishment is not known for the other insects, *H. transversovittatus* and *N. marmoratus*.

Rapid population growth by release populations can reduce extinction risk and promote persistence by reducing the amount of time the population spends at vulnerable, low densities. Grevstad (1999) found that growth rates of *Galerucella* populations following experimental release were highly variable, but the population growth rates tended to increase with increasing

size of the release populations, and *G. pusilla* increased faster than *G. californiensis*. *Galerucella* populations studied by Grevstad in New York appear to have only one generation per year, whereas Oregon populations inhabiting warmer environments, such as those along the lower Columbia River, may have two (Eric Coombs, *personal communication*); a second generation would speed population growth and reduce extinction risk. The relationship between release population size and subsequent rates of population growth is not known for the other insects, *H. transversovittatus* and *N. marmoratus*.

Spatial spread of the control organism is determined by both population growth and dispersal. In prior work, we confirmed plant damage can be used as a proxy for insect density (Schooler and McEvoy 2006), and the increase and spread of the insect populations can be estimated from increase and spread of damage for the case of *Galerucella pusilla* and *G. californiensis*. Spread increased linearly over time at Baskett Slough in the Willamette Valley, and a measure of movement rate, the diffusion coefficient  $D$ , could be estimated by substituting estimates of spread rate  $C$  and rate of increase  $\alpha$  into the equation appropriate for linear spread  $C = 2(\alpha D)^{1/2}$ .

Schooler and McEvoy (2006) compared estimates of spread, population growth, and movement for the same insects in different geographic locations using multiple methods, one using prior estimates of population growth rate  $\alpha$  and movement rate  $D$  to estimate the unknown spread rate  $c$ ; the other using direct measures of spread  $c$  and population growth rate  $\alpha$  to estimate the unknown movement rate  $D$  (**Table 1**). The approach using two parameters  $\alpha$  and  $D$  to estimate velocity  $c$  is based on independent data for *Galerucella pusilla* and *G. californiensis* (Grevstad and Herzig 1997, Grevstad 1999). Spread rates appear to be higher in Oregon due to higher rates of population growth, which appear to offset lower movement rates. Care should be exercised in interpreting these differences, as different methods of estimation were applied in different locations: NY measured beetle density, while OR measured beetle damage, or ‘effective density.’ However, we can conclude that *Galerucella* populations are expected to increase and spread rapidly. The rates of increase and spread are unknown for the other insects *H. transversovittatus* and *N. marmoratus*, although these insects are widely established in Oregon.

The degree of suppression of purple loosestrife populations by the insects has been estimated at Basket Slough (Monmouth, OR) in the Willamette. Following release and

establishment, increase and spread, of all four biocontrol agents at Baskett Slough, purple loosestrife has declined to 10% of its former abundance. Remarkably, interactions between the target plant and the insects persist at these very low population levels.

Table 1. Comparing estimates of spread, population growth, and movement for the same insects *Galerucella* spp. in different geographic locations, Oregon and New York.

| Parameter                          |          | Oregon | New York |
|------------------------------------|----------|--------|----------|
| Spread rate (m/yr)                 | C        | 260    | 175      |
| Pop Growth rate (per year)         | $\alpha$ | 2.24   | 0.64     |
| Movement rate (m <sup>2</sup> /yr) | D        | 7,559  | 12,099   |

The successional changes accompanying decrease in purple loosestrife populations have been studied in horizontal (across locations at one time) (Schooler et al. 2006) and vertical studies (across time at a very few locations) (Schooler 1998, Schat 2002). Plant diversity declines sharply with increasing abundance of purple loosestrife; however, plant diversity does not always rebound with suppression of purple loosestrife due to increase in another invader, reed canary grass (*Phalaris arundinacea* L.: Poaceae). Thus passive restoration of vegetation by biological control may not be reliable, and active management of plant succession may be required.

### 3. Factors Affecting Successful Biocontrol of Purple Loosestrife

Biological control of weeds using insects and pathogens depends on the tripartite interaction of a susceptible target organism, a virulent control



Figure 2. Pillar Rock (Downstream) Study Site, July 2006.

organism, and a favorable environment. Biological control of purple loosestrife has successfully matched four control organism species with a susceptible host, but the environment may not always be favorable.

In particular, the islands of the Lower Columbia River represent a challenging environment for terrestrial plants and insects due to periodic inundation. Tidal cycles, storm surges, and discharge of water from upstream dams all contribute to temporal variation in the degree of inundation; spatial variation is associated with variation in elevation and perhaps the structure of vegetation. There is indication that tidal areas act as a refuge for *Lythrum*, since disturbances associated with the water movement appear to prevent biocontrol agent establishment (Denoth and Myers 2005). These conditions present difficulties for the establishment, persistence, and therefore overall success of biocontrol agents.

Upon initial release, wide dispersal of the agents (i.e., spreading thinly) can influence their own population establishment by isolating individuals from mating partners (Hopper and Roush 1993). Once established, dispersal affects the rate of spread of the biocontrol agent population throughout the range of its host (Andow et al. 1990). Numbers of biocontrol agents released can also have a significant positive effect not only on population establishment, but on population growth rates as well. As mentioned above, Grevstad (1999) demonstrated that the proportion of populations successfully becoming established increased steadily as release size increased, with an optimal release number of approximately 540 individuals.

A component of this study is to characterize the physical environment at 15 release sites (**Figure 3**) in order to develop an understanding of environmental factors that may ultimately influence the successful



Figure 3. Fitzpatrick Island Study Site, July 2006.

establishment of biocontrol agents. Understanding the factors that lead to successful control will allow managers to target release sites which have a higher probability of successful establishment of the biological control agents. Moreover, these release sites may serve to re-inoculate areas in which control agent populations have been removed by periodic disturbances. We hypothesize that the following factors may be important in predicting the successful establishment of biocontrol agent populations: inundation, prevailing winds, water flow, proximity to suitable vegetation cover (e.g., hollow stems [Eric Coombs, *personal communication*], shrubs and trees), and suitable food resources.

## C. Methods

### 1. Field Sampling

Fifteen release sites were established by the US Army Corps of Engineers (USACE) in the Lower Columbia River Estuary from river miles 18-52. Each release site (**Table 2**) was marked with a metal stake which indicated a July 18, 2005 release of 1,000 *Galerucella pusilla* adults by the USACE. We visited each site by boat during two sampling periods in 2006, one in June and the second in July. Sampling at a site was timed with the tide to ensure accessibility.

We located the release stakes and measured their locations using a global positioning system (GPS). We used a Trimble GeoXH GPS (NAD83 Conus) to record the location of release stake and of at least the first and last quadrat along each transect. We measured elevations at each site using real time kinematic GPS (Thales Navigation, Z-Max Surveying System). We then sampled biocontrol agent populations and damage to *Lythrum* in 1m<sup>2</sup> quadrats arranged along transects radiating from each release stake. Square meter PVC quadrat frames were spaced at 4m intervals along each transect. Transects were approximately 50m long. In some cases, longer transects were required to sample the 50 quadrats required. At each site, we generally sampled four 50m transects with 12-13 quadrats per transect (**Figure 4**). Transects were established using a 100m tape attached to release stake. We recorded the azimuth and made GPS measurements along each transect.

On standardized data sheets, we recorded site name, time and date, weather observations, the researchers' names, and a rough site sketch. For each quadrat, we recorded the azimuth of

the transect it is located on, the distance from the release stake, and water depth (cm). Water depth was variable due to tide level.

We surveyed *Lythrum* within each quadrat for biocontrol agent presence and signs of plant damage. For *Galerucella pusilla* and *G. californiensis* the number of adults present on *Lythrum* was recorded (**Figure 5a, 5b**). We also recorded the number of native adult *Galerucella* beetles, if they were present. We recorded the number of egg masses and number of larvae of all *Galerucella* species, separating the native from non-native species. We also recorded the *Lythrum* leaf damage level (% damage as a continuous variable) from *Galerucella* with a minimum level of damage of at least 1% (**Figures 5a, 5b**).

The presence of either primary or secondary ‘tip-kill’ due to any of the four beetles, including *Hylobius* and *Nanophyes* was also noted. Tip damage signified damage to floral and shoot meristems (**Figures 5c, 5d**). For *Hylobius*, we recorded the number of adults and the percent damage level (% leaf area missing on a continuous scale averaged over all the plants within the quadrat). The number of *Nanophyes* adults and amount of damage (seed capsule holes) was recorded as well.

Within each quadrat, the number of living and dead *Lythrum* stems (> 5cm) were counted and recorded. The phenology of the plants, either flowering or vegetative, was also recorded. We then calculated the average length (cm) of living stems by randomly selecting five live *Lythrum* stems from each quadrat. Plant lengths were measured from the soil surface, even if some of plant was under water. The counting and measuring of the dead stems may allow us to assess history of reproduction. Reduction in stem number or length could be used as an indicator of successful control. For example, a decline in *Lythrum* stem length or number may indicate a loss of vigor when live stems are shorter than stems from prior years.

Damage to *Lythrum* plants by herbivores other than *Galerucella* was recorded for each quadrat. In some cases we were able to identify the herbivore believed to be responsible for the damage. We have observed slugs, snails, and Lepidoptera larvae in or on the plants. We differentiated between animals and invertebrates: nutria (*Myocaster coypus*, Rodentia: Myocastoridae) and deer break off entire stems; their damage is easily distinguished from insect damage. We also listed other plant species present within the quadrat paying particular attention to the presence of other invasive species.

We photographed the majority of quadrats to create a permanent visual record (**Figure 6**). Each photo displayed plants, quadrat frame, and a vertical reference pole. General site photos were also taken.

## **2. River Mile Calculations**

We used the National Geographic TOPO! Software (Oregon Disc 2: Portland) to measure the distance of each study site from the mouth of the Columbia. We used the measurement tool to measure the distance (mi) from the mouth of the Columbia River to each site following the navigation channel.

## **3. RTK/ GPS and DEM Generation**

We used RTK GPS to measure elevation at 150-300 points at each release site. The RTK equipment (Thales Navigation, Z-Max Surveying System), operated by Watershed Sciences, Inc., consisted of both stationary (base) and roving stations. The roving station was synced to the RTK GPS base station that was generally set up on a benchmark located within 5mi of the roving station. Geographic Information System Shapefiles were created from RTK data using the geoid-adjusted elevation values (meters). Triangular Irregular Networks (TINs) were then created from the adjusted elevation points in each shapefile using ESRI 3-D Analyst®. ESRI 3-D Analyst was then used to create a grid from the points using the Raster Tool to interpolate elevations between the shapefile points. The following Spline settings were used: Spline Type: Tension; Weight: 5; Number of points: 15; and Output Cells: 0.25m.

The HRMS (horizontal) and VRMS (vertical) error was stored for every RTK point. The vertical error was usually approximately 2cm but ranged from 0-4.5cm. We found errors to be greater in dense vegetation where the GPS radio signal was blocked.

## **4. Helicopter Video Transects**

Airborne digital video imagery of 35 transects was collected and analyzed for percent cover of *Lythrum*. On the computer, the video player viewing screen was sized to six inches

Table 2. Study Site Summary. Table displays site locations, biocontrol agents released based on available records, elevations sampled, distance to high ground (above 3.2m NAVD88), and distance to forest or shrub cover for fifteen study sites. Biocontrol agents released include agents from previous releases at or near the same release points. Abbreviations are: GAPU= *Galerucella pusilla*, GACA= *G. californiensis*, HTYR= *Hylobius transversovittatus*, NAMA= *Nanophyes marmoratus*, W= scrub/shrub wetland, U= scrub/shrub upland, DW= deciduous forest wetland, DU= deciduous forest upland, CW= coniferous forest wetland, CU= coniferous forest upland, MW= mixed forest wetland, and MU= mixed forest upland. RTK data source is Watershed Sciences, Inc. 2006. ETM+ data source is Garono et al 2003a.

| Study Site           | RTK                        |                             | ETM+                        |       |                        |       | NAVD88 Elevation Range (m) | BCAs Released       | June and July Sum |            |        |           | Lat     | Long      |
|----------------------|----------------------------|-----------------------------|-----------------------------|-------|------------------------|-------|----------------------------|---------------------|-------------------|------------|--------|-----------|---------|-----------|
|                      | Distance to 3.2m Elevation | Distance to 2.76m Elevation | Distance to Scrub Shrub (m) | Class | Distance to Forest (m) | Class |                            |                     | GAPU Adult        | GACA Adult | GA Egg | GA Larvae |         |           |
| <b>Devil's Elbow</b> | 4.8                        | 2.6                         | 36.4                        | W     | 623.0                  | DU    | 0.69-3.92                  | GAPU GACA NAMA      | 7                 | 0          | 38     | 39        | 46.2331 | -123.5545 |
| <b>Dry Dock</b>      | 25.3                       | 4.0                         | 49.0                        | U     | 43.9                   | DU    | 1.02-2.87                  | GAPU GACA           | 18                | 0          | 88     | 41        | 46.2012 | -123.4415 |
| <b>Eureka DS</b>     | 16.9                       | 0.0                         | 128.1                       | U     | 173.4                  | DU    | 1.55-3.07                  | GAPU HYTR           | 0                 | 0          | 3      | 2         | 46.1605 | -123.2306 |
| <b>Eureka US</b>     | 0.0                        | 0.0                         | 186.7                       | U     | 302.4                  | CU    | 1.61-5.25                  | GAPU HYTR           | 0                 | 0          | 9      | 8         | 46.1614 | -123.2276 |
| <b>Fitzpatrick</b>   | 52.9                       | 0.7                         | 0.0                         | W     | 592.9                  | CW    | 2.31-2.90                  | GAPU GACA NAMA      | 0                 | 0          | 1      | 0         | 46.2636 | -123.5008 |
| <b>Karlson</b>       | 4.6                        | 0.7                         | 50.1                        | W     | 388.6                  | CU    | 1.95-2.51                  | GAPU GACA NAMA      | 2                 | 0          | 3      | 2         | 46.2053 | -123.6158 |
| <b>Marsh</b>         | n/a                        | 14.5                        | 0.0                         | W     | 289.5                  | DU    | 0.67-2.49                  | GAPU GACA NAMA      | 2                 | 0          | 21     | 14        | 46.2241 | -123.5687 |
| <b>Miller DS</b>     | 6.1                        | 3.1                         | 214.2                       | W     | 670.4                  | CW    | 1.54-4.10                  | GAPU GACA NAMA      | 0                 | 0          | 0      | 0         | 46.2533 | -123.6568 |
| <b>Miller US</b>     | 1.0                        | 0.0                         | 72.0                        | W     | 124.0                  | MU    | 1.54-5.33                  | GAPU GACA NAMA      | 1                 | 0          | 11     | 4         | 46.2500 | -123.6422 |
| <b>Mott</b>          | n/a                        | n/a                         | 73.1                        | U     | 60.9                   | CW    | 1.11-5.23                  | GAPU                | 0                 | 0          | 1      | 3         | 46.1981 | -123.7431 |
| <b>Pillar DS</b>     | 53.4                       | 27.6                        | 57.4                        | W     | 216.7                  | CU    | 1.23-2.95                  | GAPU                | 0                 | 0          | 0      | 0         | 46.2511 | -123.5885 |
| <b>Pillar US</b>     | 132.7                      | 3.8                         | 19.5                        | W     | 284.4                  | CU    | 1.79-3.03                  | GAPU                | 3                 | 0          | 29     | 3         | 46.2515 | -123.5874 |
| <b>Svensen</b>       | 2.6                        | 1.4                         | 93.4                        | W     | 31.1                   | CW    | 0.68-4.13                  | GAPU                | 15                | 2          | 287    | 106       | 46.1822 | -123.6325 |
| <b>Tenasillahe</b>   | n/a                        | 7.8                         | 21.1                        | W     | 186.0                  | DU    | 1.70-2.67                  | GAPU                | 1                 | 0          | 19     | 25        | 46.2151 | -123.4380 |
| <b>Wallace</b>       | 9.0                        | 0.0                         | 265.9                       | U     | 220.2                  | DU    | 1.85-3.21                  | GAPU GACA NAMA HYTR | 6                 | 2          | 29     | 29        | 46.1505 | -123.2307 |

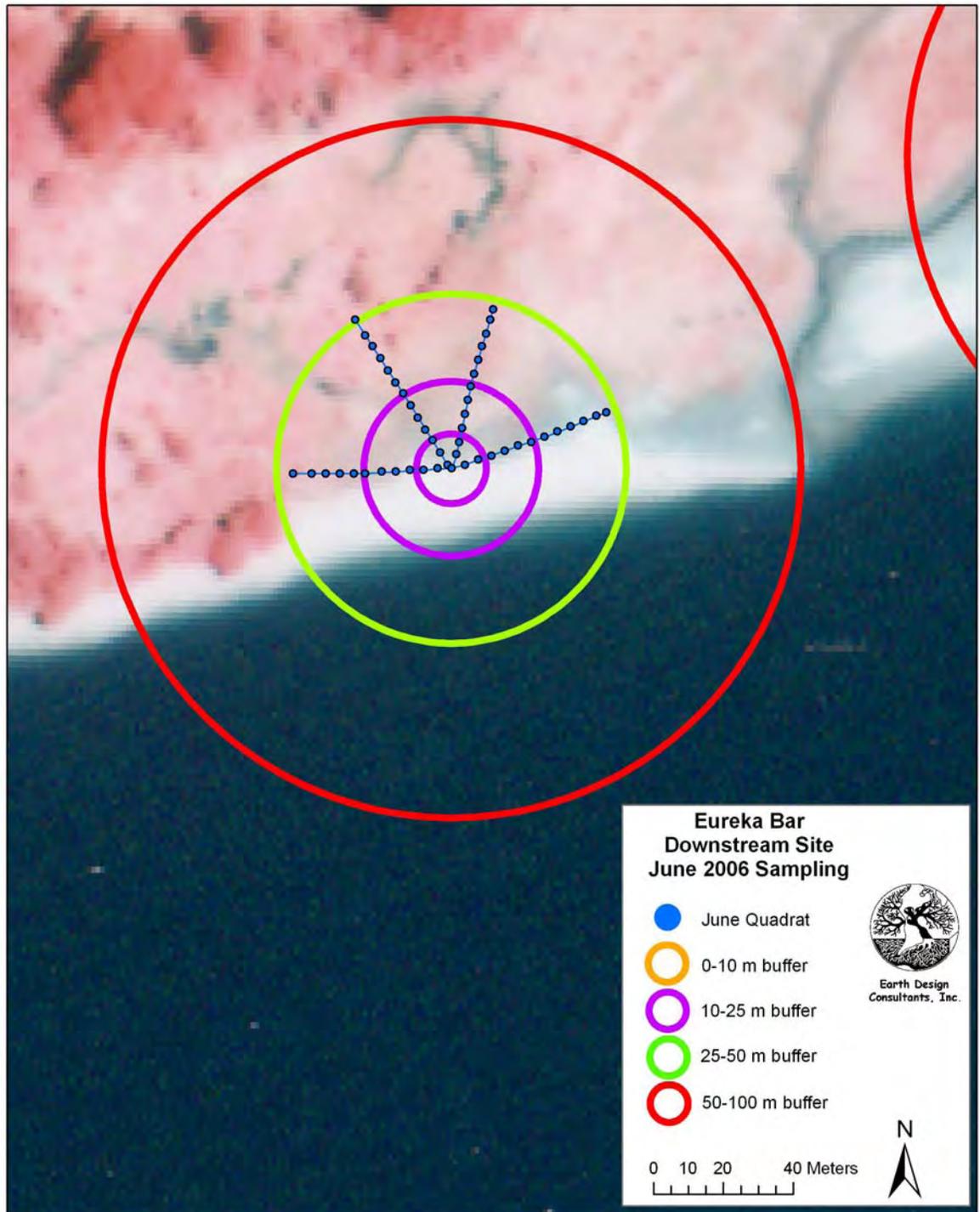


Figure 4. Example of transect layout at study site. Points along transect represent 1m<sup>2</sup> quadrats where inventory of BCA agents occurred. The rings indicate different distances (10, 25, 50, and 100m) from the original release point. *Color infrared photo courtesy of USACE and LCREP 2001.*



Figure 5a. *Galerucella calmariensis* adult (top left); *G. calmariensis* eggs and damage (top right); apical damage to purple loosestrife caused by *G. calmariensis* adult beetles (bottom). Photos courtesy of P. McEvoy.



Figure 5b. *Galerucella pusilla* adult (top); *G. pusilla* larva (bottom left); damage to *Lythrum salicaria* caused by *G. pusilla* (right). Photos courtesy of P. McEvoy.



Figure 5c. *Hylobius transversovittatus* adult (top left); larva in root material of *Lythrum salicaria* (middle); damage to *L. salicaria* typical of *H. transversovittatus* (bottom). Photos courtesy of P. McEvoy.



Figure 5d. *Nanophyes marmoratus* adult (top); *N. marmoratus* adult beetles on *Lythrum salicaria* (bottom).  
Photos courtesy of P. McEvoy.



Figure 6. Example of quadrat layout and photo documentation, Eureka Bar Upstream, July 2006.

wide by eight inches long. A Mylar® overlay of the same dimension was divided into 25 squares of equal size and placed on the screen. The presence of purple loosestrife was visually examined on a frame-by-frame basis along each transect.

We used the frame time code and GPS-tagged frames to locate the position of each frame in GIS. To do this, we recorded the time code at the beginning and end of each frame, starting at the beginning of each transect for all frames along that transect. We recorded presence / absence of purple loosestrife in each of the 25 squares of the Mylar® grid. The number of squares where *Lythrum* was present was multiplied by four to obtain an estimate of relative density of purple loosestrife for that particular frame. We estimated relative density of *Lythrum* for each frame along each of the 35 transects.

## **5. GIS and Data Analysis**

### **a. Site Maps**

Several types of imagery were used, in GIS, to characterize the vegetation within and around each release site. All imagery data were several years old. We used digital color infrared photos (USACE & LCREP 2001), black and white digital ortho quarter quads (DOQQ), Landsat 7 Enhanced Thematic Mapper (ETM+) satellite imagery (Garono *et al.* 2003a), and Compact Airborne Spectrographic Imager (CASI) imagery (Garono *et al.* 2003b). GIS was used to match up field data with these imagery data sets. We spatially coded our field data using a Trimble GeoXH GPS to record the location of each release stake and several quadrats<sup>1</sup> along each transect (NAD83 Conus Datum). The average error after differential correction of GPS files was within 39cm (S.D. +/- 23cm). GPS coordinates were then exported as shapefiles using Trimble GPS Pathfinder Office so that they could be used in GIS.

We obtained digital color infrared photos from the USACE and the Lower Columbia River Estuary Partnership (LCREP). The photos were from 2001/2002. Using GIS, we geo-referenced the photos using other black and white DOQQ imagery (WGS1984), along with our release site and sampling quadrat shapefiles as reference points (UTM Zone 10N, NAD 1983).

---

<sup>1</sup> Because we were not able to GPS all quadrats sampled, points were created for non-GPS'ed quadrat locations using the DENSIFYARC command in ArcInfo 9.0 and selecting 4m as the length between quadrat points. A line coverage connecting the release stake and all quadrats along the transect was then created.

These color photos were then used as a base map and to measure distance to shrub/forest vegetation for each release site.

In addition to photographic imagery, we also used imagery collected by other types of sensors: Landsat 7 ETM+ and CASI. Landsat and CASI imagery differ in spatial and spectral resolution: the Landsat 7 ETM+ sensor collects reflectance data in seven spectral bands with a spatial resolution of 30m and the CASI sensor collects reflectance data in 19 bands with a spatial resolution of 1.5m. In previous studies, we classified both sets of imagery and produced a spatially linked, hierarchical habitat data set for the entire Columbia River Estuary and its floodplain (Garono *et al.*, 2003a, 2003b). CASI data are not available for all of our study sites.

## **b. Buffers and Data Summaries**

We created buffers around each of the fifteen release points using the ‘BUFFER’ command in ArcMap 9.0. These ring-shaped buffers were used to summarize the quadrat data at 10m, 25m, 50m and 100m intervals from the release site. We also used buffered areas of 50m, 100m, 250m, and 500m without the previous size buffer removed (i.e., not a “ring”) to summarize major vegetation cover classes from the Landsat 7 ETM+ imagery (described above). The original 16 vegetation cover classes were grouped into six broader categories. The percent area within each buffer size of the following classes was then summarized: herbaceous vegetation, shrub, forest, open water, and other (mud and sand).

The elevation of each quadrat was determined using a grid created from the RTK data using the spline tool. A 0.25m x 0.25m grid cell size with floating point integer was selected. Using the Hawth’s Tools extension, Intersect Point Tool the RTK grid elevation of each quadrat was added to the shapefile attribute table. The RTK data is available for a limited area around each release site and therefore an elevation can not be assigned to quadrats lying outside of the covered area.

Quadrat data were also summarized by study site and for each buffered area (10, 25, 50, and 100m) for each sampling episode, June or July. The variables summarized by presence/absence and percent frequency during each sampling period include: number of *Galerucella pusilla* adults, *G. californiensis* adults, *G. nymphaeae* adults, any *Galerucella* species egg masses, any *Galerucella* species larvae, percent *Galerucella* damage, percent *H.*

*transversovittatus* damage, number of *N. marmoratus* adults, presence of other herbivore damage, number of new and old stems, and average length of five randomly selected new stems. An average, standard deviation, and range of values were summarized for some of the variables above, when appropriate.

### **c. Tides**

We selected Tongue Point and Knappa Slough Tidal Stations as reference tidal stations for the 15 release sites. We used Nobeltec Tides and Currents Software to calculate tidal heights. The Tongue Point harmonic station is located in Astoria, OR (46° 12'N, 123° 46'W, Station ID# 889). Knappa Slough (46° 11'N, 123° 35'W, Station ID# 891) tide station data is based upon the Tongue Point station and adjusted for time and distance from it. The Knappa Slough station lies upstream of Tongue Point and is not located within the main channel of the Columbia.

We used the export data tool to produce hourly tide values for each day from June 1, 2005 through December 31, 2006 for both Tongue Point and Knappa Slough stations. We then calculated the average, minimum, and maximum tides for each day, each month, and for the entire period (June 1, 2005 through December 31, 2006) from these hourly tide values.

Tidal benchmark stations located at Tongue Point and Knappa Slough are available through NOAA's Tides and Currents website ([http://tidesandcurrents.noaa.gov/station\\_retrieve.shtml?type=Bench+Mark+Data+Sheets](http://tidesandcurrents.noaa.gov/station_retrieve.shtml?type=Bench+Mark+Data+Sheets)). No tidal benchmark data are available for stations closer to study sites located further upriver, such as Wallace Island or Eureka Bar. The tidal benchmark station data relates water levels at the station in various tidal datums (MHHW, MLLW, etc.). The tidal datum levels of MHHW, MSL, and MLLW at Knappa Slough and Tongue Point benchmarks were used, along with the elevation data, to determine the cumulative amount of time each of these two sites is under water over the period of 6/1/2005-12/31/2006 (**Figure 7**). More specifically, we determined the percent of time when water is above MHHW level, above MSL, above MLLW, and below MLLW using the Nobeltec tide level summaries at each of the two tidal stations.

The values for MSL (1.55m), MHHW (2.76m), and the highest tide (3.2m) from the Knappa Slough tidal benchmark were used to examine tidal inundation at our 15 release sites (**Figure 7**). Using the RTK grid of our study sites, areas above the highest tide, between MHHW

and the highest tide, between MSL and MHHW, and below MSL were displayed in different colors to show what areas would be under water during various tide levels.

#### **d. Distance to High Ground**

The distance to high ground (i.e., above the highest tide line) from each of the 15 release sites was measured using RTK data collected at each of the sites. This high tide line was set at 3.2m/10.5ft (NAVD88). This was determined by examining the daily high tide levels from June 1, 2005 through December 31, 2006 at the Tongue Point and Knappa Slough tide stations (described above). RTK DEM data were classified so that areas above 3.2m appeared white, while all other elevations displayed black. The distance from release stake to the nearest area above 3.2m (white grids) was determined with the ArcMap measure tool (**Figure 8**).

We used the same procedure to determine the distance to areas above the MHHW line (>2.76m NAVD88). In this case the RTK data was classified so that areas above 2.76m were displayed in white and those below in black.

#### **e. Distance to Shrub/ Forested Vegetation**

The distance to scrub/shrub and forested vegetation from each of the 15 release sites was measured using CASI imagery (when available), Landsat 7 ETM+ data, and color infrared photos using the distance tool in ArcMap 9.0. The Landsat 7 ETM+ data is displayed according to vegetative cover classes of scrub/shrub wetland, scrub/shrub upland, deciduous forest wetland, deciduous forest upland, coniferous forest wetland, coniferous forest upland, mixed forest wetland, mixed forest upland, sand, mud, herbaceous wetland, herbaceous upland, water, and urban. For Landsat 7 ETM+ data, distance we measured from the release stake to the nearest pixel of scrub/shrub and the nearest pixel of forest. The type of land (wetland or upland) and specific type of forest cover was also recorded (**Figure 9**).

Using color infrared photos, the distance to shrub/forested land was measured with the distance tool in ArcMap 9.0 (**Figure 10**). Determining where shrub/forested land is located required visual interpretation of the photo and deciding what is herbaceous *versus* shrub or forest. The CASI data was displayed in subclasses of coniferous upland, coniferous wetland diked, coniferous wetland non-tidal, and coniferous wetland tidal. The same four classes were

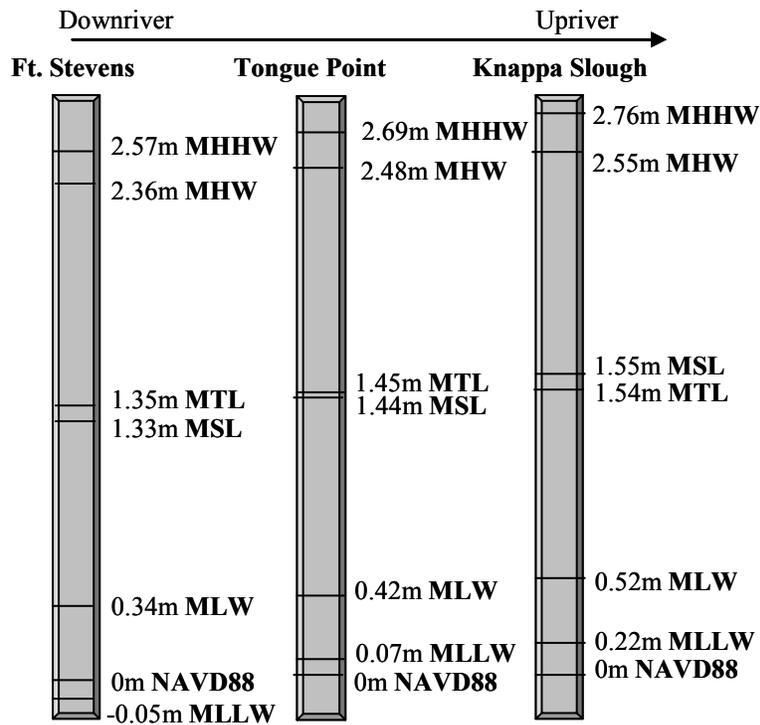


Figure 7. Comparison of Tidal Datums at Tongue Point, Knappa Slough, and Ft. Stevens tidal gauge stations. The elevation values from Knappa Slough were used to determine what areas of study sites are under water during tidal inundation. Ft. Stevens data are shown as reference and to illustrate how elevations between tidal datums change moving up or downriver.

also displayed for deciduous forests and scrub/shrub cover types (**Figure 11**). The distance to the nearest cover type of those described above was done only for Svensen, and Miller Upstream and Downstream sites because CASI data were not available for other sites.

## **6. Statistical Summaries and Analysis**

Averages, ranges, standard deviations, correlations, and frequencies were calculated using SPSS (Version 11.0). Specifically, Pearson's correlations with 2-tailed significance between quadrat field data measures and quadrat elevation were performed in SPSS software for each of the 15 release sites and separately for June and July sampling periods. Only those quadrats for which an elevation value from the RTK was assigned were included in the correlations. Significant correlations are displayed in a scattergram produced in SPSS. We also correlated the number of new purple loosestrife stems from both June and July quadrats together with the elevation of each quadrat for each of the 15 release sites.

We used JMP Start Statistics package (Version 5.1) to examine differences in biological control agent observations between quadrats located in six tidal elevation categories. For example, the number of *Galerucella* larvae in quadrats with elevations between MSL and MHHW was compared to larvae numbers in quadrats with elevations below the lowest tide, between the lowest tide and MLLW, between MLLW and MSL, between MHHW and the highest tide, and above the highest tide level. Nonparametric tests of Wilcoxon/ Kruskal-Wallis Rank Sum Tests were used to test for overall differences. We then compared differences among the tidal categories using Tukey-Kramer HSD.

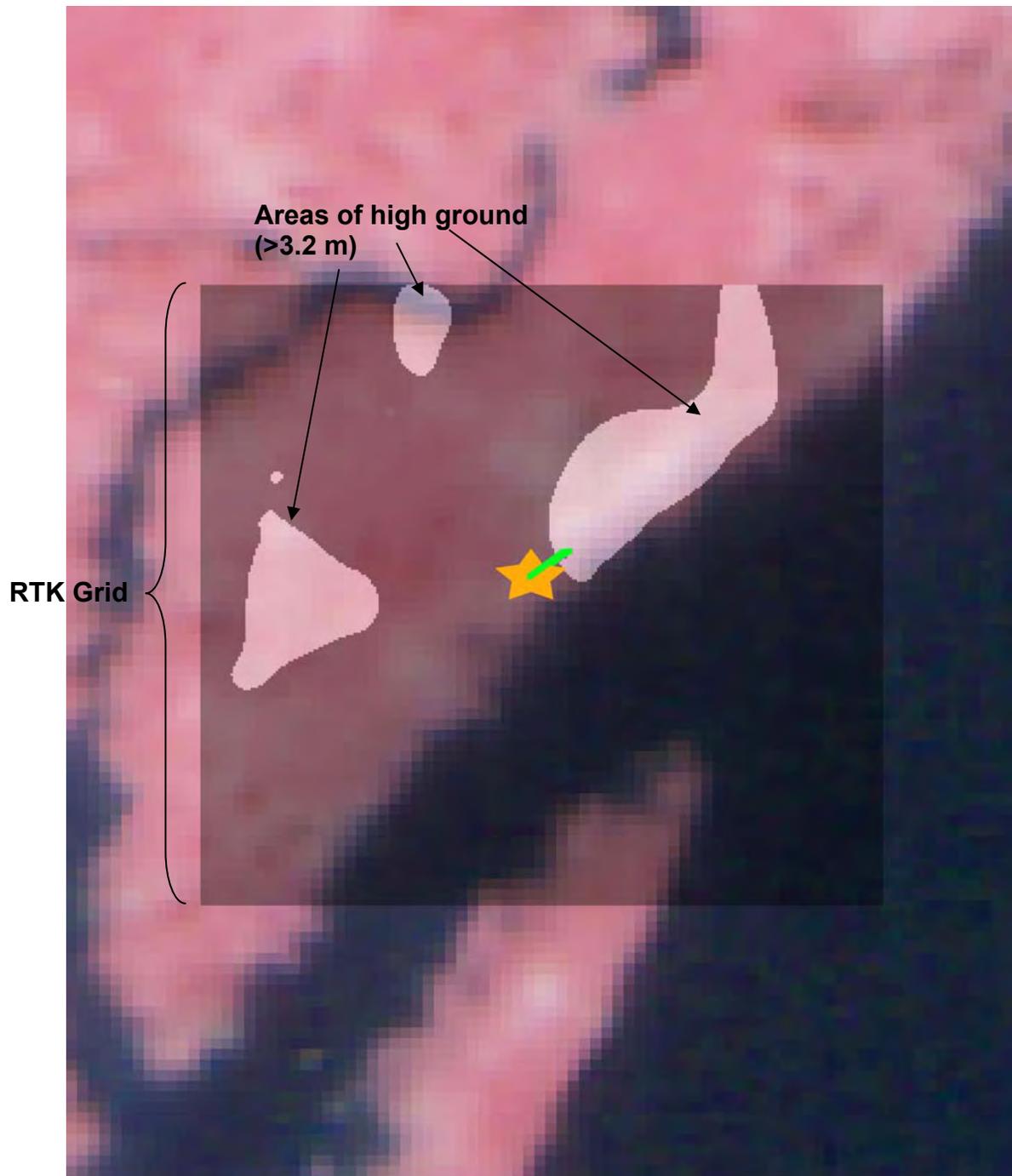


Figure 8. Example of how distance to high ground measurements were made using the RTK elevation grid for each release point. The RTK grid is the darkened square within the image and is displayed upon a color infrared photo of the study area. Areas in white on the grid are above 3.2m in elevation, vertical datum NAVD88. These areas are generally above the highest tides experienced by the study sites. The areas in black are below 3.2m. The star designates the release point and the distance tool in ArcMap was used to determine the distance from the star to the nearest area of white (>3.2m). *Color infrared photograph courtesy of USACE and LCREP 2001.*

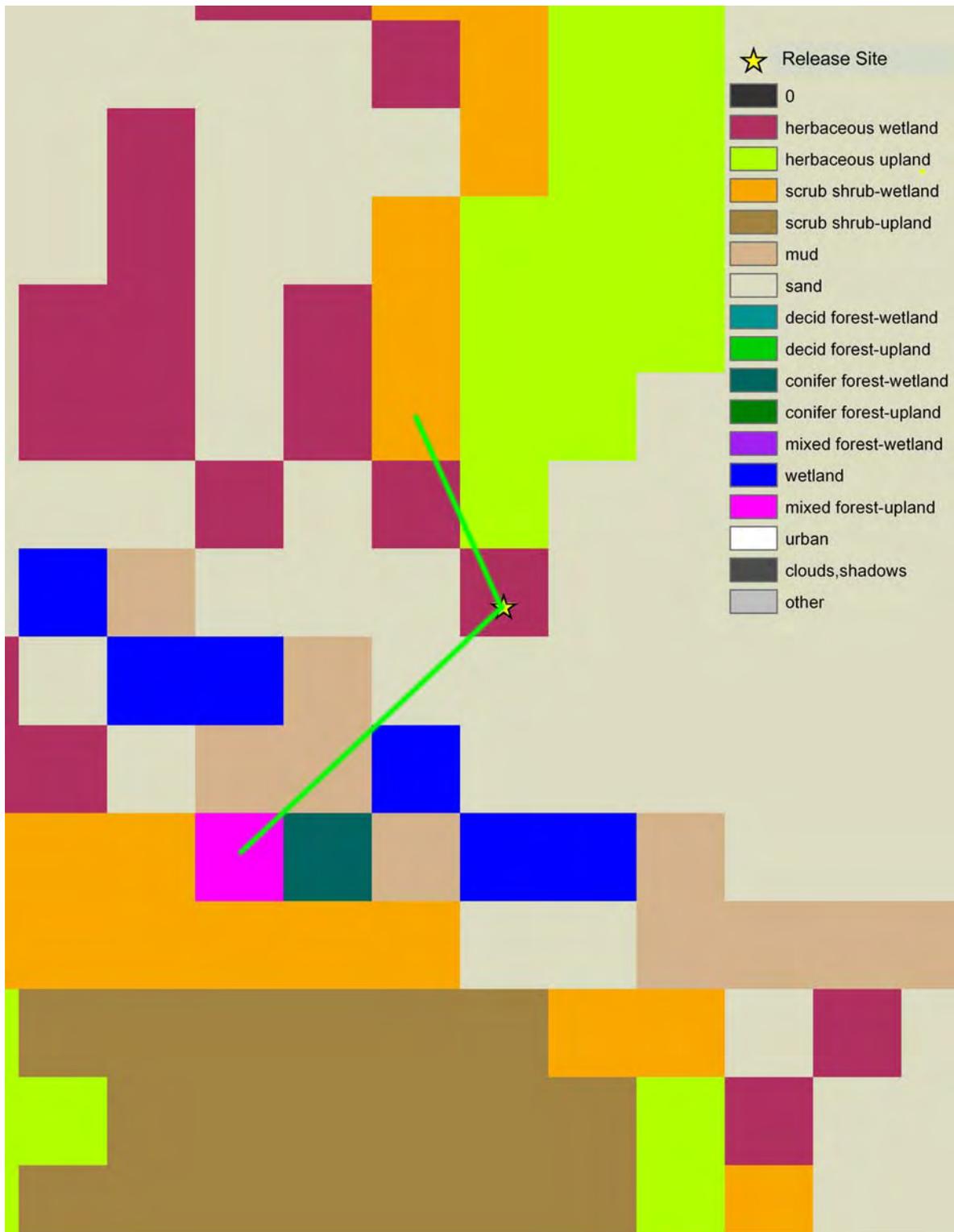


Figure 9. Example of vegetative cover measurements from release point using Landscape Enhanced Thematic Mapper + (ETM+) imagery for each study site. Measurements were made to the center of nearest vegetation class, each pixel representing 30m<sup>2</sup>. This example of Miller Sands Upstream shows 124.0m to mixed forest-upland (pink) and 72.0m to scrub shrub-wetland (orange). Imagery source Garono et al 2003a.



Figure 10. Example of how distance to forest measurements were made using color infrared photographs for each release point. The star designates the release point and the distance tool in ArcMap was used to determine the distance from the star to the nearest forested area. *Color infrared photograph courtesy of USACE and LCREP 2001.*

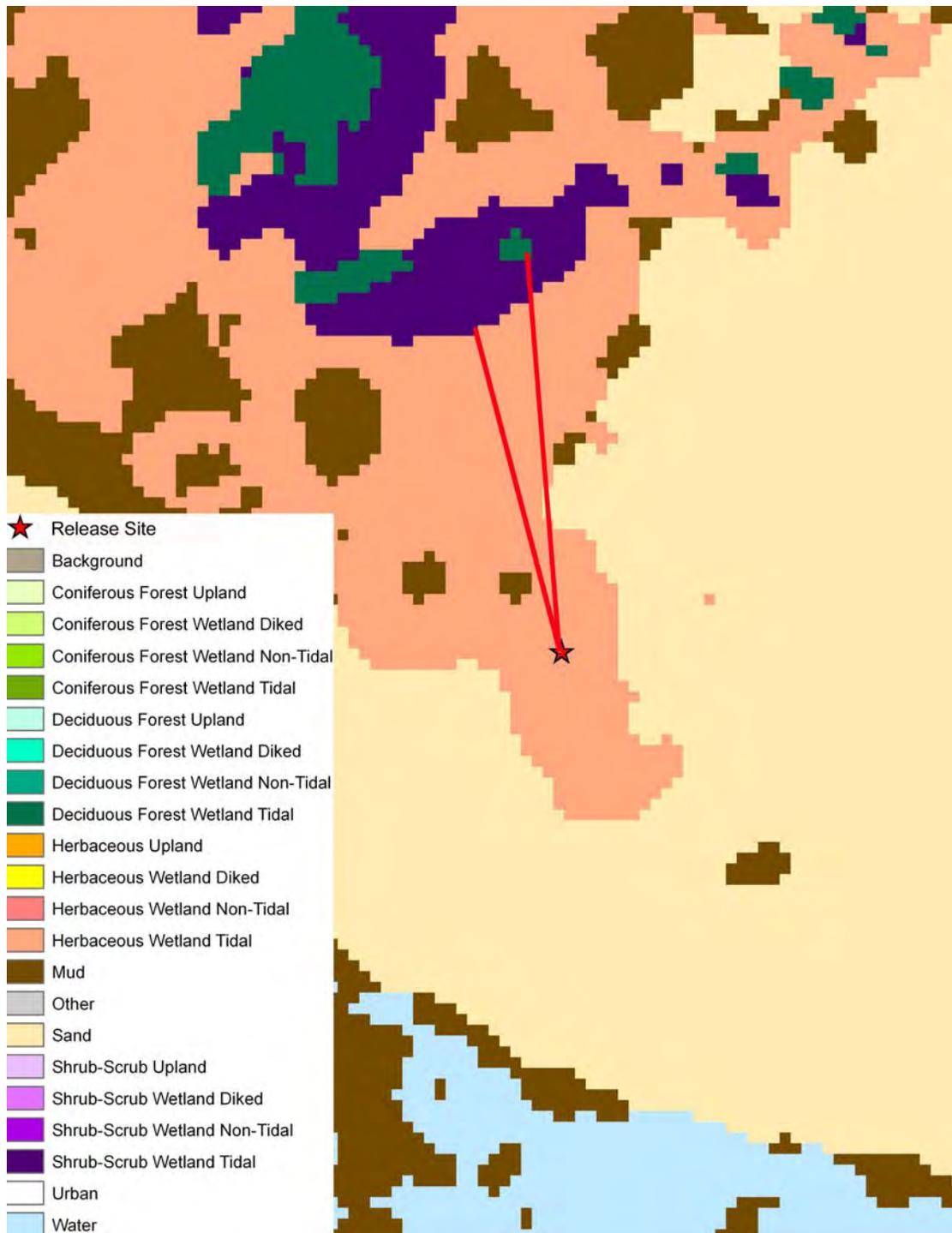


Figure 11. Example of measuring distance from each release point to vegetative classes using CASI. In this image of Miller Sands Upstream the release point (red star) was measured to be 47.0m from the nearest shrub-scrub wetland tidal area (dark purple) and 56.0m from the nearest deciduous forest wetland tidal area (dark green). Each pixel represents 1.5 m. CASI data courtesy of Garono et al. 2003b.

## D. Results

We initiated this study to determine if there was evidence of the successful establishment of biocontrol agent population at the fifteen 2005 USACE release sites. We judged populations to be established if biocontrol agents were present on site as adults, larvae, or eggs. We were also interested in assessing the degree to which the biocontrol agents spread from the release site and the degree to which *Lythrum* was controlled by the biocontrol agents. Population spread is indicative of the early stages of successful control. Finally, we recognized that biocontrol agents have successfully colonized some release sites but not others. Therefore, we sought to characterize each release site to determine the environmental factors that may lead to successful control.

We found evidence of biocontrol life stages at thirteen of fifteen release sites (**Table 3**). No observations of adults, larvae, or egg masses of biocontrol agents were made on Miller Island Downstream or Pillar Rock Island Downstream. However, damage consistent with *Galerucella* was observed at all fifteen sites (Table 3). More detailed information is given in individual site summaries found at the end of the report in **Appendix II**. Across all fifteen release sites, in both June and July sampling periods, we encountered very few adult *G. pusilla* and *G. californiensis*; although observations of immature life stages were more frequent. Adult *Galerucella* beetles were observed at nine of the 15 release sites (60%) in June and July. We observed adults at more sites in July than in June, and all the sites where adults were present in June had adults in July. We do recognize that some, if not all, of the adults observed may have been the same adults that were released in 2005.

In contrast to observations of adults, we found that the numbers of *Galerucella* larvae were much greater and encountered at more sites during June field surveys than the July surveys. We found *Galerucella* larvae at 11 of the 15 sites (73%) in June and only three (20%) of the sites in July. The three sites with larvae present in July also had larvae in June. The fact that larvae were more commonly encountered in June is consistent with what is known about the insect's life cycle. Egg masses of *Galerucella* species were observed at all but two of the study sites. We found more egg masses in July than June but at fewer sites.

Table 3. Summary of biocontrol agent observations and field survey dates. Adult *Galerucella* beetles were observed at 9 of the 15 study sites and *Galerucella* damage was noted at all but one. Observations of *Galerucella* larvae were much higher during June field surveys. Although not a component of the July 2005 Army Corps of Engineers releases, *Nanophyes* adults were located at 5 of the 15 study sites. There were no observations of *Hylobius* adult beetles at any of the study sites. See Appendix IV-3 through IV-6 for map of biological control releases made in surrounding areas.

| June and July 2006 |                 |                   |                               |                        |      |                  |      |                   |      |                         |      |                          |      |                    |      |          |      |                 |      |
|--------------------|-----------------|-------------------|-------------------------------|------------------------|------|------------------|------|-------------------|------|-------------------------|------|--------------------------|------|--------------------|------|----------|------|-----------------|------|
|                    | Site            | RTK GPS Completed | Plant-Insect Survey Completed | Galerucella egg masses |      | G. pusilla Adult |      | G. pusilla Larvae |      | G. californiensis Adult |      | G. californiensis Larvae |      | Galerucella Damage |      | Hylobius |      | Nanophyes Adult |      |
|                    |                 |                   |                               | June                   | July | June             | July | June              | July | June                    | July | June                     | July | June               | July | June     | July | June            | July |
| 1                  | Devil's Elbow   | 6/14/2006         | 6/18/2006<br>7/26/2006        | Yes                    | Yes  | Yes              | Yes  | Yes               | No   | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | No              | No   |
| 2                  | Dry Dock        | 6/16/2006         | 6/16/2006<br>7/29/2006        | Yes                    | Yes  | Yes              | Yes  | Yes               | No   | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | Yes             | Yes  |
| 3                  | Eureka Bar DS   | 6/19/2006         | 6/19/2006<br>7/28/2006        | No                     | No   | No               | No   | Yes               | Yes  | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | Yes             | Yes  |
| 4                  | Eureka Bar US   | 6/19/2006         | 6/19/2006<br>7/28/2006        | Yes                    | No   | No               | No   | Yes               | No   | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | Yes             | Yes  |
| 5                  | Fitzpatrick     | 6/14/2006         | 6/27/2006<br>7/27/2006        | No                     | Yes  | No               | No   | No                | No   | No                      | No   | No                       | No   | No                 | Yes  | No       | No   | No              | No   |
| 6                  | Karlson         | 6/15/2006         | 6/17/2006<br>7/24/2006        | Yes                    | No   | No               | Yes  | Yes               | No   | No                      | No   | No                       | No   | Yes                | No   | No       | No   | No              | No   |
| 7                  | Marsh           | 6/14/2006         | 6/18/2006<br>7/26/2006        | No                     | Yes  | Yes              | Yes  | Yes               | No   | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | No              | No   |
| 8                  | Miller Sands DS | 6/15/2006         | 6/15/2006<br>7/25/2006        | No                     | No   | No               | No   | No                | No   | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | No              | No   |
| 9                  | Miller Sands US | 6/15/2006         | 6/15/2006<br>7/25/2006        | Yes                    | Yes  | No               | Yes  | Yes               | Yes  | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | No              | No   |
| 10                 | Mott            | 6/13/2006         | 6/26/2006<br>7/26/2006        | Yes                    | Yes  | No               | No   | No                | No   | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | No              | Yes  |
| 11                 | Pillar DS       | 6/14/2006         | 6/26/2006<br>7/27/2006        | No                     | No   | No               | No   | No                | No   | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | No              | No   |
| 12                 | Pillar US       | 6/14/2006         | 6/14/2006<br>7/27/2006        | Yes                    | Yes  | Yes              | Yes  | Yes               | No   | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | No              | No   |
| 13                 | Svensen         | 6/15/2006         | 6/17/2006<br>7/26/2006        | Yes                    | Yes  | Yes              | Yes  | Yes               | Yes  | Yes                     | Yes  | No                       | No   | Yes                | Yes  | No       | No   | No              | No   |
| 14                 | Tenasillahe     | 6/16/2006         | 6/16/2006<br>7/29/2006        | No                     | Yes  | No               | Yes  | Yes               | No   | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | No              | No   |
| 15                 | Wallace         | 6/19/2006         | 6/19/2006<br>7/28/2006        | Yes                    | Yes  | Yes              | Yes  | Yes               | No   | No                      | No   | No                       | No   | Yes                | Yes  | No       | No   | Yes             | No   |

We totaled observations of *Galerucella* life stages (i.e. adults, egg masses, and larvae) for all quadrats at each of the 15 release sites to produce a single number for each life stage at each site. Since the number of quadrats sampled at each release site are nearly equal, we are comfortable making comparisons between the total number of individuals. We found the greatest number of adults at Dry Dock, Svensen Island (both shoreline sites), and Wallace Island. The number of *G. pusilla* and *G. californiensis* adults increased slightly from June to July, 11 to 48 individuals (**Tables 4a, 4b, 4c**). The greatest number of larvae and egg masses were also found at Dry Dock and Svensen Island. Wallace Island, Tenasillahe Island, and Devil’s Elbow sites also had relatively high numbers of larvae, ranging from 25-39 individual larvae (**Table 2**). The number of egg masses almost doubled from June to July, while the number of larvae drastically dropped in July from 274 to two (Tables 4a, 4b). *Galerucella* insects were not found at Pillar Rock Island Downstream and Miller Sands Downstream sites (**Table 3**). The apparent *Galerucella* damage at these sites may have been due to another insect species.

Although not a component of the July 2005 USACE releases, *Nanophyes* adults were present at five (33%) of the 15 release sites. There were no direct observations of *Hylobius* adult beetles at any of the release sites (**Table 3**). We recommend that other release information be reviewed to better understand patterns in the distribution of other biocontrol agents.

### **1. Evidence of Control to Lythrum**

We observed damage to *Lythrum* plants appearing to be due to *Galerucella* adults or larvae at all sites (**Table 3**). However, the overall level of damage observed was quite low. Plant damage is a precursor to control and can be used as evidence of biocontrol agent presence. Low levels of damage were expected with the relatively new *Galerucella* populations present in 2006. When averaged across all plants in all quadrats per sampling event, damage was less than 1% (June 0.49% +/- S.D. 2.0% vs. July 0.47% +/- S.D. 2.6%) (**Table 5**). The greatest amount of damage was seen at Svensen Island when averaged across all quadrats sampled in June and July surveys (June 2.5% +/- S.D. 5.7%, July 2.6% +/- S.D. 9.0%, June & July 2.5% +/- S.D. 7.5%; **Table 5**). Dry Dock and Tenasillahe also had average damage levels higher than most (Dry Dock: June & July

Table 4a. Summary of biocontrol agent observations for June field sampling including sums of *Galerucella pusilla* (GAPU), *Galerucella californiensis* (GACA), native *Galerucella* (GA), and the total of all *Galerucella* species observed (all GA). The average number of individuals per quadrat for each variable are also provided. The rank places sites with the highest number of total observations as 1<sup>st</sup> place and sites with smaller total observations with a lower placed rank (2<sup>nd</sup> and higher).

| JUNE          | Total # quads | GAPU Adult Sum | Rank | Avg. per quad | GACA Adult Sum | Rank | Avg. per quad | GA Adult Sum | Rank | Avg. per quad | GAPU and GACA adults Combined | All GA adults | GA egg Sum | Rank | Avg. per quad | GA larvae Sum | Rank | Avg. per quad |
|---------------|---------------|----------------|------|---------------|----------------|------|---------------|--------------|------|---------------|-------------------------------|---------------|------------|------|---------------|---------------|------|---------------|
| Devil's Elbow | 50            | 3              | 1    | 0.06          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 3                             | 3             | 33         | 2    | 0.66          | 39            | 3    | 0.78          |
| Dry Dock      | 51            | 1              | 3    | 0.02          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 1                             | 1             | 8          | 4    | 0.16          | 41            | 2    | 0.80          |
| Eureka DS     | 50            | 0              | 4    | 0.00          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 0                             | 0             | 3          | 7    | 0.06          | 2             | 9    | 0.04          |
| Eureka US     | 50            | 0              | 4    | 0.00          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 0                             | 0             | 9          | 3    | 0.18          | 8             | 7    | 0.16          |
| Fitzpatrick   | 50            | 0              | 4    | 0.00          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 0                             | 0             | 0          | 10   | 0.00          | 0             | 10   | 0.00          |
| Karlson       | 50            | 0              | 4    | 0.00          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 0                             | 0             | 3          | 7    | 0.06          | 2             | 9    | 0.04          |
| Marsh         | 55            | 1              | 3    | 0.02          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 1                             | 1             | 2          | 8    | 0.04          | 14            | 6    | 0.25          |
| Miller DS     | 50            | 0              | 4    | 0.00          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 0                             | 0             | 0          | 10   | 0.00          | 0             | 10   | 0.00          |
| Miller US     | 53            | 0              | 4    | 0.00          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 0                             | 0             | 5          | 6    | 0.09          | 3             | 8    | 0.06          |
| Mott          | 50            | 0              | 4    | 0.00          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 0                             | 0             | 1          | 9    | 0.02          | 3             | 8    | 0.06          |
| Pillar DS     | 51            | 0              | 4    | 0.00          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 0                             | 0             | 0          | 10   | 0.00          | 0             | 10   | 0.00          |
| Pillar US     | 50            | 2              | 2    | 0.04          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 2                             | 2             | 2          | 8    | 0.04          | 3             | 8    | 0.06          |
| Svensen       | 51            | 1              | 3    | 0.02          | 2              | 1    | 0.04          | 3            | 1    | 0.06          | 3                             | 6             | 110        | 1    | 2.16          | 105           | 1    | 2.06          |
| Tenasillahe   | 50            | 0              | 4    | 0.00          | 0              | 2    | 0.00          | 0            | 2    | 0.00          | 0                             | 0             | 0          | 10   | 0.00          | 25            | 5    | 0.50          |
| Wallace       | 53            | 1              | 3    | 0.02          | 0              | 2    | 0.00          | 3            | 1    | 0.06          | 1                             | 4             | 8          | 5    | 0.15          | 29            | 4    | 0.55          |
| Total         | 764           | 9              |      | 0.01          | 2              |      | 0.01          | 6            |      | 0.01          | 11                            | 17            | 184        |      | 0.24          | 274           |      | 0.36          |

Table 4b. Summary of biocontrol agent observations for July field sampling including sums of *Galerucella pusilla* (GAPU), *Galerucella californiensis* (GACA), native *Galerucella* (GA), and the total of all *Galerucella* species observed (all GA). The average number of individuals per quadrat for each variable are also provided. The rank places sites with the highest number of total observations as 1<sup>st</sup> place and sites with smaller total observations with a lower placed rank (2<sup>nd</sup> and higher).

| JULY          | Total # quads | GAPU Adult Sum | Rank | Avg. per quad | GACA Adult Sum | Rank | Avg. per quad | GA Adult Sum | Rank | Avg. per quad | GACA and GAPU adult combined | All GA Adults | GA egg Sum | Rank | Avg. per quad | GA larvae Sum | Rank | Avg. per quad |
|---------------|---------------|----------------|------|---------------|----------------|------|---------------|--------------|------|---------------|------------------------------|---------------|------------|------|---------------|---------------|------|---------------|
| Devil's Elbow | 50            | 4              | 4    | 0.08          | 0              | 2    | 0.00          | 0            | 5    | 0.00          | 4                            | 4             | 5          | 8    | 0.10          | 0             | 2    | 0.00          |
| Dry Dock      | 50            | 17             | 1    | 0.34          | 0              | 2    | 0.00          | 0            | 5    | 0.00          | 17                           | 17            | 80         | 2    | 1.60          | 0             | 2    | 0.00          |
| Eureka DS     | 50            | 0              | 7    | 0.00          | 0              | 2    | 0.00          | 0            | 5    | 0.00          | 0                            | 0             | 0          | 10   | 0.00          | 0             | 2    | 0.00          |
| Eureka US     | 50            | 0              | 7    | 0.00          | 0              | 2    | 0.00          | 0            | 5    | 0.00          | 0                            | 0             | 0          | 10   | 0.00          | 0             | 2    | 0.00          |
| Fitzpatrick   | 51            | 0              | 7    | 0.00          | 0              | 2    | 0.00          | 0            | 5    | 0.00          | 0                            | 0             | 1          | 9    | 0.02          | 0             | 2    | 0.00          |
| Karlson       | 50            | 2              | 5    | 0.04          | 0              | 2    | 0.00          | 0            | 5    | 0.00          | 2                            | 2             | 0          | 10   | 0.00          | 0             | 2    | 0.00          |
| Marsh         | 61            | 1              | 6    | 0.02          | 0              | 2    | 0.00          | 3            | 2    | 0.05          | 1                            | 4             | 19         | 6    | 0.31          | 0             | 2    | 0.00          |
| Miller DS     | 50            | 0              | 7    | 0.00          | 0              | 2    | 0.00          | 0            | 5    | 0.00          | 0                            | 0             | 0          | 10   | 0.00          | 0             | 2    | 0.00          |
| Miller US     | 50            | 1              | 6    | 0.02          | 0              | 2    | 0.00          | 2            | 3    | 0.04          | 1                            | 3             | 6          | 7    | 0.12          | 1             | 1    | 0.02          |
| Mott          | 50            | 0              | 7    | 0.00          | 0              | 2    | 0.00          | 1            | 4    | 0.02          | 0                            | 1             | 0          | 10   | 0.00          | 0             | 2    | 0.00          |
| Pillar DS     | 50            | 0              | 7    | 0.00          | 0              | 2    | 0.00          | 0            | 5    | 0.00          | 0                            | 0             | 0          | 10   | 0.00          | 0             | 2    | 0.00          |
| Pillar US     | 50            | 1              | 6    | 0.02          | 0              | 2    | 0.00          | 2            | 3    | 0.04          | 1                            | 3             | 27         | 3    | 0.54          | 0             | 2    | 0.00          |
| Svensen       | 50            | 14             | 2    | 0.28          | 0              | 2    | 0.00          | 0            | 5    | 0.00          | 14                           | 14            | 177        | 1    | 3.54          | 1             | 1    | 0.02          |
| Tenasillahe   | 50            | 1              | 6    | 0.02          | 0              | 2    | 0.00          | 3            | 1    | 0.06          | 1                            | 4             | 19         | 5    | 0.38          | 0             | 2    | 0.00          |
| Wallace       | 50            | 5              | 3    | 0.10          | 2              | 1    | 0.04          | 0            | 5    | 0.00          | 7                            | 7             | 21         | 4    | 0.42          | 0             | 2    | 0.00          |
| Total         | 762           | 46             |      | 0.06          | 2              |      | 0.00          | 11           |      | 0.01          | 48                           | 59            | 355        |      | 0.47          | 2             |      | 0.00          |

Table 4c. Summary of biocontrol agent observations for June and July field sampling including sums of *Galerucella pusilla* (GAPU), *Galerucella californiensis* (GACA), native *Galerucella* (GA), and the total of all *Galerucella* species observed (all GA). The average number of individuals per quadrat for each variable are also provided. The rank places sites with the highest number of total observations as 1<sup>st</sup> place and sites with smaller total observations with a lower placed rank (2<sup>nd</sup> and higher).

| <b>JUNE &amp; JULY</b> | Total # quads | GAPU Adult Sum | Rank | Avg. per quad | GACA Adult Sum | Rank | Avg. per quad | GA Adult Sum | Rank | Avg. per quad | GAPU and GACA adults Combined | All GA adults | GA egg Sum | Rank | Avg. per quad | GA larvae Sum | Rank | Avg. per quad |
|------------------------|---------------|----------------|------|---------------|----------------|------|---------------|--------------|------|---------------|-------------------------------|---------------|------------|------|---------------|---------------|------|---------------|
| Devil's Elbow          | 100           | 7              | 3    | 0.07          | 0              | 2    | 0.00          | 0            | 4    | 0.00          | 7                             | 7             | 38         | 3    | 0.38          | 39            | 3    | 0.39          |
| Dry Dock               | 101           | 18             | 1    | 0.18          | 0              | 2    | 0.00          | 0            | 4    | 0.00          | 18                            | 18            | 88         | 2    | 0.87          | 41            | 2    | 0.41          |
| Eureka DS              | 100           | 0              | 8    | 0.00          | 0              | 2    | 0.00          | 0            | 4    | 0.00          | 0                             | 0             | 3          | 9    | 0.03          | 2             | 10   | 0.02          |
| Eureka US              | 100           | 0              | 8    | 0.00          | 0              | 2    | 0.00          | 0            | 4    | 0.00          | 0                             | 0             | 9          | 8    | 0.09          | 8             | 7    | 0.08          |
| Fitzpatrick            | 101           | 0              | 8    | 0.00          | 0              | 2    | 0.00          | 0            | 4    | 0.00          | 0                             | 0             | 1          | 10   | 0.01          | 0             | 0    | 0.00          |
| Karlson                | 100           | 2              | 6    | 0.02          | 0              | 2    | 0.00          | 0            | 4    | 0.00          | 2                             | 2             | 3          | 9    | 0.03          | 2             | 10   | 0.02          |
| Marsh                  | 116           | 2              | 6    | 0.02          | 0              | 2    | 0.00          | 3            | 1    | 0.03          | 2                             | 5             | 21         | 5    | 0.18          | 14            | 6    | 0.12          |
| Miller DS              | 100           | 0              | 8    | 0.00          | 0              | 2    | 0.00          | 0            | 4    | 0.00          | 0                             | 0             | 0          | 11   | 0.00          | 0             | 0    | 0.00          |
| Miller US              | 103           | 1              | 7    | 0.01          | 0              | 2    | 0.00          | 2            | 2    | 0.02          | 1                             | 3             | 11         | 7    | 0.11          | 4             | 8    | 0.04          |
| Mott                   | 100           | 0              | 8    | 0.00          | 0              | 2    | 0.00          | 1            | 3    | 0.01          | 0                             | 1             | 1          | 10   | 0.01          | 3             | 9    | 0.03          |
| Pillar DS              | 101           | 0              | 8    | 0.00          | 0              | 2    | 0.00          | 0            | 4    | 0.00          | 0                             | 0             | 0          | 11   | 0.00          | 0             | 0    | 0.00          |
| Pillar US              | 100           | 3              | 5    | 0.03          | 0              | 2    | 0.00          | 2            | 2    | 0.02          | 3                             | 5             | 29         | 4    | 0.29          | 3             | 9    | 0.03          |
| Svensen                | 101           | 15             | 2    | 0.15          | 2              | 1    | 0.02          | 3            | 1    | 0.03          | 17                            | 20            | 287        | 1    | 2.84          | 106           | 1    | 1.05          |
| Tenasillahe            | 100           | 1              | 7    | 0.01          | 0              | 2    | 0.00          | 3            | 1    | 0.03          | 1                             | 4             | 19         | 6    | 0.19          | 25            | 5    | 0.25          |
| Wallace                | 103           | 6              | 4    | 0.06          | 2              | 1    | 0.02          | 3            | 1    | 0.03          | 8                             | 11            | 29         | 4    | 0.28          | 29            | 4    | 0.28          |
| <b>Total</b>           | <b>1526</b>   | <b>55</b>      |      | <b>0.04</b>   | <b>4</b>       |      | <b>0.00</b>   | <b>17</b>    |      | <b>0.01</b>   | <b>59</b>                     | <b>76</b>     | <b>539</b> |      | <b>0.35</b>   | <b>276</b>    |      | <b>0.18</b>   |

Table 5. Summary of all *Galerucella* damage observed during 2006 at 15 study sites. The mean percent damage was calculated from damage observed within the total number of quadrats (n) sampled at a given site. Standard deviation and ranges are also provided. The sum of percent damage is the total of all percent damage ratings assigned to the total number of quadrats (n) at each site and can therefore be greater than 100%.

| Island        | Month | n    | Mean % Damage | Std.Dev. | Min. | Max. | Sum of % Damage |
|---------------|-------|------|---------------|----------|------|------|-----------------|
| Devil's Elbow | June  | 50   | 0.28          | 0.9      | 0    | 5    | 14              |
|               | July  | 50   | 0.12          | 0.4      | 0    | 2    | 6               |
|               | Total | 100  | 0.20          | 0.7      | 0    | 5    |                 |
| Dry Dock      | June  | 51   | 1.06          | 3.2      | 0    | 20   | 54              |
|               | July  | 50   | 1.18          | 2.2      | 0    | 8    | 59              |
|               | Total | 101  | 1.12          | 2.7      | 0    | 20   |                 |
| Eureka Down   | June  | 50   | 0.06          | 0.2      | 0    | 1    | 3               |
|               | July  | 50   | 0.00          | 0.0      | 0    | 0    | 0               |
|               | Total | 100  | 0.03          | 0.2      | 0    | 1    |                 |
| Eureka Up     | June  | 50   | 0.22          | 0.4      | 0    | 1    | 11              |
|               | July  | 50   | 0.10          | 0.3      | 0    | 1    | 5               |
|               | Total | 100  | 0.16          | 0.4      | 0    | 1    |                 |
| Fitzpatrick   | June  | 50   | 0.00          | 0.0      | 0    | 0    | 0               |
|               | July  | 51   | 0.00          | 0.0      | 0    | 0    | 0               |
|               | Total | 101  | 0.00          | 0.0      | 0    | 0    |                 |
| Karlson       | June  | 50   | 0.36          | 1.0      | 0    | 5    | 18              |
|               | July  | 50   | 0.12          | 0.6      | 0    | 4    | 6               |
|               | Total | 100  | 0.24          | 0.8      | 0    | 5    |                 |
| Marsh         | June  | 55   | 0.13          | 0.3      | 0    | 1    | 7               |
|               | July  | 61   | 0.41          | 1.2      | 0    | 5    | 25              |
|               | Total | 116  | 0.28          | 0.9      | 0    | 5    |                 |
| Miller Down   | June  | 50   | 0.02          | 0.1      | 0    | 1    | 1               |
|               | July  | 50   | 0.02          | 0.1      | 0    | 1    | 1               |
|               | Total | 100  | 0.02          | 0.1      | 0    | 1    |                 |
| Miller Up     | June  | 53   | 0.13          | 0.4      | 0    | 2    | 7               |
|               | July  | 50   | 0.16          | 0.5      | 0    | 3    | 8               |
|               | Total | 103  | 0.15          | 0.5      | 0    | 3    |                 |
| Mott          | June  | 50   | 0.04          | 0.2      | 0    | 1    | 2               |
|               | July  | 50   | 0.34          | 1.5      | 0    | 10   | 17              |
|               | Total | 100  | 0.19          | 1.1      | 0    | 10   |                 |
| Pillar Down   | June  | 51   | 0.02          | 0.1      | 0    | 1    | 1               |
|               | July  | 50   | 0.02          | 0.1      | 0    | 1    | 1               |
|               | Total | 101  | 0.02          | 0.1      | 0    | 1    |                 |
| Pillar Up     | June  | 50   | 0.70          | 1.3      | 0    | 5    | 35              |
|               | July  | 50   | 0.36          | 0.7      | 0    | 3    | 18              |
|               | Total | 100  | 0.53          | 1.0      | 0    | 5    |                 |
| Svensen       | June  | 51   | 2.47          | 5.7      | 0    | 30   | 126             |
|               | July  | 50   | 2.58          | 9.0      | 0    | 60   | 129             |
|               | Total | 101  | 2.52          | 7.5      | 0    | 60   |                 |
| Tenasillahe   | June  | 50   | 1.14          | 2.0      | 0    | 12   | 57              |
|               | July  | 50   | 1.08          | 2.1      | 0    | 10   | 54              |
|               | Total | 100  | 1.11          | 2.0      | 0    | 12   |                 |
| Wallace       | June  | 53   | 0.70          | 1.7      | 0    | 10   | 37              |
|               | July  | 51   | 0.59          | 1.3      | 0    | 5    | 30              |
|               | Total | 104  | 0.64          | 1.5      | 0    | 10   |                 |
| <b>Total</b>  | June  | 764  | 0.49          | 2.0      | 0    | 30   | 373             |
|               | July  | 763  | 0.47          | 2.6      | 0    | 60   | 359             |
|               | Total | 1527 | 0.48          | 2.3      | 0    | 60   |                 |

1.1% +/- S.D. 2.7%, Tenasillahe: June & July 1.1% +/- S.D. 2.0%). Not surprising, the sites with the highest number of biocontrol agents also had the highest amount of damage to the host plant.

There appears to be very little difference in the amount of damage observed in July from that in June. Average damage levels in July were less than 0.1% higher than those in June (June 0.49% +/- S.D. 2.0 vs. July 0.47% +/- S.D. 2.6, **Table 5**). We expected to see more damage in July because the biocontrol agents had been present and active for longer. However, since we measured damage as leaf area removed by the beetles, the plants had grown larger by July and percent damage was measured over a much larger plant. In fact, the highest percentage of damage on a single plant, 60%, was observed in June. The total percent damage<sup>2</sup>, when all observations were added, was higher in June than July as well (373% vs. 359%, **Table 5**).

Our data show that the incidences of primary tip damage increased with increased number of *Galerucella* larvae present. For example, the highest levels of tip damage were observed at Svensen which also had the most larvae (**Figure 12, Table 4a**). We also observed an inverse relationship between the mean length of purple loosestrife stems and the number of larvae: the average plant length decreased as the frequency of larvae, and thus primary tip damage, increased. These observations are consistent with the life cycle of *Galerucella*; more than 99% of larvae observed were observed during the June sampling, rather than July. Larvae of *Galerucella* feed upon young shoot tips of leaves and flower buds, retarding the overall length of the plants.

## **2. Factors that May Affect Establishment and Spread of Biocontrol Agents in the Columbia River Estuary**

The range of physical conditions on the Columbia River Estuary is different than other wetland biocontrol sites in the Pacific Northwest. Although the average temperatures are mild year round with average high temperature for January at 48.3°F (9.1°C) and for August of 68.7°F (20.4°C) (<http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?or0328>); areas along the shore and on the channel islands are subject to frequent inundation. Flowing water and wind may disperse

---

<sup>2</sup> Total percent damage can be greater than 100% because these are cumulative percentages observed on all plants.

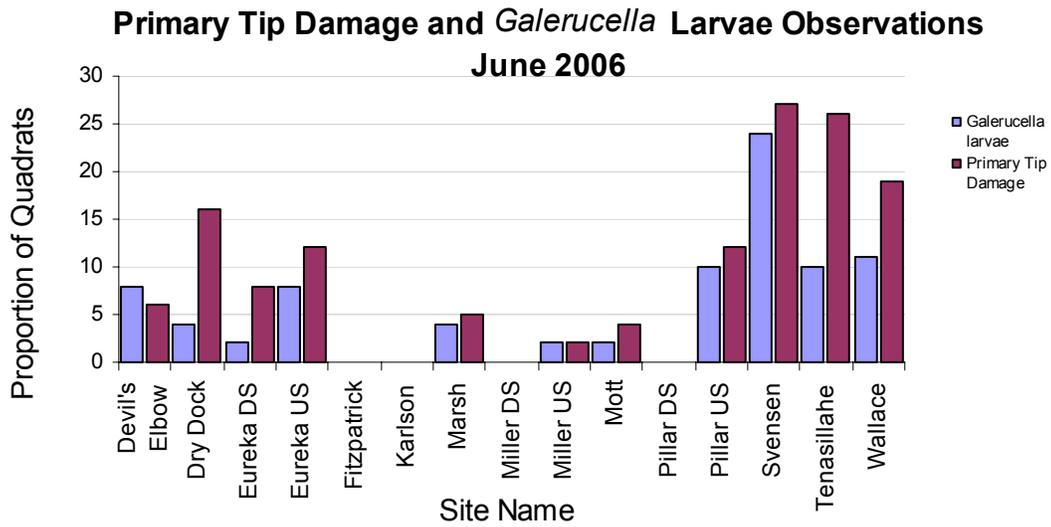


Figure 12. Proportion of quadrats in June sampling that showed presence of *Galerucella* larvae and primary tip damage, presented for each study site. Larvae of *Galerucella pusilla*, *G. calmariensis*, as well as the native *G. nymphae*, were counted together.

Table 6. Percent area of RTK DEM grids of each study site that are above and below either MSL, MHHW, or the highest tide levels. Elevations are in reference to vertical datum NAVD88 and are based upon values from the Knappa Slough tidal gauge station.

|               | Total area of RTK DEM Grid (ha) | <MSL   | >MSL   | <MHHW  | >MHHW  | <Highest Tide | >Highest Tide |
|---------------|---------------------------------|--------|--------|--------|--------|---------------|---------------|
|               |                                 | <1.55m | >1.55m | <2.76m | >2.76m | <3.2m         | >3.2m         |
| Devil's Elbow | 0.4                             | 48.5   | 51.5   | 89.2   | 10.8   | 95.2          | 4.8           |
| Dry Dock      | 0.5                             | 26.1   | 73.9   | 79.5   | 20.5   | 91.3          | 8.7           |
| Eureka DS     | 1.1                             | 13.4   | 86.6   | 93.3   | 6.7    | 98.9          | 1.1           |
| Eureka US     | 1.6                             | 28.7   | 71.3   | 98.6   | 1.4    | 99.7          | 0.3           |
| Fitzpatrick   | 1.5                             | 0.3    | 99.7   | 94.3   | 5.7    | 99.9          | 0.1           |
| Karlson       | 0.3                             | 14.6   | 85.4   | 91.8   | 8.2    | 96.1          | 3.9           |
| Marsh         | 1.5                             | 34.2   | 65.8   | 97.1   | 2.9    | 100.0         | 0.0           |
| Miller Down   | 2.8                             | 33.0   | 67.0   | 57.3   | 42.7   | 60.2          | 39.8          |
| Miller Up     | 3.4                             | 13.5   | 86.5   | 46.0   | 54.0   | 52.4          | 47.6          |
| Mott          | 1.4                             | 29.1   | 70.9   | 100.0  | 0.0    | 100.0         | 0.0           |
| Pillar Rock   | 4.2                             | 10.8   | 89.2   | 72.6   | 27.4   | 79.7          | 20.3          |
| Svensen       | 0.7                             | 54.7   | 45.3   | 81.2   | 18.8   | 85.4          | 14.6          |
| Tenasillahe   | 0.9                             | 34.1   | 65.9   | 99.3   | 0.7    | 100.0         | 0.0           |
| Wallace       | 2.1                             | 6.9    | 93.1   | 82.1   | 17.9   | 91.8          | 8.2           |

biocontrol agents thereby keeping their populations from reaching effective control levels. We hypothesize that tidal inundation and exposure to wind and water may hamper the establishment of some biocontrol agent populations. We propose that release sites should be selected carefully to maximize biocontrol agent population growth potential by minimizing loss of individuals. Site characteristics that maximize population growth potential on the Columbia River, however, are not well-known. Therefore, we propose to characterize the elevation, tidal ranges, and vegetation cover at each release site and relate these characteristics to population growth over the next few years.

### **a. Elevation**

All 15 release sites in this study are subject to tidal inundation. Tidal flushing can play a role in dispersing or redistributing biocontrol agents and may ultimately affect control of *Lythrum*. Therefore, we examined relationships between biocontrol agent populations, *Lythrum* stem lengths, and tidal levels. Using elevations and *Lythrum* stem lengths measured around each release point, we related tidal levels (e.g., mean sea level (MSL), mean higher high water (MHHW)) to these elevations and lengths at each site. Since this summary was performed using a GIS, we were able to visualize and measure distances to areas that were expected to be above the water line at particular tidal stages. The exact values for MSL and MHHW used in our analysis are based on tidal datum values for Knappa Slough tidal gauge station, vertical datum NAVD88. No adjustments were made for the distance of the study sites from the tide station because it is unknown how this distance affects tide levels at each site. It is assumed the differences would be negligible and not change the results of calculations based upon tidal datums greatly. For example, **Figure 7** displays the small differences in tidal datums between three Lower Columbia River tidal gauge stations.

We summarized the distribution of quadrat elevations (i.e., sampling effort in capturing various elevations), *Lythrum* stems, and evidence of biocontrol agents according to tidal categories. The six tidal categories in NAVD88 are as follows: lower than the lowest tide (<-0.34m), lowest tide to MLLW (-0.33 to 0.21m), MLLW to MSL (0.22 to 1.54m), MSL to MHHW (1.55 to 2.76m), MHHW to highest tide (2.77 to 3.19m), and above the highest tide (>3.20m).

The elevations of quadrats we sampled ranged from MLLW to areas above the highest tide. The majority (84%) of these quadrats fell between MSL and MHHW (1.55 – 2.76m) for both June and July sampling events. Only about three percent of the quadrats were above the highest tide levels (3.2m) experienced by the islands (**Figures 13a, 13b**). This suggests that most of the 15 release sites are strongly influenced by tidal flooding and possibly tidal flushing (removal of insects from habitat).

Using the elevation grid of each release site produced from the RTK data, we were able to examine the percentage of high ground (areas >3.2 m) near the release point. According to elevation data gathered during RTK missions at all release sites, the average distance from the release point to an area of high ground was 26m. Some sites had no high ground within the region of available RTK data (Tenasillahe, Mott, and Marsh Island). The percent area of the DEM grid above the high tide line for other study sites ranged from 0.1% at Fitzpatrick to as high as 47.6% at Miller Island Upstream. Please see **Table 6 and Figures 14a-n**. Because no other detailed elevation data is available for areas beyond the RTK DEM collected in this study, we are unable to investigate any further relationships with tidal inundation. We recommend exploring other sources of data describing elevations for the islands of the Lower Columbia River Estuary.

## **b. Relationship between *Lythrum* Stem Densities and Elevation**

We found that the number of live *Lythrum* stems was inversely related to elevation using a Pearson correlation ( $r^2=-0.113$ ,  $p<0.01$ ; **Table 7**). Quadrats we sampled ranged in elevation from MLLW to above the highest tide lines and most were between MSL-MHHW. For quadrats where at least one live purple loosestrife stem was observed, the majority of elevations of these quadrats (85-88%) also fell between MSL and MHHW (**Figure 15**). We did observe purple loosestrife at elevations ranging from MLLW to above the highest tide, i.e., in all elevations of quadrats sampled. There was very little difference between the elevations where purple loosestrife was observed between June and July.

Due to the perennial nature of purple loosestrife, stem lengths vary throughout the year and have greater potential to surpass the highest water levels during high tides later in the growing season. Therefore, we considered both the ground surface and plant lengths in our

search for areas above tidal influence. As expected, when the average live purple loosestrife stem length is added to the quadrat ground elevation, a far greater number of quadrats have combined elevations in excess of the highest tide (3.2m). In fact, 45% of quadrats sampled in June and 31% sampled in July have combined plant lengths plus elevations that exceed the highest water levels in this area of the river (**Figure 16**). From this analysis, we see that there are plants or portions of plants that are not under water during the highest tides. Thus, vegetation may play a significant role in allowing biocontrol agents to escape tidal flows.

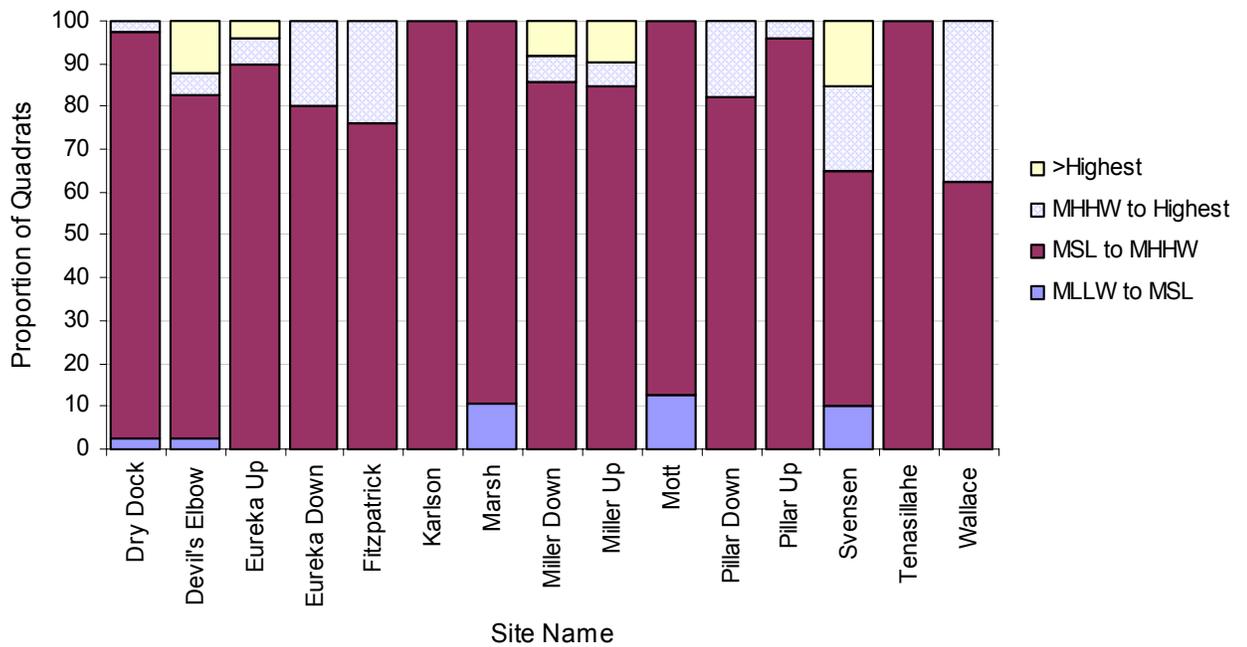


Figure 13a. Proportion of quadrats at each study site with elevations between MLLW and MSL (0.22-1.54m), MSL to MHHW (1.55-2.76m), MHHW and the highest tide (2.7-3.1m) and those above the highest tide mark (3.2m) for June 2006. Elevations referenced to NAVD88 vertical datum.

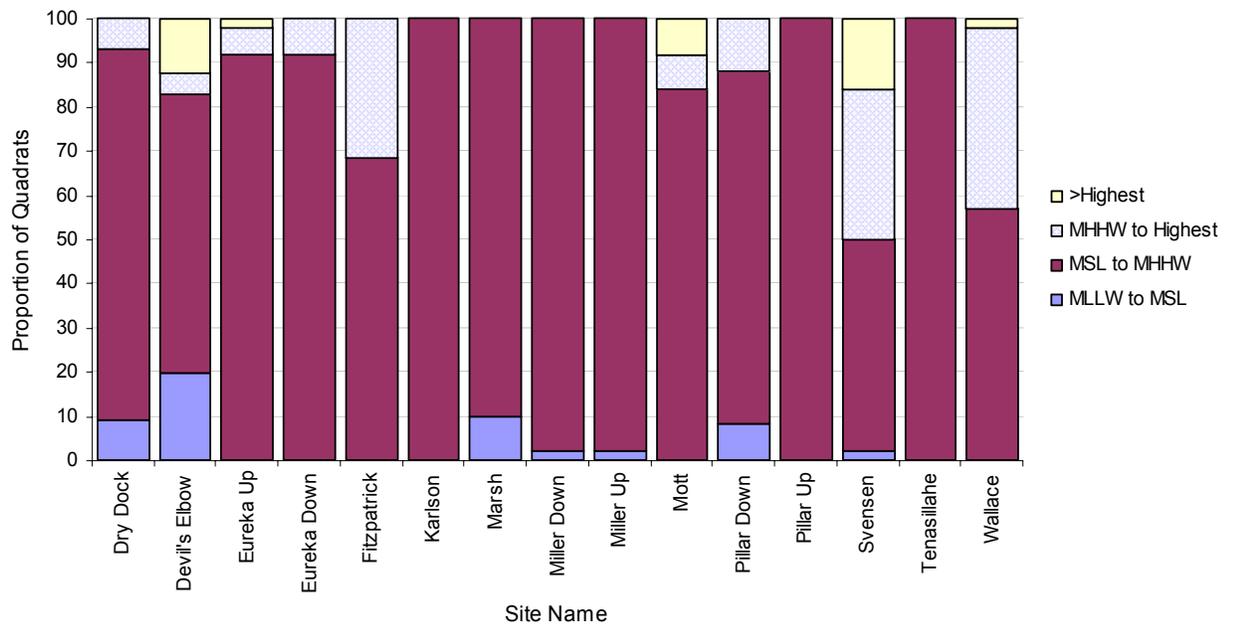


Figure 13b. Proportion of quadrats at each study site with elevations between MLLW and MSL (0.22-1.54m), MSL and MHHW (1.55-2.76m), MHHW and the highest tide (2.7-3.1m) and those above the highest tide mark (3.2m) for July 2006. Elevations are measured in reference to NAVD88 vertical datum.

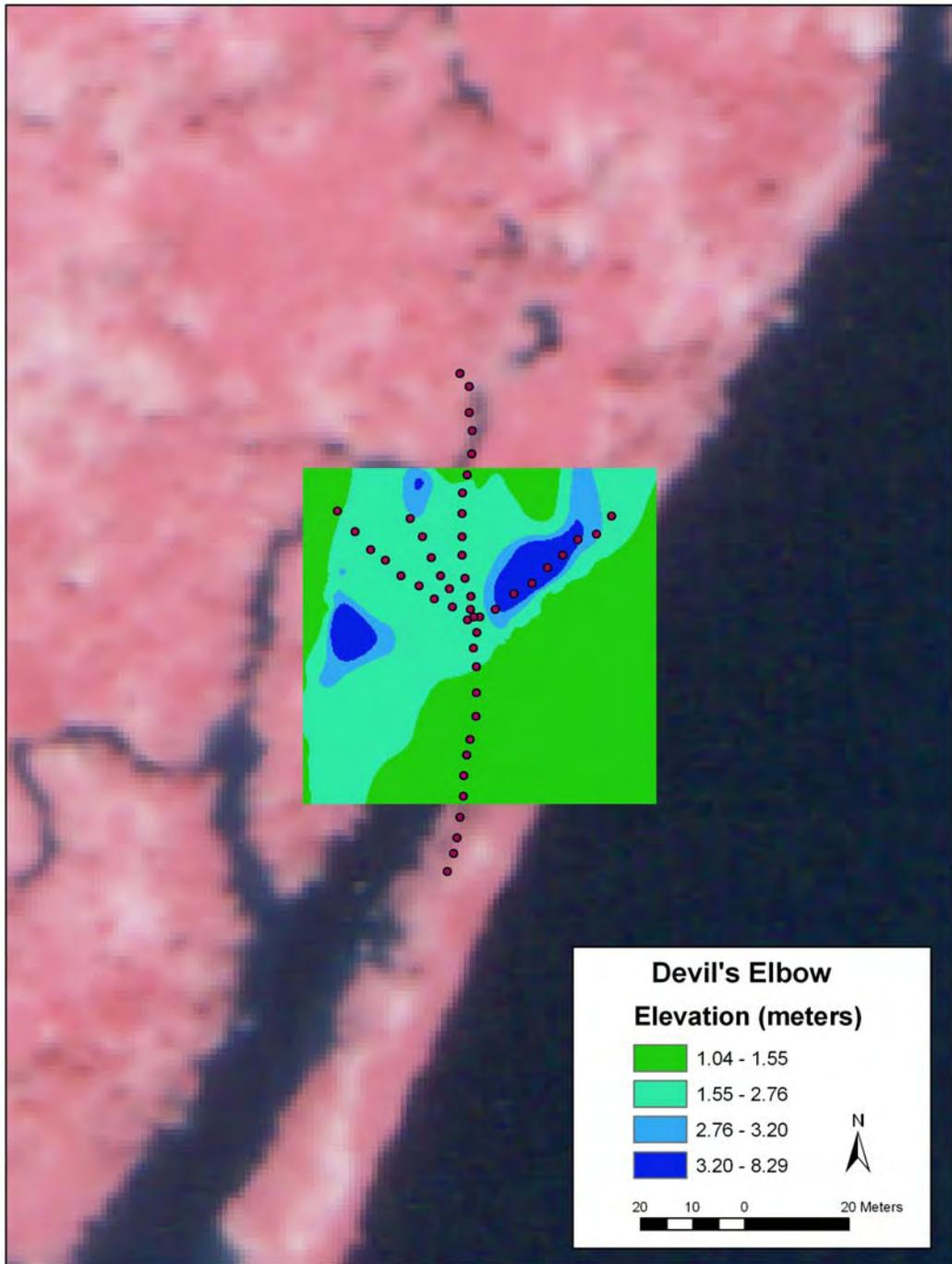


Figure 14a-n. DEM Tidal masking of study sites. The DEM produced from RTK data collection of elevation is displayed on a color infrared photo of each study site. The DEM is classified to show areas within each tidal elevation category. The area displayed in green (1.04 -1.55m or 1.04 -1.44m) are below MSL in vertical datum NAVD88. Areas between MSL – MHHW are those elevations between 1.55 – 2.76m or 1.44 – 2.69m; MHHW – Highest Tide are elevations between 2.76 – 3.20m or 2.69 – 3.17m; and areas above the highest tide are in dark blue and indicated elevations above 3.20 or 3.17m. Tidal category boundaries are based upon the nearest tidal gauge station to each study site, either Knappa Slough or Tongue Point stations.

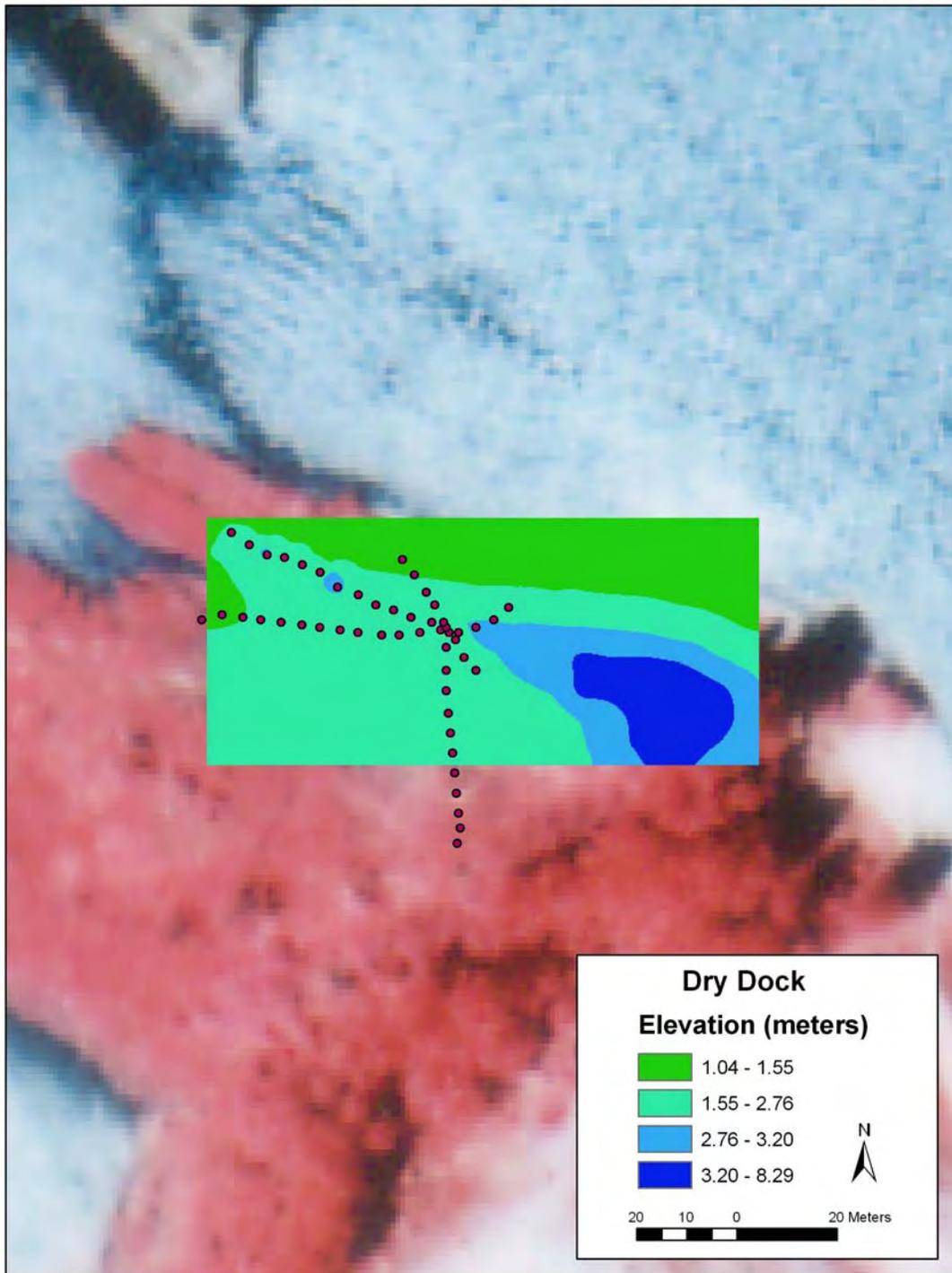


Figure 14 b. See Figure 14a for description.

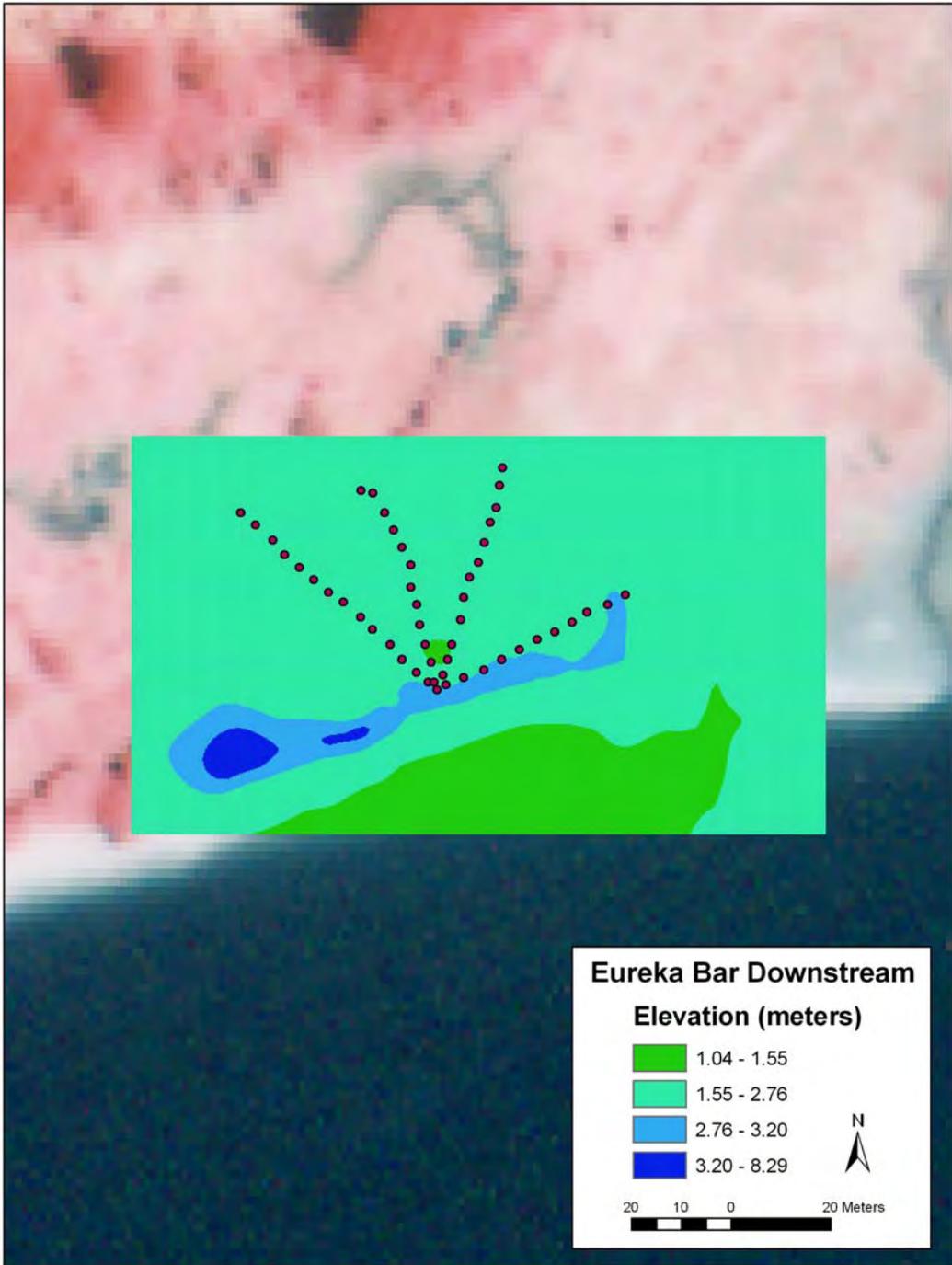


Figure 14 c. See Figure 14a for description.

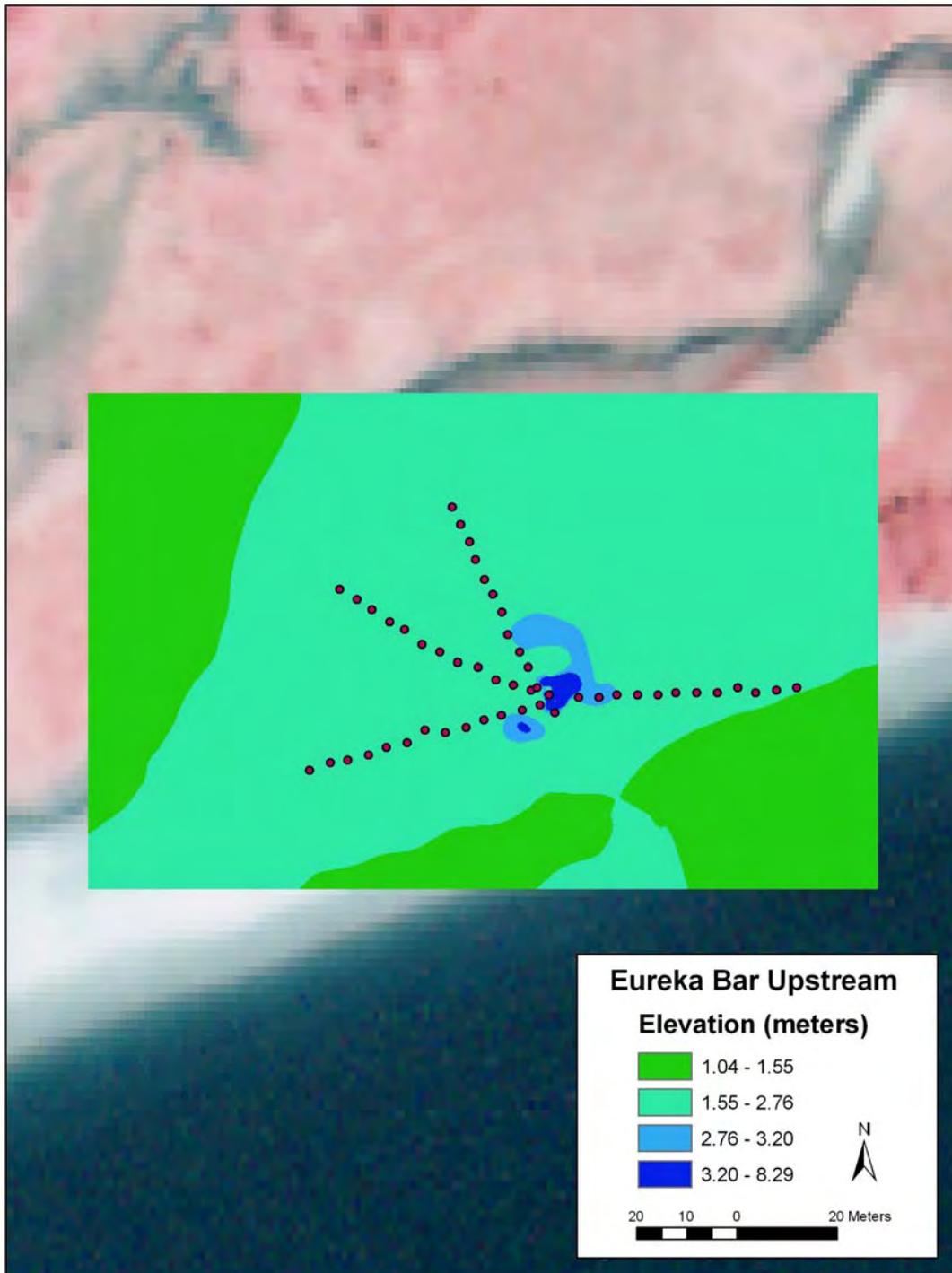


Figure 14 d. See Figure 14a for description.

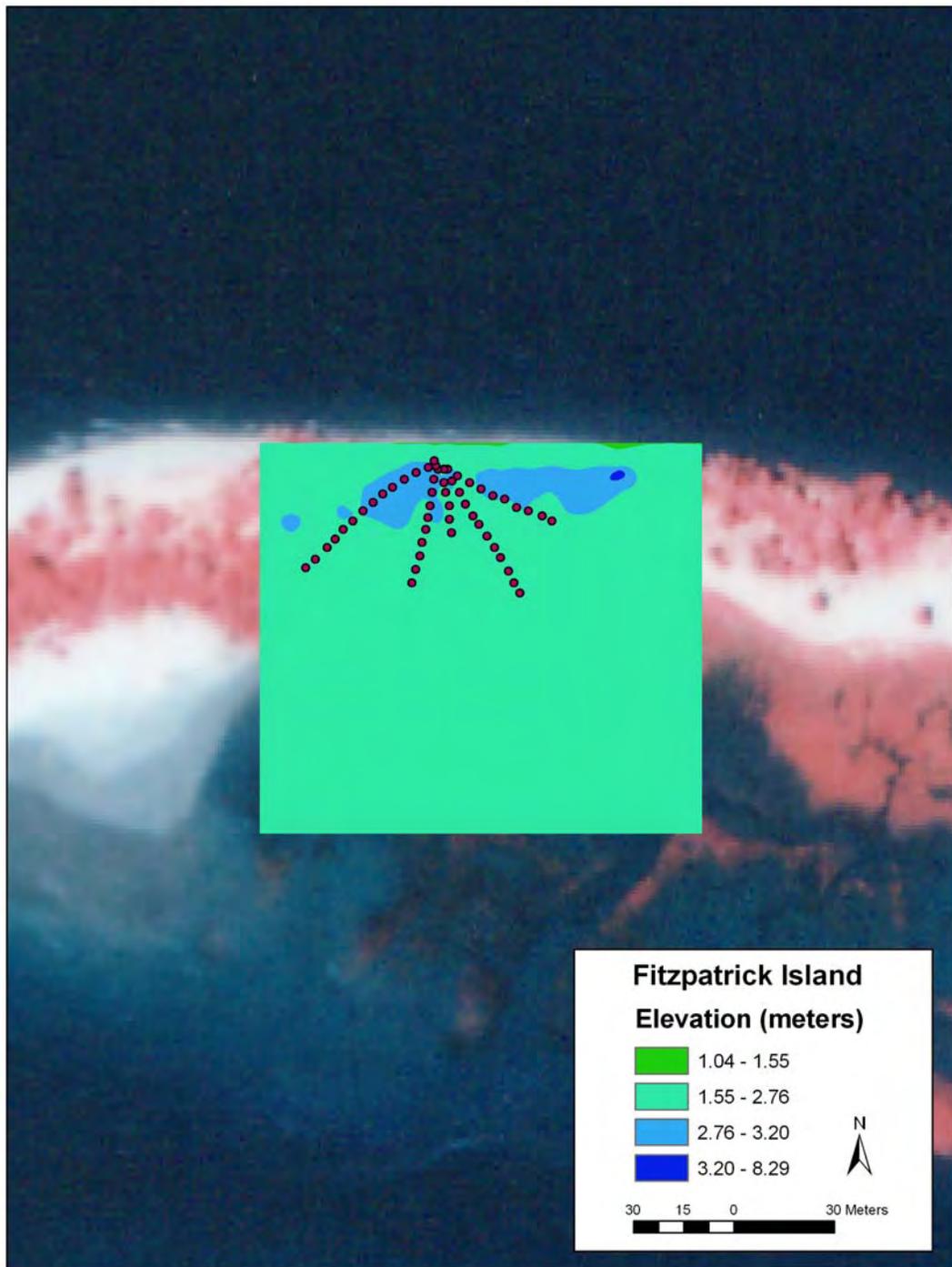


Figure 14 e. See Figure 14a for description.

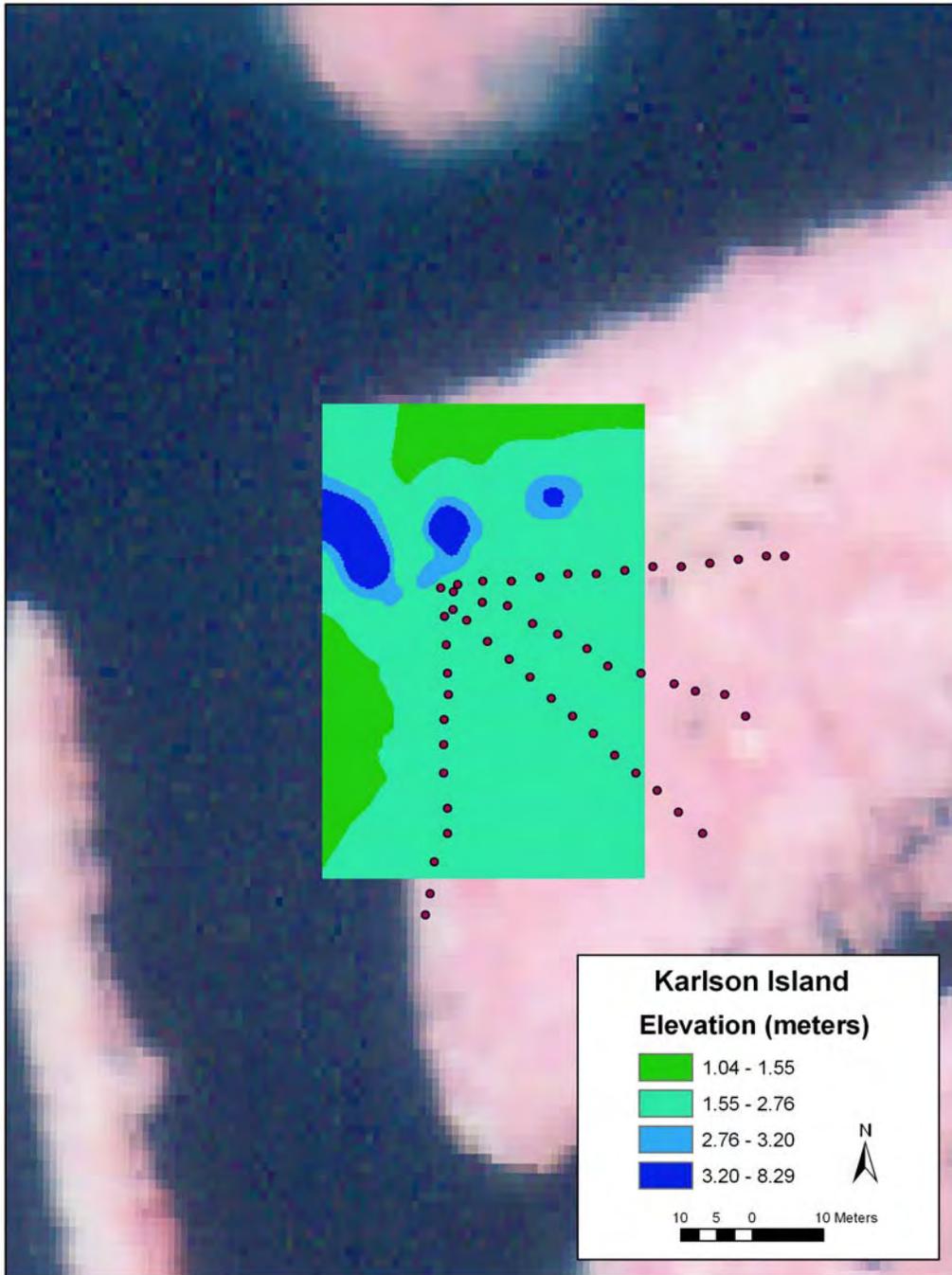


Figure 14 f. See Figure 14a for description.

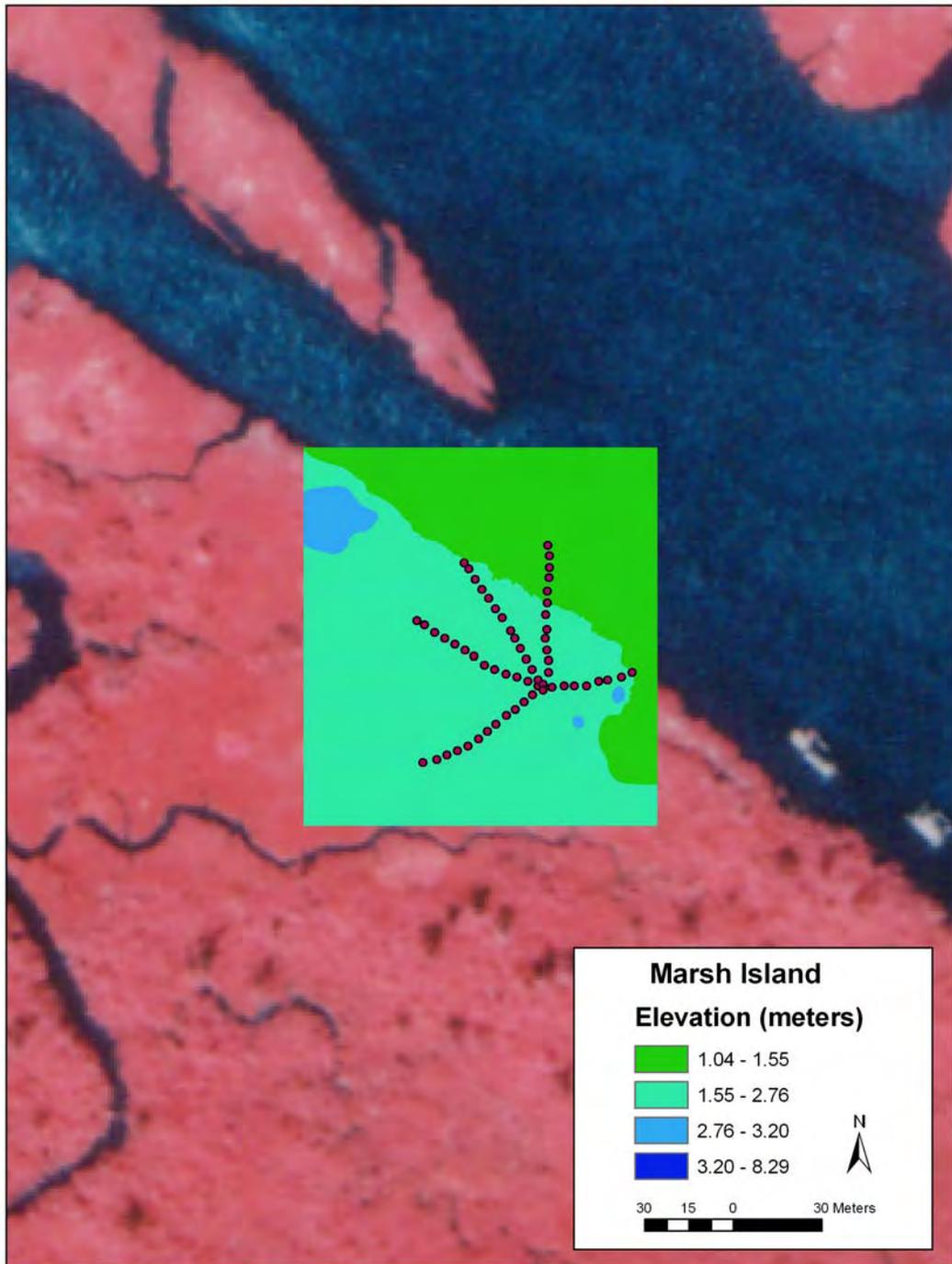


Figure 14 g. See Figure 14a for description.

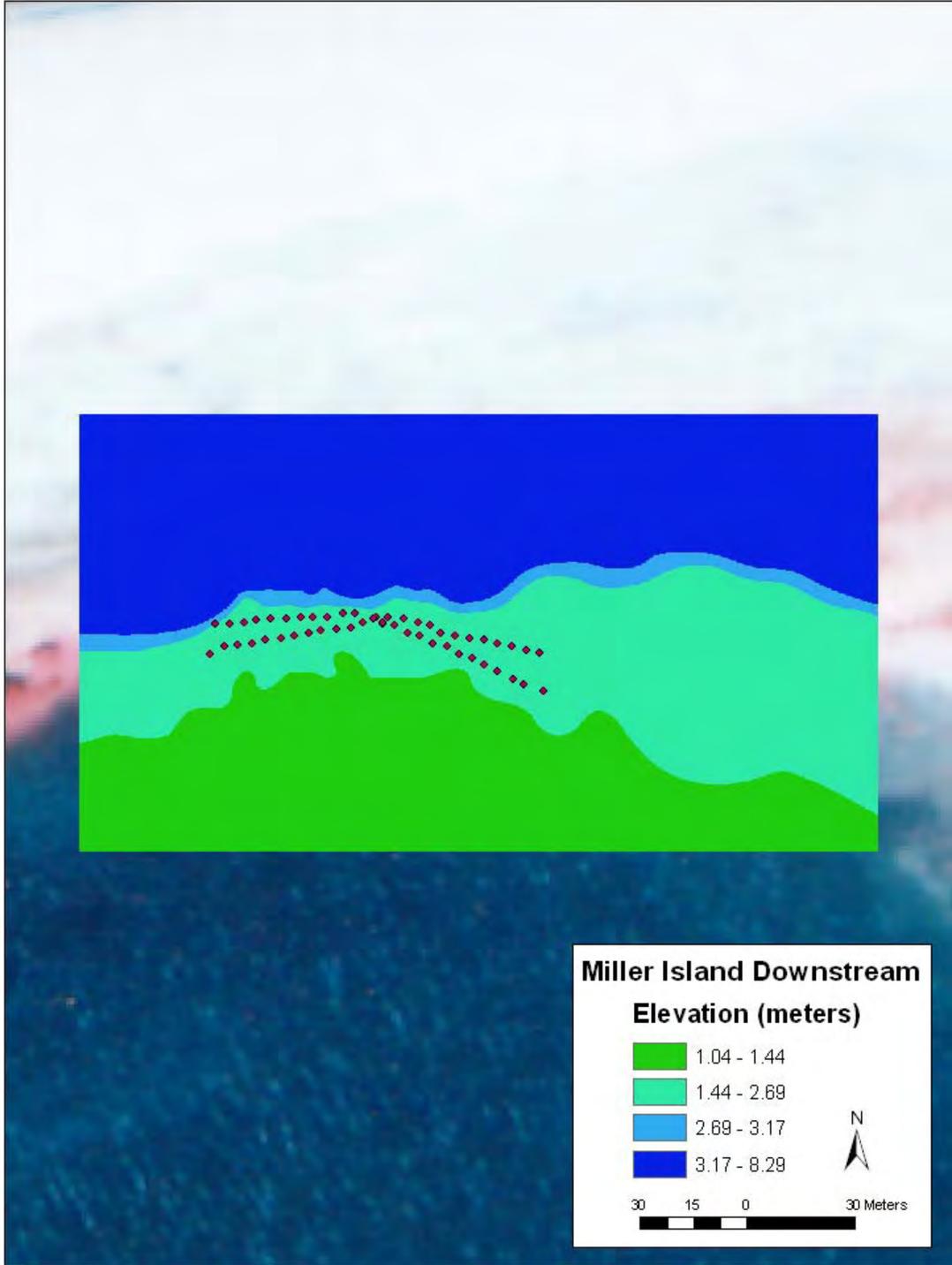


Figure 14 h. See Figure 14a for description.

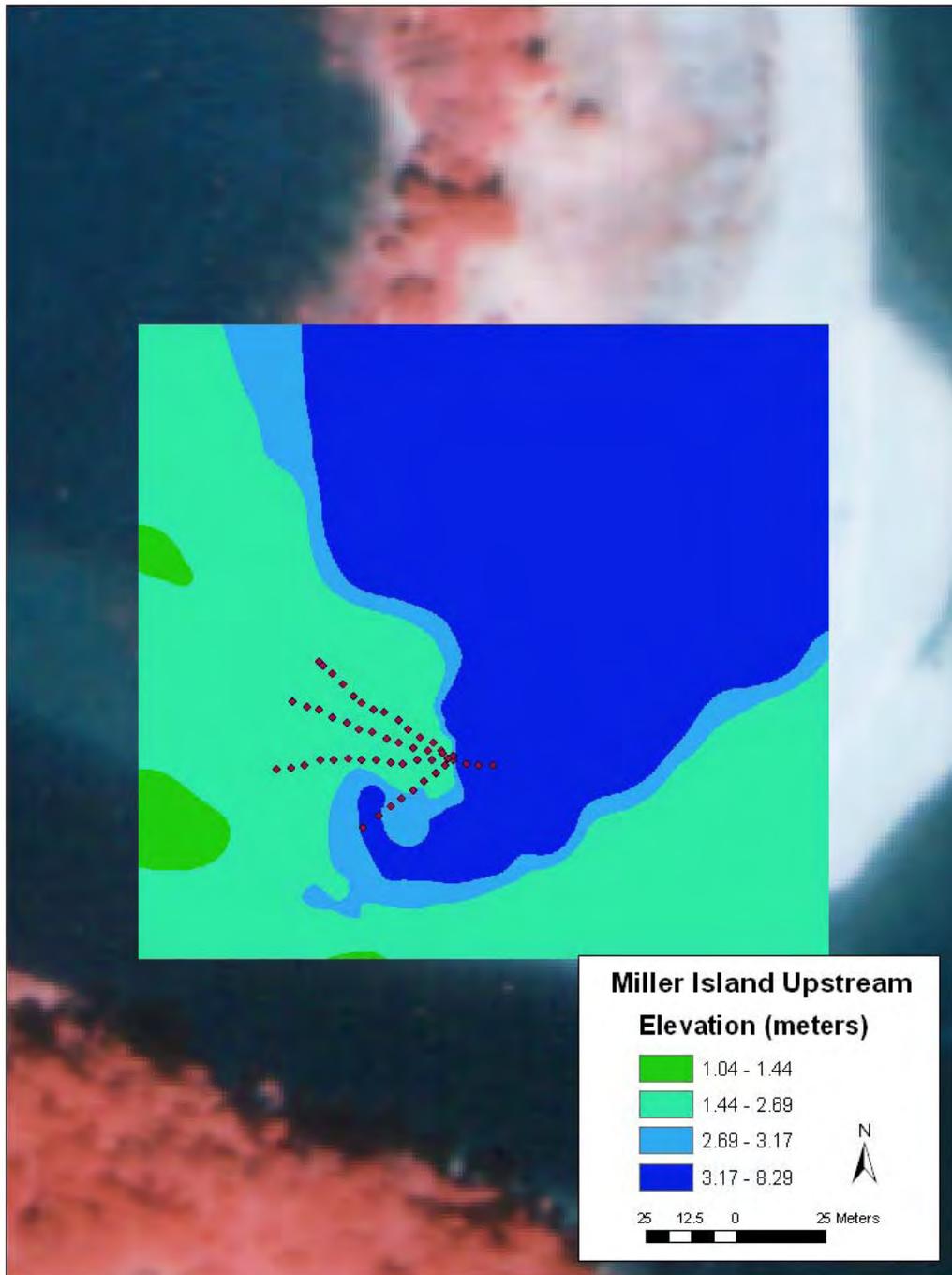


Figure 14 i. See Figure 14a for description.

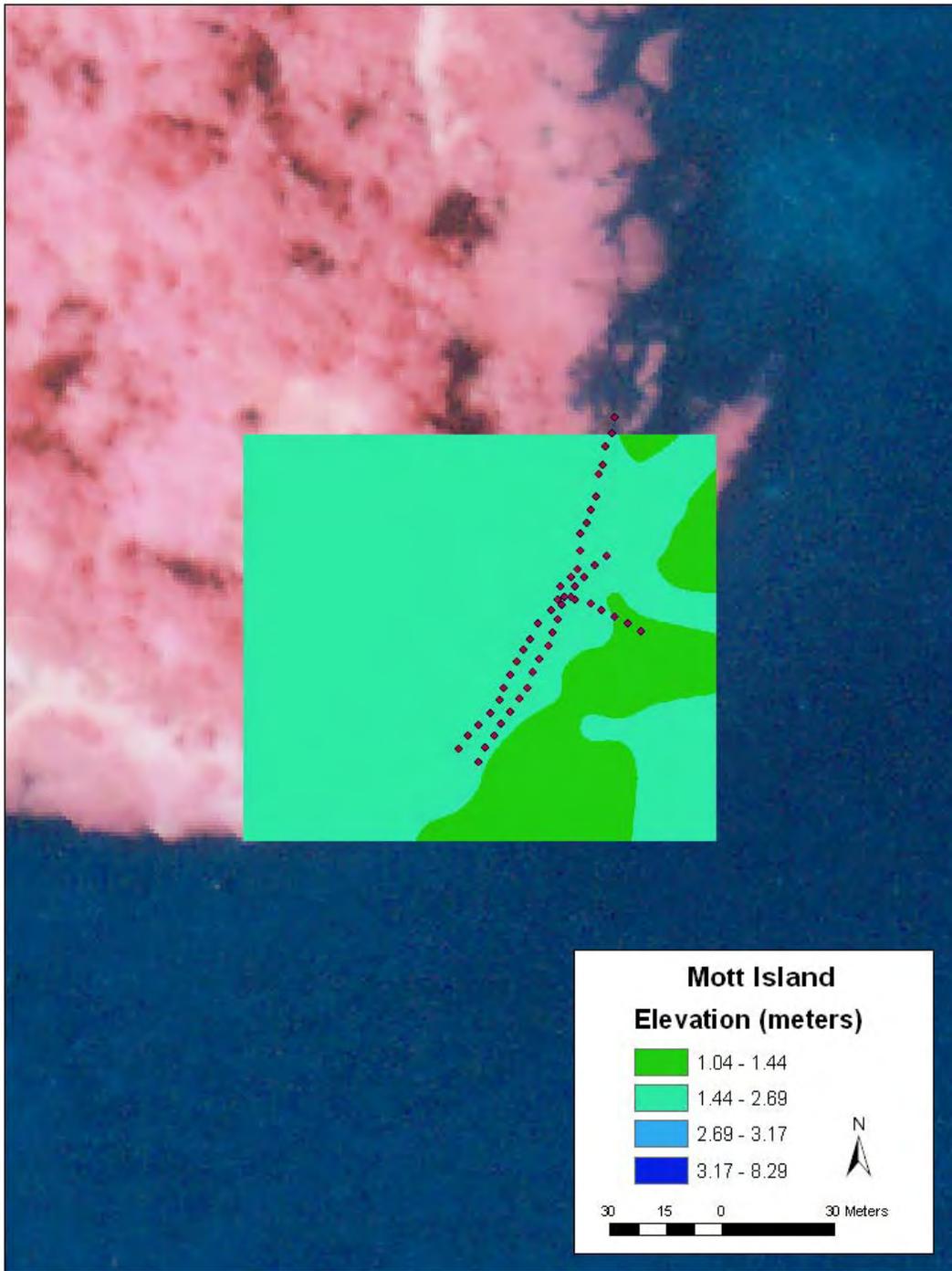


Figure 14 j. See Figure 14a for description.

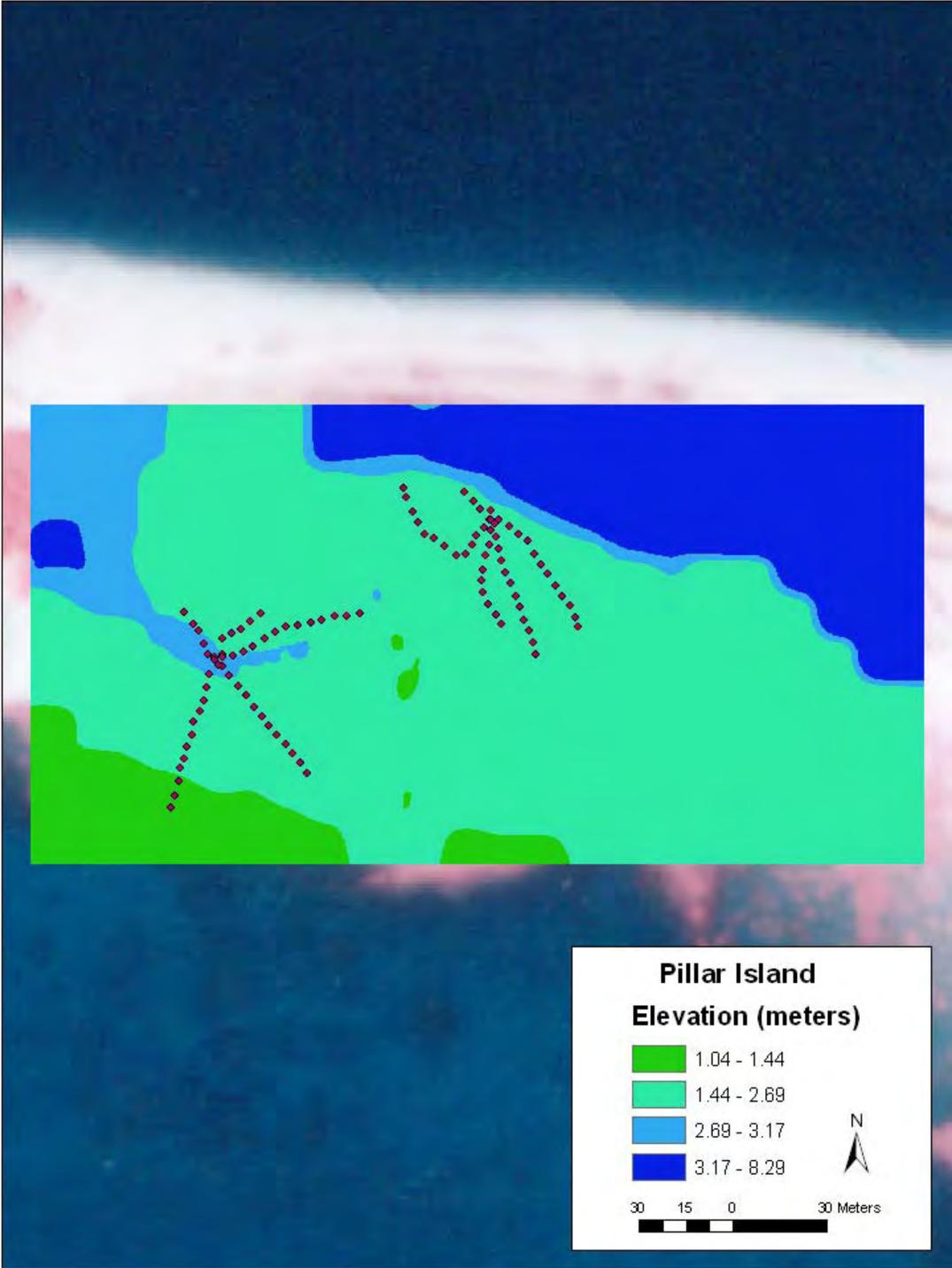


Figure 14 k. See Figure 14a for description.

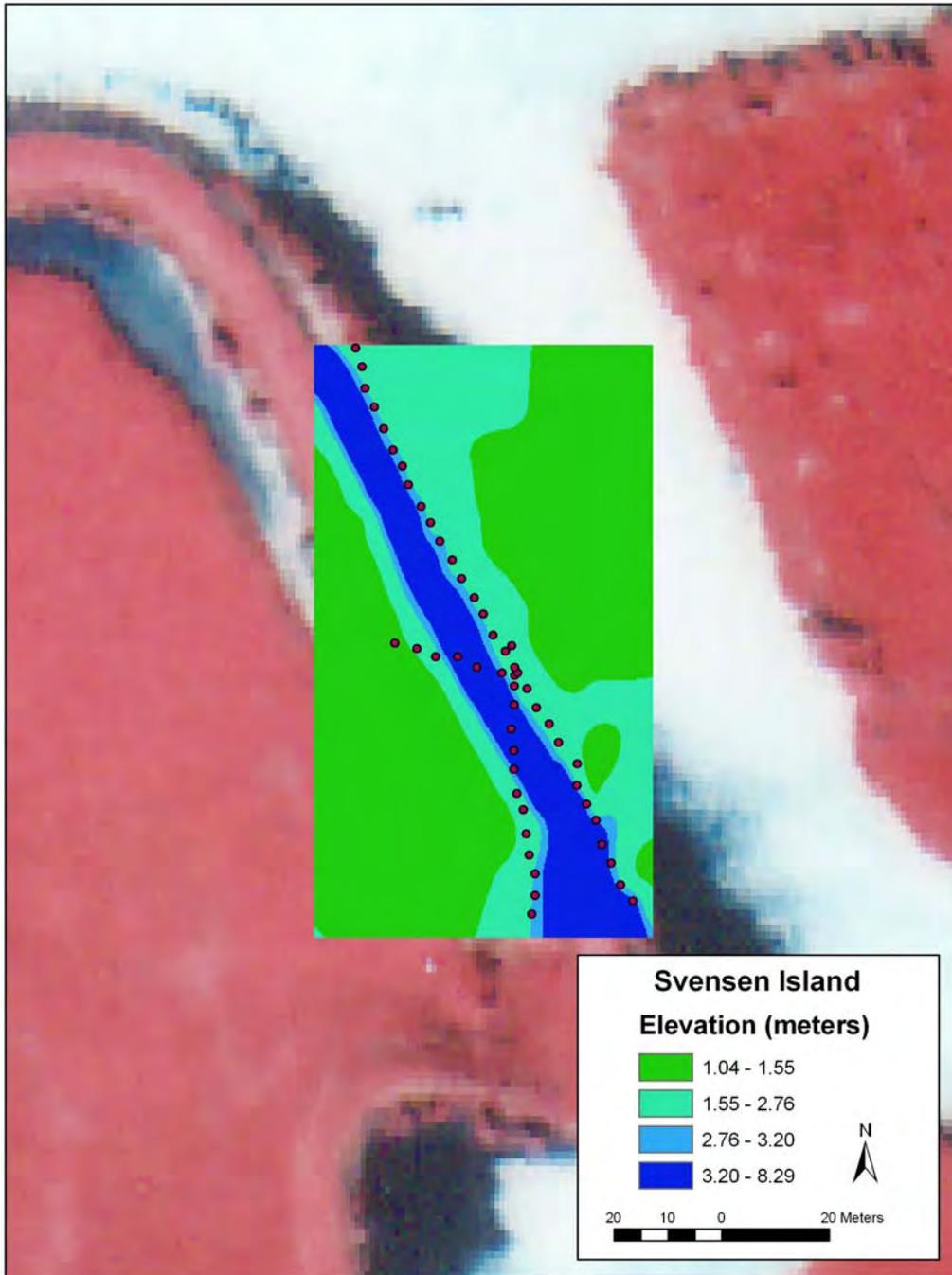


Figure 14.1. See Figure 14a for description.

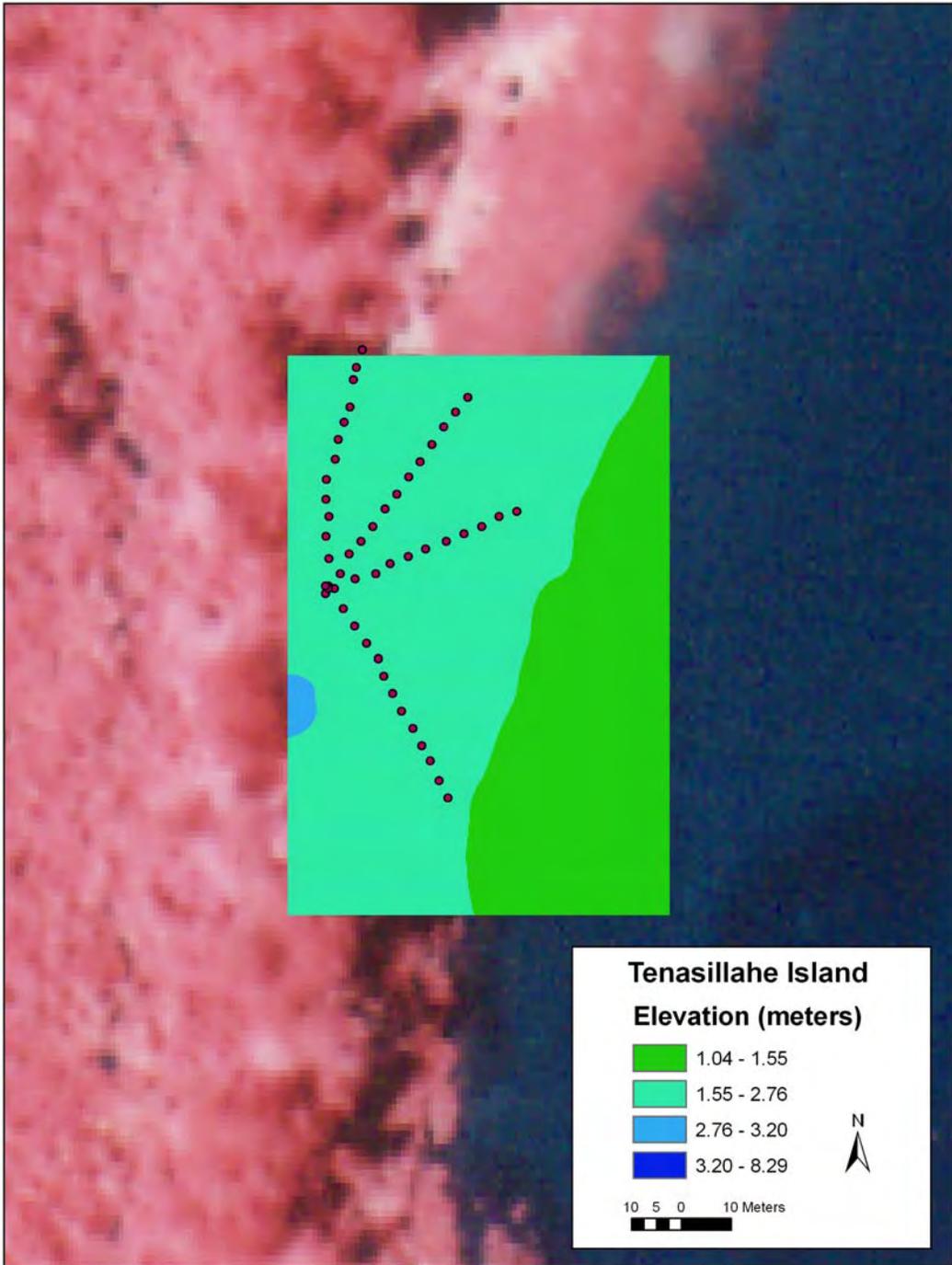


Figure 14 m. See Figure 14a for description.

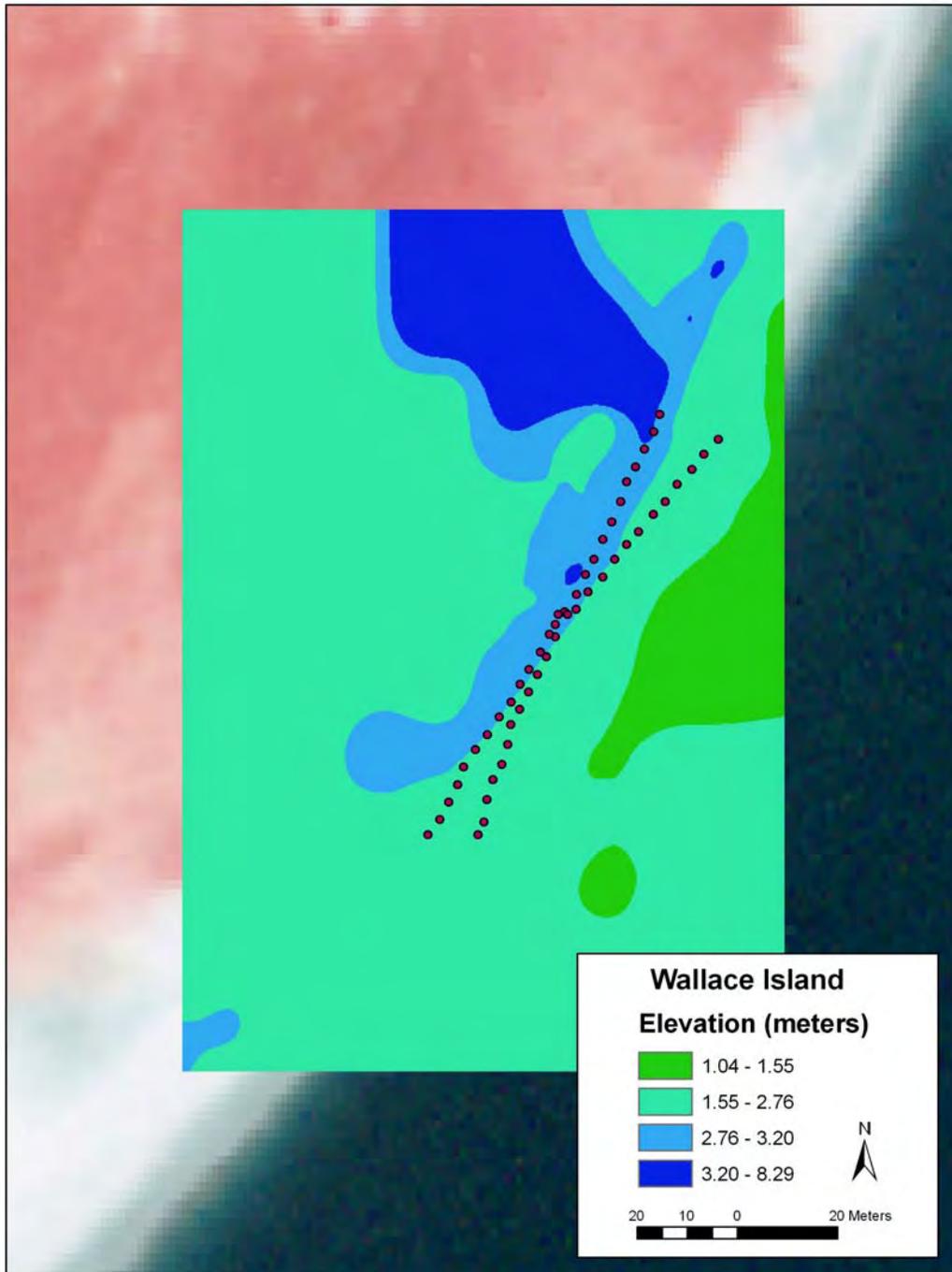
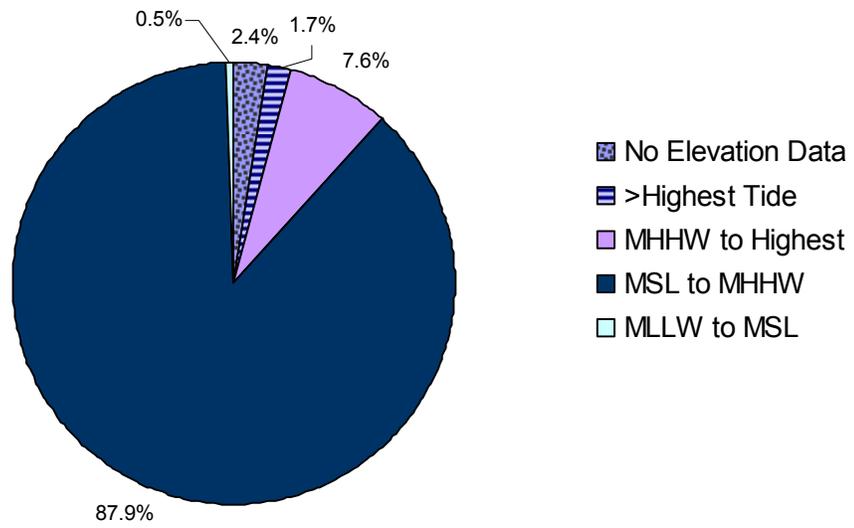


Figure 14 n. See Figure 14a for description.

Table 7. Correlations between quadrat elevation and presence of biocontrol agent observation for each of the 15 study sites are presented in the individual site summary documents. This table presents correlations across all sites. Significant correlations are noted with a single (0.05 two-tailed significance) or double asterisk (0.01 two-tailed significance). Overall, very few measures were significantly correlated with elevation.

|                       |        |                 | # GAPIU adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|-----------------------|--------|-----------------|---------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| All sites in June     | n=732  | Correlation     | 0.500         | -0.001       | -0.002     | 0.024         | 0.014       | 0.061       | 0.056         | 0.007         | -0.121**    | -0.067      |
|                       |        | Sig. (2-tailed) | 0.181         | 0.979        | 0.953      | 0.513         | 0.702       | 0.104       | 0.136         | 0.843         | 0.001       | 0.070       |
| All sites in July     | n=721  | Correlation     | 0.053         | 0.042        | -0.037     | 0.069         | 0.020       | 0.075*      | 0.003         | -0.011        | -0.111*     | -0.049      |
|                       |        | Sig. (2-tailed) | 0.151         | 0.254        | 0.324      | 0.062         | 0.585       | 0.043       | 0.940         | 0.761         | 0.003       | 0.186       |
| All sites June & July | n=1453 | Correlation     | 0.044         | 0.024        | -0.023     | 0.049         | 0.014       | 0.069**     | 0.039         | 0.004         | -0.113**    | -0.054      |
|                       |        | Sig. (2-tailed) | 0.094         | 0.355        | 0.381      | 0.061         | 0.601       | 0.009       | 0.135         | 0.876         | 0.000       | 0.041       |

## June



## July

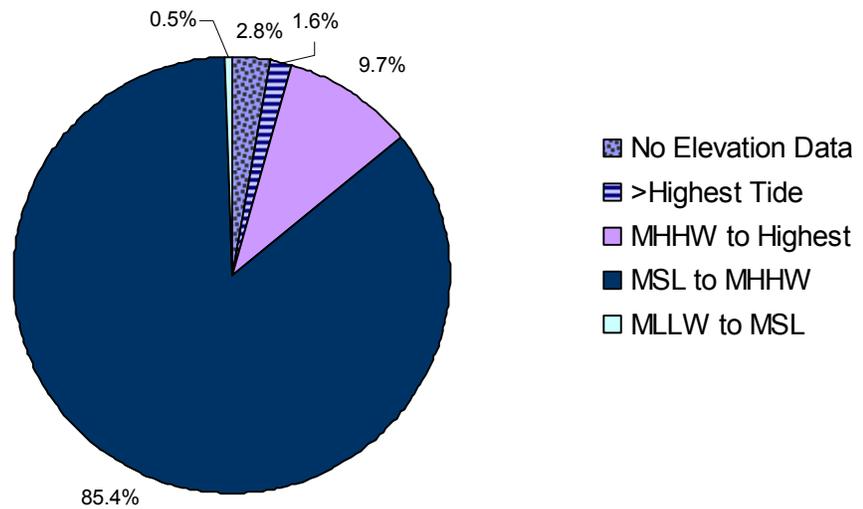
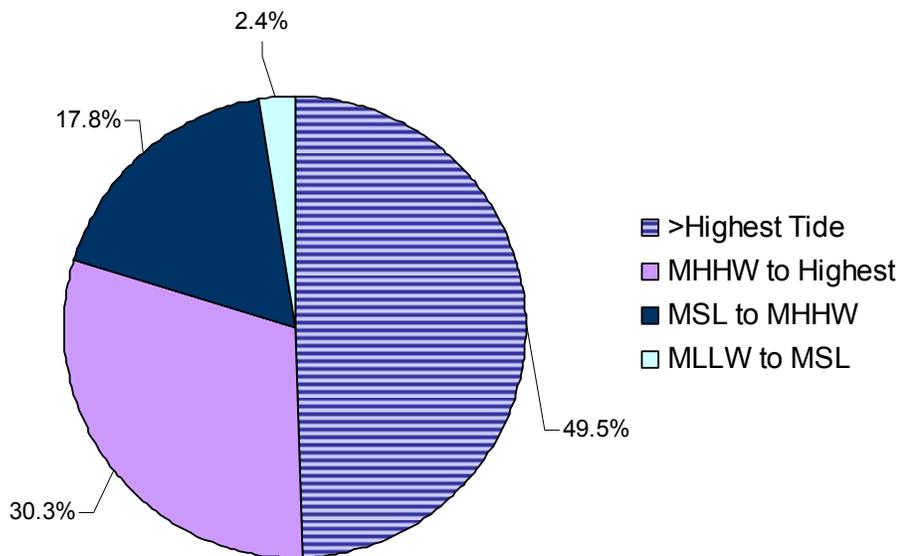


Figure 15. Proportion of quadrats with ground elevation falling into each tidal category. Only quadrats containing *Lythrum* are included.

**June**



**July**

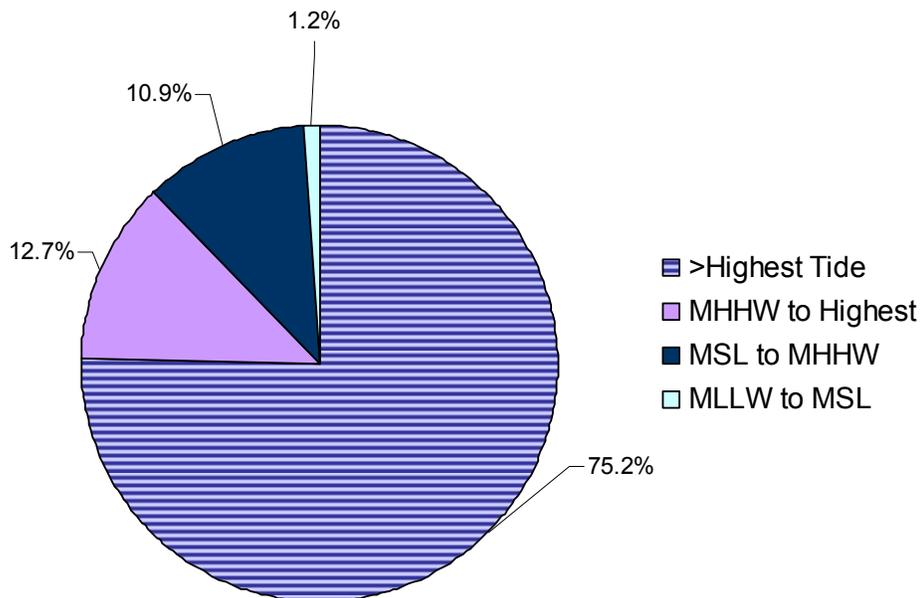


Figure 16. Proportion of quadrats with *Lythrum* tip elevation (ground elevation + mean stem length) falling into each tidal category. Only quadrats containing *Lythrum* are included.

### c. Relationship between *Galerucella* and Elevation

We also examined the tidal ranges of quadrats where biocontrol agents were observed (See **Appendices II**). Beetles were observed in quadrats with elevations above MSL through quadrats above the highest tide levels. Using the sum of all adult *Galerucella* beetles observed, we calculated the majority of beetles to be in quadrats with elevations between MSL and MHHW (**Table 8a-d**). As we stated above, this is the same tidal range where most of our sampling occurred and where the most purple loosestrife was observed. However beetles were not observed in the lowest elevations where sampling occurred, MLLW – MSL.

When we use the combined elevations of average *Lythrum* length added to quadrat elevation, we find most beetles were observed in quadrats above the highest water levels (3.2m NAVD88) (**Table 8a-d**). However, we did not find strong relationships between elevation and adult beetle presence when we considered all quadrats from all 15 sites (**Table 7**).

*Galerucella* larvae were also observed primarily in quadrats between MSL and MHHW (**Table 8a-d**). The remaining larvae were seen at elevations between MHHW – High Tide. No larvae were observed above the highest tide level or in lower elevation where quadrats were sampled (MLLW – MSL). When average plant length was added to quadrat elevation, the majority of larvae were also found in quadrats above the highest tide levels (**Table 8a-d**). However, we did not find strong relationships between elevation and the number of larvae on a quadrat by quadrat basis.

We did not find any relationship between elevation and the number of egg masses, when individual quadrats were examined (**Table 7**). We observed egg masses between MSL through elevations above the highest tide levels but almost all were found between MSL – MHHW (85% June and 86% July) (**Table 8a-d**). As with larvae and adults, egg masses were not observed in the lowest elevations sampled (MLLW – MSL). The majority of egg masses were found above 3.2m (above the highest tide levels), when mean purple loosestrife stem length was added to land elevation (**Table 8a-d**).

Although the majority of beetles (adults, larvae, and eggs) were found at elevations greater than the level of the highest tides (3.2m) when considering plant lengths, we did not explicitly sample across a wide range of elevations. Therefore, our results, based on simple correlations, may not be conclusive. We recommend that the relationship between beetle numbers and inundation be experimentally examined.

Table 8A & 8B. Distribution of observations of *Galerucella* with respect to tidal categories with consideration to elevation only and elevation combined with mean plant stem lengths. 8A. Sums of adult *Galerucella* beetles observed; 8B. Sums of *Galerucella* egg masses.

| <b>A. <i>Galerucella</i> Adult Sums Observed in Tide Categories for All Quadrats</b>    |  |                                  |                              |  |                                  |                              |
|---|--|----------------------------------|------------------------------|--|----------------------------------|------------------------------|
|   | Elevation Only                           |                                  |                              | Elevation & Stem Lengths Combined        |                                  |                              |
|   | Number of Quadrats within Tidal Category | Number of Adults within Quadrats | Proportion of Total Quadrats | Number of Quadrats within Tidal Category | Number of Adults within Quadrats | Proportion of Total Quadrats |
| <b>June</b>   |  |                                  |                              |  |                                  |                              |
| >Highest  | 22                                       | 3                                | 17.6                         | 224                                      | 12                               | 70.6                         |
| MHHW to Highest   | 73                                       | 0                                | 0                            | 169                                      | 3                                | 17.6                         |
| MSL to MHHW   | 608                                      | 12                               | 70.6                         | 312                                      | 0                                | 0                            |
| MLLW to MSL   | 18                                       | 0                                | 0                            | 26                                       | 2                                | 11.8                         |
| Lowest to MLLW  | 0  | 0                                | 0                            | 33                                       | 0                                | 0                            |
| N/A   | 43                                       | 2                                | 11.8                         | 0  | 0                                | 0                            |
| Total   | 764                                      | 17                               | 100                          | 764                                      | 17                               | 100                          |
| <b>July</b>   |  |                                  |                              |  |                                  |                              |
| >Highest  | 19                                       | 1                                | 1.7                          | 337                                      | 51                               | 86.4                         |
| MHHW to Highest   | 76                                       | 1                                | 1.7                          | 89                                       | 4                                | 6.8                          |
| MSL to MHHW   | 612                                      | 57                               | 96.6                         | 290                                      | 4                                | 6.8                          |
| MLLW to MSL   | 25                                       | 0                                | 0                            | 28                                       | 0                                | 0                            |
| Lowest to MLLW  | 0  | 0                                | 0                            | 19                                       | 0                                | 0                            |
| N/A   | 31                                       | 0                                | 0                            | 0  | 0                                | 0                            |
| Total   | 763                                      | 59                               | 100                          | 763                                      | 59                               | 100                          |
| <b>B. <i>Galerucella</i> Egg Mass Sums Observed in Tide Categories for All Quadrats</b> |  |                                  |                              |  |                                  |                              |
|   | Elevation Only                           |                                  |                              | Elevation & Stem Lengths Combined        |                                  |                              |
|   | Number of Quadrats within Tidal Category | Number of Eggs within Quadrats   | Proportion of Total Quadrats | Number of Quadrats within Tidal Category | Number of Eggs within Quadrats   | Proportion of Total Quadrats |
| <b>June</b>   |  |                                  |                              |  |                                  |                              |
| >Highest  | 22                                       | 13                               | 7.0                          | 224                                      | 161                              | 86.6                         |
| MHHW to Highest   | 73                                       | 0                                | 0.0                          | 169                                      | 5                                | 2.7                          |
| MSL to MHHW   | 608                                      | 158                              | 84.9                         | 312                                      | 5                                | 2.7                          |
| MLLW to MSL   | 18                                       | 0                                | 0.0                          | 26                                       | 13                               | 7.0                          |
| Lowest to MLLW  | 0  | 0                                | 0.0                          | 33                                       | 2                                | 1.1                          |
| N/A   | 43                                       | 15                               | 8.1                          | 0  | 0                                | 0.0                          |
| Total   | 764                                      | 186                              | 100                          | 764                                      | 186                              | 100                          |
| <b>July</b>   |  |                                  |                              |  |                                  |                              |
| >Highest  | 19                                       | 0                                | 0.0                          | 337                                      | 350                              | 98.3                         |
| MHHW to Highest   | 76                                       | 49                               | 13.8                         | 89                                       | 6                                | 1.7                          |
| MSL to MHHW   | 612                                      | 307                              | 86.2                         | 290                                      | 0                                | 0.0                          |
| MLLW to MSL   | 25                                       | 0                                | 0.0                          | 28                                       | 0                                | 0.0                          |
| Lowest to MLLW  | 0  | 0                                | 0.0                          | 19                                       | 0                                | 0.0                          |
| N/A   | 31                                       | 0                                | 0.0                          | 0  | 0                                | 0.0                          |
| Total   | 763                                      | 356                              | 100                          | 763                                      | 356                              | 100                          |

Table 8C & 8D. Distribution of observations of *Galerucella* with respect to tidal categories with consideration to elevation only and elevation combined with mean plant stem lengths. 8C. *Galerucella* larvae; and 8D. Percent *Galerucella* damage.

| <b>C. <i>Galerucella</i> Larvae Sums Observed in Tide Categories for All Quadrats</b>         |  |                                  |                        |  |                                  |                        |
|---|--|----------------------------------|------------------------|--|----------------------------------|------------------------|
|   | Elevation Only                           |                                  |                        | Elevation & Stem Lengths Combined        |                                  |                        |
|   | Number of Quadrats within Tidal Category | Number of Larvae within Quadrats | Proportion of Quadrats | Number of Quadrats within Tidal Category | Number of Larvae within Quadrats | Proportion of Quadrats |
| <b>June</b>   |  |                                  |                        |  |                                  |                        |
| >Highest  | 22                                       | 0                                | 0.0                    | 224                                      | 243                              | 88.0                   |
| MHHW to Highest   | 73                                       | 1                                | 0.5                    | 169                                      | 16                               | 5.8                    |
| MSL to MHHW   | 608                                      | 262                              | 95.0                   | 312                                      | 4                                | 1.4                    |
| MLLW to MSL   | 18                                       | 0                                | 0.0                    | 26                                       | 11                               | 4.0                    |
| Lowest to MLLW  | 0  | 0                                | 0.0                    | 33                                       | 2                                | 0.7                    |
| N/A   | 43                                       | 13                               | 4.5                    | 0  | 0                                | 0.0                    |
| Total   | 764                                      | 276                              | 100                    | 764                                      | 276                              | 100                    |
| <b>July</b>   |  |                                  |                        |  |                                  |                        |
| >Highest  | 19                                       | 0                                | 0.0                    | 337                                      | 2                                | 100.0                  |
| MHHW to Highest   | 76                                       | 1                                | 50.0                   | 89                                       | 0                                | 0.0                    |
| MSL to MHHW   | 612                                      | 1                                | 50.0                   | 290                                      | 0                                | 0.0                    |
| MLLW to MSL   | 25                                       | 0                                | 0.0                    | 28                                       | 0                                | 0.0                    |
| Lowest to MLLW  | 0  | 0                                | 0.0                    | 19                                       | 0                                | 0.0                    |
| N/A   | 31                                       | 0                                | 0.0                    | 0  | 0                                | 0.0                    |
| Total   | 763                                      | 2                                | 100                    | 763                                      | 2                                | 100                    |
| <b>D. Percent <i>Galerucella</i> Damage Sums Observed in Tide Categories for All Quadrats</b> |  |                                  |                        |  |                                  |                        |
|   | Elevation Only                           |                                  |                        | Elevation & Stem Lengths                 |                                  |                        |
|   | Number of Quadrats within Tidal Category | Percent Damage within Quadrats   | Proportion of Quadrats | Number of Quadrats within Tidal Category | Percent Damage within Quadrats   | Proportion of Quadrats |
| <b>June</b>   |  |                                  |                        |  |                                  |                        |
| >Highest  | 22                                       | 3                                | 0.8                    | 224                                      | 314                              | 84.2                   |
| MHHW to Highest   | 73                                       | 14                               | 3.8                    | 169                                      | 34                               | 9.1                    |
| MSL to MHHW   | 608                                      | 344                              | 92.2                   | 312                                      | 13                               | 3.5                    |
| MLLW to MSL   | 18                                       | 0                                | 0.0                    | 26                                       | 12                               | 3.2                    |
| Lowest to MLLW  | 0  | 0                                | 0.0                    | 33                                       | 0                                | 0.0                    |
| N/A   | 43                                       | 12                               | 3.2                    | 0  | 0                                | 0.0                    |
| Total   | 764                                      | 373                              | 100                    | 764                                      | 373                              | 100                    |
| <b>July</b>   |  |                                  |                        |  |                                  |                        |
| >Highest  | 19                                       | 4                                | 1.1                    | 337                                      | 323                              | 90.0                   |
| MHHW to Highest   | 76                                       | 20                               | 5.6                    | 89                                       | 21                               | 5.8                    |
| MSL to MHHW   | 612                                      | 323                              | 90.0                   | 290                                      | 8                                | 2.2                    |
| MLLW to MSL   | 25                                       | 0                                | 0.0                    | 28                                       | 7                                | 1.9                    |
| Lowest to MLLW  | 0  | 0                                | 0.0                    | 19                                       | 0                                | 0.0                    |
| N/A   | 31                                       | 12                               | 3.3                    | 0  | 0                                | 0.0                    |
| Total   | 763                                      | 359                              | 100                    | 763                                      | 359                              | 100                    |

Damage from *Galerucella*, as indirect evidence of biocontrol agent presence, appears to be weakly, but positively related to quadrat elevation (July Pearson  $r^2=0.075$ ,  $p=0.043$ ; June & July  $r^2=0.069$ ,  $p=0.009$ ; **Table 7**). We encountered *Galerucella* damage from MSL through the highest elevations sampled (1.55 – >3.2m; **Table 8a-d**). No damage was observed in the lowest elevations (MLLW – MSL). As with the other field measures, damage from *Galerucella* was most frequently observed in quadrats found between MSL and MHHW. The majority also shifted to elevations above the highest tide when average plant lengths were added (**Table 8a-d**). As with the adults, larvae, and eggs, the trends in damage are likely related to the fact that the majority of our quadrats were between MSL and MHHW.

Statistical comparisons of the number of *Galerucella* egg masses, total number of all *Galerucella* species adults, number of *Galerucella* larvae, and percent *Galerucella* damage revealed no statistically significant differences in these numbers amongst the six tidal elevation categories. This was true for all June quadrats and also for all July quadrats.

#### **d. Shrub and Forest Cover as Refugia**

We used three different information resources to examine the patterns in landcover around each of the 15 study sites. Landsat 7 ETM+, CASI, and Color Infrared Photography were used to measure the distance between the release point and shrub/ forest cover. We found considerable heterogeneity in land cover, specifically shrub and forest cover, at each study site. We speculate that shrub and forest cover may serve as refuge for biocontrol agents during tidal flooding and may mitigate water velocities during tidal inundation.

We found that, in general, shrubby cover was closer than forest cover at 11 of the 15 release points (**Table 9**). In fact, using Landsat 7 ETM+ data, release points at Marsh and Fitzpatrick Islands were actually within an area of shrubby vegetation (**Table 9**). In addition, we found that areas of shrub cover were further from release points than areas of high ground (>3.2m in elevation). The average distance to shrub cover from the release point was 84m across all sites, compared to 26m for high ground (**Table 9**). The average distance to forest was 280 m when measured on Landsat 7 ETM+ data (Median distance 220m, S.D.+/- 207m). Our field observations show that woody vegetation typically consists of a combination of *Salix* spp., *Alnus rubra*, and *Populus* spp.

We examined land cover around each release point within 50, 100, 250, and 500m buffers radiating from release points. At most sites, the dominant land cover types within 50 and 100m buffers included herbaceous plants, mud and sand (other), and open water. Only at Mott, Marsh, and Tenasillahe Islands did shrubby cover dominate within the 50 and 100m buffers around the release point (**Table 10**). Shrubby cover was also dominate within the 100m buffer at Devil's Elbow (**Table 10**).

As described above, observations of *Galerucella* adults, egg masses, and larvae were totaled across all quadrats sampled at each of the 15 study sites, yielding a single number for each life stage at each site. These fifteen sums were then plotted as a function of the distance to high ground (elevations >3.2m) measured from the release point, the distance to shrubby land cover measured from the release point, and the distance to forest land cover measured from the release point to further explore possible relationships between these variables. We did observe a smaller total number of *Galerucella* adults at sites where high ground was further from the release point (**Figures 17a-i, 18a-i**). However, there does not appear to be any strong relationship between the total number of *Galerucella* adults and the distance to shrub or forest cover among the sites (**Figures 17a-i, 18a-i**). At a cursory level, there also does not appear to be any strong relationship between the sum of larvae or egg masses and the distance to shrub, forest, or high ground from the release point.

#### **e. Trends in *Lythrum* Damage**

Across all quadrats sampled in June, observations of *Galerucella* adults, damage, larvae, and egg masses appear to be similar, regardless of distance from release point, with only slightly higher observations at 10m or less from the release point (**Figures 19a-b**). The same is true for July. Some of the observations of life stages increased at quadrats located 50-100m from the release point. However, this trend appears to be due to data from Svensen Island only. We then looked specifically at biocontrol agent observations at Dry Dock, Svensen, and Devil's Elbow study sites because they had higher evidence of agents (**Figures 20a-c, 21a-c, 22a-c**). From these three sites, on average, the highest number of observations was within 10m of the release stake.

## f. Helicopter Videography of Transects

Thirty-five helicopter transects were flown in order to collect digital imagery to evaluate percent cover of purple loosestrife (See **Appendix II**). The average percent cover observed in the 474 frames of all transects was 19% +/- S.D. 27% (**Table 11**). The range in cover included sites with no loosestrife, to areas with 100% cover. The highest average of percent cover observed during the video transects was 81% for Transect 23 when averaged across all frames along that transect (**Table 11**). Four of the 35 transects had no purple loosestrife present. Almost half (44%) of all frames from all 35 transects had no purple loosestrife present. The next most frequent coverage assigned to transect frames was 1-25% (**Table 11**). Even smaller numbers of frames were observed in the higher coverage categories (26-50%, 51-75%, and 76-100%)-13% of frames, 9% of frames, and 7% of frames, respectively (**Table 11**).

To assess the quality of our video interpretation and understand the frequency of observer error, we had a second observer estimate percent coverage of *Lythrum* on five of the thirty-five video transects. The difference between observers is presented graphically in **Figure 23**. Because the boundaries of each frame are tied to time in hundredths of a second, it is difficult to perform observations on the exact same frame each and every time. Therefore some large errors can occur in percent *Lythrum* coverage by a simple one second difference in time when the frame starts. Despite this difficulty, for the majority of frames the difference between observers was 4% or less. This indicates significant agreement between observers when you remember 4% is equivalent to a difference in presence or absence of *Lythrum* within 1 of 25 grid cells within a frame.

Table 9. Summary of the distance to shrub and/or forest cover, and distance to land with elevations greater than the highest tides (3.2m) from release point at the fifteen study sites. Cover class abbreviations are as follows: W= scrub/shrub wetland, U= scrub/shrub upland, DW= deciduous forest wetland, DU= deciduous forest upland, CW= coniferous forest wetland, CU= coniferous forest upland, MW= mixed forest wetland, MU= mixed forest upland, WT= scrub/shrub wetland tidal, WD= scrub/shrub wetland diked, and DFWT= deciduous forest wetland tidal. CASI data are only available for three of the 15 sites (Garono et al. 2003b). *Landsat 7 ETM+ data courtesy of Garono et al. 2003a and CIR photos from USACE and LCREP 2001.*

| Study Site     | RTK              |                   | Landsat ETM+                |       |                        |       | CIR                                | CASI                        |       |                        |       |
|----------------|------------------|-------------------|-----------------------------|-------|------------------------|-------|------------------------------------|-----------------------------|-------|------------------------|-------|
|                | Distance to 3.2m | Distance to 2.76m | Distance to Scrub Shrub (m) | Class | Distance to Forest (m) | Class | Distance to Scrub Shrub/Forest (m) | Distance to Scrub Shrub (m) | Class | Distance to Forest (m) | Class |
| Devil's Elbow  | 4.8              | 2.6               | 36.4                        | W     | 623.0                  | DU    | 11.2                               |                             |       |                        |       |
| DryDock        | 25.3             | 4.0               | 49.0                        | U     | 43.9                   | DU    | 44.2                               |                             |       |                        |       |
| Eureka DS      | 16.9             | 0.0               | 128.1                       | U     | 173.4                  | DU    | 188.9                              |                             |       |                        |       |
| Eureka US      | 0.0              | 0.0               | 186.7                       | U     | 302.4                  | CU    | 32.7                               |                             |       |                        |       |
| Fitzpatrick    | 52.9             | 0.7               | 0.0                         | W     | 592.9                  | CW    | 24.4                               |                             |       |                        |       |
| Karlson        | 4.6              | 0.7               | 50.1                        | W     | 388.6                  | CU    | 33.9                               |                             |       |                        |       |
| Marsh          | N/A              | 14.5              | 0.0                         | W     | 289.5                  | DU    | 0.0                                |                             |       |                        |       |
| Miller DS      | 6.1              | 3.1               | 214.2                       | W     | 670.4                  | CW    | 18.5                               | 13.6                        | WT    | 87.6                   | DFWT  |
| Miller US      | 1.0              | 0.0               | 72.0                        | W     | 124.0                  | MU    | 56.0                               | 47.2                        | WT    | 56.0                   | DFWT  |
| Mott           | N/A              | N/A               | 73.1                        | U     | 60.9                   | CW    | 41.3                               |                             |       |                        |       |
| Pillar DS      | 53.4             | 27.6              | 57.4                        | W     | 216.7                  | CU    | 25.7                               |                             |       |                        |       |
| Pillar US      | 132.7            | 3.8               | 19.5                        | W     | 284.4                  | CU    | 26.9                               |                             |       |                        |       |
| Svensen        | 2.6              | 1.4               | 93.4                        | W     | 31.1                   | CW    | 29.4                               | 23.8                        | WD    | 25.3                   | DU    |
| Tenasillahe    | N/A              | 7.8               | 21.1                        | W     | 186.0                  | DU    | 0.0                                |                             |       |                        |       |
| Wallace        | 9.0              | 0.0               | 265.9                       | U     | 220.2                  | DU    | 251.9                              |                             |       |                        |       |
| All Sites Avg. | 25.8             | 4.7               | 84.5                        |       | 280.5                  |       | 52.3                               | 28.2                        |       | 56.3                   |       |

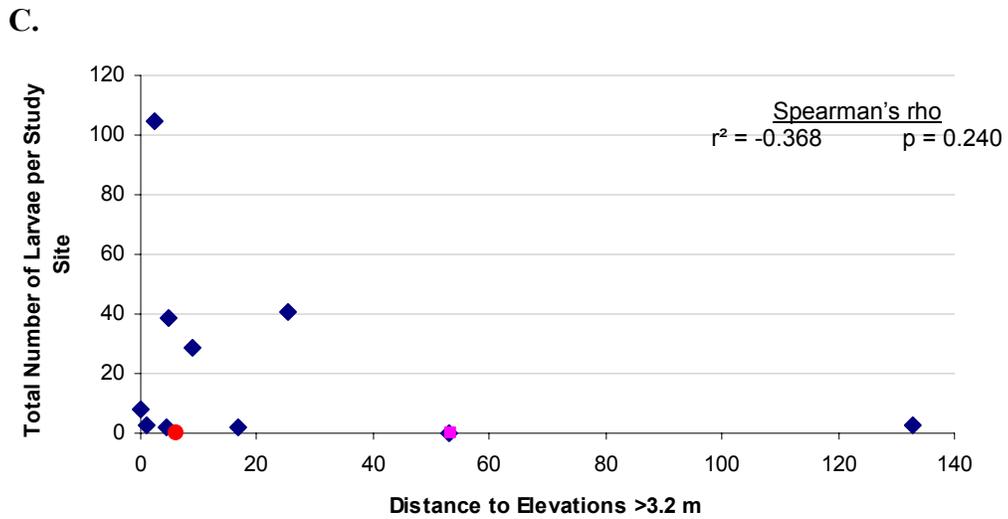
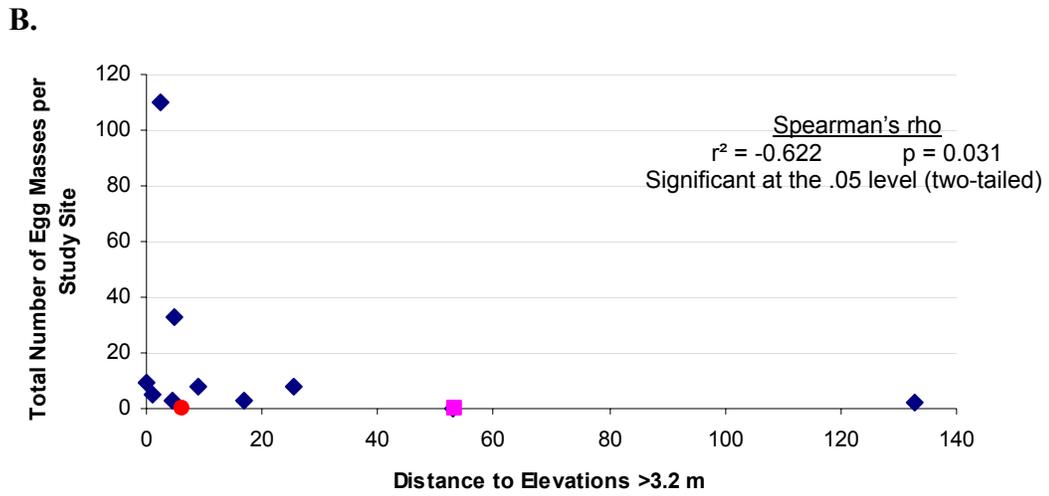
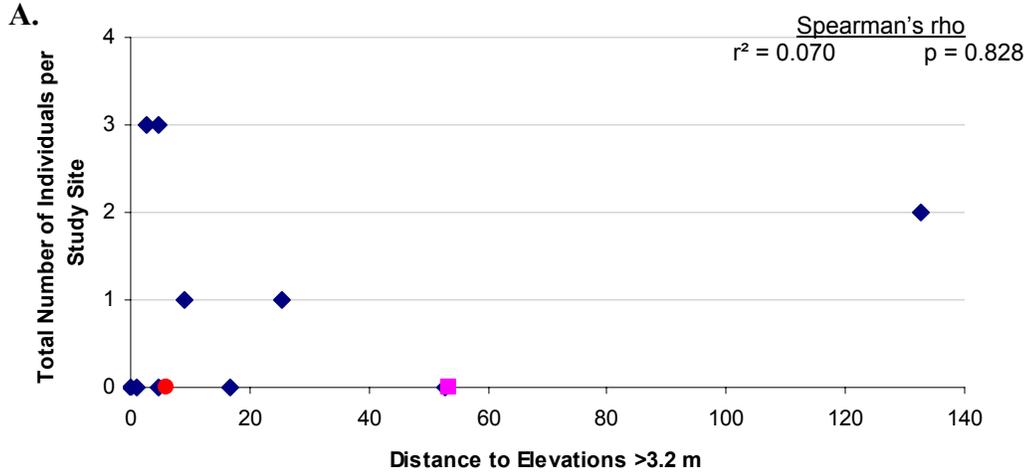
Table 10. Landsat 7 ETM+ imagery was used to create this vegetative summary across the 15 study sites as a function of distance from release point. The buffers are continuous from release point, e.g., the 50m buffer includes all areas within a 50m diameter circle with the release point in the center; the 100m buffer includes all areas within a 100m diameter circle, etc. The “Other” category consists of mud and sand.

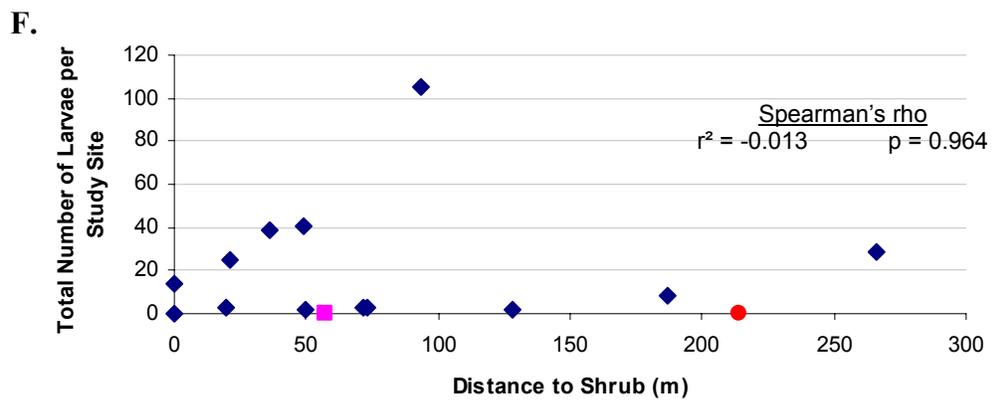
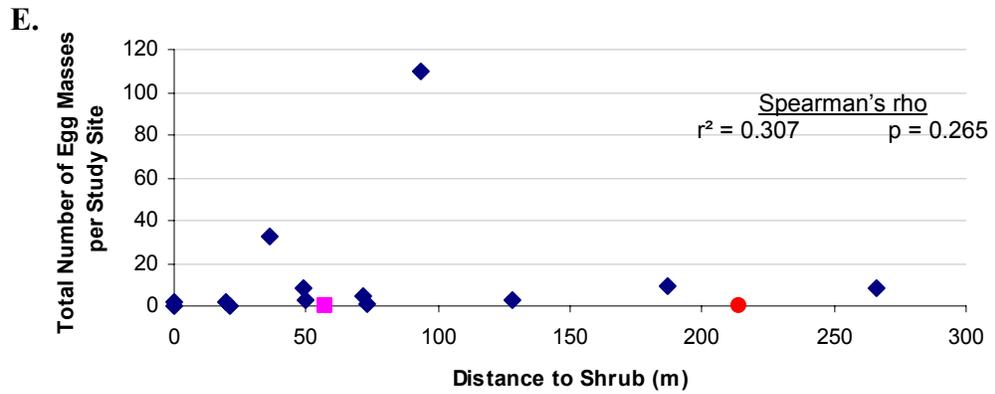
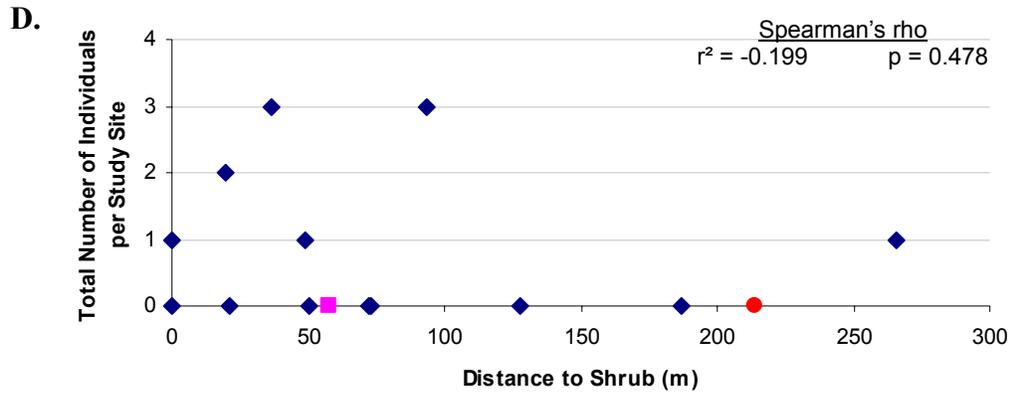
|                  | <b>50 m buffer around each release point</b>  |                |                 |                   |              | <b>100 m buffer around each release point</b> |                |                 |                   |              |
|------------------|---|----------------|-----------------|-------------------|--------------|---|----------------|-----------------|-------------------|--------------|
| <b>SITE</b>      | <b>Herbaceous</b>                             | <b>Shrubby</b> | <b>Forested</b> | <b>Open water</b> | <b>Other</b> | <b>Herbaceous</b>                             | <b>Shrubby</b> | <b>Forested</b> | <b>Open water</b> | <b>Other</b> |
| Devil's Elbow    | 63%   | 25%            | 0%              | 0%                | 13%          | 29%   | 43%            | 0%              | 26%               | 3%           |
| Dry Dock         | 63%   | 0%             | 13%             | 25%               | 0%           | 40%   | 11%            | 9%              | 34%               | 6%           |
| Eureka Bar DS    | 25%   | 0%             | 0%              | 38%               | 38%          | 50%   | 0%             | 0%              | 42%               | 8%           |
| Eureka Bar US    | 33%   | 0%             | 0%              | 56%               | 11%          | 42%   | 0%             | 0%              | 58%               | 0%           |
| Fitzpatrick      | 33%   | 33%            | 0%              | 0%                | 33%          | 37%   | 17%            | 0%              | 17%               | 29%          |
| Karlson          | 13%   | 13%            | 0%              | 38%               | 38%          | 34%   | 9%             | 0%              | 23%               | 34%          |
| Marsh Island     | 38%   | 63%            | 0%              | 0%                | 0%           | 23%   | 54%            | 0%              | 6%                | 17%          |
| Miller Sands DS  | 67%   | 0%             | 0%              | 0%                | 33%          | 49%   | 0%             | 0%              | 0%                | 51%          |
| Miller Sands US  | 33%   | 0%             | 0%              | 0%                | 67%          | 24%   | 5%             | 0%              | 11%               | 59%          |
| Mott Island      | 0%  | 67%            | 0%              | 0%                | 33%          | 0%  | 49%            | 3%              | 11%               | 37%          |
| Pillar Island DS | 67%   | 0%             | 0%              | 0%                | 33%          | 59%   | 11%            | 0%              | 0%                | 30%          |
| Pillar Island US | 88%   | 13%            | 0%              | 0%                | 0%           | 78%   | 19%            | 0%              | 0%                | 3%           |
| Svensen          | 67%   | 0%             | 22%             | 0%                | 11%          | 66%   | 3%             | 11%             | 0%                | 20%          |
| Tenasillahe      | 44%   | 56%            | 0%              | 0%                | 0%           | 22%   | 59%            | 0%              | 0%                | 19%          |
| Wallace          | 13%   | 0%             | 0%              | 0%                | 88%          | 23%   | 0%             | 0%              | 34%               | 43%          |
|                  | <b>250 m buffer around each release point</b> |                |                 |                   |              | <b>500 m buffer around each release point</b> |                |                 |                   |              |
| Devil's Elbow    | 14%   | 48%            | 0%              | 35%               | 3%           | 11%   | 48%            | 0%              | 33%               | 8%           |
| Dry Dock         | 31%   | 8%             | 4%              | 42%               | 15%          | 24%   | 11%            | 10%             | 49%               | 6%           |
| Eureka Bar DS    | 38%   | 5%             | 4%              | 49%               | 4%           | 22%   | 2%             | 3%              | 68%               | 5%           |
| Eureka Bar US    | 45%   | 1%             | 0%              | 52%               | 2%           | 25%   | 3%             | 5%              | 62%               | 5%           |
| Fitzpatrick      | 14%   | 3%             | 0%              | 52%               | 31%          | 6%  | 2%             | 0%              | 80%               | 12%          |
| Karlson          | 69%   | 6%             | 0%              | 10%               | 15%          | 66%   | 10%            | 0%              | 9%                | 15%          |
| Marsh Island     | 19%   | 48%            | 0%              | 17%               | 17%          | 21%   | 52%            | 1%              | 13%               | 13%          |
| Miller Sands DS  | 26%   | 0%             | 0%              | 3%                | 70%          | 16%   | 2%             | 0%              | 26%               | 57%          |
| Miller Sands US  | 22%   | 20%            | 0%              | 3%                | 56%          | 18%   | 19%            | 1%              | 12%               | 51%          |
| Mott Island      | 2%  | 31%            | 1%              | 45%               | 20%          | 4%  | 21%            | 0%              | 59%               | 16%          |
| Pillar Island DS | 29%   | 13%            | 0%              | 14%               | 44%          | 17%   | 5%             | 0%              | 36%               | 42%          |
| Pillar Island US | 31%   | 14%            | 0%              | 25%               | 30%          | 19%   | 5%             | 0%              | 39%               | 37%          |
| Svensen          | 46%   | 10%            | 14%             | 7%                | 23%          | 30%   | 7%             | 11%             | 24%               | 29%          |
| Tenasillahe      | 15%   | 54%            | 1%              | 0%                | 31%          | 24%   | 44%            | 3%              | 4%                | 25%          |
| Wallace          | 15%   | 0%             | 1%              | 53%               | 32%          | 8%  | 2%             | 6%              | 71%               | 13%          |

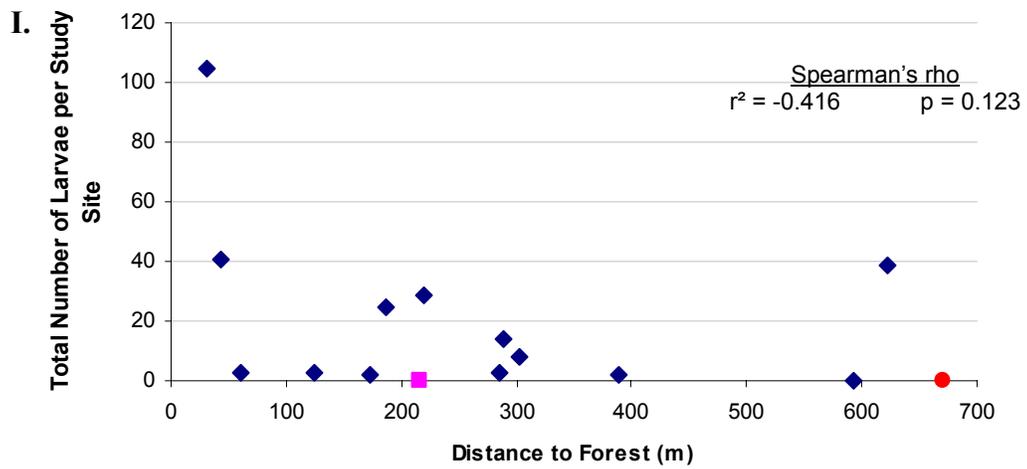
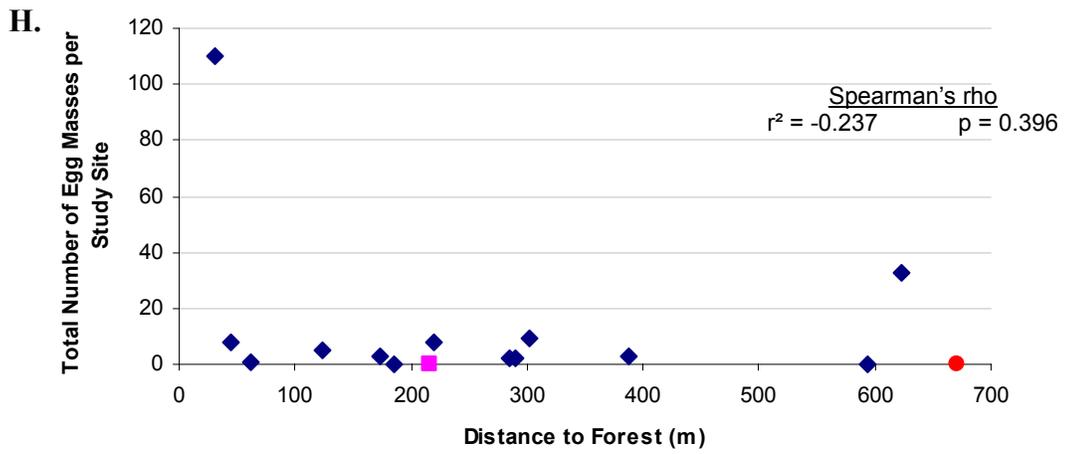
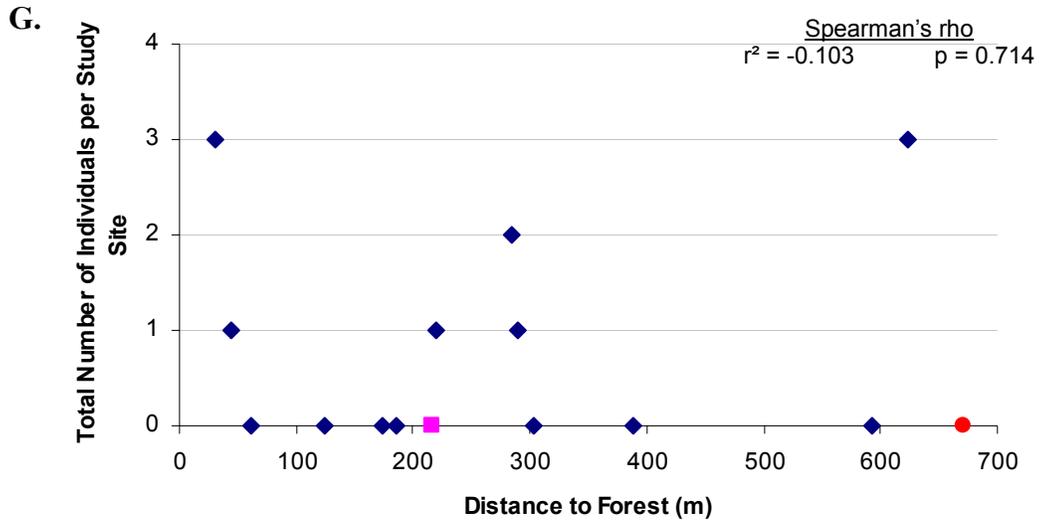
Table 11. Summary of *Lythrum* relative density as evaluated in 35 helicopter transects. Each frame was designated by selecting an object in the forward (left) edge of the frame and allowing the video to run until this same object traveled to the rear (right) edge of the viewing field. The time code was recorded as the end of the previous frame and the beginning of the next. The average number of frames per transect was 14. Percent mean cover, standard deviation, and range for each frame is provided. The percent relative density of purple loosestrife per frame was broken into classes (0, 1-25, 25-50, 51-75, and 76-100%).

| Transect No.     | Pass No. | Total # of Frames | Mean % Cover | Standard Deviation | Minimum | Maximum | Frequency of frames with 0% | Frequency of frames with 1-25% | Frequency of frames with 26-50% | Frequency of frames with 51-75% | Frequency of frames with 76-100% |
|------------------|----------|-------------------|--------------|--------------------|---------|---------|-----------------------------|--------------------------------|---------------------------------|---------------------------------|----------------------------------|
| 1                | 1        | 13                | 16           | 13                 | 0       | 40      | 15                          | 54                             | 31                              | 0                               | 0                                |
| 2                | 1        | 14                | 17           | 17                 | 0       | 48      | 14                          | 50                             | 36                              | 0                               | 0                                |
| 3                | 2        | 11                | 14           | 12                 | 0       | 32      | 27                          | 46                             | 27                              | 0                               | 0                                |
| 4                | 1        | 18                | 4            | 6                  | 0       | 20      | 50                          | 50                             | 0                               | 0                               | 0                                |
| 5                | 2        | 15                | 4            | 9                  | 0       | 36      | 73                          | 20                             | 7                               | 0                               | 0                                |
| 6                | 1        | 14                | 3            | 5                  | 0       | 13      | 64                          | 36                             | 0                               | 0                               | 0                                |
| 7                | 1        | 17                | 0            | 0                  | 0       | 0       | 100                         | 0                              | 0                               | 0                               | 0                                |
| 8                | 1        | 18                | 5            | 6                  | 0       | 16      | 50                          | 50                             | 0                               | 0                               | 0                                |
| 9                | 1        | 13                | 18           | 12                 | 0       | 44      | 8                           | 77                             | 15                              | 0                               | 0                                |
| 10               | 1        | 10                | 32           | 26                 | 0       | 80      | 10                          | 20                             | 50                              | 10                              | 10                               |
| 11               | 1        | 11                | 24           | 24                 | 0       | 56      | 18                          | 37                             | 18                              | 27                              | 0                                |
| 12               | 1        | 16                | 26           | 19                 | 0       | 64      | 6                           | 56                             | 25                              | 13                              | 0                                |
| 13               | 2        | 14                | 39           | 23                 | 0       | 72      | 14                          | 14                             | 36                              | 36                              | 0                                |
| 14               | 1        | 12                | 0            | 0                  | 0       | 0       | 100                         | 0                              | 0                               | 0                               | 0                                |
| 15               | 2        | 13                | 45           | 30                 | 0       | 92      | 15                          | 8                              | 39                              | 23                              | 15                               |
| 16               | 1        | 11                | 0            | 1                  | 0       | 4       | 91                          | 9                              | 0                               | 0                               | 0                                |
| 17               | 2        | 17                | 15           | 16                 | 0       | 56      | 29                          | 59                             | 6                               | 6                               | 0                                |
| 18               | 1        | 15                | 5            | 6                  | 0       | 20      | 33                          | 67                             | 0                               | 0                               | 0                                |
| 19               | 1        | 14                | 3            | 5                  | 0       | 12      | 71                          | 29                             | 0                               | 0                               | 0                                |
| 20               | 1        | 10                | 5            | 5                  | 0       | 12      | 50                          | 50                             | 0                               | 0                               | 0                                |
| 21               | 1        | 16                | 57           | 24                 | 0       | 96      | 6                           | 0                              | 25                              | 44                              | 25                               |
| 22               | 2        | 8                 | 7            | 7                  | 0       | 16      | 38                          | 62                             | 0                               | 0                               | 0                                |
| 23               | 1        | 17                | 81           | 23                 | 12      | 100     | 0                           | 6                              | 6                               | 12                              | 76                               |
| 24               | 1        | 10                | 4            | 8                  | 0       | 24      | 70                          | 30                             | 0                               | 0                               | 0                                |
| 25               | 1        | 10                | 0            | 0                  | 0       | 0       | 100                         | 0                              | 0                               | 0                               | 0                                |
| 26               | 1        | 12                | 22           | 28                 | 0       | 80      | 50                          | 8                              | 26                              | 8                               | 8                                |
| 27               | 1        | 11                | 3            | 4                  | 0       | 12      | 64                          | 36                             | 0                               | 0                               | 0                                |
| 28               | 2        | 19                | 2            | 4                  | 0       | 12      | 79                          | 21                             | 0                               | 0                               | 0                                |
| 29               | 2        | 13                | 57           | 29                 | 8       | 96      | 0                           | 15                             | 15                              | 39                              | 31                               |
| 30               | 2        | 14                | 74           | 16                 | 36      | 92      | 0                           | 0                              | 7                               | 36                              | 57                               |
| 31               | 2        | 12                | 18           | 21                 | 0       | 60      | 33                          | 25                             | 25                              | 17                              | 0                                |
| 32               | 2        | 15                | 53           | 18                 | 32      | 92      | 0                           | 0                              | 47                              | 40                              | 13                               |
| 33               | 1        | 10                | 0            | 0                  | 0       | 0       | 100                         | 0                              | 0                               | 0                               | 0                                |
| 34               | 2        | 21                | 1            | 4                  | 0       | 20      | 95                          | 5                              | 0                               | 0                               | 0                                |
| 35               | 1        | 10                | 1            | 2                  | 0       | 4       | 80                          | 20                             | 0                               | 0                               | 0                                |
| Overall averages |          | 474               | 19           | 27                 | 0       | 100     | 44                          | 27                             | 13                              | 9                               | 7                                |

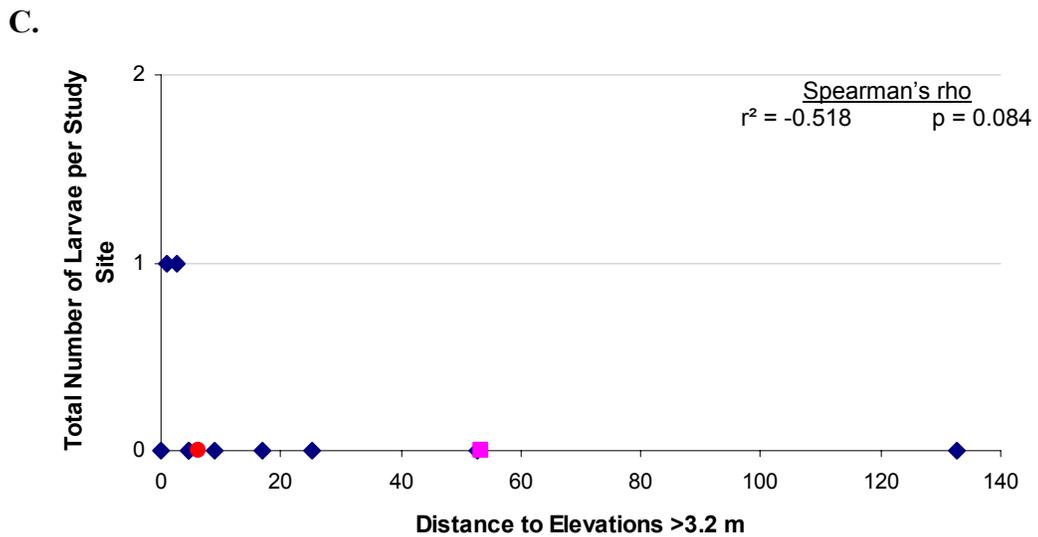
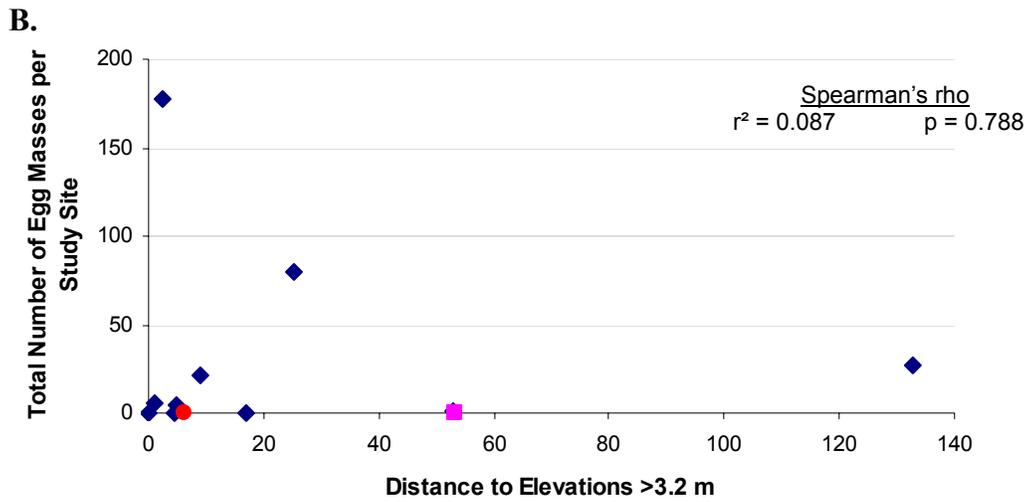
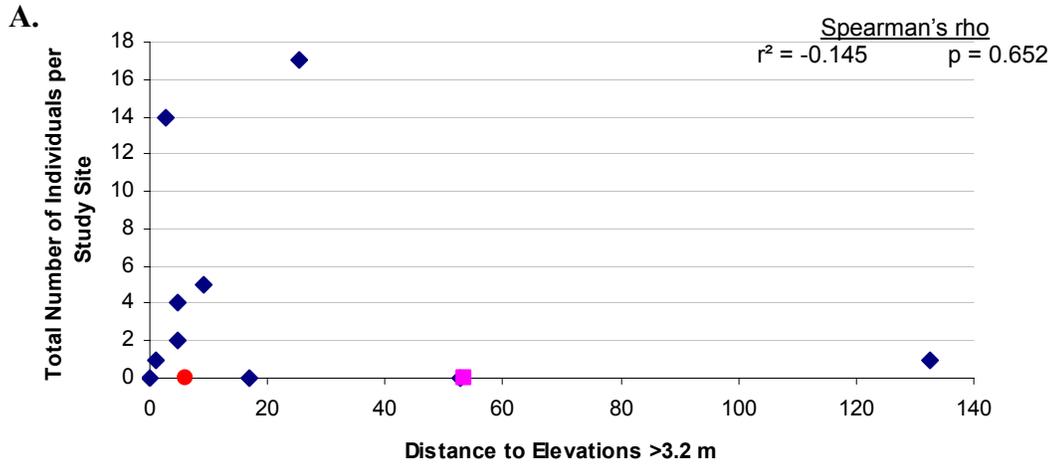
Figures 17a-i. Total number of *G. calmariensis* and *G. pusilla adults* combined for all June quadrats at a study site, plotted against distance to areas of elevation >3.2 m, distance to shrub (m), and distance to forest (m) from ETM+ data (Garono et al. 2003a). Sum of *Galerucella* eggs and larvae plotted against same. Pillar Downstream (pink square) and Miller Downstream (red circle) are the only two study sites that yielded no observations of the biocontrol agents in any life stage.



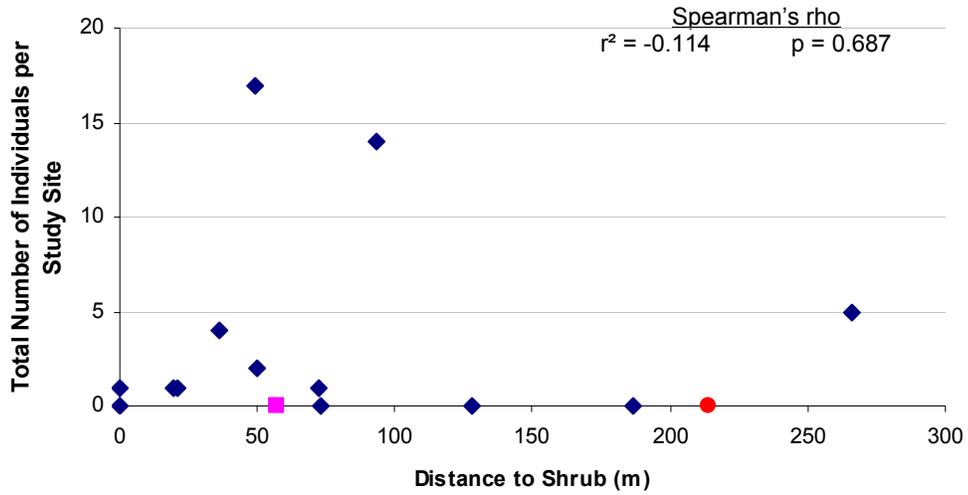




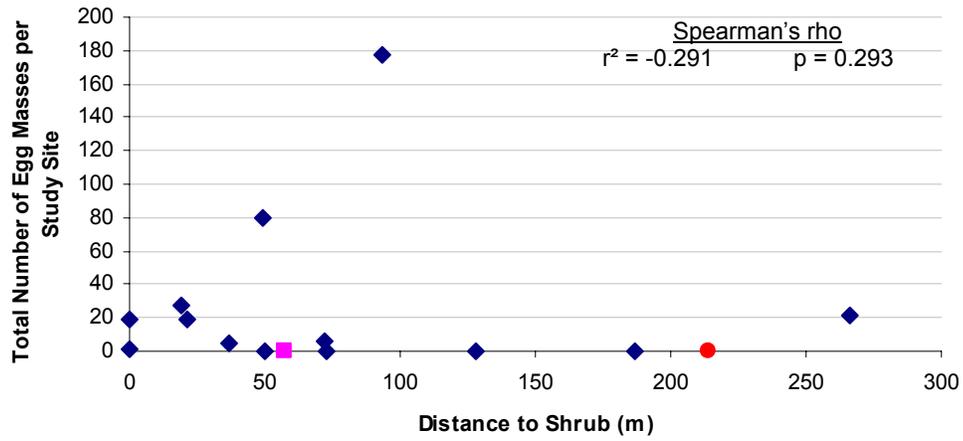
Figures 18a-i. Total number of *G. calmariensis* and *G. pusilla* adults combined for all July quadrats at a study site, plotted against distance to areas of elevation >3.2 m, distance to shrub (m), and distance to forest (m) from ETM+ data (Garono et al. 2003a). Sum of *Galerucella* eggs and larvae plotted against same. Pillar Downstream (pink square) and Miller Downstream (red circle) are the only two study sites that yielded no observations of the biocontrol agents in any life stage.



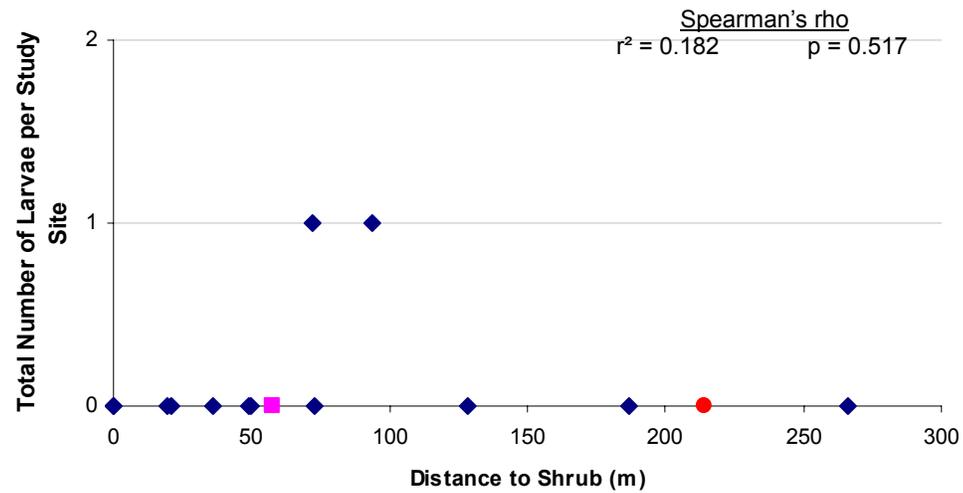
D.

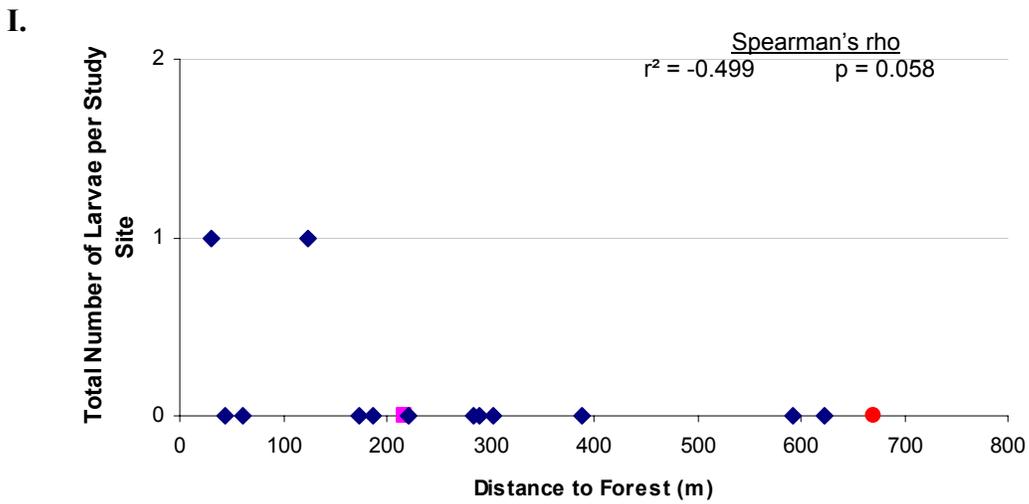
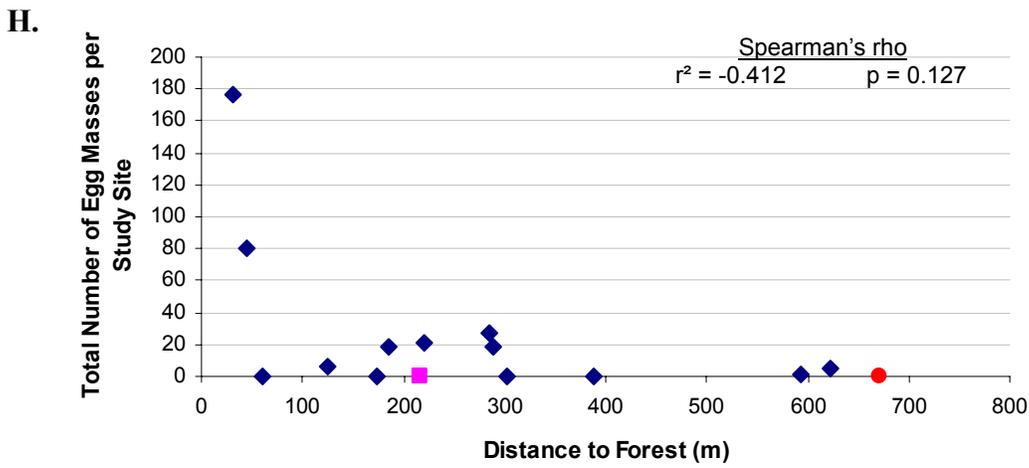
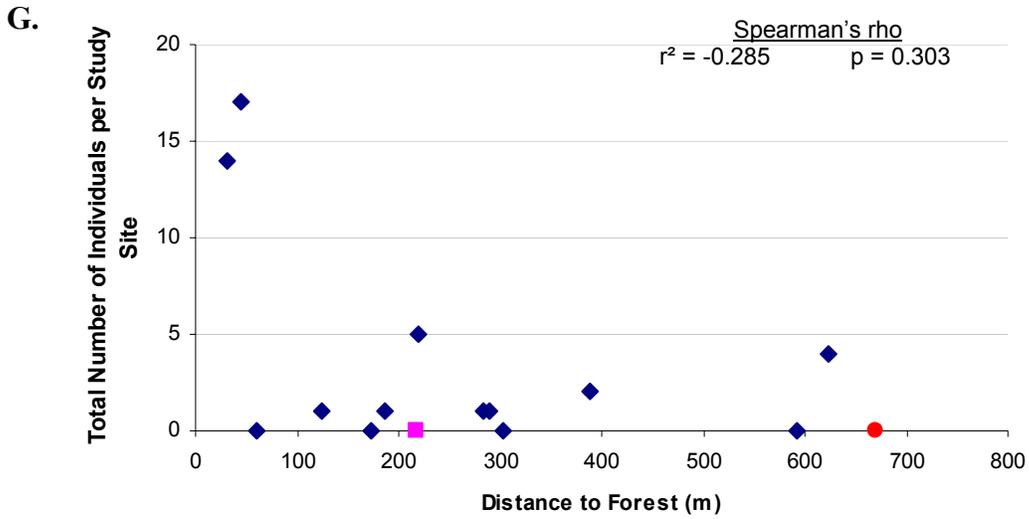


E.



F.





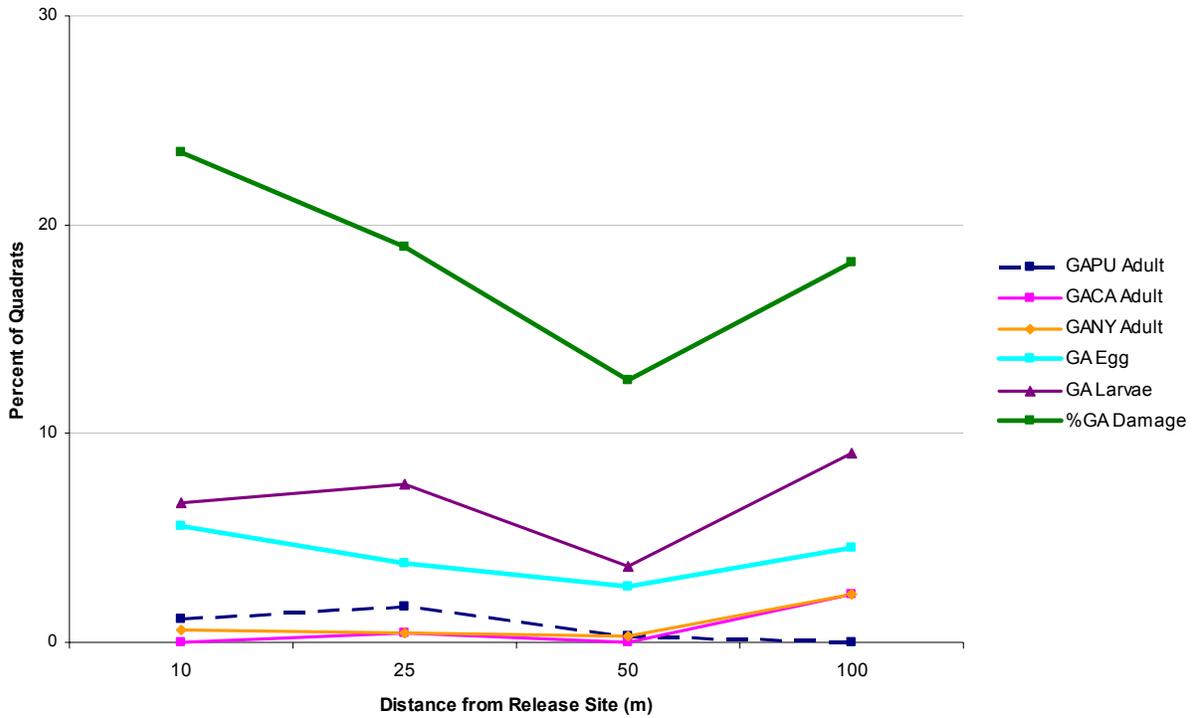


Figure 19a. Proportion of June quadrats at all study sites in which evidence of *Galerucella* was observed as a function of distance from release point. GAPU denotes *Galerucella pusilla*, GACA denotes *Galerucella calmariensis*, and GANY denotes the native *Galerucella nymphaeae*. All species of *Galerucella* are included when only GA is used. Buffered distances are calculated by meters from release site minus previous buffer e.g., 10 is from the release point to a distance of 10m from the release point; 25 falls in area from 10m to 25m from release point; 50 is from 25m to 50m from release point; 100 is from 50m to 100m from release point, etc.

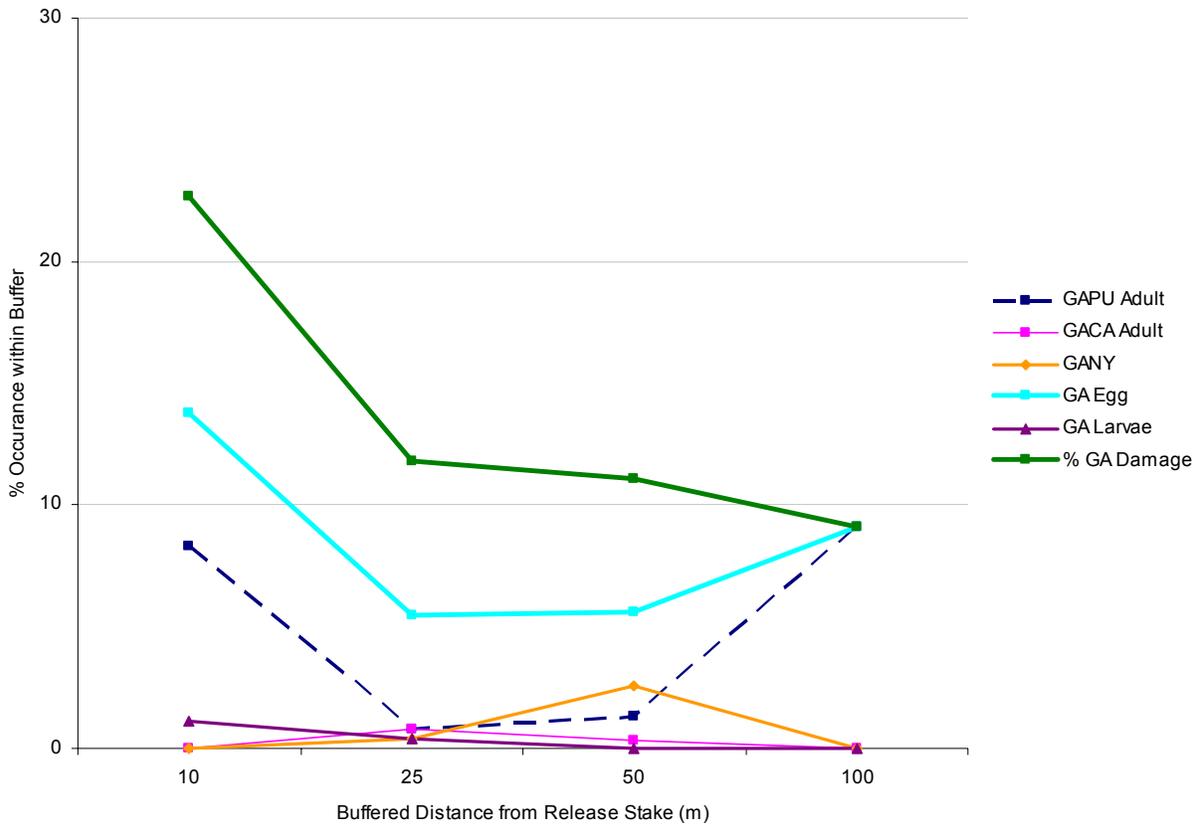


Figure 19b. Proportion of July quadrats at all study sites in which evidence of *Galerucella* was observed as a function of distance from release point. GAPU denotes *Galerucella pusilla*, GACA denotes *Galerucella calmariensis*, and GANY denotes the native *Galerucella nymphaeae*. All species of *Galerucella* are included when only GA is used. Buffered distances are calculated by meters from release site minus previous buffer e.g., 10 is from the release point to a distance of 10m from the release point; 25 falls in area from 10m to 25m from release point; 50 is from 25m to 50m from release point, etc.

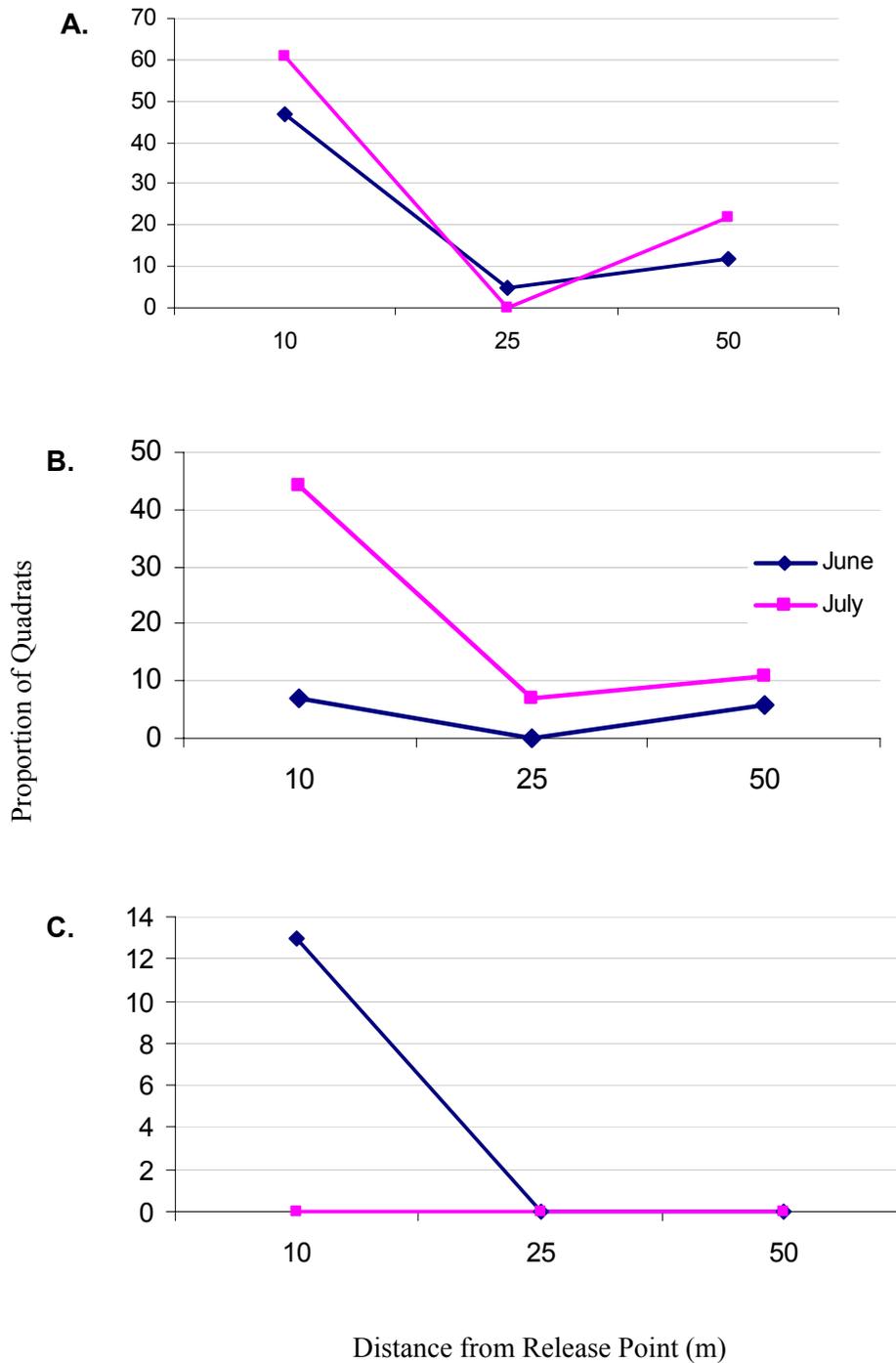


Figure 20. Change in field variables from June to July as a function of distance from release point at Dry Dock. A. Observations of *Galerucella* damage, B. Observations of *Galerucella* egg masses, C. Observations of *Galerucella* larvae. Buffered distances are calculated by meters from release point minus previous buffer e.g., 10 is from the release point to 10m away from the release point; 25 falls in area from 10m to 25m from release point; 50 is from 25m to 50m from release point, etc.

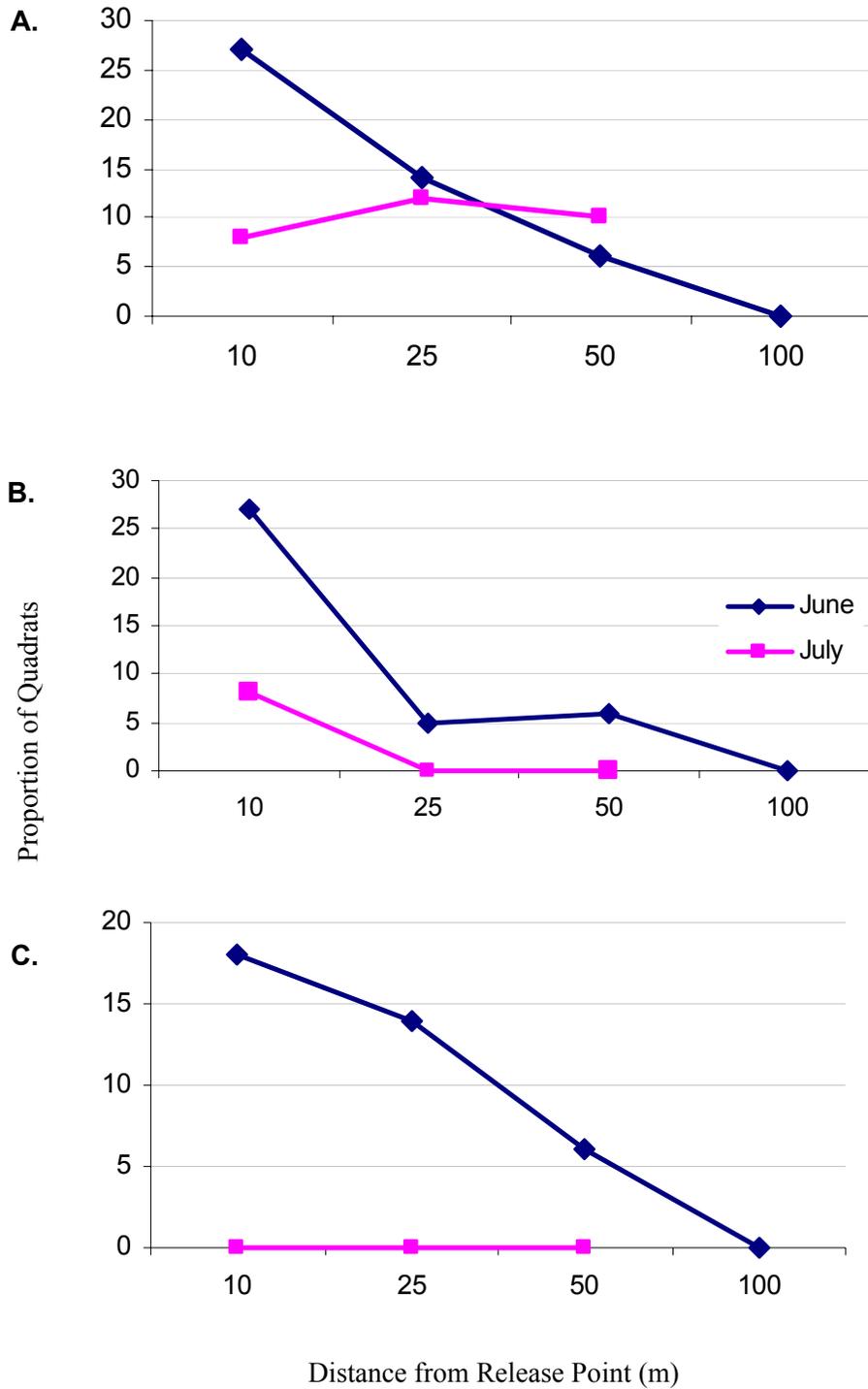


Figure 21. Change in field variables from June to July as a function of distance from release point at Devil’s Elbow. A. Observations of *Galerucella* damage, B. Observations of *Galerucella* egg masses, C. Observations of *Galerucella* larvae. Buffered distances are calculated by meters from release point minus previous buffer e.g., 10 is from the release point to 10m away from the release point; 25 falls in area from 10m to 25m from release point; 50 is from 25m to 50m from release point, etc.

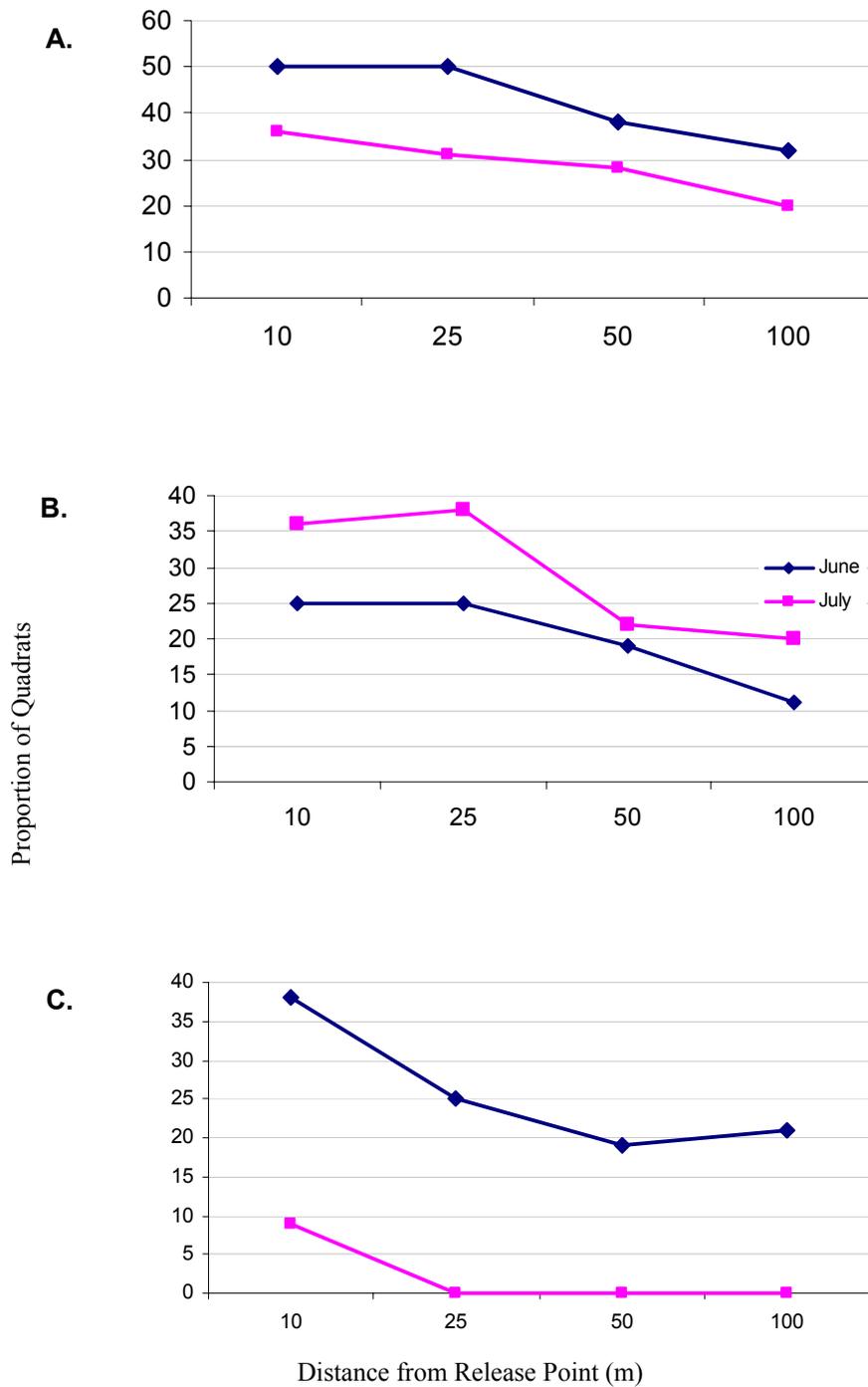


Figure 22. Change in field variables from June to July as a function of distance from release point at Svensen. A. Observations of *Galerucella* damage, B. Observations of *Galerucella* egg masses, C. Observations of *Galerucella* larvae. Buffered distances are calculated by meters from release point minus previous buffer e.g., 10 is from the release point to 10m away from the release point; 25 falls in area from 10m to 25m from release point; 50 is from 25m to 50m from release point, etc.

## Percentage of Error Between Video Transect Observers

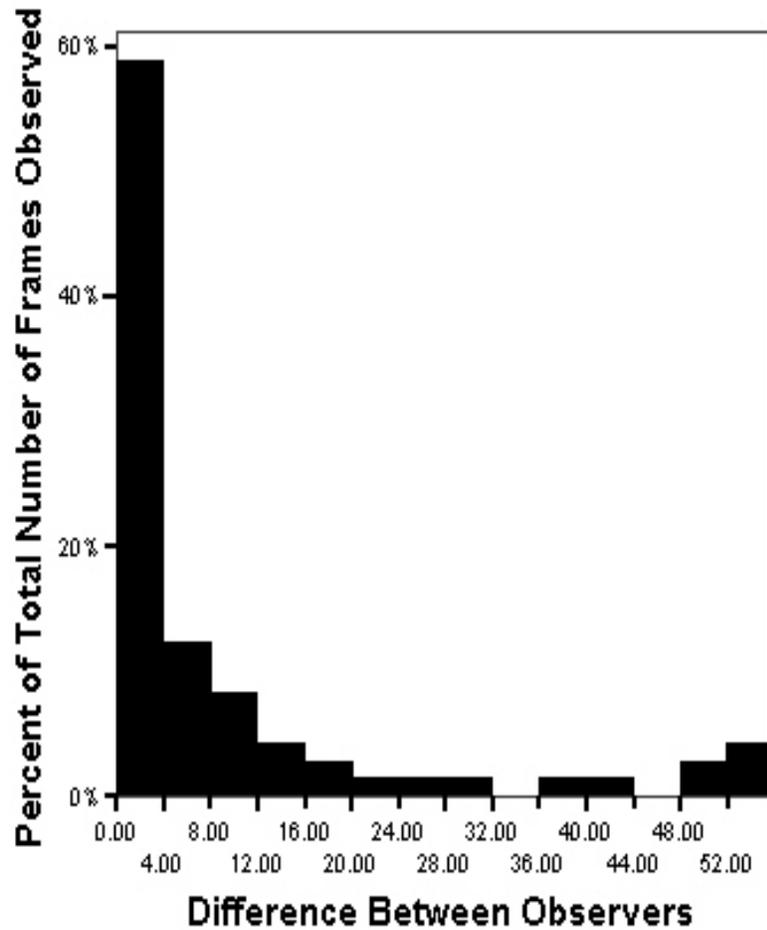


Figure 23. Differences in frame-by-frame observations of helicopter video transects by two different observers. Frames within the video transect were observed to determine presence or absence of *L. salicaria* with a 25-cell grid. The total number of grids containing *L. salicaria* was multiplied by 4 to obtain an estimated percent coverage of *L. salicaria* for the frame. Differences are in 4% increments.

## **E. Summary & Discussion**

### **1. Summary of Results**

We found strong evidence of biocontrol population establishment at most release sites (13 of 15). Although at least three years of observations are necessary to determine whether or not a biocontrol population has become successfully established, we considered the presence of adults, larvae, eggs and plant damage to be indicative of potential establishment. The few adult *G. pusilla* and *G. californiensis* encountered at nine of the fifteen release sites were more numerous in July and were most likely the same adults that the USACE released in 2005. The small number of adults observed may have been due to the timing of our sampling or the sampling method may have disturbed the few beetles that were present. Beetles respond to disturbance by dropping from the plant to the ground and may have been dislodged as field teams established transects. Finally, populations just may not have had time to grow.

In spite of the low numbers of adults, we did see relatively high numbers of eggs (539 total egg masses, 87% of sites) and larvae (276 total larvae, 80% of sites) of all three *Galerucella* species around the release site stakes. Egg masses were more abundant in July, similar to adults, but larvae were more common in the June survey. The presence of larva and egg life stages strongly suggests that populations are becoming established. We also observed plant damage attributed to the beetles suggesting that the potential for effective control. Although damage levels at any particular study site, when averaged across all *Lythrum* stems, were never above 3%, total damage was as high as 129% at Svensen Island. Total percent damage appears to be strongly related to the total number of biocontrol agents present at the site (all life stages). Typically, damage increases linearly with beetle density in the exponential phase of population growth. Low levels of damage are expected for recently established populations of control agents, with levels commonly reaching 100% after five years in populations studied elsewhere.

Looking specifically at individual sites, Svensen Island and Devil's Elbow had the most adults of all species in June while Dry Dock and Svensen had the most in July. Just over 100 larvae were observed at Svensen Island during June. Tenasillahe Island, Wallace Island, Devil's Elbow, and Dry Dock had between 25-41 larvae in June. Svensen and Devil's Elbow also had much higher numbers of egg masses compared to the other sites sampled in June. In July,

Svensen Island and Dry Dock had large numbers of egg masses present compared to the other 13 sites. Only two larvae were observed at all quadrats sampled in July.

## **2. Distinctions about Sites with Evidence of *Galerucella***

Svensen and Dry Dock had high levels of beetles and *Lythrum* damage. However, we sampled at two sites where no beetles, in any life stage, were observed. The exposed, Pillar Rock Island Downstream and Miller Sands Downstream did not show indication of the insects at any life stages, but damage to *Lythrum* was noted at both locations. The damage could be explained by *Galerucella* that were not detected by our field teams or could be due to other insect herbivores. Although we do not have direct evidence, we believe proximity of shrub or forest cover and the amount of tidal inundation the site experiences may ultimately affect establishment. We can explore these concepts with our data by measuring the distance to shrub and forest cover from various image types and estimating tidal inundation with elevation data and tidal gauge predictions. Other factors may include wind and wave exposure for which we have no way to measure in this study.

### **a. Inundation/Elevation**

Although we sampled quadrats at the lowest elevations (MLLW – MSL) and observed purple loosestrife stems at these elevations, we did not find any evidence of *Galerucella* in these lowest quadrats: *Galerucella* presence, observed as adults, larvae, eggs or *Lythrum* damage, was only observed at elevations greater than MSL. Our data suggest that elevation alone does not guarantee successful biocontrol agent establishment. For example, both Miller Island sites and the Pillar Rock Island sites had the greatest amount of high ground surrounding the release points. Yet, both Miller Sands and Pillar Rock Island had very little evidence of beetles. Interestingly, Devil’s Elbow and Svensen Island have the highest amount of area at elevations below MSL, almost 50%, surrounding the release point (based on RTK elevation model data).

Quadrats in this study were not selected by elevation. We may have observed more evidence of *Galerucella* at Svensen Island and Devil’s Elbow simply because we sampled more higher elevation quadrats at these sites compared to other sites. However, the relationship between *Galerucella* observations and elevation was not strong so we recommend that field or

greenhouse studies be conducted before conclusions can be drawn about the relationship between beetle abundance and elevation.

Additional environmental conditions in the islands of the Lower Columbia River Estuary present difficulties to establishment, persistence, and therefore overall success of biocontrol organisms. In fact, tidal areas may even act as refuge for *Lythrum* because of the difficulties in biocontrol agent establishment (Denoth and Myers 2005). Plants and biocontrol agents must endure tidal cycles, storm surges, and discharge of water from dams upriver that all contribute to temporal variation in the degree of inundation. In addition, variation in elevation and structure of vegetation at a site influence patterns of inundation. Rare or one-time events, such as floods, can also impair establishment. In a February 1996 Columbia River flood event, water levels were as much as 1.6m higher than average high tide levels (Beaver Army Terminal, Quincy Oregon tidal gage station #14246900). The current, or speed at which the tide level ebbs and flows, can also affect biocontrol organism establishment in their ability to flee from rising water. Maximum predicted currents for 2006-2010 in the main channel of the Columbia are 1.2 to 1.3 knots for flooding and -4.1 to -4.2 knots for ebbing. These conditions can vary on a site to site basis so it is difficult to make broad statements about establishment at our fifteen sites but further investigation of real-time water levels and high water events with tidal gages is warranted.

## **b. Distance to Shrub/Forest Cover**

The relationship between beetle abundance and landcover is not obvious. For example, Devil's Elbow and Svensen Island differ in the distance between the release stake to the nearest area of shrubby cover, and in the amount of shrubby cover. On Marsh and Tenasillahe Islands, the release sites are actually located in a shrubby area. However, these two sites had less evidence of biocontrol agent presence than did the Svensen Island and Devil's Elbow sites.

We recommend more detailed studies to better understand the relationship between land cover and beetle populations.

## **c. Role of Other Releases**

Additional biocontrol agent releases have been made by other groups in the Lower Columbia River Estuary, so we cannot yet reconstruct the history of each population at our study

sites (see **Appendix III**). The age of a population (time since release) is crucial for predicting establishment, increase, and spread of control organisms, as well as level of suppression in target weed populations. We observed other biocontrol organisms that were not the recent *Galerucella* releases by the USACE. For example, *Nanophyes marmoratus* was observed at five of fifteen sites. In order to truly understand the role and effects of these other biocontrol organisms, we recommend organizing a master database that catalogues all releases of *Lythrum* biocontrol agents in the Columbia River. This database should detail exact location coordinates of what was released, how many, when, and by whom. The independent and interacting effects of control organisms will depend on populations of each species vary and covary across space and time.

We have begun to organize records that are available to us, including releases made by Oregon Department of Agriculture and the Lower Columbia River Watershed Council. We believe the first biological control-agent release in the Lower Columbia River Estuary was made in 1997. *Galerucella pusilla* was the first agent released, and over 79% of the releases made since have been of *G. pusilla*. All four biocontrol agents have been released in sites all over the state. One of the most successful and well-known sites is Baskett Slough, west of Salem.

Some of our study sites have had extensive numbers of biocontrol agent releases, especially Wallace Island. (**Appendix III**). Numbers of all agents released on Wallace Island and the surrounding area are over 15,000 individuals. Fitzpatrick has had over 6,000 individuals released. Until the 2005 release of *G. pusilla* by the USACE, some of our study sites had not been subject to other biocontrol agent releases including Eureka Bar Up and Downstream, Marsh Island, Miller Downstream, Mott Island, Pillar Rock Island Up and Downstream, and Tenasillahe Island. Maps of releases that have occurred in the Lower Columbia River Estuary are located in Appendix III. For sites where multiple releases have occurred at one location, information tables list the number of what biocontrol agent have been released, when, and by what agency (**Appendix III**).

## **F. Recommendations**

### **1. The Match Between Control Organism Life Cycles and Environment**

We did not see clear relationships between site elevation, land cover, and number of biocontrol organisms. However, quadrats and transects were not established as part of an experimental design to answer these questions. When plant length was considered, in addition to ground elevation, we observed the majority of control agents (adults, larvae, and eggs) at elevations greater than the level of the highest tides (3.2m), although we did not explicitly sample across a wide range of elevations. We recommend that a study be initiated to determine what role, if any, elevation and land cover (shrubby and forested vegetation, in particular) play in successful biocontrol of *Lythrum*. We also recommend further investigation into tidal cycles and high water events specific to individual study sites using tidal gages.

We recommend examining the elevation and plant cover for the entire Columbia River Estuary, if suitable data sets are available, to identify release sites where successful biocontrol populations are likely to become established. Evaluation of release sites will be based upon elevation, tidal levels, and availability of shrub and forest cover. This will allow us to more closely follow a step by step approach of monitoring- from release, to establishment, to increasing and redistributing control organisms, to damaging and suppressing the target organism, and finally to managing plant succession. Releases in the Lower Columbia River are relatively recent, so the initial focus of evaluation is on the release and establishment phase as a function of the identity of species and the number of individuals released over time at each site. The age of the release can be determined by compiling the master biocontrol agent release database for *Lythrum*, focusing on the Lower Columbia River. Using GIS, release locations can be compared to inundation patterns, exposure, land cover and other factors that may ultimately affect biocontrol success.

### **2. Helicopter Video**

We found that the quality of the video collected by helicopter adequate for monitoring *Lythrum* along 35 transects. The video imagery was collected at the lowest safe flight altitude and slowest safe airspeed. Better video imagery would be difficult to acquire. Interpretation of

the video imagery was highly subjective, although we found good agreement between independent observers. Recent advances in airborne imagery may make acquisition and interpretation of imagery a much more affordable option than it once was. We recommend that alternative types of imagery be considered for future monitoring. Consideration should be given to spatial and spectral resolution, as well, as ease of acquisition. See Garono et al. 2003a, b for more information.

### **3. Change in Survey Schedule**

We propose the following schedule of insect and plant surveys to provide the most consistent year-to-year measures for detecting long-term change in agent populations. Our primary assessment of *Gallerucella* abundance will take place in late April, shortly after adults emerge from winter diapause. Quantifying population abundance is straightforward at this time of year because the populations are synchronized in the adult stage. In addition, the plants are small and the adults are easy to find as they mate and feed at the tips of the plants. Moreover, overwintered *Gallerucella* are more easily distinguished to species because their coloration is fully developed.

We will measure impacts to plants in late summer, after the beetles have finished feeding and the plants have reached full height. In each of 100 – 1m<sup>2</sup> quadrats, we will count the number of stems and inflorescences, and measure the lengths of 5 randomly selected stems.

We suspect that the beetles have only one generation in the Lower Columbia River region, but we do not know this for sure. In some other locations in the U.S. and Canada, *Gallerucella* are reported to have two full generations per year, with the second generation of adults emerging in late September. We will carry out surveys for a second generation of adults in late September at a subset of the release sites.

### **4. Consider Additional Biocontrol Agents**

Prior biocontrol releases in the Columbia River have been primarily of *Gallerucella pusilla*. We propose additional releases of *G. californiensis* (collected from other field sites in Oregon) and *Hylobius transversovittatus* (reared at ODA insectary). These releases should take place in late April when the insects will be at a peak in reproductive value. Because it is difficult

to field collect large numbers of *Galerucella* in the spring when their densities are low, these releases will be relatively small. In preparation for much larger releases to be made in 2008, we will collect insects in July for storage over winter and mass rearing in early spring.

**Late April:** Collect and release *Galerucella californiensis* and *Hylobius transversovittatus*. First survey - Direct counts of adult insects in quadrats along transects. Estimate percent leaf area removed.

**Mid-August:** Second survey - End of season plant measurements in quadrats. Note any larvae present to suggest a second generation. If possible, acquire remote sensing imagery at time of peak flower.

**Late September:** Timed searches at subset of release sites to determine if there is a second generation of *Galerucella* in the Lower Columbia region.

We also recommend examining releases made by other organizations to better understand the current distribution of biocontrol agents in the Lower Columbia River Estuary.

## **5. Release Recommendations**

We recommend that future releases are of at least 540 individuals to maximize the probability of establishment based on Grevstad (1999) study.

## G. Literature Cited

- Andow D. A., P. M. Kareiva, S. A. Levin, A. Okubo. 1990. Spread of invading organisms. *Landscape Ecology* 4: 177-188
- Coombs, E. M. 2006. Personal Communication. Oregon Department of Agriculture.
- Coombs, E. M., J. K. Clark, G. L. Piper, and A. Cofrancesco, editors. 2004. Biological control of invasive plants in the United States. Oregon State University Press, Corvallis, Oregon.
- Garono, R. J., R. Robinson, and C. Simenstad. 2003a. Estuarine and Tidal Freshwater Habitat Cover Types Along the Lower Columbia River Estuary Determined from Landsat 7 ETM+ Imagery. Lower Columbia River Estuary Partnership technical report.
- Garono, R. J., R. Robinson, and C. Simenstad. 2003b. Estuarine Landcover Along the Lower Columbia River Estuary Determined from Compact Airborne Spectrographic Imager (CASI) Imagery. Lower Columbia River Estuary Partnership technical report.
- Grevstad, F. S. 1999. Experimental invasions using biological control introductions: the influence of release size on the chance of population establishment. *Biological Invasions* 1:313-323.
- Grevstad, F. S., and A. L. Herzig. 1997. Quantifying the effects of distance and conspecifics on colonization: experiments and models using the loosestrife leaf beetle, *Galerucella californiensis*. *Oecologia* 110:60-68.
- Denoth, Madlen and Judith H. Myers. 2005. Variable success of biological control of *Lythrum salicaria* in British Columbia. *Biological Control* 32 (2005) 269-279.
- Hopper, K. R. and R.T. Roush. 1993. Mate finding, dispersal, number released and the success of biological control introductions. *Ecol Entomol* 18: 321-330
- NOAA. 2006. Tides and Currents Benchmark data sheets. Retrieved from [http://tidesandcurrents.noaa.gov/station\\_retrieve.shtml?type=Bench+Mark+Data+Sheets](http://tidesandcurrents.noaa.gov/station_retrieve.shtml?type=Bench+Mark+Data+Sheets)
- Schat, M. 2002. Biological control of purple loosestrife *Lythrum salicaria* (Lythraceae): stability of control and integration with wetland management practices. MS Thesis. Oregon State University, Corvallis, Oregon.
- Schooler, S. S. 1998. Biological control of purple loosestrife *Lythrum salicaria* by two chrysomelid beetles *Galerucella pusilla* and *G. californiensis*. M.S. Thesis. Oregon State University, Corvallis, Oregon, USA.

- Schooler, S. S., and P. B. McEvoy. 2006. Relationship between insect density and plant damage for the golden loosestrife beetle, *Galerucella pusilla*, on purple loosestrife (*Lythrum salicaria*). *Biological Control* **36**:100-105.
- Schooler, S. S., P. B. McEvoy, and E. M. Coombs. 2006. Negative per capita effects of purple loosestrife and reed canary grass on plant diversity of wetland communities. *Diversity and Distributions* **12**:351-363.
- Western Regional Climate Center. Accessed October 12, 2006. Astoria airport monthly climate summary. Retrieved from <http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?or0328>
- USACE & LCREP. 2001. Color infrared photography of Lower Columbia River. Courtesy of U.S. Army Corps of Engineers and Lower Columbia River Estuary Partnership. Flown 2001-2002.

## **H. Acknowledgements**

We would like to acknowledge the U.S. Army Corps of Engineers for the opportunity and funding to conduct this study. We thank Chris Grunow, Katri Laukkanen, and David Shipley for assistance in the field. Margaret Magruder of the Lower Columbia River Watershed Council and Dave Ambrose of Clatsop Soil and Water Conservation District for providing information about biocontrol agent releases in the Lower Columbia River Estuary area. We would also like to thank Eric Coombs of the Oregon Department of Agriculture for his extensive knowledge of the biocontrol of purple loosestrife and his assistance in all aspects of the project.

# **I. Appendices**

I. Individual Study Site Summaries - A-O

II. Helicopter Transects

III. Other Known Biocontrol Agent Release Sites in the Lower Columbia River

IV. Daily High Tide Levels by Month for June 2005-December 2006

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Devil's Elbow (also referred to as Horseshoe Island)

**Dates:** June 18 & July 26, 2006

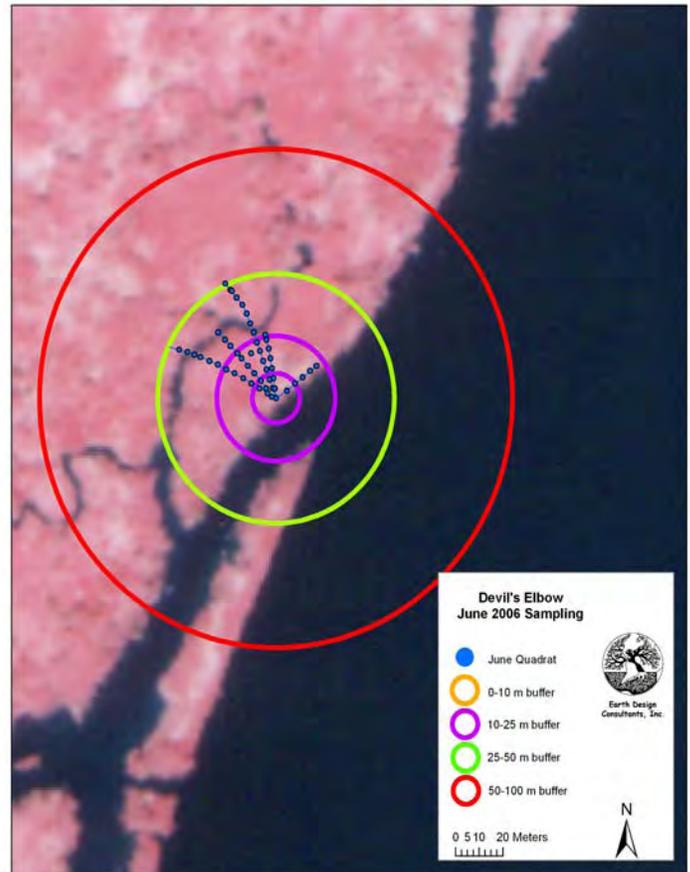
**Lat/Long:** 46.233137088 N,  
123.554466268 W NAD83 Conus

**Columbia River Mile:** ~ 31

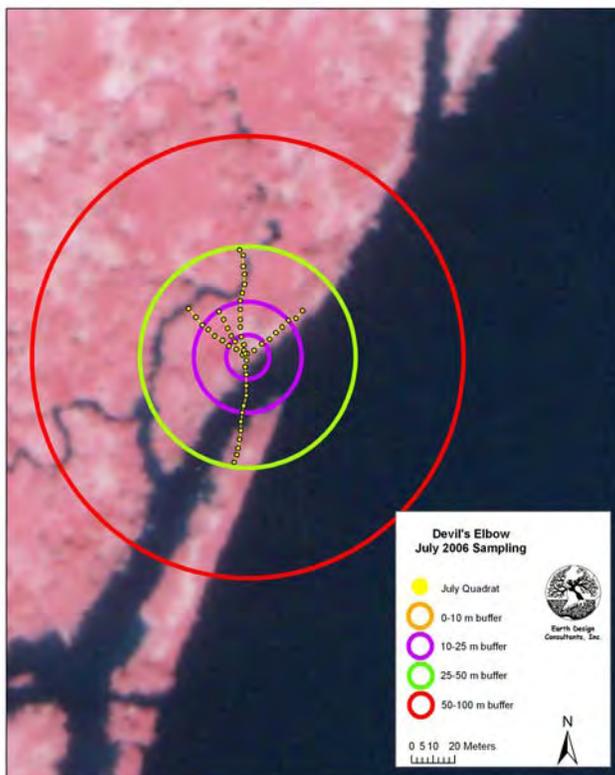
**Mean +/- S.D, Range in Elevation:**  
2.3 m +/- 0.7, 0.7-3.9 m NAVD88

**Distance to High Ground:** 4.77m  
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 11.2m            | 36.4m             |
| <b>Forest</b> | NA                | 11.2m            | 623.0m            |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a function of distance from the initial biocontrol release

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

point.

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 1                      | 1                         | 0                           |   |                                   |                        | 1               | 131                  | 1               |
| st dev      | 0                                | 0                                       | 0                                  | 2                      | 5                         | 1                           |   |                                   |                        | 3               | 24                   | 3               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 55                   | 0               |
| max         | 3                                | 0                                       | 0                                  | 8                      | 33                        | 5                           |   |                                   |                        | 15              | 178                  | 12              |
| proport     | 1/50                             | 0/50                                    | 0/50                               | 5/50                   | 4/50                      | 7/50                        | 0/50  | 0/50                              | 2/50                   | 10/50           |                      | 7/50            |
| %           | 2                                | 0                                       | 0                                  | 10                     | 8                         | 14                          | 0   | 0                                 | 4                      | 20              |                      | 14              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 1               | 152                  | 0               |
| st dev      | 0                                | 0                                       | 0                                  | 1                      | 0                         | 0                           |   |                                   |                        | 3               | 42                   | 0               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 62                   | 0               |
| max         | 2                                | 0                                       | 0                                  | 5                      | 0                         | 2                           |   |                                   |                        | 17              | 212                  | 1               |
| proport     | 3/50                             | 0/50                                    | 0/50                               | 1/50                   | 0/50                      | 5/50                        | 0/50  | 0/50                              | 2/50                   | 9/50            |                      | 1/50            |
| %           | 6                                | 0                                       | 0                                  | 2                      | 0                         | 10                          | 0   | 0                                 | 4                      | 18              |                      | 2               |

## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

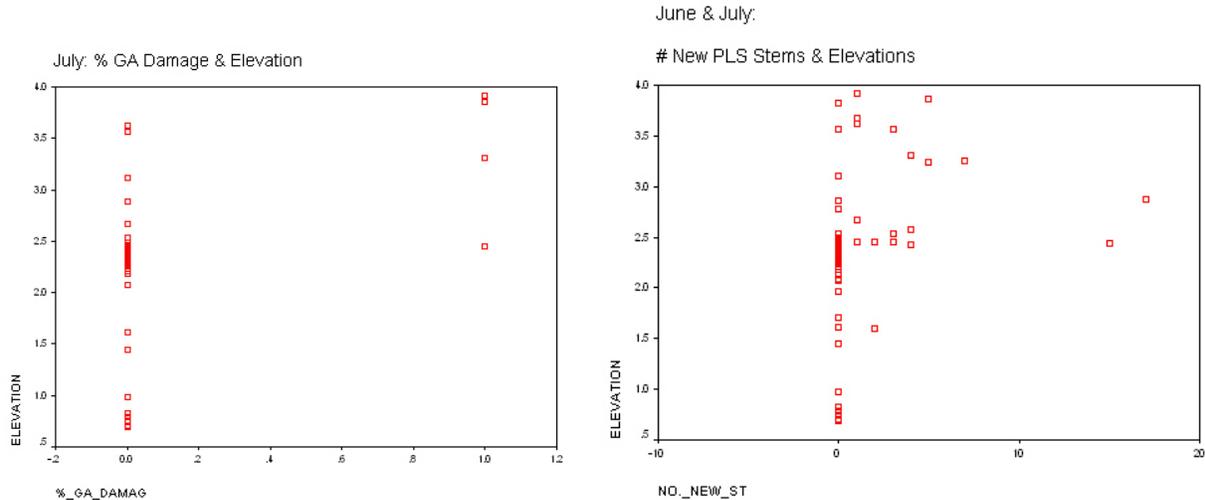
|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | 0.249        | (a)          | (a)        | 0.189         | 0.003       | 0.063       | (a)           | (a)           | 0.235       | 0.048       |
|      | Sig. (2-tailed) | 0.116        |              |            | 0.236         | 0.983       | 0.696       |               |               | 0.138       | 0.767       |
|      | N               | 41           | 41           | 41         | 41            | 41          | 41          | 41            | 41            | 41          | 41          |
| July | Correlation     | 0.179        | (a)          | (a)        | 0.04          | (a)         | .455(**)    | (a)           | 0.297         | (a)         | (a)         |
|      | Sig. (2-tailed) | 0.262        |              |            | 0.803         |             | 0.003       |               | 0.059         |             |             |
|      | N               | 41           | 41           | 41         | 41            | 41          | 41          | 41            | 41            | 41          | 41          |

# new *L. salicaria* stems from June and July (82 quadrats) correlated with elevation is significant at the  $p=0.05$  level – Pearson’s correlation  $r=0.27$ ,  $p=0.014$ .

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

*July: % GA damage and elevation*

*June and July together: # new L. salicaria stems and elevation*





|      | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 153                  |                 |
|      | st dev  | 1                                | 0                                       | 0                                  | 1                      | 0                         | 0                           |   |                                   |                        | 1               | 50                   |                 |
|      | min     | 2                                | 0                                       | 0                                  | 5                      | 0                         | 1                           |   |                                   |                        | 3               | 205                  |                 |
|      | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 90                   |                 |
|      | proport | 2/13                             | 0/13                                    | 0/13                               | 1/13                   | 0/13                      | 1/13                        | 0/13  | 0/13                              | 1/13                   | 3/13            |                      | 0/13            |
|      | %       | 15                               | 0                                       | 0                                  | 8                      | 0                         | 8                           | 0   | 0                                 | 23                     | 23              |                      | 0               |
| 25 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 168                  |                 |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 1               | 54                   |                 |
|      | min     | 1                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 5               | 204                  |                 |
|      | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 62                   |                 |
|      | proport | 1/17                             | 0/17                                    | 0/17                               | 0/17                   | 0/17                      | 2/17                        | 0/17  | 0/17                              | 0/17                   | 3/17            |                      | 0/17            |
|      | %       | 6                                | 0                                       | 0                                  | 0                      | 0                         | 12                          | 0   | 0                                 | 0                      | 18              |                      | 0               |
| 50 m | mean    |                                  |   |                                    |                        |                           | 0                           |   |                                   |                        | 1               | 142                  | 0               |
|      | st dev  |                                  |   |                                    |                        |                           | 0                           |   |                                   |                        | 4               | 35                   | 0               |
|      | min     |                                  |   |                                    |                        |                           | 2                           |   |                                   |                        | 17              | 212                  | 1               |
|      | max     |                                  |   |                                    |                        |                           | 0                           |   |                                   |                        | 0               | 99                   | 0               |
|      | proport | 0/20                             | 0/20                                    | 0/20                               | 0/20                   | 0/20                      | 2/20                        | 0/20  | 0/20                              | 0/20                   | 5/20            |                      | 1/20            |
|      | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 10                          | 0   | 0                                 | 0                      | 25              |                      | 5               |

No quadrats fell in the 100 m buffer area during the July 2006 sampling.

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 12.2 | 12.2 |
| 2.77 to 3.1    | MHHW to Highest Tide | 4.9  | 4.9  |
| 1.55 to 2.76   | MSL to MHHW          | 80.5 | 63.4 |
| 0.22 to 1.54   | MLLW to MSL          | 2.4  | 19.5 |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table to the left presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m

| Knappa Slough | Tide Level (zero is MLLW) | Cumulative Percentage of Time | Elevation (NAVD88) |
|---------------|---------------------------|-------------------------------|--------------------|
| >MHHW         | >8.3 ft                   | 3.2%                          | >9.0 ft            |
| >MSL          | >4.3 ft                   | 48.3%                         | >5.1 ft            |
| >MLLW         | >0 ft                     | 94%                           | >0.7 ft            |
| <MLLW         | <0 ft                     | 94.7-100%                     | <0.7 ft            |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Knappa Slough; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL, >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.3 ft MLLW) at this site. Forty-eight percent of the time water levels exceed MSL (4.3 ft), 94% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



Looking south of initial biocontrol release point.  
July, 2006.

View toward southeast, back to release point. July, 2006.

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Dry Dock

**Dates:** June 16 & July 29, 2006

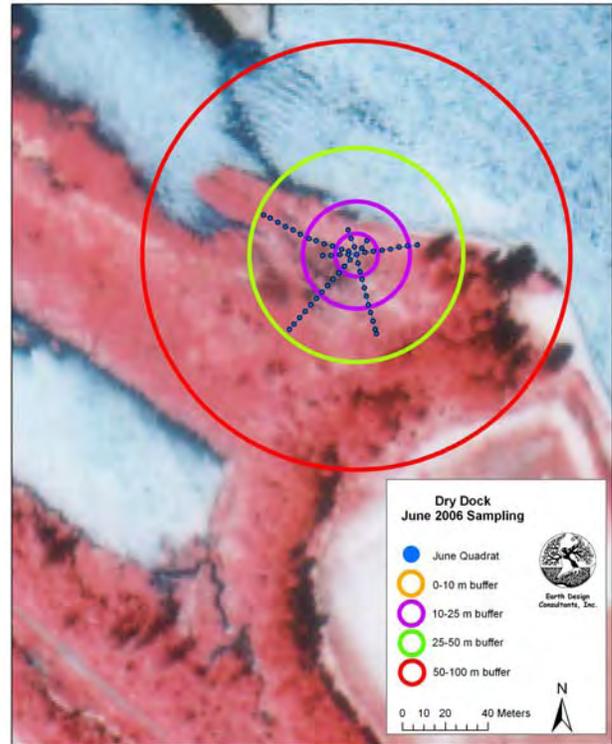
**Lat/Long:** 46.201218062,  
123.441531124 NAD83 Conus

**Columbia River Mile:** ~41

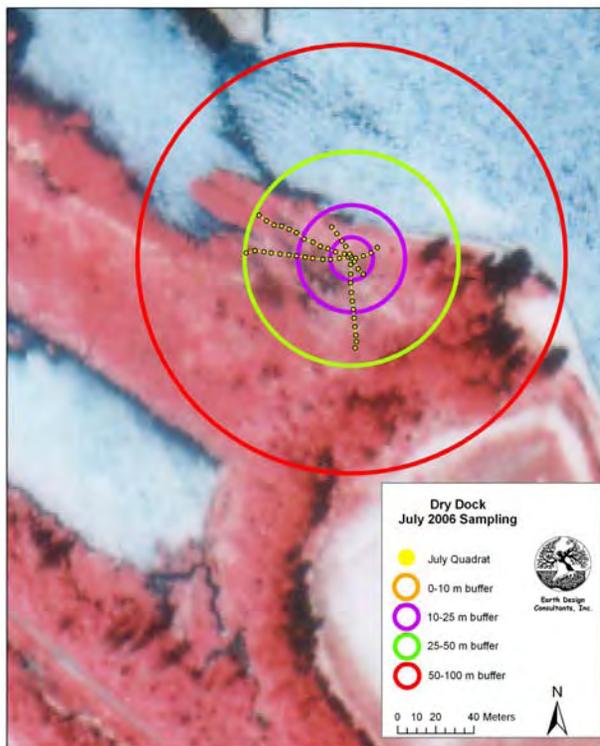
**Mean +/- S.D, Range in Elevation:**  
2.3 m +/- 0.4, 1.0-2.9 m NAVD88

**Distance to High Ground:** 25.3 m  
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 44.2m            | 49.0m             |
| <b>Forest</b> | NA                | 44.2m            | 43.9m             |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

function of distance from the initial biocontrol release point.

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 1                         | 1                           |   |                                   |                        | 2               | 90                   | 2               |
| st dev      | 0                                | 0                                       | 0                                  | 1                      | 6                         | 3                           |   |                                   |                        | 5               | 29                   | 7               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 10                   | 0               |
| max         | 1                                | 0                                       | 0                                  | 6                      | 40                        | 20                          |   |                                   |                        | 30              | 132                  | 45              |
| proport     | 1/51                             | 0/51                                    | 0/51                               | 2/51                   | 2/51                      | 10/51                       | 0/51  | 5/51                              | 4/51                   | 20/51           |                      | 13/51           |
| %           | 2                                | 0                                       | 0                                  | 4                      | 4                         | 20                          | 0   | 10                                | 8                      | 39              |                      | 25              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 2                      | 0                         | 1                           |   |                                   |                        | 4               | 160                  | 3               |
| st dev      | 1                                | 0                                       | 0                                  | 4                      | 0                         | 2                           |   |                                   |                        | 9               | 44                   | 9               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 48                   | 0               |
| max         | 7                                | 0                                       | 0                                  | 26                     | 0                         | 8                           |   |                                   |                        | 40              | 250                  | 52              |
| proport     | 6/50                             | 0/50                                    | 0/50                               | 11/50                  | 0/50                      | 15/50                       | 0/50  | 1/50                              | 15/50                  | 18/50           |                      | 10/50           |
| %           | 12                               | 0                                       | 0                                  | 2                      | 0                         | 30                          | 0   | 2                                 | 30                     | 36              |                      | 20              |

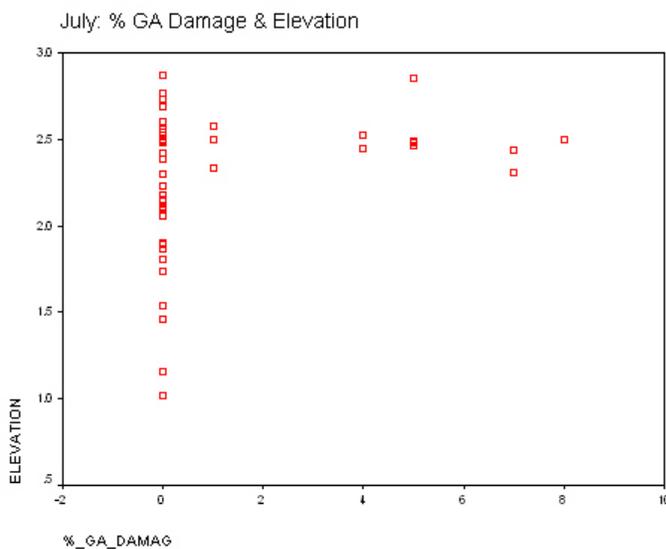
## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from the RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | -0.126       | (a)          | (a)        | -0.023        | -0.025      | 0.263       | 0.101         | (a)           | 0.097       | 0.084       |
|      | Sig. (2-tailed) | 0.419        |              |            | 0.883         | 0.875       | 0.089       | 0.521         |               | 0.537       | 0.593       |
|      | N               | 43           | 43           | 43         | 43            | 43          | 43          | 43            | 43            | 43          | 43          |
| July | Correlation     | 0.179        | (a)          | (a)        | 0.165         | (a)         | .309(*)     | 0.023         | 0.246         | (a)         | 0.161       |
|      | Sig. (2-tailed) | 0.245        |              |            | 0.284         |             | 0.041       | 0.881         | 0.107         |             | 0.297       |
|      | N               | 44           | 44           | 44         | 44            | 44          | 44          | 44            | 44            | 44          | 44          |

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

*July: % GA damage and elevation*



## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|      |         | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m | June    |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
|      | mean    | 0                                | 0                                       | 0                                  | 0                      | 3                         | 3                           | 0   | 0                                 |                        | 6               | 90                   | 5               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 10                        | 5                           | 0   | 0                                 |                        | 9               | 27                   | 12              |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 40                        | 20                          | 0   | 0                                 |                        | 30              | 33                   | 45              |
|      | max     | 0                                | 0                                       | 0                                  | 6                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 132                  | 0               |
|      | proport | 0/15                             | 0/15                                    | 0/15                               | 1/15                   | 2/15                      | 7/15                        | 0/15  | 4/15                              | 1/15                   | 12/15           |                      | 8/15            |
|      | %       | 0                                | 0                                       | 0                                  | 7                      | 13                        | 46.7                        | 0   | 27                                | 7                      | 80              |                      | 53              |
| 25 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   |                                   |                        | 0               | 69                   | 0               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   |                                   |                        | 1               | 46                   | 1               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   |                                   |                        | 0               | 10                   | 0               |
|      | max     | 1                                | 0                                       | 0                                  | 0                      | 0                         | 2                           | 0   |                                   |                        | 3               | 131                  | 2               |
|      | proport | 1/19                             | 0/19                                    | 0/19                               | 0/19                   | 0/19                      | 1/19                        | 0/19  | 1/19                              | 2/19                   | 3/19            |                      | 2/19            |
|      |         | %                                | 5                                       | 0                                  | 0                      | 0                         | 0                           | 5   | 0                                 | 5                      | 11              | 16                   |                 |
| 50 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   |                                   |                        | 1               | 100                  | 1               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           | 0   |                                   |                        | 2               | 19                   | 3               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   |                                   |                        | 0               | 70                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 2                      | 0                         | 2                           | 0   |                                   |                        | 8               | 130                  | 13              |
|      | proport | 0/17                             | 0/17                                    | 0/17                               | 1/17                   | 0/17                      | 2/17                        | 0/17  | 0/17                              | 1/17                   | 5/17            |                      | 3/17            |
|      |         | %                                | 0                                       | 0                                  | 0                      | 6                         | 0                           | 12  | 0                                 | 0                      | 6               | 29                   |                 |

No quadrats fell in the 100 m buffer area during the June 2006 sampling.

|      | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m | mean    | 1                                | 0                                       | 0                                  | 4                      | 0                         | 3                           |   |                                   |                        | 7               | 157                  | 7               |
|      | st dev  | 2                                | 0                                       | 0                                  | 7                      | 0                         | 3                           |   |                                   |                        | 10              | 41                   | 13              |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 48                   | 0               |
|      | max     | 7                                | 0                                       | 0                                  | 26                     | 0                         | 7                           |   |                                   |                        | 37              | 249                  | 52              |
|      | proport | 5/18                             | 0/18                                    | 0/18                               | 8/18                   | 0/18                      | 11/18                       | 0/18  | 1/18                              | 9/18                   | 12/18           |                      | 7/18            |
|      | %       | 28                               | 0                                       | 0                                  | 44                     | 0                         | 61                          | 0   | 6                                 | 50                     | 67              |                      | 39              |
| 25 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 166                  | 0               |
|      | st dev  | 0                                | 0                                       | 0                                  | 1                      | 0                         | 0                           |   |                                   |                        | 1               | 29                   | 0               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 139                  | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 3                      | 0                         | 0                           |   |                                   |                        | 3               | 196                  | 0               |
|      | proport | 0/14                             | 0/14                                    | 0/14                               | 1/14                   | 1/14                      | 0/14                        | 0/14  | 0/14                              | 1/14                   | 1/14            |                      | 0/14            |
|      | %       | 28                               | 0                                       | 0                                  | 7                      | 0                         | 0                           | 0   | 7                                 | 7                      |                 | 0                    |                 |
| 50 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 5               | 158                  | 3               |
|      | st dev  | 1                                | 0                                       | 0                                  | 1                      | 0                         | 2                           |   |                                   |                        | 10              | 51                   | 5               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 69                   | 0               |
|      | max     | 4                                | 0                                       | 0                                  | 3                      | 0                         | 8                           |   |                                   |                        | 40              | 244                  | 15              |
|      | proport | 1/18                             | 0/18                                    | 0/18                               | 2/18                   | 0/18                      | 4/18                        | 0/18  | 0/18                              | 5/18                   | 5/18            |                      | 4/18            |
|      | %       | 6                                | 0                                       | 0                                  | 11                     | 0                         | 22                          | 0   | 0                                 | 28                     | 28              |                      | 22              |

No quadrats fell in the 100 m buffer area during the July 2006 sampling.

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 0    | 0    |
| 2.77 to 3.1    | MHHW to Highest Tide | 2.3  | 6.8  |
| 1.55 to 2.76   | MSL to MHHW          | 95.3 | 84.1 |
| 0.22 to 1.54   | MLLW to MSL          | 2.3  | 9.1  |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL

and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m NAVD88.

| <b>Knappa Slough</b> | <b>Tide Level (zero is MLLW)</b> | <b>Cumulative Percentage of Time</b> | <b>Elevation (NAVD88)</b> |
|----------------------|----------------------------------|--------------------------------------|---------------------------|
| >MHHW                | >8.3 ft                          | 3.2%                                 | >9.0 ft                   |
| >MSL                 | >4.3 ft                          | 48.3%                                | >5.1 ft                   |
| >MLLW                | >0 ft                            | 94%                                  | >0.7 ft                   |
| <MLLW                | <0 ft                            | 94.7-100%                            | <0.7 ft                   |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Knappa Slough; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL, >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.3 ft MLLW) at this site. Forty-eight percent of the time water levels exceed MSL (4.3 ft), 94% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Site Photos



*Galerucella pusilla* on purple loosestrife (*Lythrum salicaria*).  
July, 2006



View to northwest. June, 2006.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Eureka Bar (Downstream)

**Dates:** June 19 & July 28, 2006

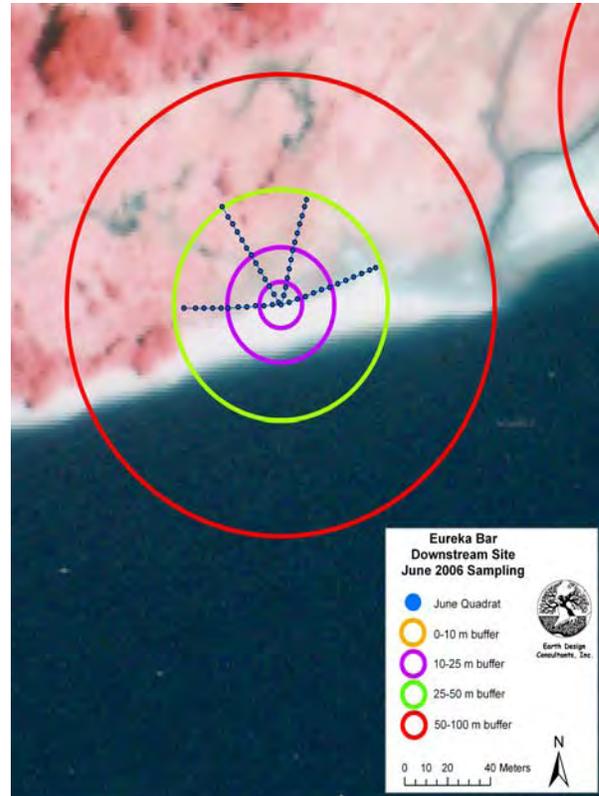
**Lat/Long:** 46.160541958 N,  
123.230569125 W NAD83 Conus

**Columbia River Mile:** ~ 53

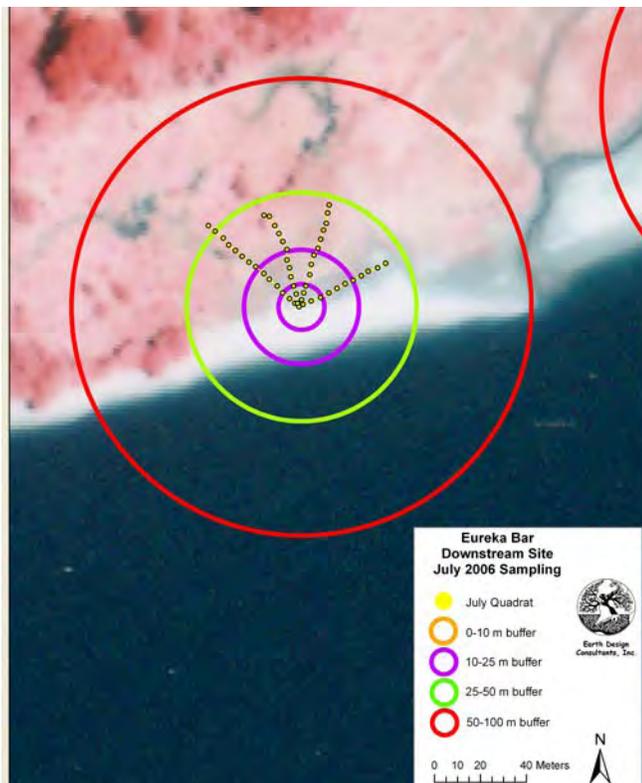
**Mean +/- S.D., Range in Elevation:**  
2.2 m +/- 0.4, 1.6-3.1 m NAVD88

**Distance to High Ground:** 16.86 m  
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 188.9            | 128.1             |
| <b>Forest</b> | NA                | 188.9            | 173.4             |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a function of distance from the initial release point.

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 23              | 74                   | 14              |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 19              | 32                   | 14              |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 8                    | 0               |
| max         | 0                                | 0                                       | 0                                  | 3                      | 2                         | 1                           |   |                                   |                        | 83              | 150                  | 58              |
| proport     | 0/50                             | 0/50                                    | 0/50                               | 1/50                   | 1/50                      | 3/50                        | 0/50  | 1/50                              | 14/50                  | 5/50            |                      | 42/50           |
| %           | 0                                | 0                                       | 0                                  | 2                      | 2                         | 6                           | 0   | 2                                 | 28                     | 10              |                      | 84              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 25              | 128                  | 11              |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 18              | 46                   | 12              |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 24                   | 0               |
| max         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 68              | 226                  | 47              |
| proport     | 6/50                             | 0/50                                    | 0/50                               | 0/50                   | 0/50                      | 0/50                        | 0/50  | 0/50                              | 22/50                  | 46/50           |                      | 35/50           |
| %           | 12                               | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 44                     | 92              |                      | 70              |

## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from the RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | (a)          | (a)          | (a)        | 0.025         | 0.116       | 0.23        | 0.116         | (a)           | -0.081      | 0.039       |
|      | Sig. (2-tailed) |              |              |            | 0.863         | 0.423       | 0.109       | 0.423         |               | 0.577       | 0.787       |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |
| July | Correlation     | (a)          | (a)          | (a)        | (a)           | (a)         | (a)         | (a)           | 0.026         | (a)         | 0.109       |
|      | Sig. (2-tailed) |              |              |            |               |             |             |               | 0.856         |             | 0.452       |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

*None*

## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|       |         | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m  | June    |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 24              | 55                   | 14              |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 21              | 27                   | 10              |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 2               | 8                    | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 74              | 148                  | 30              |
|       | proport | 0/11                             | 0/11                                    | 0/11                               | 0/11                   | 0/11                      | 0/11                        | 0/11  | 0/11                              | 3/11                   | 11/11           |                      | 9/11            |
| 25 m  | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 27                     | 100             |                      | 82              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 29              | 68                   | 17              |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 17              | 30                   | 13              |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 5               | 20                   | 3               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           | 0   | 0                                 |                        | 5               | 135                  | 46              |
|       | proport | 0/15                             | 0/15                                    | 0/15                               | 0/15                   | 0/15                      | 1/15                        | 0/15  | 0/15                              | 3/15                   | 15/15           |                      | 15/15           |
| 50 m  | %       | 0                                | 0                                       | 0                                  | 6                      | 0                         | 7                           | 0   | 0                                 | 20                     | 100             |                      | 100             |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 20              | 87                   | 13              |
|       | st dev  | 0                                | 0                                       | 0                                  | 1                      | 0                         | 0                           | 0   | 0                                 |                        | 21              | 32                   | 16              |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 21                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 3                      | 2                         | 1                           | 0   | 0                                 |                        | 83              | 150                  | 58              |
|       | proport | 0/23                             | 0/23                                    | 0/23                               | 1/23                   | 1/23                      | 2/23                        | 0/23  | 1/23                              | 8/23                   | 18/23           |                      | 18/23           |
| 100 m | %       | 0                                | 0                                       | 0                                  | 4                      | 4                         | 9                           | 0   | 4                                 | 35                     | 78              |                      | 78              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 20              | 77                   | 0               |
|       | st dev  | n/a                              | n/a                                     | n/a                                | n/a                    | n/a                       | n/a                         | n/a   | 0                                 |                        | n/a             | 26                   | n/a             |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 20              | 39                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 20              | 103                  | 0               |
|       | proport | 0/1                              | 0/1                                     | 0/1                                | 0/1                    | 0/1                       | 0/1                         | 0/1   | 0/1                               | 0/1                    | 1/1             |                      | 0/1             |
| %     | 0       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 100                    |                 | 0                    |                 |

|       | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 30              | 113                  | 11              |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 16              | 36                   | 13              |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 2               | 39                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 53              | 187                  | 44              |
|       | proport | 0/12                             | 0/12                                    | 0/12                               | 0/12                   | 0/12                      | 0/12                        | 0/12  | 0/12                              | 4/12                   | 12/12           |                      | 9/12            |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 33                     | 100             |                      | 75              |
| 25 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 24              | 108                  | 14              |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 20              | 48                   | 14              |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 24                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 55              | 193                  | 47              |
|       | proport | 0/13                             | 0/13                                    | 0/13                               | 0/13                   | 0/13                      | 0/13                        | 0/13  | 0/13                              | 7/13                   | 12/13           |                      | 9/13            |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 54                     | 92              |                      | 69              |
| 50 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 23              | 146                  | 9               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 19              | 43                   | 11              |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 48                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 68              | 223                  | 31              |
|       | proport | 0/23                             | 0/23                                    | 0/23                               | 0/23                   | 0/23                      | 0/23                        | 0/23  | 0/23                              | 11/23                  | 20/23           |                      | 16/23           |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 48                     | 87              |                      | 70              |
| 100 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 16              | 160                  | 1               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 9               | 47                   | 1               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 9               | 66                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 22              | 226                  | 1               |
|       | proport | 0/2                              | 0/2                                     | 0/2                                | 0/2                    | 0/2                       | 0/2                         | 0/2   | 0/2                               | 0/2                    | 2/2             |                      | 1/2             |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 100                    |                 |                      | 50              |

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 0    | 0    |
| 2.77 to 3.1    | MHHW to Highest Tide | 20   | 8    |
| 1.55 to 2.76   | MSL to MHHW          | 80   | 92   |
| 0.22 to 1.54   | MLLW to MSL          | 0    | 0    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m NAVD88.

| <b>Knappa Slough</b> | <b>Tide Level (zero is MLLW)</b> | <b>Cumulative Percentage of Time</b> | <b>Elevation (NAVD88)</b> |
|----------------------|----------------------------------|--------------------------------------|---------------------------|
| >MHHW                | >8.3 ft                          | 3.2%                                 | >9.0 ft                   |
| >MSL                 | >4.3 ft                          | 48.3%                                | >5.1 ft                   |
| >MLLW                | >0 ft                            | 94%                                  | >0.7 ft                   |
| <MLLW                | <0 ft                            | 94.7-100%                            | <0.7 ft                   |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Knappa Slough; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL, >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.3 ft MLLW) at this site. Forty-eight percent of the time water levels exceed MSL (4.3 ft), 94% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



View to northwest. June, 2006

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Eureka Bar (Upstream)

**Dates:** June 19 & July 28, 2006

**Lat/Long:** 46.161353780 N,  
123.227587710 W NAD83 Conus

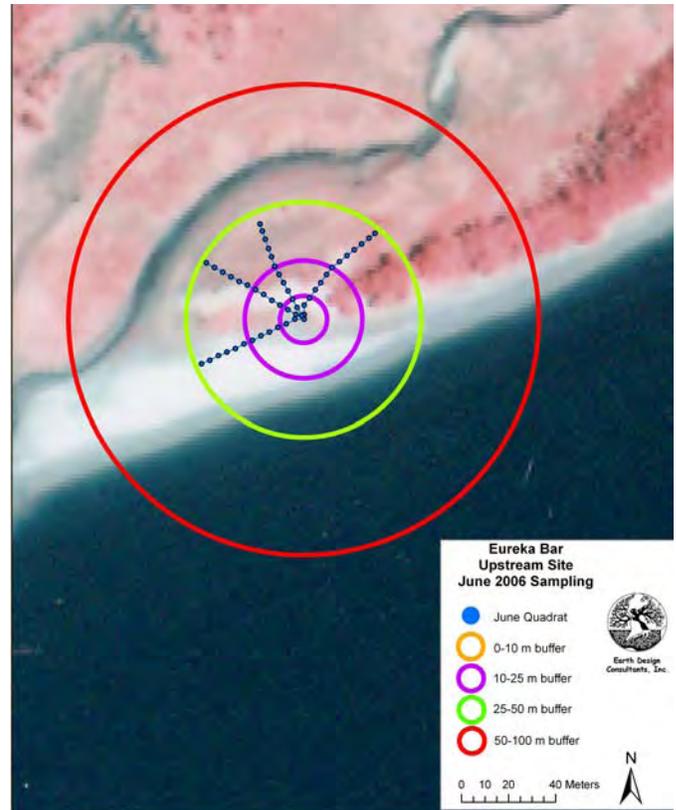
**Columbia River Mile:** ~ 53

**Mean +/- S.D., Range in Elevation:**  
2.4 m +/- 0.5, 1.6-5.3 m NAVD88

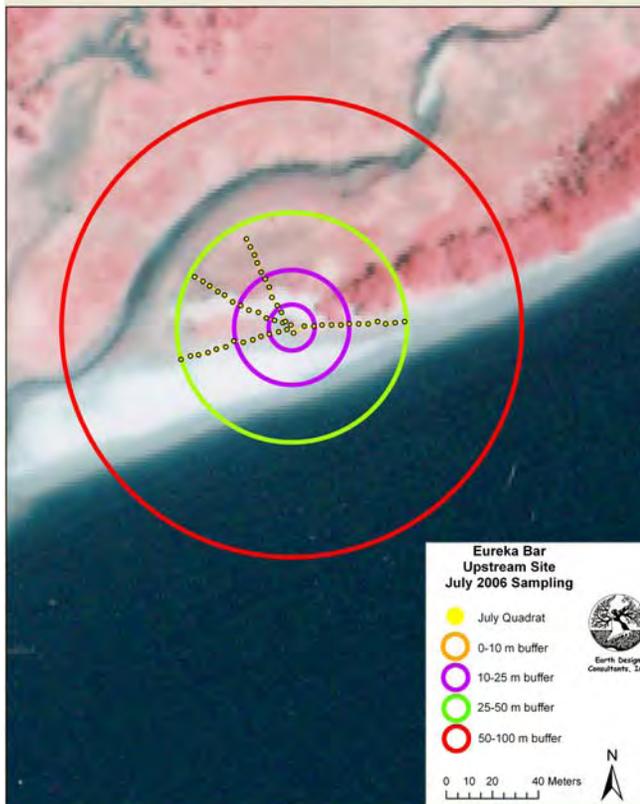
**Distance to High Ground:**  
Not available

**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 32.7m            | 186.7m            |
| <b>Forest</b> | NA                | 32.7m            | 302.4m            |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the original biocontrol release point. These buffers are used to summarize various field measures as a function of distance from the initial biocontrol release point.

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; TM=enhanced thematic mapper plus; see main report for details

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 22              | 75                   | 10              |
| st dev      | 0                                | 0                                       | 0                                  | 1                      | 1                         | 0                           |   |                                   |                        | 17              | 33                   | 10              |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 9                    | 0               |
| max         | 0                                | 0                                       | 0                                  | 4                      | 3                         | 1                           |   |                                   |                        | 60              | 173                  | 40              |
| proport     | 0/50                             | 0/50                                    | 0/50                               | 3/50                   | 4/50                      | 11/50                       | 0/50  | 3/50                              | 12/50                  | 3/50            |                      | 11/50           |
| %           | 0                                | 0                                       | 0                                  | 6                      | 8                         | 22                          | 0   | 6                                 | 24                     | 0               |                      | 0               |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 18              | 125                  | 5               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 16              | 38                   | 6               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 20                   | 0               |
| max         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 81              | 205                  | 27              |
| proport     | 0/50                             | 0/50                                    | 0/50                               | 0/50                   | 0/50                      | 5/50                        | 0/50  | 0/50                              | 19/50                  | 44/50           |                      | 33/50           |
| %           | 0                                | 0                                       | 0                                  | 0                      | 0                         | 100                         | 0   | 0                                 | 38                     | 88              |                      | 66              |

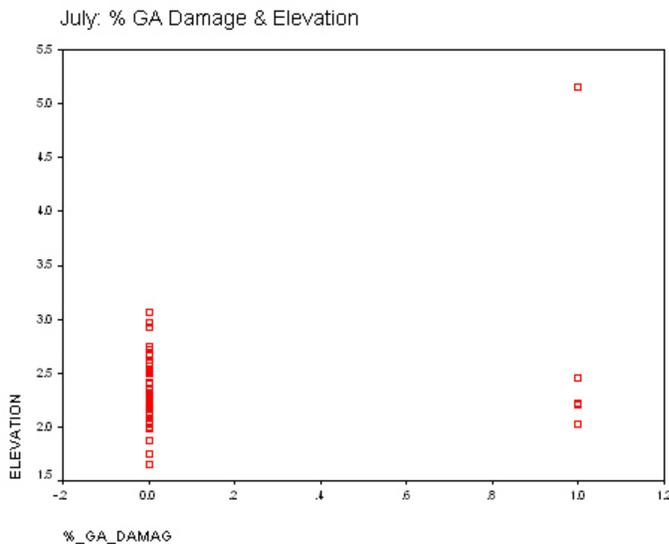
## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | (a)          | (a)          | (a)        | 0.085         | 0.092       | 0.005       | 0.237         | (a)           | 0.135       | -0.111      |
|      | Sig. (2-tailed) |              |              |            | 0.559         | 0.525       | 0.971       | 0.097         |               | 0.349       | 0.444       |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |
| July | Correlation     | (a)          | (a)          | (a)        | (a)           | (a)         | .293(*)     | (a)           | -0.01         | (a)         | -0.008      |
|      | Sig. (2-tailed) |              |              |            |               |             | 0.039       |               | 0.947         |             | 0.955       |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

### July: % GA damage and elevation



## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|      | June    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 13              | 64                   | 6               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 10              | 23                   | 5               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 0                      | 2               | 22                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 1                                 | 0                      | 32              | 150                  | 17              |
|      | proport | 0/11                             | 0/11                                    | 0/11                               | 0/11                   | 0/11                      | 0/11                        | 0/11  | 1/11                              | 2/11                   | 11/11           |                      | 10/11           |
| 25 m | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 9                                 | 18                     | 100             |                      | 91              |
|      | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 27              | 65                   | 10              |
|      | st dev  | 0                                | 0                                       | 0                                  | 1                      | 1                         | 0                           | 0   | 0                                 |                        | 20              | 31                   | 12              |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 0                      | 4               | 9                    | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 4                      | 3                         | 1                           | 0   | 1                                 | 0                      | 60              | 134                  | 40              |
| 50 m | proport | 0/14                             | 0/14                                    | 0/14                               | 2/14                   | 3/14                      | 5/14                        | 0/14  | 2/14                              | 4/14                   | 14/14           |                      | 9/14            |
|      | %       | 0                                | 0                                       | 0                                  | 14                     | 21                        | 36                          | 0   | 14                                | 29                     | 100             |                      | 64              |
|      | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 0                      | 23              | 85                   | 11              |
|      | st dev  | 0                                | 0                                       | 0                                  | 1                      | 0                         | 0                           | 0   | 0                                 | 0                      | 16              | 35                   | 9               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 0                      | 0               | 11                   | 0               |
| 50 m | max     | 0                                | 0                                       | 0                                  | 3                      | 2                         | 1                           | 0   | 0                                 | 0                      | 58              | 173                  | 34              |
|      | proport | 0/25                             | 0/25                                    | 0/25                               | 1/25                   | 1/25                      | 6/25                        | 0/25  | 0/25                              | 6/25                   | 22/25           |                      | 20/25           |
|      | %       | 0                                | 0                                       | 0                                  | 4                      | 4                         | 24                          | 0   | 0                                 | 24                     | 88              |                      | 80              |

No quadrats fell in the 100 m buffer area during the June 2006 sampling.

|       | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 19              | 124                  | 4               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 11              | 31                   | 3               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 2               | 27                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 44              | 200                  | 9               |
|       | proport | 0/10                             | 0/10                                    | 0/10                               | 0/10                   | 0/10                      | 2/10                        | 0/10  | 0/10                              | 1/10                   | 10/10           |                      | 7/10            |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 20                          | 0   | 0                                 | 10                     | 100             |                      | 70              |
| 25 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 15              | 118                  | 5               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 13              | 37                   | 7               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 30                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 43              | 180                  | 24              |
|       | proport | 0/15                             | 0/15                                    | 0/15                               | 0/15                   | 0/15                      | 1/15                        | 0/15  | 0/15                              | 7/15                   | 14/15           |                      | 9/15            |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 7                           | 0   | 0                                 | 47                     | 93              |                      | 60              |
| 50 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 20              | 130                  | 5               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 20              | 42                   | 7               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 20                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 81              | 205                  | 27              |
|       | proport | 0/24                             | 0/24                                    | 0/24                               | 0/24                   | 0/24                      | 2/24                        | 0/24  | 0/24                              | 11/24                  | 19/24           |                      | 16/24           |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 8                           | 0   | 0                                 | 46                     | 79              |                      | 67              |
| 100 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 19              | 109                  | 8               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        |                 | 34                   |                 |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 19              | 63                   | 8               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 19              | 157                  | 8               |
|       | proport | 0/1                              | 0/1                                     | 0/1                                | 0/1                    | 0/1                       | 0/1                         | 0/1   | 0/1                               | 0/1                    | 1/1             |                      | 1/1             |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 100                    |                 |                      | 100             |

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 4    | 2    |
| 2.77 to 3.1    | MHHW to Highest Tide | 6    | 6    |
| 1.55 to 2.76   | MSL to MHHW          | 90   | 92   |
| 0.22 to 1.54   | MLLW to MSL          | 0    | 0    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL

and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m NAVD88.

| Knappa Slough | Tide Level (zero is MLLW) | Cumulative Percentage of Time | Elevation (NAVD88) |
|---------------|---------------------------|-------------------------------|--------------------|
| >MHHW         | >8.3 ft                   | 3.2%                          | >9.0 ft            |
| >MSL          | >4.3 ft                   | 48.3%                         | >5.1 ft            |
| >MLLW         | >0 ft                     | 94%                           | >0.7 ft            |
| <MLLW         | <0 ft                     | 94.7-100%                     | <0.7 ft            |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Knappa Slough; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL, >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.3 ft MLLW) at this site. Forty-eight percent of the time water levels exceed MSL (4.3 ft), 94% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos

Purple loosestrife (*L. salicaria*) at site (upper right).

Release of *Hylobius transversovittatus* eggs (lower left).

July 2006.



<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Fitzpatrick Island

**Dates:** June 27 & July 27, 2006

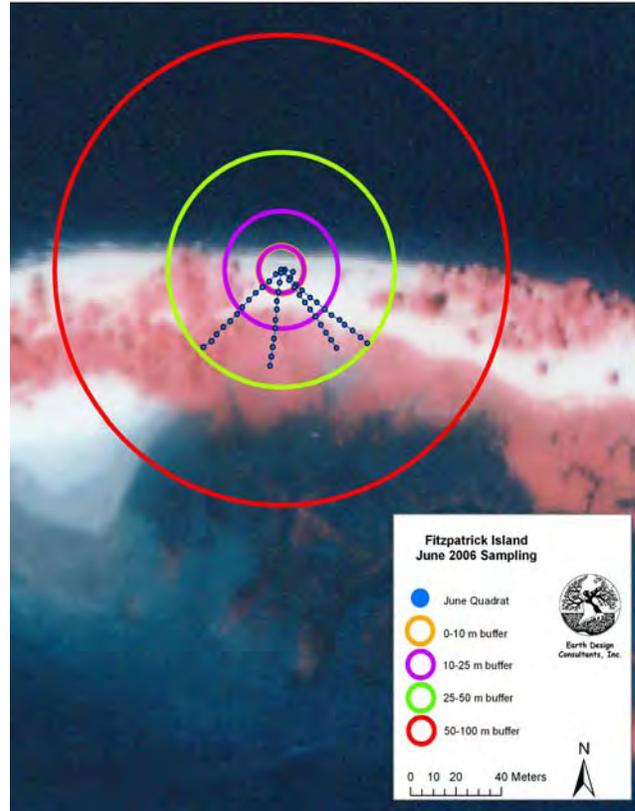
**Lat/Long:** 46.263591751 N,  
123.500761798 W NAD83 Conus

**Columbia River Mile:** ~ 34

**Mean +/- S.D., Range in Elevation:**  
2.7 m +/- 0.1, 2.3-2.9 m NAVD88

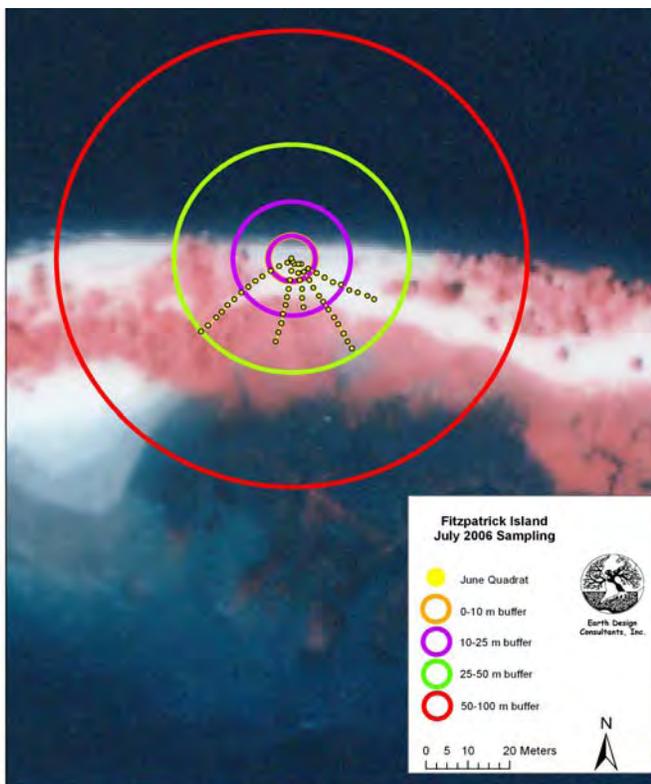
**Distance to High Ground:** 52.89 m  
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 24.4             | 0.0               |
| <b>Forest</b> | NA                | 24.4             | 592.9             |



June quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.



July quadrat locations.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a function of distance from the initial biocontrol release point.

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 7               | 64                   | 0               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 8               | 28                   | 0               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 10                   | 0               |
| max         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 37              | 125                  | 3               |
| proport     | 0/50                             | 0/50                                    | 0/50                               | 0/50                   | 0/50                      | 0/50                        | 0/50  | 0/50                              | 6/50                   | 34/50           |                      | 4/50            |
| %           | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 12                     | 68              |                      | 8               |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 7               | 78                   | 0               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 8               | 35                   | 0               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 9                    | 0               |
| max         | 0                                | 0                                       | 0                                  | 1                      | 0                         | 0                           |   |                                   |                        | 35              | 204                  | 1               |
| proport     | 0/51                             | 0/51                                    | 0/51                               | 1/51                   | 0/51                      | 0/51                        | 0/51  | 0/51                              | 15/51                  | 38/51           |                      | 2/51            |
| %           | 0                                | 0                                       | 0                                  | 2                      | 0                         | 0                           | 0   | 0                                 | 29                     | 75              |                      | 4               |

## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from the RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | (a)          | (a)          | (a)        | (a)           | (a)         | (a)         | (a)           | (a)           | 0.146       | 0.021       |
|      | Sig. (2-tailed) |              |              |            |               |             |             |               |               | 0.312       | 0.887       |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |
| July | Correlation     | (a)          | (a)          | (a)        | 0.205         | (a)         | (a)         | (a)           | 0.18          | (a)         | 0.253       |
|      | Sig. (2-tailed) |              |              |            | 0.149         |             |             |               | 0.207         |             | 0.074       |
|      | N               | 51           | 51           | 51         | 51            | 51          | 51          | 51            | 51            | 51          | 51          |

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

*None*

## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|      |         | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage<br><i>G. nymphaeae</i> | <i>transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|--|----------------------------------|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m | June    |                                  |   |                                    |                        |                           |  |                                  |                                   |                        |                 |                      |                 |
|      | mean    |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 10              | 71                   | 0               |
|      | st dev  |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 10              | 32                   | 1               |
|      | min     |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 0               | 11                   | 0               |
|      | max     |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 37              | 125                  | 3               |
|      | proport | 0/14                             | 0/14                                    | 0/14                               | 0/14                   | 0/14                      | 0/14   | 0/14                             | 0/14                              | 2/14                   | 13/14           |                      | 2/14            |
| 25 m | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 14                     | 93              |                      | 14              |
|      | mean    |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 7               | 61                   | 0               |
|      | st dev  |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 7               | 25                   | 0               |
|      | min     |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 0               | 10                   | 0               |
|      | max     |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 23              | 111                  | 1               |
|      | proport | 0/14                             | 0/14                                    | 0/14                               | 0/14                   | 0/14                      | 0/14   | 0/14                             | 0/14                              | 4/14                   | 11/14           |                      | 1/14            |
| 50 m | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 29                     | 79              |                      | 7               |
|      | mean    |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 4               | 60                   | 0               |
|      | st dev  |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 6               | 25                   | 0               |
|      | min     |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 0               | 15                   | 0               |
|      | max     |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 24              | 116                  | 1               |
|      | proport | 0/22                             | 0/22                                    | 0/22                               | 0/22                   | 0/22                      | 0/22   | 0/22                             | 0/22                              | 1/22                   | 10/22           |                      | 1/22            |
| %    | 0       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 5                                 | 45                     |                 | 5                    |                 |

No quadrats fell in the 100 m buffer area during the June 2006 sampling.

|      | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage<br>to <i>Nyctoporus</i> | <i>transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|---|----------------------------------|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m | mean    |                                  |   |                                    | 0                      |                           |   |                                  |                                   |                        | 9               | 82                   | 0               |
|      | st dev  |                                  |   |                                    | 0                      |                           |   |                                  |                                   |                        | 8               | 34                   | 0               |
|      | min     |                                  |   |                                    | 0                      |                           |   |                                  |                                   |                        | 0               | 10                   | 0               |
|      | max     |                                  |   |                                    | 1                      |                           |   |                                  |                                   |                        | 28              | 131                  | 1               |
|      | proport | 0/12                             | 0/12                                    | 0/12                               | 1/12                   | 0/12                      | 0/12  | 0/12                             | 0/12                              | 7/12                   | 10/12           |                      | 2/12            |
| %    | 0       | 0                                | 0                                       | 8                                  | 0                      | 0                         | 0   | 0                                | 58                                | 83                     |                 | 17                   |                 |
| 25 m | mean    |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 7               | 82                   |                 |
|      | st dev  |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 10              | 35                   |                 |
|      | min     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 0               | 12                   |                 |
|      | max     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 35              | 204                  |                 |
|      | proport | 0/19                             | 0/19                                    | 0/19                               | 0/19                   | 0/19                      | 0/19  | 0/19                             | 0/19                              | 4/19                   | 15/19           |                      | 0/19            |
| %    | 0       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   | 0                                | 21                                | 79                     |                 | 0                    |                 |
| 50 m | mean    |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 5               | 70                   |                 |
|      | st dev  |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 6               | 34                   |                 |
|      | min     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 0               | 9                    |                 |
|      | max     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 24              | 142                  |                 |
|      | proport | 0/20                             | 0/20                                    | 0/20                               | 0/20                   | 0/20                      | 0/20  | 0/20                             | 0/20                              | 4/20                   | 13/20           |                      | 0/20            |
| %    | 0       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   | 0                                | 20                                | 65                     |                 | 0                    |                 |

No quadrats fell in the 100 m buffer area during the July 2006 sampling.

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 0    | 0    |
| 2.77 to 3.1    | MHHW to Highest Tide | 24   | 31.4 |
| 1.55 to 2.76   | MSL to MHHW          | 76   | 68.6 |
| 0.22 to 1.54   | MLLW to MSL          | 0    | 0    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m NAVD88.

| Tongue Pt | Tide Level (zero is MLLW) | Cumulative Percentage of Time | Elevation (NAVD88) |
|-----------|---------------------------|-------------------------------|--------------------|
| >MHHW     | >8.6 ft                   | 3%                            | >8.8 ft            |
| >MSL      | >4.5 ft                   | 49%                           | >4.6 ft            |
| >MLLW     | >0 ft                     | 95%                           | >0.2 ft            |
| <MLLW     | <0 ft                     | 95-100%                       | <0.2 ft            |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Tongue Point; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL; >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.6 ft MLLW) at this site. Forty-nine percent of the time water levels exceed MSL (4.5 ft), 95% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



View of site looking north. July, 2006.



View toward south. June, 2006.

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Karlson Island

**Dates:** June 17 & July 24, 2006

**Lat/Long:** 46.205319766 N,  
123.615763939 W NAD83 Conus

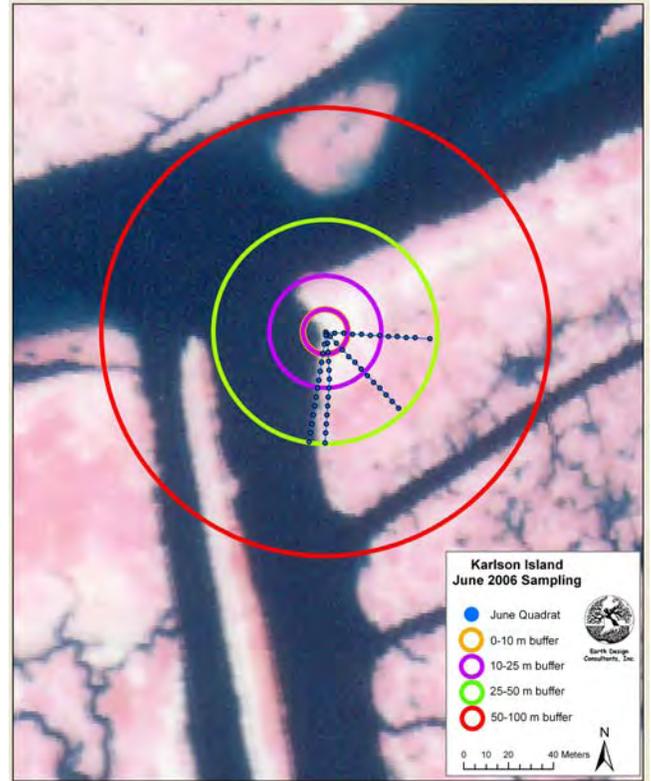
**Columbia River Mile:** ~ 28

**Mean +/- S.D., Range in Elevation:**  
2.2 m +/- 0.1, 2.0-2.5 m NAVD88

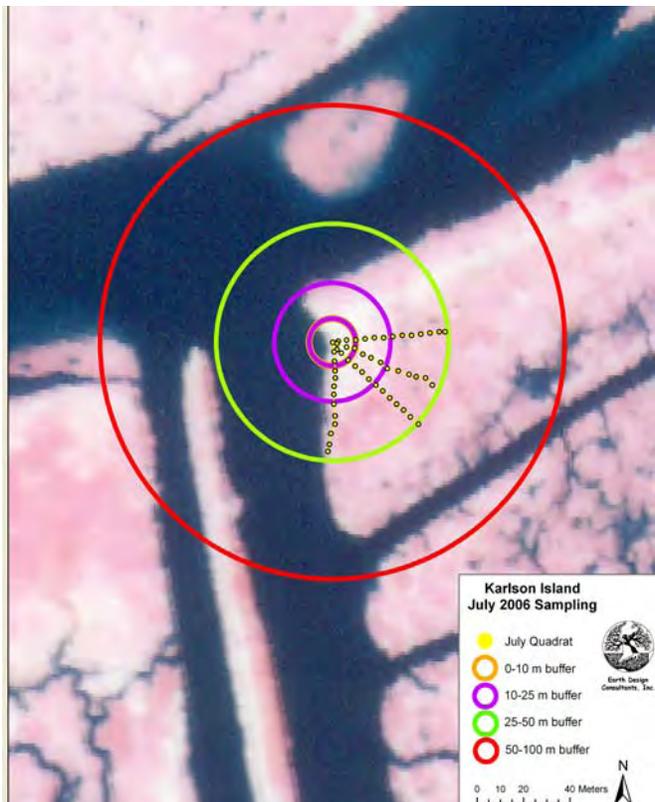
**Distance to High Ground:** 4.6m

**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 33.9m            | 50.8m             |
| <b>Forest</b> | NA                | 33.9m            | 388.6m            |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

function of distance from the initial biocontrol release point.

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|-----------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                 |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 7               | 100             | 0               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 8               | 26              | 0               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 33              | 0               |
| max         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 37              | 150             | 3               |
| proport     | 0/50                             | 0/50                                    | 0/50                               | 0/50                   | 0/50                      | 0/50                        | 0/50  | 0/50                              | 6/50                   | 34/50           |                 | 4/50            |
| %           | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 12                     | 68              |                 | 8               |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                 |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 4               | 152             | 1               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 7               | 33              | 2               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 61              | 0               |
| max         | 1                                | 0                                       | 0                                  | 0                      | 0                         | 4                           |   |                                   |                        | 25              | 208             | 9               |
| proport     | 2/50                             | 0/50                                    | 0/50                               | 0/50                   | 0/50                      | 3/50                        | 0/50  | 0/50                              | 5/50                   | 20/50           |                 | 7/50            |
| %           | 4                                | 0                                       | 0                                  | 0                      | 0                         | 6                           | 0   | 0                                 | 10                     | 40              |                 | 14              |

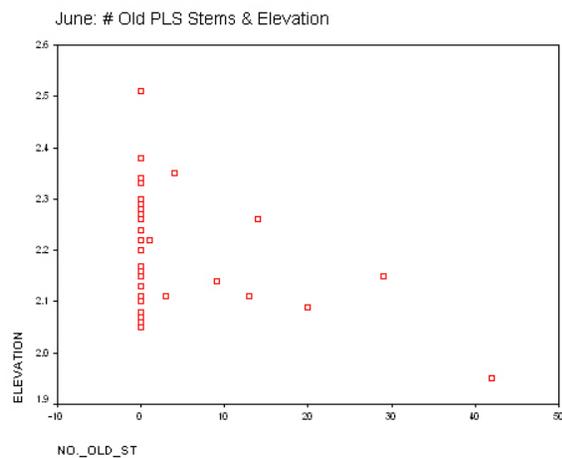
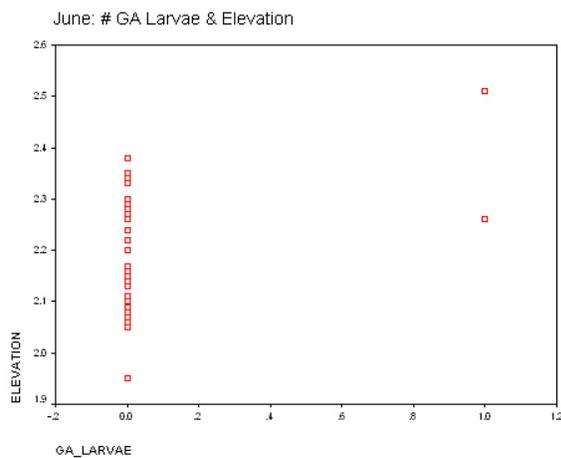
## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from TRK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | (a)          | (a)          | (a)        | 0.06          | .410(*)     | 0.204       | (a)           | (a)           | -0.306      | -0.352(*)   |
|      | Sig. (2-tailed) |              |              |            | 0.722         | 0.011       | 0.219       |               |               | 0.062       | 0.03        |
|      | N               | 38           | 38           | 38         | 38            | 38          | 38          | 38            | 38            | 38          | 38          |
| July | Correlation     | 0.274        | (a)          | (a)        | (a)           | (a)         | 0.193       | (a)           | 0.039         | (a)         | -0.133      |
|      | Sig. (2-tailed) | 0.111        |              |            |               |             | 0.268       |               | 0.825         |             | 0.448       |
|      | N               | 35           | 35           | 35         | 35            | 35          | 35          | 35            | 35            | 35          | 35          |

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

*June: # GA larvae and elevation*  
*June: # old L. salicaria stems and elevation*



## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|     |           | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |      |
|-----|-----------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|------|
| 10m | June      |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |      |
|     | mean      | 0                                | 0                                       | 0                                  | 0.18                   | 0.18                      | 0.91                        | 0   | 0                                 |                        | 7.09            | 92.8                 | 1.727           |      |
|     | st dev    | 0                                | 0                                       | 0                                  | 0.6                    | 0.4                       | 1.14                        | 0   | 0                                 |                        | 6.92            | 30.3                 | 4.245           |      |
|     | min       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 33                   | 0               |      |
|     | max       | 0                                | 0                                       | 0                                  | 2                      | 1                         | 3                           | 0   | 0                                 |                        | 20              | 150                  | 14              |      |
|     | proport % | 0/11                             | 0/11                                    | 0/11                               | 1/11                   | 2/11                      | 5/11                        | 0/11  | 0/11                              | 1/11                   | 8/11            |                      |                 | 3/11 |
| 25m | mean      | 0                                | 0                                       | 0                                  | 0.07                   | 0                         | 0.21                        | 0   | 0                                 |                        | 8.23            | 109                  | 3.643           |      |
|     | st dev    | 0                                | 0                                       | 0                                  | 0.27                   | 0                         | 0.58                        | 0   | 0                                 |                        | 16              | 18.8                 | 8.345           |      |
|     | min       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 81                   | 0               |      |
|     | max       | 0                                | 0                                       | 0                                  | 1                      | 0                         | 2                           | 0   | 0                                 |                        | 52              | 146                  | 29              |      |
|     | proport % | 0/14                             | 0/14                                    | 0/14                               | 1/14                   | 0/14                      | 2/14                        | 0/14  | 0/14                              | 0/14                   | 4/14            |                      |                 | 3/14 |
|     | mean      | 0                                | 0                                       | 0                                  | 7.14                   | 0                         | 14.3                        | 0   | 0                                 | 0                      | 28.6            |                      |                 | 21   |
| 50m | mean      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0.2                         | 0   | 0                                 |                        | 7.32            | 103                  | 3.6             |      |
|     | st dev    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           | 0   | 0                                 |                        | 21.2            | 20.7                 | 9.491           |      |
|     | min       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 63                   | 0               |      |
|     | max       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 5                           | 0   | 0                                 |                        | 104             | 141                  | 42              |      |
|     | proport % | 0/25                             | 0/25                                    | 0/25                               | 0/25                   | 0/25                      | 1/25                        | 0/25  | 0/25                              | 1/25                   | 6/25            |                      |                 | 5/25 |
|     | mean      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 4                           | 0   | 0                                 | 4                      | 24              |                      |                 | 20   |

No quadrats fell in the 100 m buffer area during the June 2006 sampling.

|      | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 4               | 133                  | 0               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 7               | 33                   | 1               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 78                   | 0               |
|      | max     | 1                                | 0                                       | 0                                  | 0                      | 0                         | 4                           |   |                                   |                        | 18              | 170                  | 2               |
|      | proport | 2/9                              | 0/9                                     | 0/9                                | 0/9                    | 0/9                       | 1/9                         | 0/9   | 0/9                               | 1/9                    | 4/9             |                      | 1/9             |
|      | %       | 22                               | 0                                       | 0                                  | 0                      | 0                         | 11                          | 0   | 0                                 | 11                     | 44              |                      | 11              |
| 25m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 1               | 148                  | 1               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 3               | 34                   | 2               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 91                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 12              | 184                  | 9               |
|      | proport | 0/15                             | 0/15                                    | 0/15                               | 0/15                   | 0/15                      | 2/15                        | 0/15  | 0/15                              | 0/15                   | 5/15            |                      | 2/15            |
|      | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 13                          | 0   | 0                                 | 0                      | 33              |                      | 13              |
| 50m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 5               | 160                  | 1               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 8               | 32                   | 2               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 61                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 25              | 208                  | 9               |
|      | proport | 0/25                             | 0/25                                    | 0/25                               | 0/25                   | 0/25                      | 0/25                        | 0/25  | 0/25                              | 3/25                   | 10/25           |                      | 4/25            |
|      | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 12                     | 40              |                      | 16              |
| 100m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 13              | 157                  | 0               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        |                 | 11                   |                 |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 13              | 144                  | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 13              | 172                  | 0               |
|      | proport | 0/1                              | 0/1                                     | 0/1                                | 0/1                    | 0/1                       | 0/1                         | 0/1   | 0/1                               | 1/1                    | 1/1             |                      | 0/1             |
|      | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 100                    | 100             |                      | 0               |

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 0    | 0    |
| 2.77 to 3.1    | MHHW to Highest Tide | 0    | 0    |
| 1.55 to 2.76   | MSL to MHHW          | 100  | 100  |
| 0.22 to 1.54   | MLLW to MSL          | 0    | 0    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL and the lowest tide water level, and below the water level of the lowest tide. All quadrats are between MSL and MHHW, roughly 1.5 – 2.76 m NAVD88.

| Knappa Slough | Tide Level (zero is MLLW) | Cumulative Percentage of Time | Elevation (NAVD88) |
|---------------|---------------------------|-------------------------------|--------------------|
| >MHHW         | >8.3 ft                   | 3.2%                          | >9.0 ft            |
| >MSL          | >4.3 ft                   | 48.3%                         | >5.1 ft            |
| >MLLW         | >0 ft                     | 94%                           | >0.7 ft            |
| <MLLW         | <0 ft                     | 94.7-100%                     | <0.7 ft            |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Knappa Slough; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL, >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.3 ft MLLW) at this site. Forty-eight percent of the time water levels exceed MSL (4.3 ft), 94% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



View of site, looking north toward release point. June, 2006 (Right).

Field sampling. July, 2006 (Above).



<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Marsh Island

**Dates:** June 18 & July 26, 2006

**Lat/Long:** 46.224094449 N,  
123.568720039 W NAD83 Conus

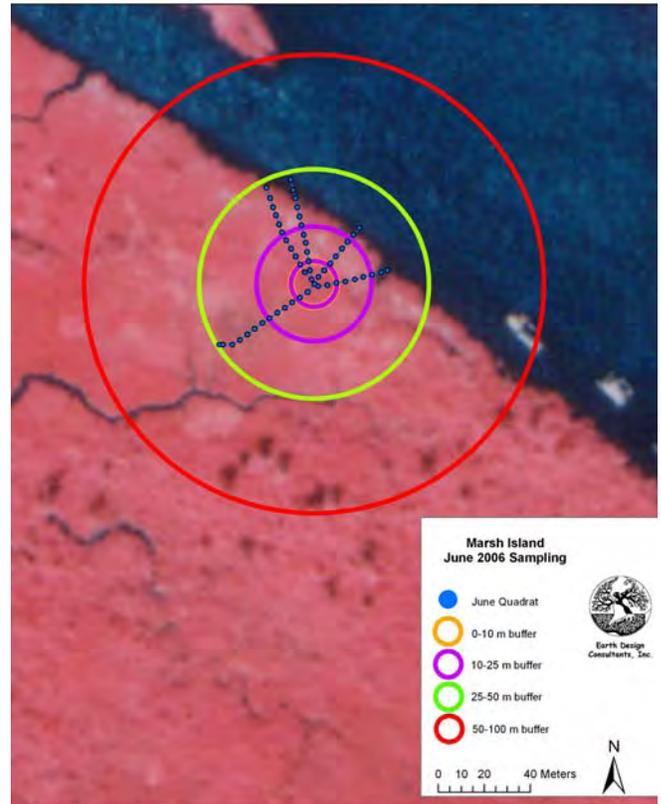
**Columbia River Mile:** ~ 30

**Mean +/- S.D., Range in Elevation:**  
2.1 m +/- 0.4, 0.7-2.5 m NAVD88

**Distance to High Ground:**  
Not available

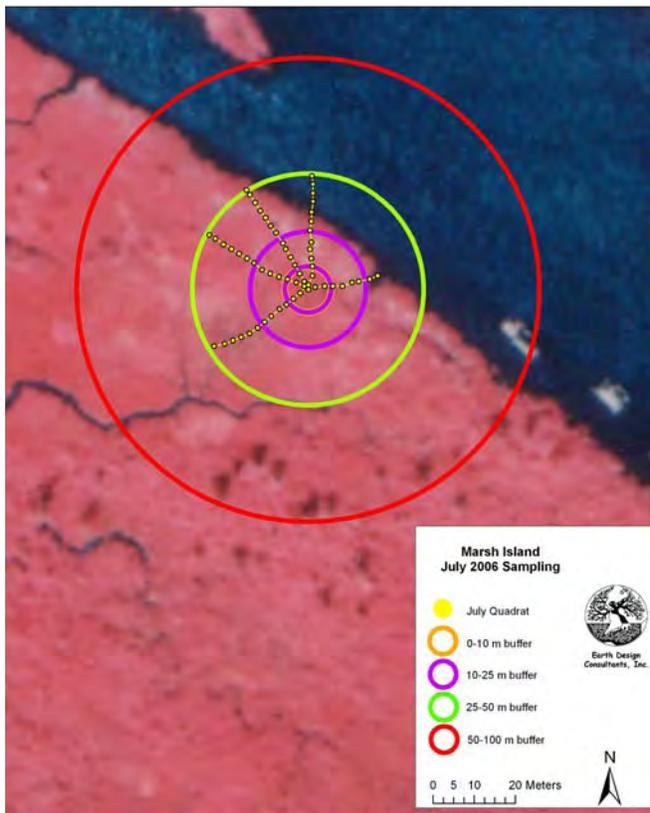
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 0m               | 0m                |
| <b>Forest</b> | NA                | 0m               | 388.6m            |



June quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.



July quadrat locations.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

field measures as a function of distance from the initial biocontrol release point.

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 6               | 116                  | 3               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 2                         | 0                           |   |                                   |                        | 17              | 27                   | 7               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 43                   | 0               |
| max         | 1                                | 0                                       | 0                                  | 2                      | 12                        | 1                           |   |                                   |                        | 116             | 160                  | 27              |
| proport     | 1/55                             | 0/55                                    | 0/55                               | 1/55                   | 2/55                      | 7/55                        | 0/50  | 0/50                              | 11/55                  | 15/55           |                      | 9/55            |
| %           | 2                                | 0                                       | 0                                  | 2                      | 4                         | 13                          | 0   | 0                                 | 20                     | 27              |                      | 16              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 3               | 157                  | 1               |
| st dev      | 0                                | 0                                       | 0                                  | 1                      | 0                         | 1                           |   |                                   |                        | 6               | 31                   | 3               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 62                   | 0               |
| max         | 1                                | 0                                       | 1                                  | 8                      | 0                         | 5                           |   |                                   |                        | 25              | 240                  | 17              |
| proport     | 0/61                             | 0/61                                    | 3/61                               | 6/61                   | 0/61                      | 10/61                       | 0/61  | 0/61                              | 8/61                   | 16/61           |                      | 7/61            |
| %           | 0                                | 0                                       | 5                                  | 10                     | 0                         | 16                          | 0   | 0                                 | 13                     | 26              |                      | 11              |

## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | 0.092        | (a)          | (a)        | 0.092         | 0.026       | 0.089       | (a)           | (a)           | 0.06        | 0.116       |
|      | Sig. (2-tailed) | 0.506        |              |            | 0.506         | 0.853       | 0.518       |               |               | 0.665       | 0.399       |
|      | N               | 55           | 55           | 55         | 55            | 55          | 55          | 55            | 55            | 55          | 55          |
| July | Correlation     | 0.053        | (a)          | 0.081      | -0.026        | (a)         | 0.07        | (a)           | 0.04          | (a)         | 0.085       |
|      | Sig. (2-tailed) | 0.685        |              | 0.535      | 0.844         |             | 0.591       |               | 0.757         |             | 0.516       |
|      | N               | 61           | 61           | 61         | 61            | 61          | 61          | 61            | 61            | 61          | 61          |

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

*None*

## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|     |         | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-----|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10m | June    |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
|     | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 3               | 126                  | 3               |
|     | st dev  | 0                                | 0                                       | 0                                  | 1                      | 1                         | 0                           | 0   | 0                                 |                        | 5               | 24                   | 6               |
|     | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 82                   | 0               |
|     | max     | 1                                | 0                                       | 0                                  | 2                      | 2                         | 1                           | 0   | 0                                 |                        | 12              | 160                  | 16              |
| 25m | proport | 1/12                             | 0/12                                    | 0/12                               | 1/12                   | 1/12                      | 3/12                        | 0/12  | 0/12                              | 3/12                   | 4/12            |                      | 3/12            |
|     | %       | 8                                | 0                                       | 0                                  | 8                      | 8                         | 25                          | 0   | 0                                 | 25                     | 33              |                      | 25              |
|     | mean    | 0                                | 0                                       | 0                                  | 0                      | 1                         | 0                           | 0   | 0                                 |                        | 4               | 18                   | 3               |
|     | st dev  | 0                                | 0                                       | 0                                  | 0                      | 3                         | 0                           | 0   | 0                                 |                        | 10              | 48                   | 8               |
|     | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 0                    | 0               |
| 50m | max     | 0                                | 0                                       | 0                                  | 0                      | 12                        | 1                           | 0   | 0                                 |                        | 34              | 150                  | 27              |
|     | proport | 0/19                             | 0/19                                    | 0/19                               | 0/19                   | 1/19                      | 3/19                        | 0/19  | 0/19                              | 3/19                   | 4/19            |                      | 3/19            |
|     | %       | 0                                | 0                                       | 0                                  | 0                      | 5                         | 16                          | 0   | 0                                 | 16                     | 21              |                      | 16              |
|     | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 8               | 108                  | 2               |
|     | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 24              | 29                   | 7               |
|     | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 43                   | 0               |
|     | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           | 0   | 0                                 |                        | 116             | 147                  | 27              |
|     | proport | 0/24                             | 0/24                                    | 0/24                               | 0/24                   | 0/24                      | 1/24                        | 0/24  | 0/24                              | 5/24                   | 7/24            |                      | 3/24            |
|     | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 4                           | 0   | 0                                 | 21                     | 29              |                      | 13              |

No quadrats fell in the 100 m buffer area during the June 2006 sampling.

|      | July      | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|-----------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10m  | mean      | 0                                |   |                                    |                        |                           | 0                           |   |                                   |                        | 1               | 165                  | 1               |
|      | st dev    | 0                                |   |                                    |                        |                           | 1                           |   |                                   |                        | 3               | 39                   | 5               |
|      | min       | 0                                |   |                                    |                        |                           | 0                           |   |                                   |                        | 0               | 110                  | 0               |
|      | max       | 1                                |   |                                    |                        |                           | 2                           |   |                                   |                        | 9               | 240                  | 17              |
|      | proport % | 1/13                             | 0/13                                    | 0/13                               | 0/13                   | 0/13                      | 2/13                        | 0/13  | 0/13                              | 1/13                   | 3/13            |                      | 2/13            |
| 25m  | mean      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 3               | 160                  | 1               |
|      | st dev    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 8               | 28                   | 3               |
|      | min       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 108                  | 0               |
|      | max       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 5                           |   |                                   |                        | 25              | 203                  | 10              |
|      | proport % | 0/19                             | 0/19                                    | 0/19                               | 4/19                   | 0/19                      | 4/19                        | 0/19  | 0/19                              | 3/19                   | 5/19            |                      | 2/19            |
| 50m  | mean      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 3               | 152                  | 1               |
|      | st dev    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 6               | 31                   | 2               |
|      | min       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 62                   | 0               |
|      | max       | 0                                | 0                                       | 1                                  | 2                      | 0                         | 5                           |   |                                   |                        | 23              | 195                  | 11              |
|      | proport % | 0/28                             | 0/28                                    | 3/28                               | 2/28                   | 0/28                      | 4/28                        | 0/28  | 0/28                              | 4/28                   | 8/28            |                      | 3/28            |
| 100m | mean      | 0                                | 0                                       | 11                                 | 7                      | 0                         | 14                          | 0   | 0                                 | 14                     | 29              |                      | 11              |
|      | st dev    |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
|      | min       |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
|      | max       |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
|      | proport % | 0/1                              | 0/1                                     | 0/1                                | 0/1                    | 0/1                       | 0/1                         | 0/1   | 0/1                               | 0/1                    | 0/1             |                      | 0/1             |

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 0    | 0    |
| 2.77 to 3.1    | MHHW to Highest Tide | 0    | 0    |
| 1.55 to 2.76   | MSL to MHHW          | 89.1 | 90.2 |
| 0.22 to 1.54   | MLLW to MSL          | 10.9 | 9.8  |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL

and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m NAVD88. 95.9-100% of the time.

| Knappa Slough | Tide Level (zero is MLLW) | Cumulative Percentage of Time | Elevation (NAVD88) |
|---------------|---------------------------|-------------------------------|--------------------|
| >MHHW         | >8.3 ft                   | 3.2%                          | >9.0 ft            |
| >MSL          | >4.3 ft                   | 48.3%                         | >5.1 ft            |
| >MLLW         | >0 ft                     | 94%                           | >0.7 ft            |
| <MLLW         | <0 ft                     | 94.7-100%                     | <0.7 ft            |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Knappa Slough; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL, >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.3 ft MLLW) at this site. Forty-eight percent of the time water levels exceed MSL (4.3 ft), 94% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



View from west side of site. June, 2006.



View from east side of site. June, 2006.



July, 2006.

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Miller Sands (Downstream)

**Dates:** June 15 & July 25, 2006

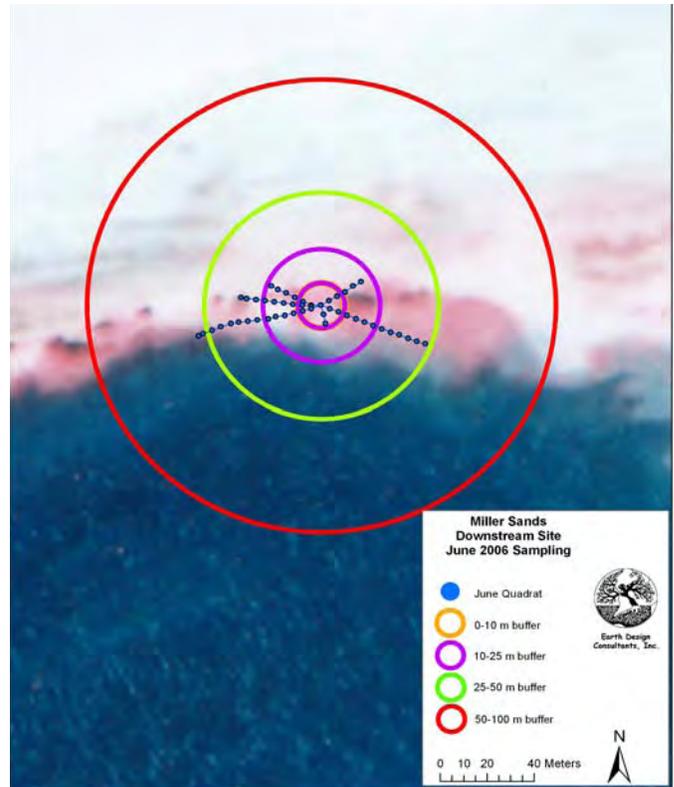
**Lat/Long:** 46.253257448 N,  
123.656826458 W NAD83 Conus

**Columbia River Mile:** ~ 26

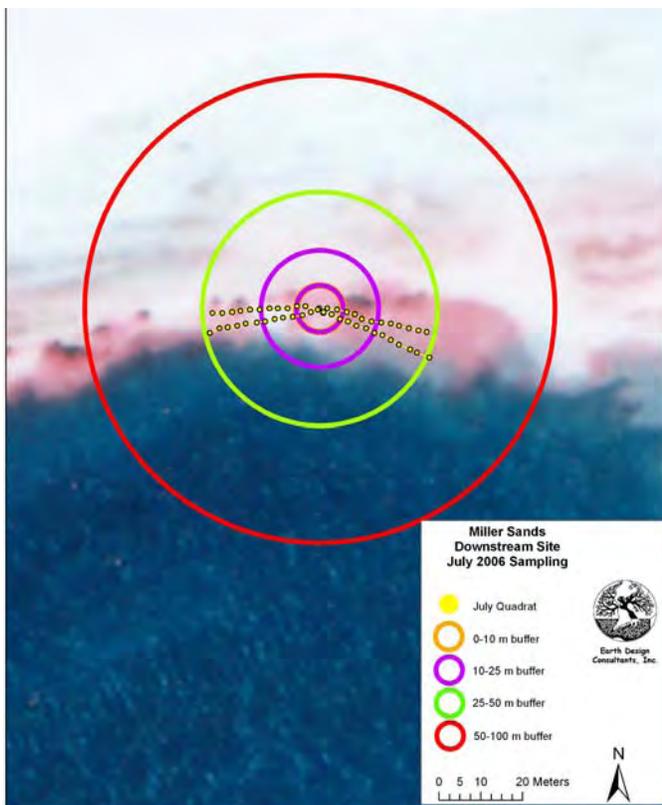
**Mean +/- S.D., Range in Elevation:**  
2.1 m +/- 0.5, 1.5-4.1 m NAVD88

**Distance to High Ground:** 6.14 m  
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | 13.6m             | 18.5m            | 214.2m            |
| <b>Forest</b> | 87.6m             | 18.5m            | 670.4m            |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a function of distance from the initial biocontrol release point.

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 8               | 56                   | 1               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 12              | 27                   | 2               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 5                    | 0               |
| max         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 43              | 117                  | 12              |
| proport     | 0/50                             | 0/50                                    | 0/50                               | 0/50                   | 0/50                      | 1/50                        | 0/50  | 0/50                              | 3/50                   | 24/50           |                      | 11/50           |
| %           | 0                                | 0                                       | 0                                  | 0                      | 0                         | 2                           | 0   | 0                                 | 6                      | 48              |                      | 22              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 18              | 114                  | 3               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 20              | 43                   | 5               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 13                   | 0               |
| max         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 83              | 205                  | 21              |
| proport     | 0/50                             | 0/50                                    | 0/50                               | 8/50                   | 0/50                      | 1/50                        | 0/50  | 0/50                              | 8/50                   | 39/50           |                      | 22/50           |
| %           | 0                                | 0                                       | 0                                  | 16                     | 0                         | 2                           | 0   | 0                                 | 16                     | 78              |                      | 44              |

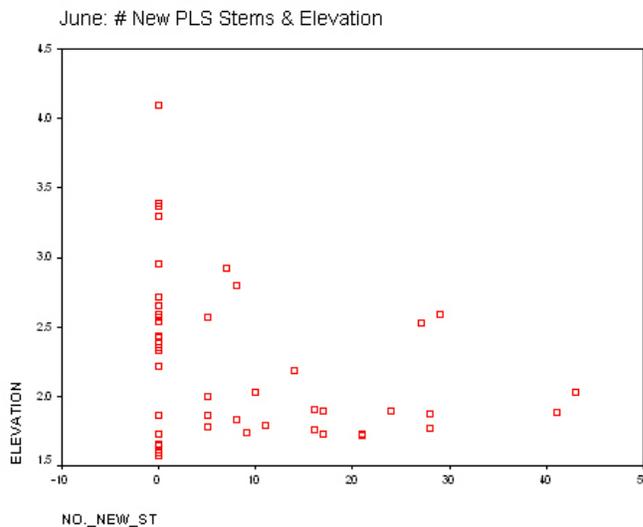
## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | (a)          | (a)          | (a)        | (a)           | (a)         | 0.094       | (a)           | (a)           | -.288(*)    | -0.202      |
|      | Sig. (2-tailed) |              |              |            |               |             | 0.515       |               |               | 0.042       | 0.16        |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |
| July | Correlation     | (a)          | (a)          | (a)        | (a)           | (a)         | 0.186       | (a)           | 0.075         | (a)         | 0.128       |
|      | Sig. (2-tailed) |              |              |            |               |             | 0.196       |               | 0.604         |             | 0.374       |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

### June: # new *L. salicaria* stems and elevation



## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|       |         | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage<br><i>G. nymphaeae</i> | <i>transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|--|----------------------------------|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m  | June    |                                  |   |                                    |                        |                           |  |                                  |                                   |                        |                 |                      |                 |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 10              | 46                   | 1               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 14              | 25                   | 3               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 0               | 10                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1  | 0                                | 0                                 | 0                      | 43              | 111                  | 12              |
|       | proport | 0/14                             | 0/14                                    | 0/14                               | 0/14                   | 0/14                      | 0/14   | 0/14                             | 0/14                              | 1/14                   | 7/14            |                      | 2/14            |
| 25 m  | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 7                      | 50              |                      | 14              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 6               | 58                   | 1               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 9               | 33                   | 2               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 0               | 5                    | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 28              | 117                  | 9               |
|       | proport | 0/19                             | 0/19                                    | 0/19                               | 0/19                   | 0/19                      | 0/19   | 0/19                             | 0/19                              | 2/19                   | 8/19            |                      | 3/19            |
| 50 m  | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 11                     | 42              |                      | 16              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 8               | 62                   | 1               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 10              | 16                   | 1               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 0               | 30                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 28              | 100                  | 5               |
|       | proport | 0/15                             | 0/15                                    | 0/15                               | 0/15                   | 0/15                      | 0/15   | 0/15                             | 0/15                              | 0/15                   | 7/15            |                      | 5/15            |
| 100 m | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 47              |                      | 33              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 25              | 57                   | 1               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 23              | 33                   | 1               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 8               | 10                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 41              | 110                  | 1               |
|       | proport | 0/2                              | 0/2                                     | 0/2                                | 0/2                    | 0/2                       | 0/2  | 0/2                              | 0/2                               | 0/2                    | 2/2             |                      | 1/2             |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 0                      | 100             |                      | 50              |

|       |         | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage<br>to <i>Nyctoporus</i> | <i>transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|---|----------------------------------|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m  | July    |                                  |   |                                    |                        |                           |   |                                  |                                   |                        |                 |                      |                 |
|       | mean    |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 18              | 113                  | 2               |
|       | st dev  |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 21              | 27                   | 3               |
|       | min     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 0               | 68                   | 0               |
|       | max     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 72              | 165                  | 11              |
| 25 m  | proport | 0/11                             | 0/11                                    | 0/11                               | 0/11                   | 0/11                      | 0/11  | 0/11                             | 0/11                              | 2/11                   | 10/11           |                      | 5/11            |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   | 0                                | 0                                 |                        | 91              |                      | 45              |
|       | mean    |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 10              | 136                  | 2               |
|       | st dev  |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 11              | 32                   | 4               |
|       | min     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 0               | 20                   | 0               |
| 50 m  | max     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 34              | 180                  | 13              |
|       | proport | 0/14                             | 0/14                                    | 0/14                               | 0/14                   | 0/14                      | 0/14  | 0/14                             | 0/14                              | 2/14                   | 8/14            |                      | 6/14            |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   | 0                                | 0                                 | 14                     | 57              |                      | 43              |
|       | mean    |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 23              | 110                  | 4               |
|       | st dev  |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 23              | 47                   | 6               |
| 100 m | min     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 0               | 15                   | 0               |
|       | max     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 83              | 205                  | 21              |
|       | proport | 0/24                             | 0/24                                    | 0/24                               | 0/24                   | 0/24                      | 0/24  | 0/24                             | 0/24                              | 4/24                   | 19/24           | 0                    | 11/24           |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   | 0                                | 0                                 | 17                     | 79              | 0                    | 46              |
|       | mean    |                                  |   |                                    |                        |                           |   |                                  |                                   |                        |                 | 27                   |                 |
|       | st dev  |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 10              |                      |                 |
|       | min     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 13              |                      |                 |
|       | max     |                                  |   |                                    |                        |                           |   |                                  |                                   |                        | 35              |                      |                 |
|       | proport | 0/1                              | 0/1                                     | 0/1                                | 0/1                    | 0/1                       | 0/1   | 0/1                              | 0/1                               | 1/1                    | 1/1             |                      | 0/1             |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   | 0                                | 0                                 | 100                    | 100             |                      | 0               |

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 8    | 0    |
| 2.77 to 3.1    | MHHW to Highest Tide | 6    | 0    |
| 1.55 to 2.76   | MSL to MHHW          | 86   | 98   |
| 0.22 to 1.54   | MLLW to MSL          | 0    | 2    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL

and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m NAVD88.

| <b>Tongue Pt</b> | <b>Tide Level (zero is MLLW)</b> | <b>Cumulative Percentage of Time</b> | <b>Elevation (NAVD88)</b> |
|------------------|----------------------------------|--------------------------------------|---------------------------|
| >MHHW            | >8.6 ft                          | 3%                                   | >8.8 ft                   |
| >MSL             | >4.5 ft                          | 49%                                  | >4.6 ft                   |
| >MLLW            | >0 ft                            | 95%                                  | >0.2 ft                   |
| <MLLW            | <0 ft                            | 95-100%                              | <0.2 ft                   |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Tongue Point; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL; >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.6 ft MLLW) at this site. Forty-nine percent of the time water levels exceed MSL (4.5 ft), 95% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



View to south. June, 2006.



View to east. July, 2006.

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Miller Sands (Upstream)

**Dates:** June 15 & July 25, 2006

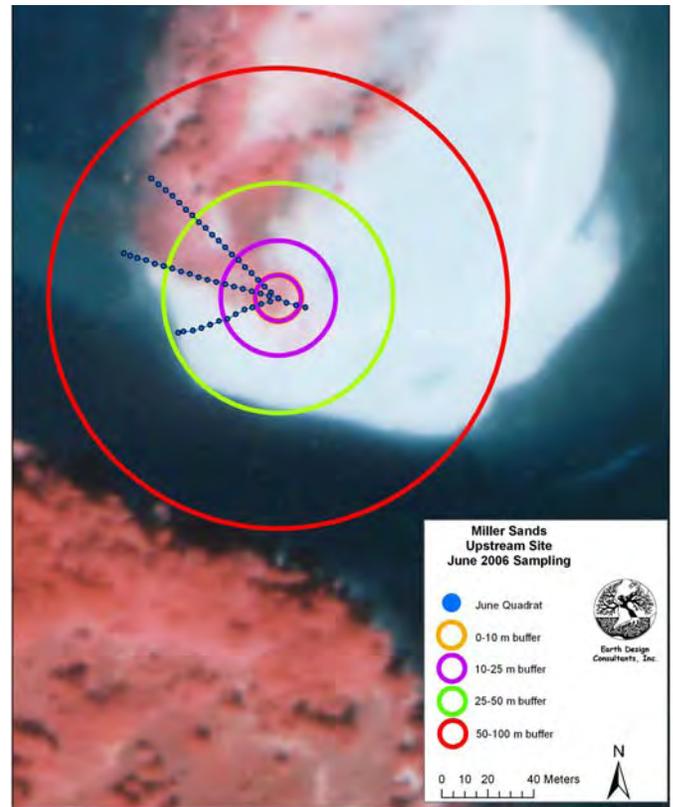
**Lat/Long:** 46.249989596 N,  
123.642237004 W NAD83 Conus

**Columbia River Mile:** ~ 26

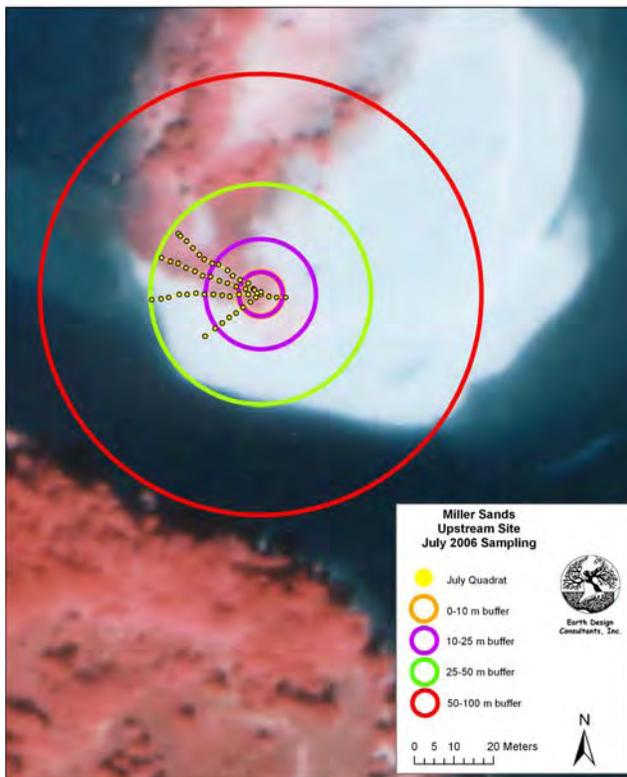
**Mean +/- S.D., Range in Elevation:**  
2.2 m +/- 0.6, 1.5-5.3 m NAVD88

**Distance to High Ground:** 1.03 m  
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | 41.2m             | 56.0m            | 72.0m             |
| <b>Forest</b> | 56.0m             | 56.0m            | 124.0m            |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a function of distance from the initial biocontrol release point.

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 21              | 38                   | 7               |
| st dev      | 0                                | 0                                       | 0                                  | 1                      | 0                         | 0                           |   |                                   |                        | 26              | 48                   | 13              |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 0                    | 0               |
| max         | 0                                | 0                                       | 0                                  | 5                      | 3                         | 2                           |   |                                   |                        | 132             | 197                  | 81              |
| proport     | 0/53                             | 0/53                                    | 0/53                               | 1/53                   | 1/53                      | 6/53                        | 1/53  | 0/53                              | 11/53                  | 39/53           |                      | 27/53           |
| %           | 0                                | 0                                       | 0                                  | 2                      | 2                         | 11                          | 2   | 0                                 | 21                     | 74              |                      | 51              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 13              | 138                  | 4               |
| st dev      | 0                                | 0                                       | 0                                  | 1                      | 0                         | 1                           |   |                                   |                        | 16              | 36                   | 5               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 24                   | 0               |
| max         | 1                                | 0                                       | 2                                  | 6                      | 1                         | 3                           |   |                                   |                        | 61              | 201                  | 18              |
| proport     | 1/50                             | 0/50                                    | 1/50                               | 1/50                   | 1/50                      | 5/50                        | 0/50  | 0/50                              | 12/50                  | 29/50           |                      | 27/50           |
| %           | 2                                | 0                                       | 2                                  | 2                      | 2                         | 10                          | 0   | 0                                 | 24                     | 58              |                      | 54              |

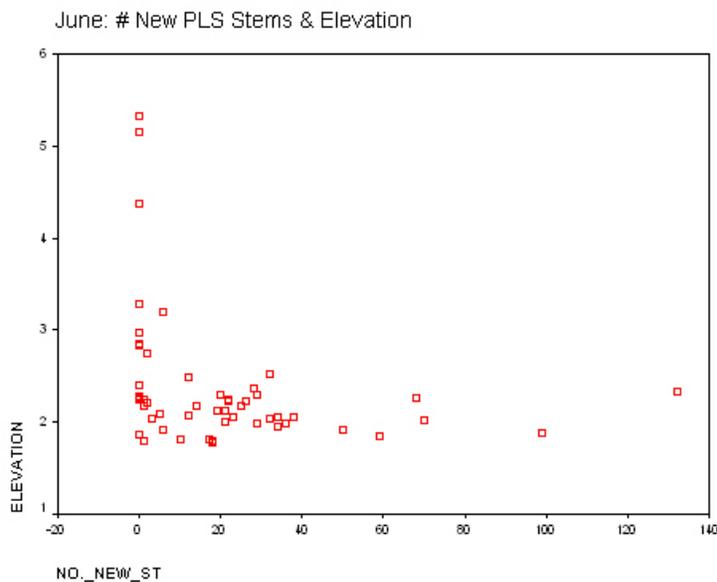
## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | (a)          | (a)          | (a)        | -0.013        | -0.013      | -0.037      | (a)           | (a)           | -.289(*)    | -0.169      |
|      | Sig. (2-tailed) |              |              |            | 0.926         | 0.926       | 0.791       |               |               | 0.036       | 0.227       |
|      | N               | 53           | 53           | 53         | 53            | 53          | 53          | 53            | 53            | 53          | 53          |
| July | Correlation     | -0.033       | (a)          | -0.226     | -0.033        | -0.028      | -0.197      | (a)           | -0.094        | (a)         | 0.085       |
|      | Sig. (2-tailed) | 0.82         |              | 0.115      | 0.82          | 0.848       | 0.169       |               | 0.517         |             | 0.558       |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

### June: # new *L. salicaria* stems and elevation



## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|       |         | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m  | June    |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
|       | mean    | 0                                | 0                                       | 0                                  | 1                      | 0                         | 0                           | 0   | 0                                 |                        | 22              | 113                  | 3               |
|       | st dev  | 0                                | 0                                       | 0                                  | 2                      | 1                         | 1                           | 0   | 0                                 |                        | 43              | 28                   | 6               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 68                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 5                      | 3                         | 2                           | 0   | 0                                 |                        | 132             | 151                  | 17              |
|       | proport | 0/9                              | 0/9                                     | 0/9                                | 1/9                    | 1/9                       | 2/9                         | 0/9   | 0/9                               | 1/9                    | 5/9             |                      | 3/9             |
| 25 m  | %       | 0                                | 0                                       | 0                                  | 5                      | 11                        | 22                          | 0   | 0                                 | 11                     | 56              |                      | 33              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 16              | 98                   | 6               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 20              | 23                   | 7               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 50                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           | 1   | 0                                 |                        | 68              | 154                  | 22              |
|       | proport | 0/13                             | 0/13                                    | 0/13                               | 0/13                   | 0/13                      | 3/13                        | 1/13  | 0/13                              | 1/13                   | 8/13            |                      | 8/13            |
| 50 m  | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 8                           | 8   | 0                                 | 8                      | 62              |                      | 62              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 21              | 67                   | 12              |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 20              | 34                   | 20              |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 10                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           | 0   | 0                                 |                        | 70              | 197                  | 81              |
|       | proport | 0/18                             | 0/18                                    | 0/18                               | 0/18                   | 0/18                      | 1/18                        | 0/18  | 0/18                              | 5/18                   | 15/18           |                      | 9/18            |
| 100 m | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 6                           | 0   | 0                                 | 28                     | 83              |                      | 50              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 24              | 44                   | 6               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 28              | 26                   | 9               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 9                    | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 99              | 110                  | 27              |
|       | proport | 0/13                             | 0/13                                    | 0/13                               | 0/13                   | 0/13                      | 0/13                        | 0/13  | 0/13                              | 4/13                   | 12/13           |                      | 7/13            |
| %     | 0       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 31                                | 92                     |                 | 54                   |                 |

|      | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m | mean    | 0                                |   |                                    | 0                      | 0                         | 0                           |   |                                   |                        | 6               | 161                  | 2               |
|      | st dev  | 0                                |   |                                    | 2                      | 0                         | 0                           |   |                                   |                        | 9               | 33                   | 3               |
|      | min     | 0                                |   |                                    | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 56                   | 0               |
|      | max     | 1                                |   |                                    | 6                      | 1                         | 1                           |   |                                   |                        | 25              | 199                  | 9               |
|      | proport | 1/13                             | 0/13                                    | 0/13                               | 1/13                   | 1/13                      | 3/13                        | 0/13  | 0/13                              | 2/13                   | 5/13            |                      | 5/13            |
| %    | 8       | 0                                | 0                                       | 8                                  | 8                      | 23                        | 0                           | 0   | 15                                | 38                     |                 | 38                   |                 |
| 25 m | mean    |                                  |   |                                    |                        |                           |                             |   |                                   |                        | 13              | 145                  | 5               |
|      | st dev  |                                  |   |                                    |                        |                           |                             |   |                                   |                        | 13              | 33                   | 5               |
|      | min     |                                  |   |                                    |                        |                           |                             |   |                                   |                        | 0               | 24                   | 0               |
|      | max     |                                  |   |                                    |                        |                           |                             |   |                                   |                        | 41              | 201                  | 13              |
|      | proport | 0/15                             | 0/15                                    | 0/15                               | 0/15                   | 0/15                      | 0/15                        | 0/15  | 0/15                              | 5/15                   | 10/15           |                      | 10/15           |
| %    | 0       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 33                                | 67                     |                 | 67                   |                 |
| 50 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 18              | 125                  | 4               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 20              | 36                   | 6               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 27                   | 0               |
|      | max     | 0                                | 0                                       | 2                                  | 0                      | 0                         | 3                           |   |                                   |                        | 61              | 186                  | 18              |
|      | proport | 0/22                             | 0/22                                    | 1/22                               | 0/22                   | 0/22                      | 2/22                        | 0/22  | 0/22                              | 5/22                   | 14/22           |                      | 12/22           |
| %    | 0       | 0                                | 5                                       | 0                                  | 0                      | 9                         | 0                           | 0   | 23                                | 64                     |                 | 55                   |                 |

No quadrats fell in the 100 m buffer area during the July 2006 sampling.

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 9.4  | 0    |
| 2.77 to 3.1    | MHHW to Highest Tide | 5.7  | 0    |
| 1.55 to 2.76   | MSL to MHHW          | 84.9 | 98   |
| 0.22 to 1.54   | MLLW to MSL          | 0    | 2    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL

and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m NAVD88.

| <b>Tongue Pt</b> | <b>Tide Level (zero is MLLW)</b> | <b>Cumulative Percentage of Time</b> | <b>Elevation (NAVD88)</b> |
|------------------|----------------------------------|--------------------------------------|---------------------------|
| >MHHW            | >8.6 ft                          | 3%                                   | >8.8 ft                   |
| >MSL             | >4.5 ft                          | 49%                                  | >4.6 ft                   |
| >MLLW            | >0 ft                            | 95%                                  | >0.2 ft                   |
| <MLLW            | <0 ft                            | 95-100%                              | <0.2 ft                   |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Tongue Point; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL; >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.6 ft MLLW) at this site. Forty-nine percent of the time water levels exceed MSL (4.5 ft), 95% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



View from biocontrol release point looking west; June 2006 (left) and July 2006 (right).

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Mott Island

**Dates:** June 26 & July 25, 2006

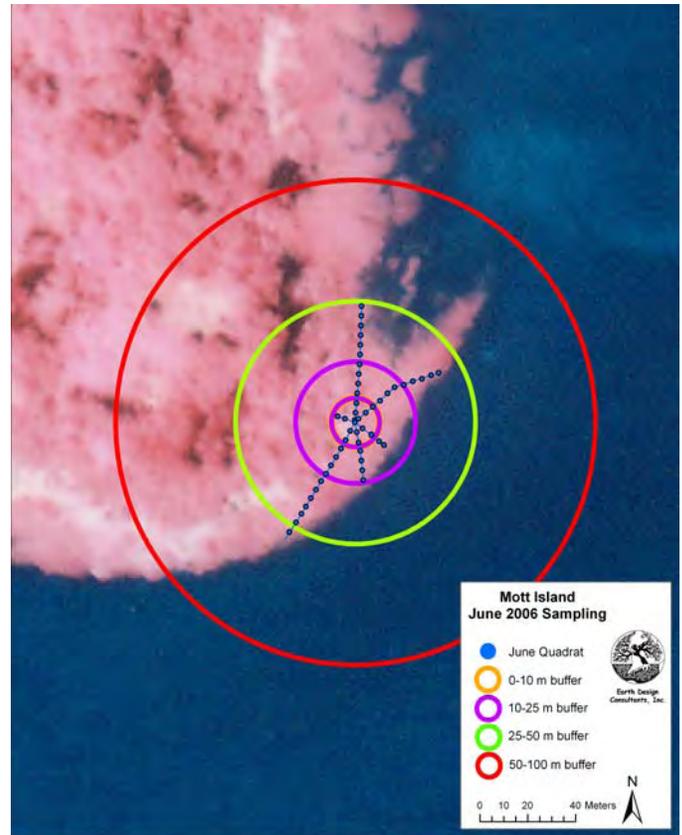
**Lat/Long:** 46.198051399 N,  
123.743099393 W NAD83 Conus

**Columbia River Mile:** ~ 21

**Mean +/- S.D., Range in Elevation:**  
2.1 m +/- 0.6, 1.1-5.2 m NAVD88

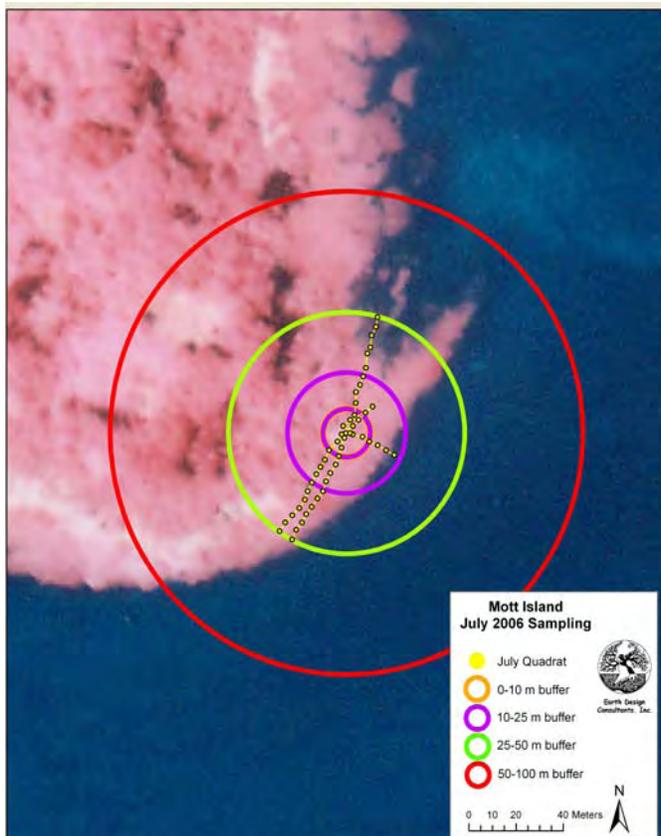
**Distance to High Ground:** N/A  
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 41.3m            | 73.1m             |
| <b>Forest</b> | NA                | 41.3m            | 60.9m             |



June quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.



July quadrat locations.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a function of distance from the initial

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

biocontrol release point.

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation at each site.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 5               | 50                   | 1               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 10              | 59                   | 4               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 0                    | 0               |
| max         | 0                                | 0                                       | 0                                  | 1                      | 3                         | 1                           |   |                                   |                        | 57              | 197                  | 17              |
| proport     | 0/50                             | 0/50                                    | 0/50                               | 1/50                   | 1/50                      | 2/50                        | 1/53  | 0/50                              | 4/50                   | 20/50           |                      | 7/50            |
| %           | 0                                | 0                                       | 0                                  | 2                      | 2                         | 4                           | 2   | 0                                 | 8                      | 40              |                      | 14              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 5               | 150                  | 1               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 2                           |   |                                   |                        | 7               | 33                   | 3               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 54                   | 0               |
| max         | 0                                | 0                                       | 1                                  | 0                      | 0                         | 10                          |   |                                   |                        | 29              | 228                  | 18              |
| proport     | 0/50                             | 0/50                                    | 1/50                               | 1/50                   | 0/50                      | 5/50                        | 0/50  | 0/50                              | 11/50                  | 24/50           |                      | 16/50           |
| %           | 0                                | 0                                       | 2                                  | 2                      | 0                         | 10                          | 0   | 0                                 | 22                     | 48              |                      | 32              |

## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from the RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | (a)          | (a)          | (a)        | -0.138        | -0.061      | -0.142      | (a)           | (a)           | -0.064      | -0.176      |
|      | Sig. (2-tailed) |              |              |            | 0.349         | 0.681       | 0.334       |               |               | 0.664       | 0.233       |
|      | N               | 48           | 48           | 48         | 48            | 48          | 48          | 48            | 48            | 48          | 48          |
| July | Correlation     | (a)          | (a)          | -0.006     | -0.006        | (a)         | -0.028      | (a)           | -0.023        | (a)         | 0.044       |
|      | Sig. (2-tailed) |              |              | 0.965      | 0.965         |             | 0.848       |               | 0.872         |             | 0.76        |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

*None*

## Buffered Distance Summaries:

In the following tables, variables measured during the field point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|      | June    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 7               | 114                  | 2               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 10              | 28                   | 4               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 60                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 28              | 182                  | 13              |
|      | proport | 0/15                             | 0/15                                    | 0/15                               | 0/15                   | 0/15                      | 0/15                        | 0/15  | 0/15                              | 1/15                   | 9/15            |                      | 3/15            |
| 25m  | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 | 7                      | 60              |                      | 20              |
|      | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 5               | 124                  | 2               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 14              | 32                   | 5               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 62                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 1                      | 0                         | 1                           |   |                                   |                        | 57              | 169                  | 17              |
| 50m  | proport | 0/17                             | 0/17                                    | 0/17                               | 1/17                   | 1/17                      | 1/17                        | 0/17  | 0/17                              | 0/17                   | 4/17            |                      | 2/17            |
|      | %       | 0                                | 0                                       | 0                                  | 6                      | 6                         | 6                           | 0   | 0                                 | 0                      | 24              |                      | 12              |
|      | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 2               | 114                  | 0               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 1                         | 0                           |   |                                   |                        | 4               | 16                   | 1               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 78                   | 0               |
| 100m | max     | 0                                | 0                                       | 0                                  | 0                      | 3                         | 1                           |   |                                   |                        | 16              | 135                  | 2               |
|      | proport | 0/17                             | 0/17                                    | 0/17                               | 0/17                   | 1/17                      | 1/17                        | 0/17  | 0/17                              | 3/17                   | 6/17            |                      | 2/17            |
|      | %       | 0                                | 0                                       | 0                                  | 0                      | 6                         | 6                           | 0   | 0                                 | 18                     | 35              |                      | 12              |
|      | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 2               | 90                   | 0               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 9                    | 0               |
| 100m | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 2               | 83                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 2               | 96                   | 0               |
|      | proport | 0/1                              | 0/1                                     | 0/1                                | 0/1                    | 0/1                       | 0/1                         | 0/1   | 0/1                               | 0/1                    | 1/1             |                      | 0/1             |
|      | %       | 0                                | 0                                       | 0                                  | 6                      | 6                         | 6                           | 0   | 0                                 | 0                      | 100             |                      | 0               |

|     | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-----|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 6               | 148                  | 1               |
|     | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 8               | 42                   | 2               |
|     | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 54                   | 7               |
|     | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 25              | 228                  | 0               |
|     | proport | 0/12                             | 0/12                                    | 0/12                               | 0/12                   | 0/12                      | 2/12                        | 0/12  | 0/12                              | 5/12                   | 7/12            |                      | 5/12            |
| 25m | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 17                          | 0   | 0                                 | 42                     | 58              |                      | 42              |
|     | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 6               | 156                  | 1               |
|     | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 8               | 32                   | 3               |
|     | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 71                   | 0               |
|     | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 4                           |   |                                   |                        | 25              | 205                  | 9               |
| 50m | proport | 0/18                             | 0/18                                    | 0/18                               | 0/18                   | 0/18                      | 2/18                        | 0/18  | 0/18                              | 2/18                   | 10/18           |                      | 6/18            |
|     | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 11                          | 0   | 0                                 | 11                     | 56              |                      | 33              |
|     | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 3               | 142                  | 1               |
|     | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 2                           |   |                                   |                        | 7               | 23                   | 4               |
|     | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 102                  | 0               |
| 50m | max     | 0                                | 0                                       | 1                                  | 0                      | 0                         | 10                          |   |                                   |                        | 29              | 180                  | 18              |
|     | proport | 0/20                             | 0/20                                    | 1/20                               | 0/20                   | 0/20                      | 1/20                        | 0/20  | 0/20                              | 4/20                   | 7/20            |                      | 5/20            |
|     | %       | 0                                | 0                                       | 5                                  | 0                      | 0                         | 5                           | 0   | 0                                 | 20                     | 35              |                      | 25              |

No quadrats fell in the 100 m buffer area during the July 2006 sampling.

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 0    | 8    |
| 2.77 to 3.1    | MHHW to Highest Tide | 0    | 8    |
| 1.55 to 2.76   | MSL to MHHW          | 87.5 | 84   |
| 0.22 to 1.54   | MLLW to MSL          | 12.5 | 0    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL

and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m NAVD88.

| Tongue Pt | Tide Level (zero is MLLW) | Cumulative Percentage of Time | Elevation (NAVD88) |
|-----------|---------------------------|-------------------------------|--------------------|
| >MHHW     | >8.6 ft                   | 3%                            | >8.8 ft            |
| >MSL      | >4.5 ft                   | 49%                           | >4.6 ft            |
| >MLLW     | >0 ft                     | 95%                           | >0.2 ft            |
| <MLLW     | <0 ft                     | 95-100%                       | <0.2 ft            |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Tongue Point; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL; >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.6 ft MLLW) at this site. Forty-nine percent of the time water levels exceed MSL (4.5 ft), 95% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



Right: Site photo, looking north. Above: Pollinator on purple loosestrife (*Lythrum salicaria*). July, 2006.

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Pillar Rock Island  
(Downstream)

**Dates:** June 26 & July 27, 2006

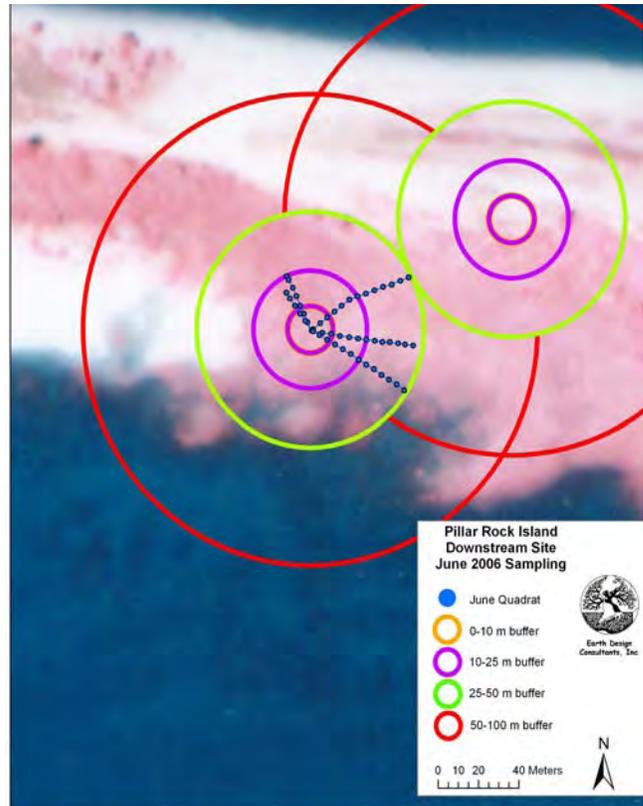
**Lat/Long:** 46.251109401 N,  
123.588509643 W NAD83 Conus

**Columbia River Mile:** ~ 30

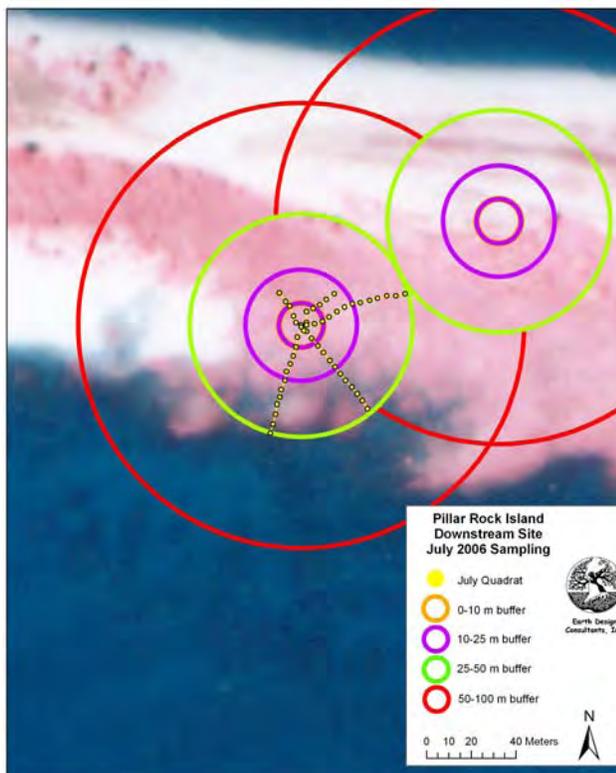
**Mean +/- S.D., Range in Elevation:**  
2.2 m +/- 0.4, 1.2-3.0 m NAVD88

**Distance to High Ground:** 53.37 m  
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 25.7m            | 57.4m             |
| <b>Forest</b> | NA                | 25.7m            | 216.7m            |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a function of distance from the initial biocontrol release point.

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 15              | 55                   | 5               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 17              | 60                   | 7               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 0                    | 0               |
| max         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 52              | 197                  | 23              |
| proport     | 0/51                             | 0/51                                    | 0/51                               | 0/51                   | 0/51                      | 1/51                        | 0/51  | 0/51                              | 7/51                   | 30/51           |                      | 26/51           |
| %           | 0                                | 0                                       | 0                                  | 0                      | 0                         | 2                           | 0   | 0                                 | 14                     | 59              |                      | 51              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 16              | 120                  | 3               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 17              | 44                   | 5               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 19                   | 0               |
| max         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 79              | 220                  | 18              |
| proport     | 0/50                             | 0/50                                    | 0/50                               | 0/50                   | 0/50                      | 1/50                        | 0/50  | 0/50                              | 16/50                  | 4/50            |                      | 15/50           |
| %           | 0                                | 0                                       | 0                                  | 0                      | 0                         | 2                           | 0   | 0                                 | 32                     | 80              |                      | 30              |

## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | (a)          | (a)          | (a)        | (a)           | (a)         | -0.037      | (a)           | (a)           | -.372(**)   | -0.312(*)   |
|      | Sig. (2-tailed) |              |              |            |               |             | 0.795       |               |               | 0.007       | 0.026       |
|      | N               | 51           | 51           | 51         | 51            | 51          | 51          | 51            | 51            | 51          | 51          |
| July | Correlation     | (a)          | (a)          | (a)        | (a)           | (a)         | -0.141      | (a)           | -0.113        | (a)         | -0.02       |
|      | Sig. (2-tailed) |              |              |            |               |             | 0.328       |               | 0.433         |             | 0.889       |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |

# new *L. salicaria* stems from June and July (101 quadrats) correlated with elevation is significant at the p=0.05 level – Pearson’s correlation r=-0.225, p=0.024.

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

*June: # old L. salicaria Stems and elevation*

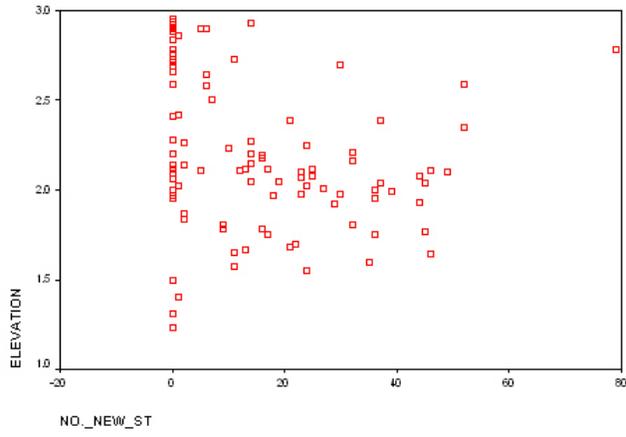
*June and July together: # new L. salicaria stems and elevation*

**Correlations between these field variables and quadrat elevation were significant at the 0.01 level at this site:**

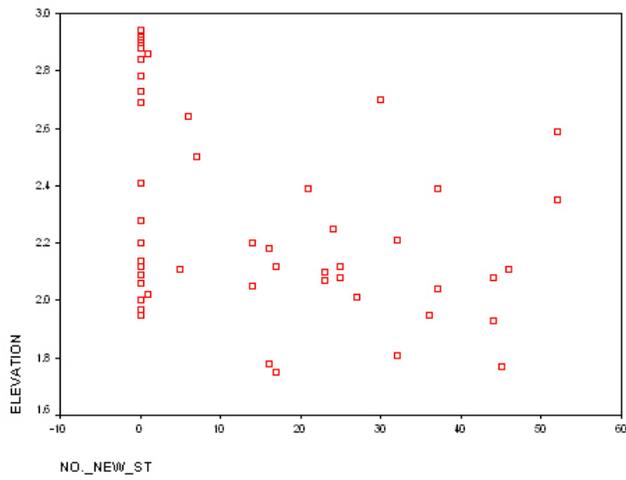
*June: # new L. salicaria stems and elevation*

June & July:

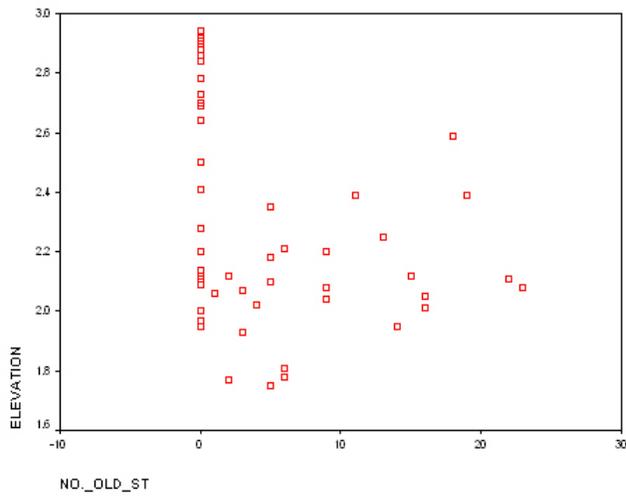
# New PLS Stems & Elevation



June: # New PLS Stems & Elevation



June: # Old PLS Stems & Elevation



## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|      |         | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage<br><i>G. nymphaeae</i> | <i>transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|--|----------------------------------|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m | June    |                                  |   |                                    |                        |                           |  |                                  |                                   |                        |                 |                      |                 |
|      | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 |                        | 13              | 84                   | 3               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 |                        | 19              | 34                   | 7               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 |                        | 0               | 13                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 |                        | 52              | 137                  | 22              |
|      | proport | 0/13                             | 0/13                                    | 0/13                               | 0/13                   | 0/13                      | 0/13   | 0/13                             | 0/13                              | 3/13                   | 6/13            |                      | 4/13            |
| 25 m | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 23                     | 46              |                      | 31              |
|      | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 |                        | 13              | 94                   | 5               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 |                        | 16              | 42                   | 7               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 |                        | 0               | 13                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 |                        | 44              | 185                  | 23              |
|      | proport | 0/17                             | 0/17                                    | 0/17                               | 0/17                   | 0/17                      | 0/17   | 0/17                             | 0/17                              | 2/17                   | 9/17            |                      | 7/17            |
| 50 m | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 12                     | 53              |                      | 41              |
|      | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                |                                   |                        | 18              | 124                  | 6               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                |                                   |                        | 17              | 32                   | 6               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                |                                   |                        | 0               | 11                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1  | 0                                |                                   |                        | 52              | 190                  | 18              |
|      | proport | 0/21                             | 0/21                                    | 0/21                               | 0/21                   | 0/21                      | 1/21   | 0/21                             | 3/21                              | 3/21                   | 14/21           |                      | 14/21           |
| %    | 0       | 0                                | 0                                       | 0                                  | 0                      | 5                         | 0  | 14                               | 14                                | 67                     |                 | 67                   |                 |

No quadrats fell in the 100 m buffer area during the June 2006 sampling.

|       | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage<br>to <i>Nyctaginia</i> | <i>transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|---|----------------------------------|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 15              | 121                  | 4               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 24              | 42                   | 7               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 0               | 42                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 79              | 220                  | 18              |
|       | proport | 0/13                             | 0/13                                    | 0/13                               | 0/13                   | 0/13                      | 0/13  | 0/13                             | 0/13                              | 6/13                   | 9/13            |                      | 4/13            |
| %     | 0       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   | 0                                | 46                                | 69                     |                 | 31                   |                 |
| 25 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 14              | 122                  | 2               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 13              | 43                   | 4               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 0               | 32                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 45              | 211                  | 12              |
|       | proport | 0/17                             | 0/17                                    | 0/17                               | 0/17                   | 0/17                      | 0/17  | 0/17                             | 0/17                              | 4/17                   | 14/17           |                      | 7/17            |
| %     | 0       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   | 0                                | 24                                | 82                     |                 | 41                   |                 |
| 50 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 19              | 118                  | 2               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 15              | 45                   | 4               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 0               | 19                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1   |                                  |                                   |                        | 46              | 208                  | 15              |
|       | proport | 0/19                             | 0/19                                    | 0/19                               | 0/19                   | 0/19                      | 1/19  | 0/19                             | 0/19                              | 6/19                   | 17/19           |                      | 4/19            |
| %     | 0       | 0                                | 0                                       | 0                                  | 0                      | 5                         | 0   | 0                                | 32                                | 89                     |                 | 21                   |                 |
| 100 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 0               | 0                    | 0               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 0               | 0                    | 0               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 0               | 0                    | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 0               | 0                    | 0               |
|       | proport | 0/1                              | 0/1                                     | 0/1                                | 0/1                    | 0/1                       | 0/1   | 0/1                              | 0/1                               | 0/1                    | 0/1             |                      | 0/1             |
| %     | 0       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   | 0                                | 0                                 | 0                      |                 | 0                    |                 |

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 0    | 0    |
| 2.77 to 3.1    | MHHW to Highest Tide | 17.6 | 12   |
| 1.55 to 2.76   | MSL to MHHW          | 82.4 | 80   |
| 0.22 to 1.54   | MLLW to MSL          | 0    | 8    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL

and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m NAVD88.

| Tongue Pt | Tide Level (zero is MLLW) | Cumulative Percentage of Time | Elevation (NAVD88) |
|-----------|---------------------------|-------------------------------|--------------------|
| >MHHW     | >8.6 ft                   | 3%                            | >8.8 ft            |
| >MSL      | >4.5 ft                   | 49%                           | >4.6 ft            |
| >MLLW     | >0 ft                     | 95%                           | >0.2 ft            |
| <MLLW     | <0 ft                     | 95-100%                       | <0.2 ft            |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Tongue Point; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL; >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.6 ft MLLW) at this site. Forty-nine percent of the time water levels exceed MSL (4.5 ft), 95% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



Left: View looking southeast toward biocontrol release point June, 2006;  
Right: Field sampling July, 2006.

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Pillar Rock Island  
(Upstream)

**Dates:** June 14 & July 27, 2006

**Lat/Long:** 46.251536630 N,  
123.587364116 W NAD83 Conus

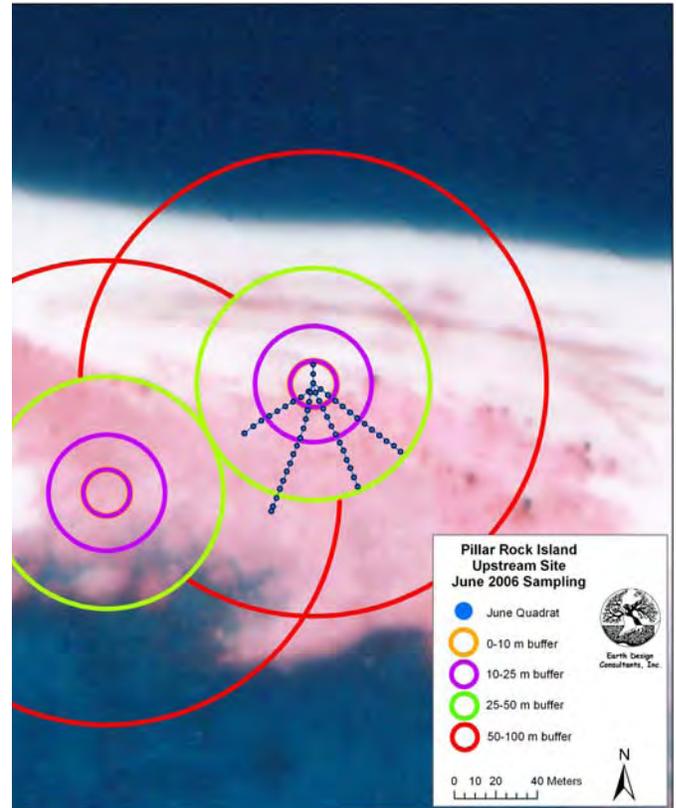
**Columbia River Mile:** ~ 30

**Mean +/- S.D., Range in Elevation:**  
2.0 m +/- 0.2, 1.8-3.0 m NAVD88

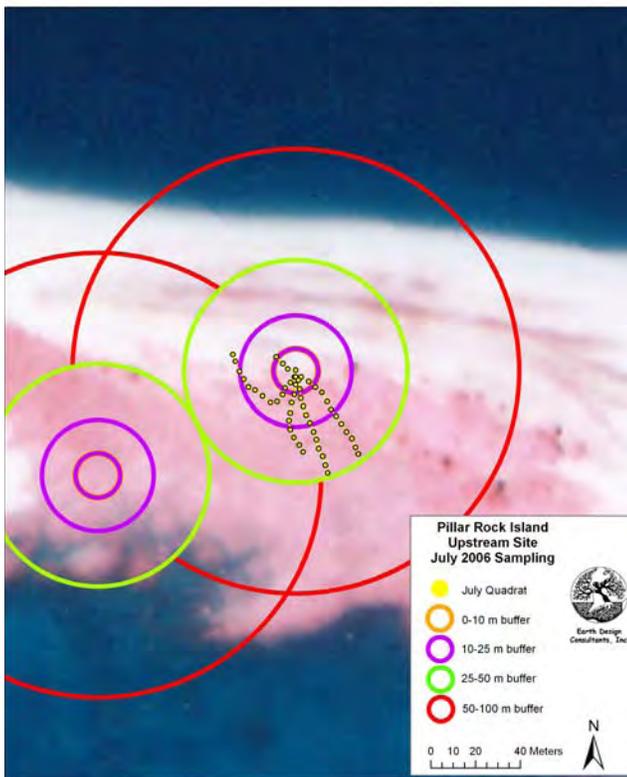
**Distance to High Ground:** 132.68 m

**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 26.9m            | 19.5m             |
| <b>Forest</b> | NA                | 26.9m            | 284.4m            |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a function of distance from the initial biocontrol release point.

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation at each site.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 20              | 63                   | 4               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 21              | 60                   | 6               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 0                    | 0               |
| max         | 1                                | 0                                       | 0                                  | 1                      | 1                         | 5                           |   |                                   |                        | 73              | 197                  | 21              |
| proport     | 1/50                             | 0/50                                    | 0/50                               | 4/50                   | 5/50                      | 19/50                       | 3/50  | 0/50                              | 12/50                  | 38/50           |                      | 26/50           |
| %           | 2                                | 0                                       | 0                                  | 8                      | 10                        | 38                          | 6   | 0                                 | 24                     | 76              |                      | 52              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 1                      | 0                         | 0                           |   |                                   |                        | 15              | 169                  | 3               |
| st dev      | 0                                | 0                                       | 0                                  | 2                      | 0                         | 1                           |   |                                   |                        | 14              | 45                   | 5               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 34                   | 0               |
| max         | 1                                | 0                                       | 2                                  | 13                     | 0                         | 3                           |   |                                   |                        | 47              | 260                  | 20              |
| proport     | 1/50                             | 0/50                                    | 1/50                               | 8/50                   | 0/50                      | 14/50                       | 1/50  | 0/50                              | 18/50                  | 42/50           |                      | 27/50           |
| %           | 2                                | 0                                       | 2                                  | 16                     | 0                         | 28                          | 2   | 0                                 | 36                     | 84              |                      | 54              |

## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from the RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | -0.032 (a)   | (a)          | (a)        | 0.184         | 0.162       | 0.162 (a)   | (a)           | 0.044         | -0.341(*)   | -0.233      |
|      | Sig. (2-tailed) | 0.827        |              |            | 0.201         | 0.261       | 0.261       |               | 0.759         | 0.015       | 0.103       |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |
| July | Correlation     | 0.132 (a)    | (a)          | -0.209     | .363(**)      | (a)         | .389(**)    | (a)           | -.332(*)      | 0.047       | -0.24       |
|      | Sig. (2-tailed) | 0.36         |              | 0.145      | 0.009         |             | 0.005       |               | 0.019         | 0.746       | 0.094       |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |

# new *L. salicaria* stems from June and July (100 quadrats) correlated with elevation is significant at the p=0.01 level – Pearson’s correlation r=-0.316, p=0.001.

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

*June: # new L. salicaria stems and elevation*

*July: % GA damage and elevation*

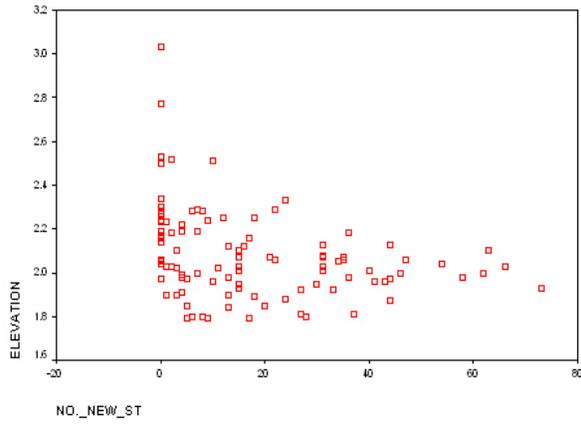
*July: # GA egg masses and elevation*

*July: # new L. salicaria stems and elevation*

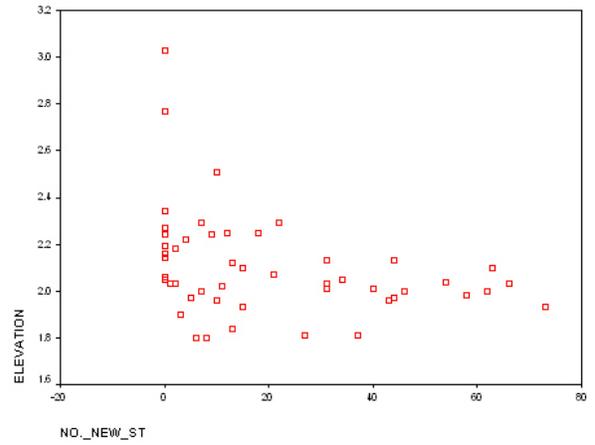
*June and July together: # new L. salicaria stems and elevation*

June & July:

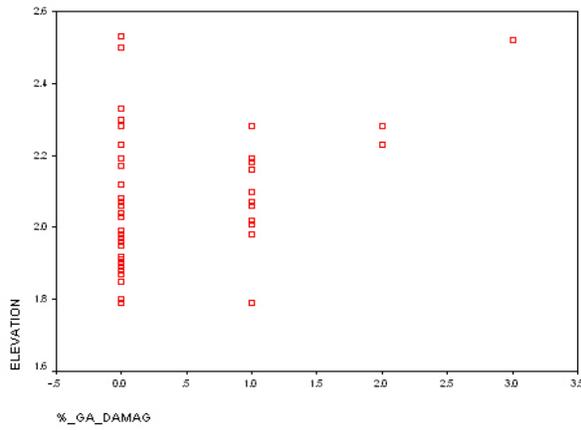
# New PLS Stems & Elevation



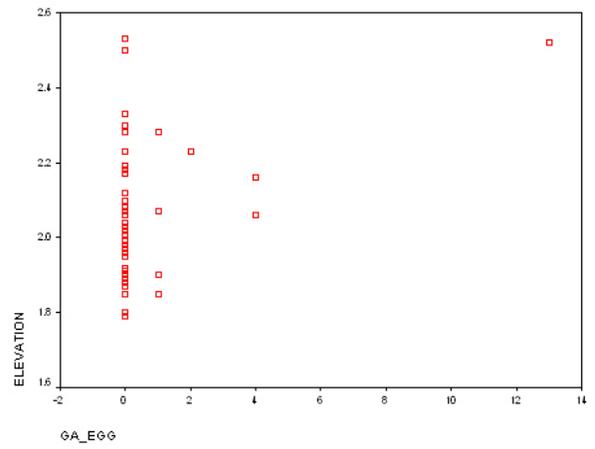
June: # New PLS Stems & Elevation



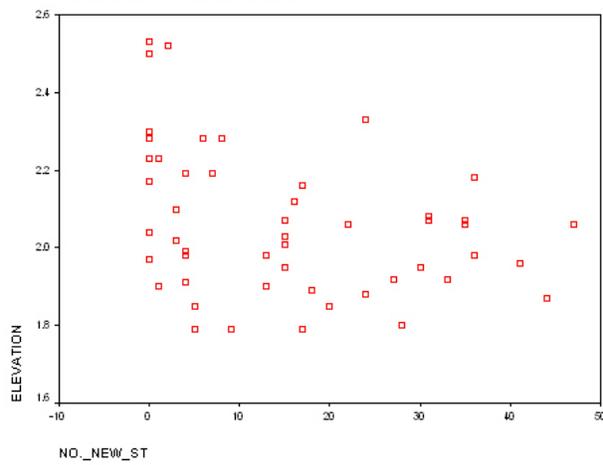
July: % GA Damage & Elevation



July: # GA Egg Masses & Elevation



July: # New PLS Stems & Elevation



## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|       | June    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage<br><i>G. nymphaeae</i> | <i>transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|--|----------------------------------|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1  |                                  |                                   |                        | 4               | 90                   | 0               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 2  |                                  |                                   |                        | 5               | 50                   | 1               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  |                                  |                                   |                        | 0               | 10                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 1                      | 0                         | 5  |                                  |                                   |                        | 13              | 176                  | 2               |
|       | proport | 0/11                             | 0/11                                    | 0/11                               | 1/11                   | 0/11                      | 5/11   | 1/11                             | 0/11                              | 2/11                   | 5/11            |                      | 3/11            |
| %     | 0       | 0                                | 0                                       | 9                                  | 0                      | 45                        | 9  | 0                                | 18                                | 45                     |                 | 27                   |                 |
| 25 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1  | 0                                | 0                                 |                        | 27              | 115                  | 3               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1  | 0                                | 0                                 |                        | 26              | 28                   | 4               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 |                        | 0               | 29                   | 0               |
|       | max     | 1                                | 0                                       | 0                                  | 0                      | 1                         | 5  | 1                                | 0                                 |                        | 66              | 156                  | 14              |
|       | proport | 1/16                             | 0/16                                    | 0/16                               | 0/16                   | 1/16                      | 8/16   | 1/16                             | 0/16                              | 3/16                   | 3/16            |                      | 9/16            |
| %     | 6       | 0                                | 0                                       | 0                                  | 6                      | 50                        | 6  | 0                                | 19                                | 81                     |                 | 56                   |                 |
| 50 m  | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1  | 0                                |                                   |                        | 24              | 104                  | 7               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1  | 0                                |                                   |                        | 19              | 33                   | 8               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                |                                   |                        | 0               | 13                   | 0               |
|       | max     | 1                                | 0                                       | 0                                  | 1                      | 1                         | 5  | 1                                |                                   |                        | 73              | 169                  | 21              |
|       | proport | 1/21                             | 0/21                                    | 0/21                               | 1/21                   | 2/21                      | 6/21   | 1/21                             | 0/21                              | 7/21                   | 20/21           |                      | 13/21           |
| %     | 5       | 0                                | 0                                       | 5                                  | 10                     | 29                        | 5  | 0                                | 33                                | 95                     |                 | 62                   |                 |
| 100 m | mean    |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 5               | 112                  | 2               |
|       | st dev  |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 1               | 19                   | 2               |
|       | min     |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 4               | 73                   | 0               |
|       | max     |                                  |   |                                    |                        |                           |  |                                  |                                   |                        | 6               | 139                  | 3               |
|       | proport | 0/2                              | 0/2                                     | 0/2                                | 0/2                    | 0/2                       | 0/2  | 0/2                              | 0/2                               | 0/2                    | 2/2             |                      | 1/2             |
| %     | 0       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0  | 0                                | 0                                 | 100                    |                 | 50                   |                 |

|       | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage to <i>Nymphaeas</i> | <i>transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|---|----------------------------------|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m  | mean    | 0                                | 0                                       | 0                                  | 2                      | 0                         | 1   |                                  |                                   |                        | 4               | 171                  | 1               |
|       | st dev  | 0                                | 0                                       | 0                                  | 4                      | 0                         | 1   |                                  |                                   |                        | 5               | 52                   | 2               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 0               | 46                   | 0               |
|       | max     | 1                                | 0                                       | 0                                  | 13                     | 0                         | 3   |                                  |                                   |                        | 17              | 232                  | 6               |
|       | proport | 1/11                             | 0/11                                    | 0/11                               | 4/11                   | 0/11                      | 7/11  | 0/11                             | 0/11                              | 5/11                   | 7/11            |                      | 4/11            |
| 25 m  | %       | 9                                | 0                                       | 0                                  | 36                     | 0                         | 64  | 0                                | 0                                 | 45                     | 64              |                      | 36              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 18              | 170                  | 3               |
|       | st dev  | 0                                | 0                                       | 0                                  | 1                      | 0                         | 0   |                                  |                                   |                        | 14              | 49                   | 5               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 0               | 55                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 4                      | 0                         | 1   |                                  |                                   |                        | 47              | 260                  | 20              |
| 50 m  | proport | 0/20                             | 0/20                                    | 0/20                               | 2/20                   | 0/20                      | 6/20  | 1/20                             | 0/20                              | 7/20                   | 7/20            |                      | 12/20           |
|       | %       | 0                                | 0                                       | 0                                  | 10                     | 0                         | 30  | 5                                | 0                                 | 35                     | 85              |                      | 60              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 19              | 167                  | 5               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 14              | 37                   | 5               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0   |                                  |                                   |                        | 0               | 34                   | 0               |
| 100 m | max     | 0                                | 0                                       | 2                                  | 1                      | 0                         | 1   |                                  |                                   |                        | 44              | 250                  | 16              |
|       | proport | 0/19                             | 0/19                                    | 1/19                               | 2/19                   | 0/19                      | 1/19  | 0/19                             | 0/19                              | 6/19                   | 8/19            |                      | 11/19           |
|       | %       | 0                                | 0                                       | 5                                  | 11                     | 0                         | 5   | 0                                | 0                                 | 32                     | 95              |                      | 58              |

No quadrats fell in the 100 m buffer area during the July 2006 sampling.

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 0    | 0    |
| 2.77 to 3.1    | MHHW to Highest Tide | 4    | 0    |
| 1.55 to 2.76   | MSL to MHHW          | 96   | 100  |
| 0.22 to 1.54   | MLLW to MSL          | 0    | 0    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m NAVD88.

| <b>Tongue Pt</b> | <b>Tide Level (zero is MLLW)</b> | <b>Cumulative Percentage of Time</b> | <b>Elevation (NAVD88)</b> |
|------------------|----------------------------------|--------------------------------------|---------------------------|
| >MHHW            | >8.6 ft                          | 3%                                   | >8.8 ft                   |
| >MSL             | >4.5 ft                          | 49%                                  | >4.6 ft                   |
| >MLLW            | >0 ft                            | 95%                                  | >0.2 ft                   |
| <MLLW            | <0 ft                            | 95-100%                              | <0.2 ft                   |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Tongue Point; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL; >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.6 ft MLLW) at this site. Forty-nine percent of the time water levels exceed MSL (4.5 ft), 95% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



View to north. July, 2006.

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Svensen Island

**Dates:** June 17 & July 26, 2006

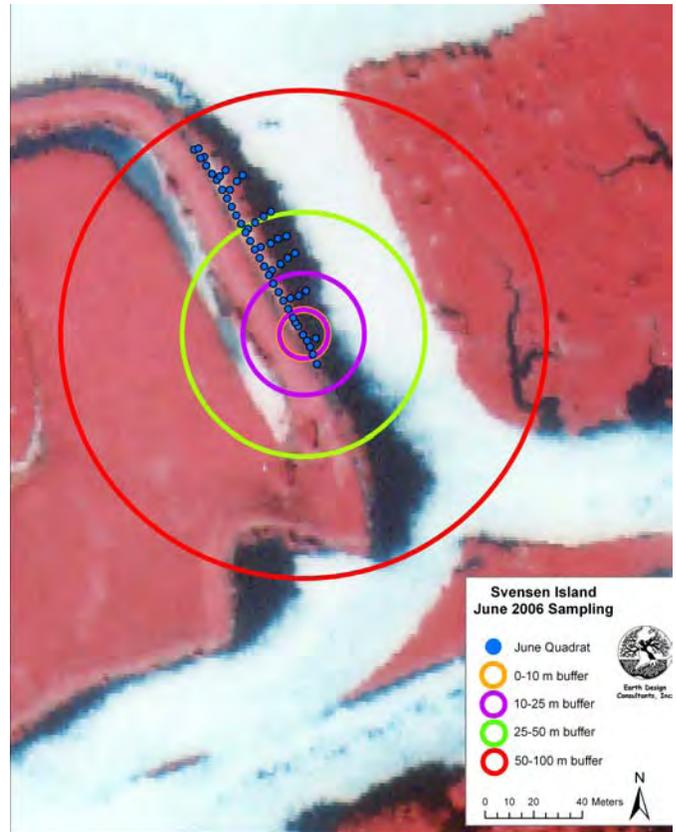
**Lat/Long:** 46.182243987 N,  
123.632526530 W NAD83 Conus

**Columbia River Mile:** ~ 24

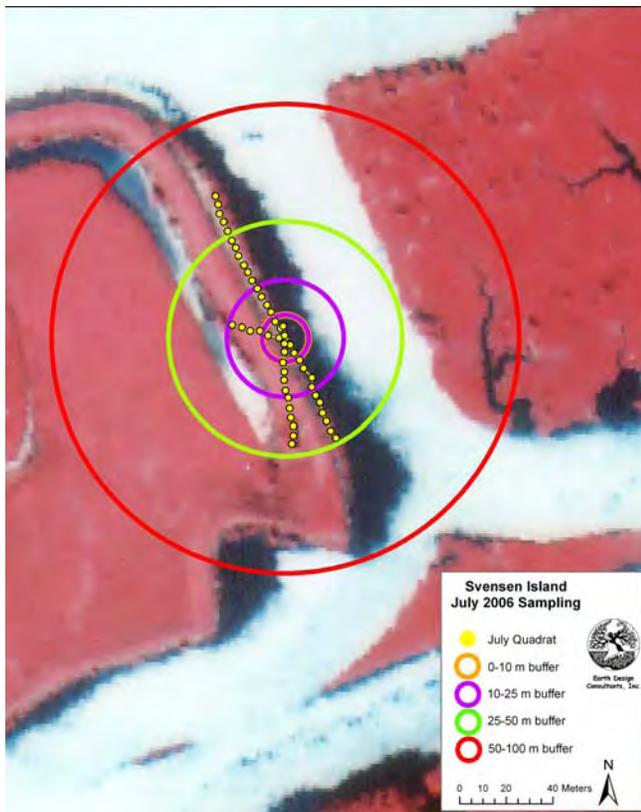
**Mean +/- S.D, Range in Elevation:**  
2.6 m +/- 0.6, 0.7-4.1 m NAVD88

**Distance to High Ground:** 2.56 m  
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | 23.8              | 29.4m            | 93.4m             |
| <b>Forest</b> | 25.3              | 29.4m            | 31.1m             |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a function of distance from the initial biocontrol release point.

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 2                      | 2                         | 2                           |   |                                   |                        | 5               | 68                   | 3               |
| st dev      | 0                                | 0                                       | 0                                  | 8                      | 7                         | 6                           |   |                                   |                        | 7               | 59                   | 6               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 0                    | 0               |
| max         | 1                                | 1                                       | 1                                  | 50                     | 40                        | 30                          |   |                                   |                        | 34              | 197                  | 22              |
| proport     | 1/51                             | 2/51                                    | 3/51                               | 8/51                   | 12/51                     | 20/51                       | 0/51  | 0/51                              | 10/51                  | 23/51           |                      | 13/51           |
| %           | 2                                | 4                                       | 6                                  | 16                     | 24                        | 39                          | 0   | 0                                 | 20                     | 45              |                      | 25              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 4                      | 0                         | 3                           |   |                                   |                        | 3               | 142                  | 1               |
| st dev      | 1                                | 0                                       | 0                                  | 11                     | 0                         | 9                           |   |                                   |                        | 6               | 32                   | 3               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 70                   | 0               |
| max         | 6                                | 0                                       | 0                                  | 65                     | 1                         | 60                          |   |                                   |                        | 35              | 211                  | 15              |
| proport     | 4/50                             | 0/50                                    | 0/50                               | 15/50                  | 1/50                      | 15/50                       | 0/50  | 0/50                              | 4/50                   | 28/50           |                      | 7/50            |
| %           | 8                                | 0                                       | 0                                  | 30                     | 2                         | 30                          | 0   | 0                                 | 8                      | 56              |                      | 14              |

## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | -0.003       | -0.048       | -0.036     | -0.067        | -0.061      | 0.001       | (a)           | (a)           | -0.183      | -0.126      |
|      | Sig. (2-tailed) | 0.986        | 0.77         | 0.824      | 0.683         | 0.709       | 0.994       |               |               | 0.257       | 0.44        |
|      | N               | 40           | 40           | 40         | 40            | 40          | 40          | 40            | 40            | 40          | 40          |
| July | Correlation     | -0.119       | (a)          | (a)        | -0.052        | 0.064       | -0.048      | (a)           | -0.137        | (a)         | -0.127      |
|      | Sig. (2-tailed) | 0.409        |              |            | 0.722         | 0.659       | 0.74        |               | 0.343         |             | 0.379       |
|      | N               | 50           | 50           | 50         | 50            | 50          | 50          | 50            | 50            | 50          | 50          |

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

*None*

## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|      | June    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10m  | mean    | 0                                | 0                                       | 0                                  | 2                      | 3                         | 9                           |   |                                   |                        | 3               | 106                  | 1               |
|      | st dev  | 0                                | 0                                       | 0                                  | 5                      | 6                         | 12                          |   |                                   |                        | 4               | 21                   | 2               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 63                   | 0               |
|      | max     | 1                                | 0                                       | 1                                  | 15                     | 17                        | 30                          |   |                                   |                        | 11              | 143                  | 6               |
|      | proport | 1/8                              | 0/8                                     | 1/8                                | 2/8                    | 3/8                       | 4/8                         | 0/8   | 0/8                               | 2/8                    | 4/8             |                      | 2/8             |
|      | %       | 13                               | 0                                       | 13                                 | 25                     | 38                        | 50                          | 0   | 0                                 | 25                     | 50              |                      | 25              |
| 25m  | mean    | 0                                | 0                                       | 0                                  | 3                      | 5                         | 3                           |   |                                   |                        | 7               | 124                  | 5               |
|      | st dev  | 0                                | 0                                       | 0                                  | 7                      | 14                        | 4                           |   |                                   |                        | 11              | 34                   | 9               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 48                   | 0               |
|      | max     | 0                                | 1                                       | 1                                  | 20                     | 40                        | 11                          |   |                                   |                        | 28              | 172                  | 21              |
|      | proport | 0/8                              | 1/8                                     | 1/8                                | 2/8                    | 2/8                       | 4/8                         | 0/8   | 0/8                               | 4/8                    | 5/8             |                      | 3/8             |
|      | %       | 0                                | 13                                      | 13                                 | 25                     | 25                        | 50                          | 0   | 0                                 | 50                     | 63              |                      | 38              |
| 50m  | mean    | 0                                | 0                                       | 0                                  | 4                      | 2                         | 1                           |   |                                   |                        | 5               | 116                  | 4               |
|      | st dev  | 0                                | 0                                       | 0                                  | 13                     | 5                         | 2                           |   |                                   |                        | 6               | 39                   | 8               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 30                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 50                     | 19                        | 5                           |   |                                   |                        | 15              | 167                  | 22              |
|      | proport | 0/16                             | 0/16                                    | 0/16                               | 3/16                   | 3/16                      | 6/16                        | 0/16  | 0/16                              | 2/16                   | 8/16            |                      | 4/16            |
|      | %       | 0                                | 0                                       | 0                                  | 19                     | 19                        | 38                          | 0   | 0                                 | 13                     | 50              |                      | 25              |
| 100m | mean    | 0                                | 0                                       | 0                                  | 1                      | 1                         | 1                           |   |                                   |                        | 5               | 4                    | 90              |
|      | st dev  | 0                                | 0                                       | 0                                  | 3                      | 2                         | 1                           |   |                                   |                        | 6               | 9                    | 22              |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 0                    | 54              |
|      | max     | 0                                | 1                                       | 1                                  | 12                     | 8                         | 5                           |   |                                   |                        | 15              | 34                   | 127             |
|      | proport | 0/19                             | 1/19                                    | 1/19                               | 2/19                   | 4/19                      | 6/19                        | 0/19  | 0/19                              | 2/19                   | 7/19            |                      | 4/19            |
|      | %       | 0                                | 5                                       | 5                                  | 11                     | 21                        | 32                          | 0   | 0                                 | 11                     | 37              |                      | 21              |

|      | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10m  | mean    | 1                                | 0                                       | 0                                  | 11                     | 0                         | 9                           |   |                                   |                        | 3               | 130                  | 1               |
|      | st dev  | 2                                | 0                                       | 0                                  | 21                     | 0                         | 18                          |   |                                   |                        | 5               | 21                   | 3               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 100                  | 0               |
|      | max     | 6                                | 0                                       | 0                                  | 65                     | 1                         | 60                          |   |                                   |                        | 14              | 171                  | 9               |
|      | proport | 2/11                             | 0/11                                    | 0/11                               | 4/11                   | 1/11                      | 4/11                        | 0/11  | 0/11                              | 0/11                   | 5/11            |                      | 2/11            |
| %    | 18      | 0                                | 0                                       | 36                                 | 9                      | 36                        | 0                           | 0   | 0                                 | 45                     |                 | 18                   |                 |
| 25m  | mean    | 0                                | 0                                       | 0                                  | 2                      | 0                         | 1                           |   |                                   |                        | 3               | 139                  | 1               |
|      | st dev  | 1                                | 0                                       | 0                                  | 3                      | 0                         | 3                           |   |                                   |                        | 5               | 34                   | 4               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 80                   | 0               |
|      | max     | 2                                | 0                                       | 0                                  | 10                     | 0                         | 10                          |   |                                   |                        | 14              | 196                  | 15              |
|      | proport | 1/16                             | 0/16                                    | 0/16                               | 6/16                   | 0/16                      | 5/16                        | 0/16  | 0/16                              | 2/16                   | 8/16            |                      | 1/16            |
| %    | 6       | 0                                | 0                                       | 38                                 | 0                      | 31                        | 0                           | 0   | 13                                | 50                     |                 | 6                    |                 |
| 50m  | mean    | 0                                | 0                                       | 0                                  | 1                      | 0                         | 1                           |   |                                   |                        | 4               | 148                  | 1               |
|      | st dev  | 0                                | 0                                       | 0                                  | 2                      | 0                         | 1                           |   |                                   |                        | 8               | 36                   | 2               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 70                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 9                      | 0                         | 5                           |   |                                   |                        | 35              | 211                  | 5               |
|      | proport | 1/18                             | 1/18                                    | 1/18                               | 4/18                   | 0/18                      | 5/18                        | 1/18  | 1/18                              | 1/18                   | 11/18           |                      | 3/18            |
| %    | 0       | 0                                | 0                                       | 22                                 | 0                      | 28                        | 0                           | 0   | 5                                 | 61                     |                 | 17                   |                 |
| 100m | mean    | 0                                | 0                                       | 0                                  | 1                      | 0                         | 0                           |   |                                   |                        | 5               | 157                  | 1               |
|      | st dev  | 0                                | 0                                       | 0                                  | 1                      | 0                         | 0                           |   |                                   |                        | 9               | 24                   | 1               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 120                  | 0               |
|      | max     | 1                                | 0                                       | 0                                  | 3                      | 0                         | 1                           |   |                                   |                        | 21              | 193                  | 3               |
|      | proport | 1/5                              | 0/5                                     | 0/5                                | 1/5                    | 0/5                       | 1/5                         | 0/5   | 0/5                               | 1/5                    | 4/5             |                      | 1/5             |
| %    | 20      | 0                                | 0                                       | 20                                 | 0                      | 20                        | 0                           | 0   | 20                                | 80                     |                 | 20                   |                 |

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 15   | 16   |
| 2.77 to 3.1    | MHHW to Highest Tide | 20   | 34   |
| 1.55 to 2.76   | MSL to MHHW          | 55   | 48   |
| 0.22 to 1.54   | MLLW to MSL          | 10   | 2    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrat are above MSL, roughly 1.5 m NAVD88.

| Knappa Slough | Tide Level (zero is MLLW) | Cumulative Percentage of Time | Elevation (NAVD88) |
|---------------|---------------------------|-------------------------------|--------------------|
| >MHHW         | >8.3 ft                   | 3.2%                          | >9.0 ft            |
| >MSL          | >4.3 ft                   | 48.3%                         | >5.1 ft            |
| >MLLW         | >0 ft                     | 94%                           | >0.7 ft            |
| <MLLW         | <0 ft                     | 94.7-100%                     | <0.7 ft            |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Knappa Slough; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL, >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.3 ft MLLW) at this site. Forty-eight percent of the time water levels exceed MSL (4.3 ft), 94% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Site Photos



View south; toward the biocontrol  
release point.  
June, 2006



View north. July, 2006.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Tenasillahe Island

**Dates:** June 16 & July 29, 2006

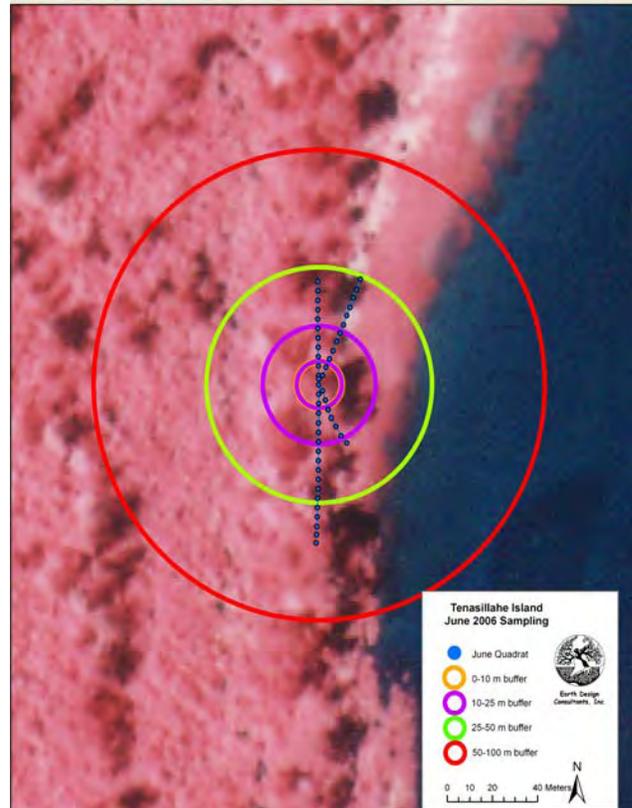
**Lat/Long:** 46.215062576 N,  
123.437970297 W NAD83 Conus

**Columbia River Mile:** ~ 39

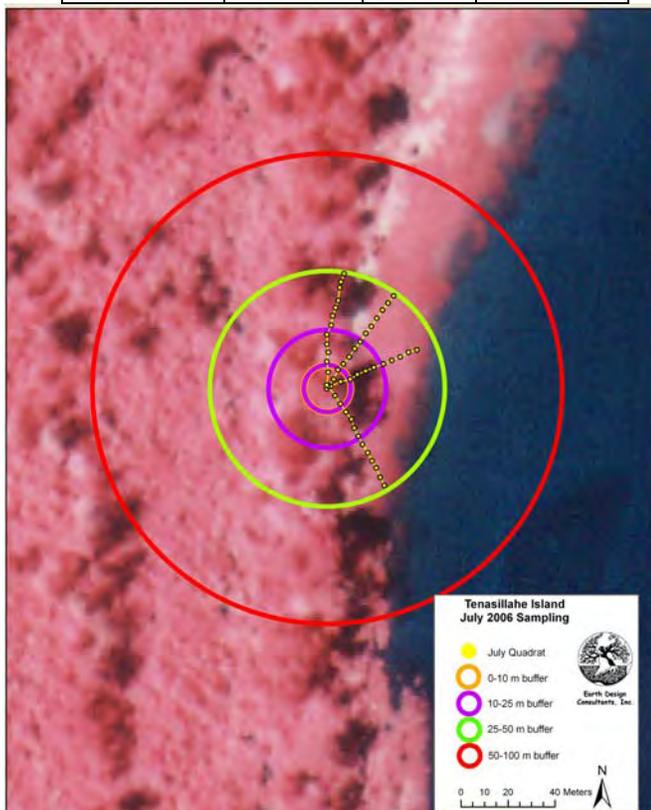
**Mean +/- S.D., Range in Elevation:**  
2.2 m +/- 0.2, 1.7-2.7 m NAVD88

**Distance to High Ground:** 7.78 m  
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 0.0              | 21.1m             |
| <b>Forest</b> | NA                | 0.0              | 186.0m            |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a function of

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

distance from the initial biocontrol release point.

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 1                         | 1                           |   |                                   |                        | 6               | 62                   | 2               |
| st dev      | 0                                | 0                                       | 0                                  | 0                      | 2                         | 2                           |   |                                   |                        | 8               | 63                   | 4               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 0                    | 0               |
| max         | 0                                | 0                                       | 0                                  | 0                      | 11                        | 12                          |   |                                   |                        | 36              | 197                  | 19              |
| proport     | 0                                | 0/50                                    | 0/50                               | 0/50                   | 5/50                      | 23/50                       | 0/50  | 0/50                              | 3/50                   | 28/50           |                      | 15/50           |
| %           | 0                                | 0                                       | 0                                  | 0                      | 10                        | 46                          | 0   | 0                                 | 6                      | 56              |                      | 25              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 4               | 155                  | 1               |
| st dev      | 0                                | 0                                       | 0                                  | 1                      | 0                         | 2                           |   |                                   |                        | 6               | 61                   | 3               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 31                   | 0               |
| max         | 1                                | 0                                       | 2                                  | 3                      | 0                         | 10                          |   |                                   |                        | 30              | 260                  | 13              |
| proport     | 1/50                             | 0/50                                    | 2/50                               | 8/50                   | 0/50                      | 16/50                       | 0/50  | 0/50                              | 17/50                  | 18/50           |                      | 6/50            |
| %           | 2                                | 0                                       | 4                                  | 16                     | 0                         | 32                          | 0   | 0                                 | 34                     | 36              |                      | 12              |

## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | (a)          | (a)          | (a)        | (a)           | 0.13        | 0.106       | (a)           | (a)           | 0.019       | 0.214       |
|      | Sig. (2-tailed) |              |              |            |               | 0.372       | 0.47        |               |               | 0.895       | 0.141       |
|      | N               | 49           | 49           | 49         | 49            | 49          | 49          | 49            | 49            | 49          | 49          |
| July | Correlation     | 0.112        | (a)          | 0.231      | .359(*)       | (a)         | .434(**)    | (a)           | .475(**)      | (a)         | 0.332*      |
|      | Sig. (2-tailed) | 0.445        |              | 0.111      | 0.011         |             | 0.002       |               | 0.001         |             | 0.02        |
|      | N               | 49           | 49           | 49         | 49            | 49          | 49          | 49            | 49            | 49          | 49          |

# new *L. salicaria* stems from June and July (98 quadrats) correlated with elevation is significant at the p=0.01 level – Pearson’s correlation r=0.3, p=0.003.

**Correlations between these field variables and quadrat elevation were significant at the 0.05 level at this site:**

*July: # GA eggs and elevation*

*July: # old L. salicaria stems and elevation*

**Correlations between these field variables and quadrat elevation were significant at the 0.01 level at this site:**

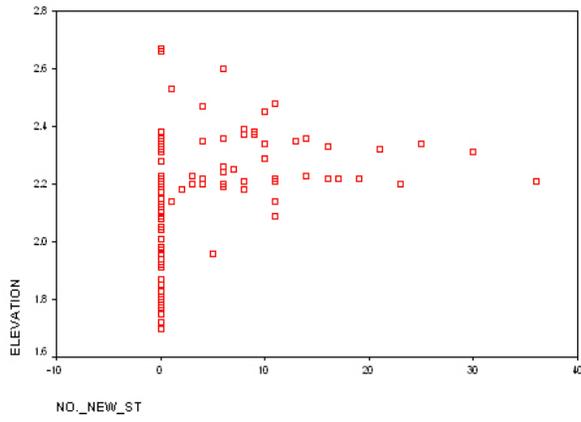
*June and July together: # new L. salicaria and elevation*

*July: % GA damage and elevation*

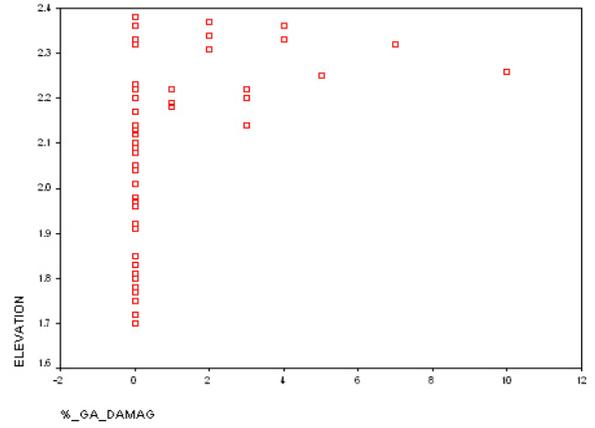
*July: # new L. salicaria and elevation*

June & July:

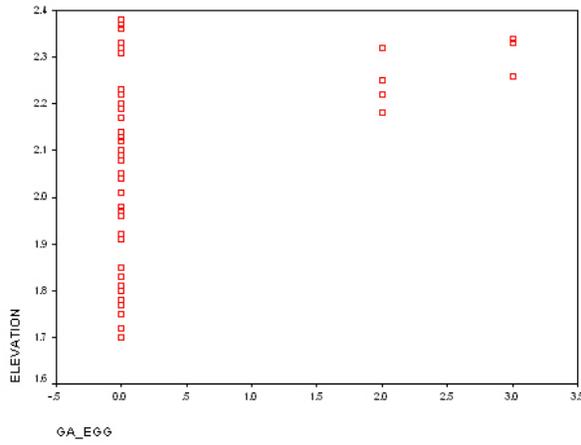
# New PLS Stems & Elevation



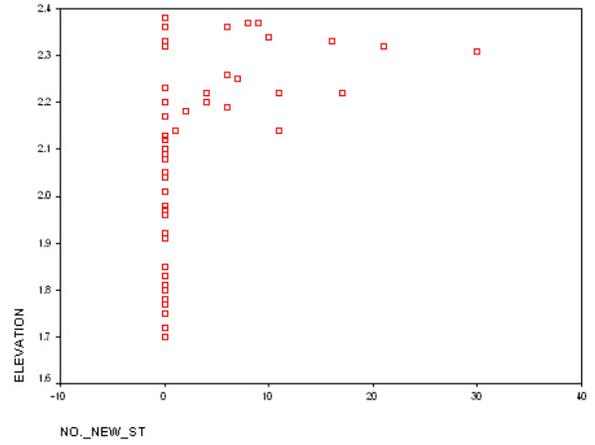
July: % GA Damage & Elevation



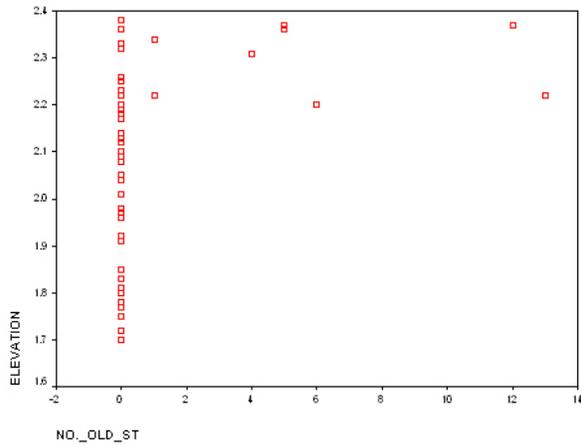
July: # GA Egg Masses & Elevation



July: # New PLS Stems & Elevation



July: # Old Stems & Elevation



## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|       |         | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m  | June    |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           | 0   | 0                                 |                        | 11              | 105                  | 1               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 2                         | 2                           | 0   | 0                                 |                        | 11              | 47                   | 2               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 6                    | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 5                         | 5                           | 0   | 0                                 |                        | 36              | 171                  | 5               |
|       | proport | 0/11                             | 0/11                                    | 0/11                               | 0/11                   | 1/11                      | 7/11                        | 0/11  | 0/11                              | 0/11                   | 8/11            |                      | 5/11            |
| 25 m  | %       | 0                                | 0                                       | 0                                  | 0                      | 9                         | 64                          | 0   | 0                                 | 0                      | 73              |                      | 45              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 1                         | 2                           |   |                                   |                        | 6               | 115                  | 4               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 1                         | 3                           |   |                                   |                        | 6               | 28                   | 6               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 15                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 5                         | 12                          |   |                                   |                        | 23              | 148                  | 19              |
|       | proport | 0/16                             | 0/16                                    | 0/16                               | 0/16                   | 3/16                      | 8/16                        | 0/16  | 0/16                              | 3/16                   | 11/16           |                      | 8/16            |
| 50 m  | %       | 0                                | 0                                       | 0                                  | 0                      | 19                        | 50                          | 0   | 0                                 | 19                     | 69              |                      | 50              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 1                         | 1                           |   |                                   |                        | 4               | 104                  | 1               |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 3                         | 1                           |   |                                   |                        | 7               | 34                   | 1               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 33                   | 0               |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 11                        | 3                           |   |                                   |                        | 25              | 162                  | 5               |
|       | proport | 0/18                             | 0/18                                    | 0/18                               | 0/18                   | 1/18                      | 6/18                        | 0/18  | 0/18                              | 0/18                   | 6/18            |                      | 2/18            |
| 100 m | %       | 0                                | 0                                       | 0                                  | 0                      | 6                         | 33                          | 0   | 0                                 | 0                      | 33              |                      | 11              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 4               | 115                  |                 |
|       | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 2                           |   |                                   |                        | 5               | 29                   |                 |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 75                   |                 |
|       | max     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 5                           |   |                                   |                        | 11              | 160                  |                 |
|       | proport | 0/5                              | 0/5                                     | 0/5                                | 0/5                    | 0/5                       | 2/5                         | 0/5   | 0/5                               | 0/5                    | 3/5             |                      | 0/5             |
|       | %       | 0                                | 0                                       | 0                                  | 0                      | 0                         | 40                          | 0   | 0                                 | 0                      | 60              |                      | 0               |

|       | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m  | mean    | 0                                | 0                                       | 0                                  | 1                      | 0                         | 2                           |   |                                   |                        | 6               | 156                  | 1               |
|       | st dev  | 0                                | 0                                       | 0                                  | 1                      | 0                         | 3                           |   |                                   |                        | 5               | 64                   | 4               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 31                   | 0               |
|       | max     | 1                                | 0                                       | 0                                  | 3                      | 0                         | 10                          |   |                                   |                        | 17              | 260                  | 13              |
|       | proport | 1/10                             | 0/10                                    | 0/10                               | 5/10                   | 0/10                      | 7/10                        | 0/10  | 0/10                              | 7/10                   | 8/10            |                      | 2/10            |
| 25 m  | %       | 10                               | 0                                       | 0                                  | 50                     | 0                         | 70                          | 0   | 0                                 | 70                     | 80              |                      | 20              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 2               | 176                  | 2               |
|       | st dev  | 0                                | 0                                       | 0                                  | 1                      | 0                         | 1                           |   |                                   |                        | 4               | 44                   | 3               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 53                   | 0               |
|       | max     | 0                                | 0                                       | 1                                  | 3                      | 0                         | 4                           |   |                                   |                        | 10              | 243                  | 12              |
| 50 m  | proport | 0/16                             | 0/16                                    | 1/16                               | 1/16                   | 0/16                      | 5/16                        | 0/16  | 0/16                              | 6/16                   | 6/16            |                      | 5/16            |
|       | %       | 0                                | 0                                       | 6                                  | 6                      | 0                         | 31                          | 0   | 0                                 | 38                     | 38              |                      | 31              |
|       | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 3               | 128                  | 0               |
|       | st dev  | 0                                | 0                                       | 0                                  | 1                      | 0                         | 2                           |   |                                   |                        | 8               | 65                   | 1               |
|       | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 53                   | 0               |
| 100 m | max     | 0                                | 0                                       | 2                                  | 3                      | 0                         | 7                           |   |                                   |                        | 30              | 250                  | 4               |
|       | proport | 0/24                             | 0/24                                    | 1/24                               | 2/24                   | 0/24                      | 4/24                        | 0/24  | 0/24                              | 4/24                   | 4/24            |                      | 1/24            |
|       | %       | 0                                | 0                                       | 4                                  | 8                      | 0                         | 17                          | 0   | 0                                 | 17                     | 17              |                      | 4               |

No quadrats fell in the 100 m buffer area during the July 2006 sampling.

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 0    | 0    |
| 2.77 to 3.1    | MHHW to Highest Tide | 0    | 0    |
| 1.55 to 2.76   | MSL to MHHW          | 100  | 100  |
| 0.22 to 1.54   | MLLW to MSL          | 0    | 0    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL and the lowest tide water level, and below the water level of the lowest tide. All quadrats are between MSL and MHHW, roughly 1.5 m NAVD88.

| <b>Knappa Slough</b> | <b>Tide Level (zero is MLLW)</b> | <b>Cumulative Percentage of Time</b> | <b>Elevation (NAVD88)</b> |
|----------------------|----------------------------------|--------------------------------------|---------------------------|
| >MHHW                | >8.3 ft                          | 3.2%                                 | >9.0 ft                   |
| >MSL                 | >4.3 ft                          | 48.3%                                | >5.1 ft                   |
| >MLLW                | >0 ft                            | 94%                                  | >0.7 ft                   |
| <MLLW                | <0 ft                            | 94.7-100%                            | <0.7 ft                   |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Knappa Slough; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL, >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.3 ft MLLW) at this site. Forty-eight percent of the time water levels exceed MSL (4.3 ft), 94% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



View to south. June, 2006.



View to northeast. July, 2006.

<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

## Purple Loosestrife Biocontrol Agent Monitoring Project 2006

Earth Design Consultants, Inc.  
www.earthdesign.com

**Site:** Wallace Island

**Dates:** June 19 & July 28, 2006

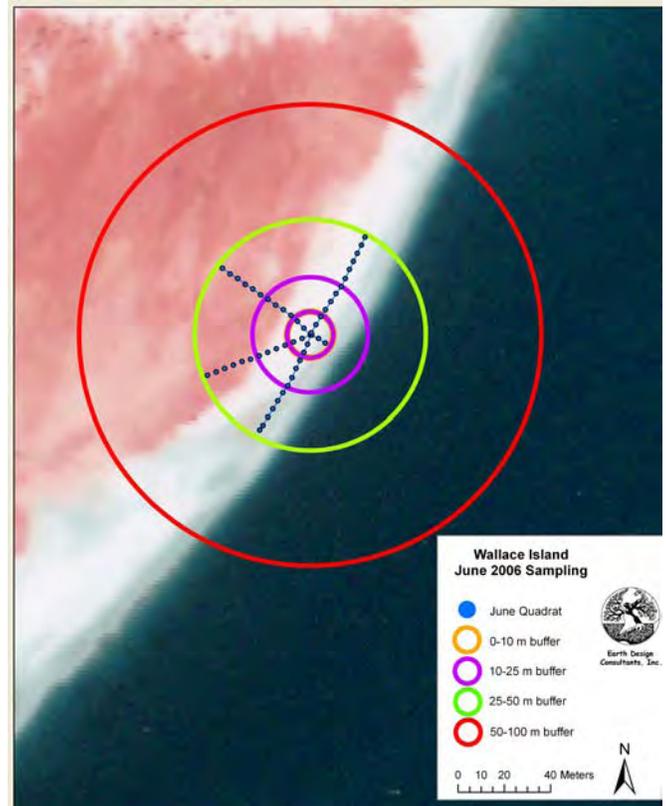
**Lat/Long:** 46.150535875 N,  
123.230713792 W NAD83 Conus

**Columbia River Mile:** ~ 53

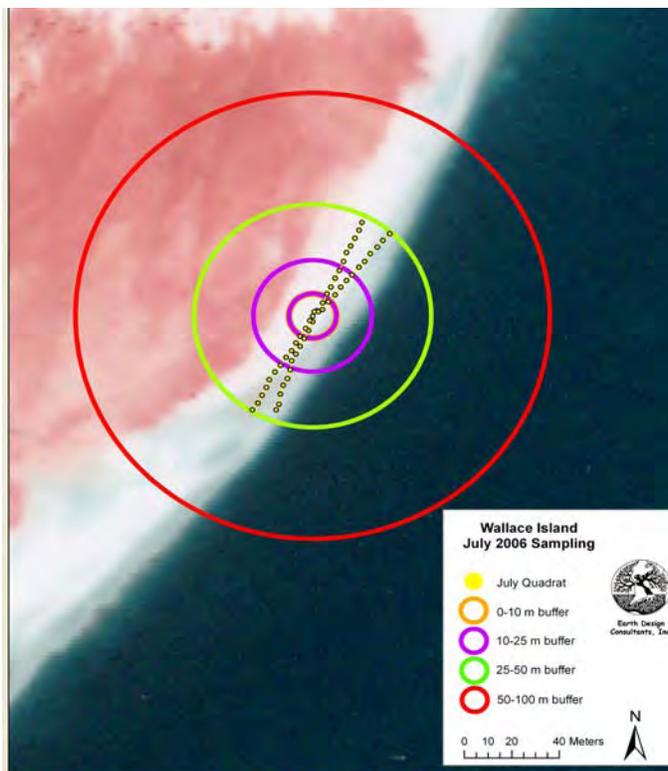
**Mean +/- S.D., Range in Elevation:**  
2.7 m +/- 0.4, 1.9-3.2 m NAVD88

**Distance to High Ground:** 9.0 m  
**Distance to Shrub/Forest Cover:**

|               | CASI <sup>1</sup> | CIR <sup>1</sup> | ETM+ <sup>1</sup> |
|---------------|-------------------|------------------|-------------------|
| <b>Shrub</b>  | NA                | 251.9m           | 265.9m            |
| <b>Forest</b> | NA                | 251.9m           | 220.2m            |



June quadrat locations.



July quadrat locations.

Field sampling was conducted during two separate periods during 2006, June and July. During each sampling period, 50 1m<sup>2</sup> quadrats were sampled along variable length transects radiating from a biocontrol agent release point.

The quadrat locations from each sampling period are displayed on color infrared photos of the site. The rings or buffers around each site indicate different distances (10, 25, 50, and 100 m) from the initial biocontrol release point. These buffers are used to summarize various field measures as a function of distance from the initial

<sup>1</sup> CASI=compact airborne spectrographic imager; CIR=color infrared photos; ETM+=enhanced thematic mapper plus; see main report for details

biocontrol release point.

Observations of the presence and number of biocontrol agents including *Galerucella pusilla* (GAPU), *G. californiensis* (GACA), *Hylobius transversovittatus* (HYTR), and *Nanophyes marmoratus* (NAMA), were made. We also observed the percent damage caused by the biocontrol agents, the number of new and old purple loosestrife (*Lythrum salicaria*), and noted other plant damage.

We created a digital elevation model (DEM) for each site using points collected using RTK (real time kinematic) GPS. Elevation was measured to within 2cm accuracy at approximately 200 points around the initial biocontrol release point during the RTK data collection and a grid was then created from this data. We used this DEM to assign elevation values to each quadrat. These elevations will be used to examine tidal inundation and relationships between biocontrol agent success and elevation.

## Site Summaries for each month

In the following tables, variables measured during the field sampling are summarized by sampling period (June or July). Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats sampled in either the June or July period.

|             | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|-------------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| <b>June</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 1                         | 1                           |   |                                   |                        | 5               | 60                   | 2               |
| st dev      | 0                                | 0                                       | 0                                  | 1                      | 2                         | 2                           |   |                                   |                        | 7               | 59                   | 4               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 0                    | 0               |
| max         | 1                                | 0                                       | 3                                  | 7                      | 14                        | 10                          |   |                                   |                        | 25              | 197                  | 23              |
| proport     | 1/53                             | 0/53                                    | 1/53                               | 2/53                   | 6/53                      | 16/53                       | 3/53  | 2/53                              | 10/53                  | 32/53           |                      | 13/53           |
| %           | 2                                | 0                                       | 2                                  | 4                      | 11                        | 30                          | 6   | 4                                 | 19                     | 60              |                      | 25              |
| <b>July</b> |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
| mean        | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 4               | 116                  | 1               |
| st dev      | 1                                | 0                                       | 0                                  | 1                      | 0                         | 1                           |   |                                   |                        | 7               | 49                   | 3               |
| min         | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 1                    | 0               |
| max         | 4                                | 1                                       | 0                                  | 7                      | 0                         | 5                           |   |                                   |                        | 39              | 216                  | 20              |
| proport     | 2/51                             | 2/51                                    | 0/51                               | 6/51                   | 0/51                      | 12/51                       | 0/51  | 0/51                              | 14/51                  | 20/51           |                      | 4/51            |
| %           | 4                                | 4                                       | 0                                  | 12                     | 0                         | 24                          | 0   | 0                                 | 27                     | 39              |                      | 8               |

## Relationship between elevation, biocontrol agents, and *L. salicaria*

Correlations between quadrat elevation, biocontrol agent measures, and the number of purple loosestrife stems are presented in the tables below. Only those quadrats for which an elevation value was available from RTK data are included in these correlations. Variables for which the Pearson correlation value is “(a)” indicate no correlation because one of the variables was constant. Significant correlations are indicated with a single asterisk (\*) at 0.05 level (2 tailed significance) and a double asterisk (\*\*) at the 0.01 level (2 tailed). Scatter plots of statistically significant correlations are also displayed.

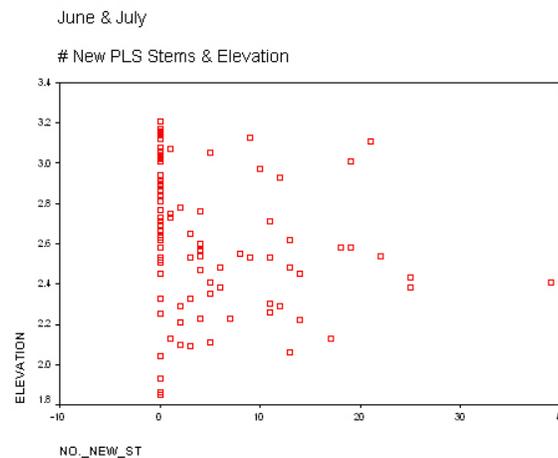
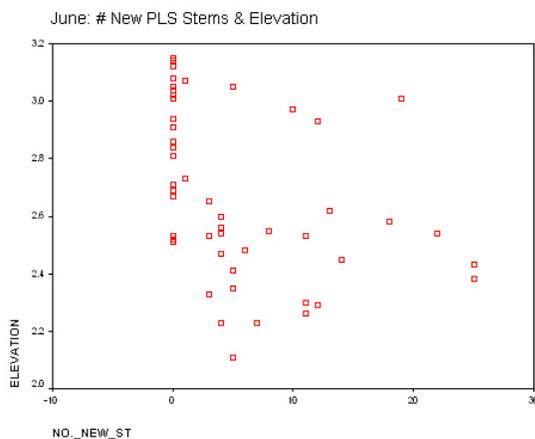
|      |                 | # GAPI adult | # GACA adult | # GA adult | # GA egg mass | # GA larvae | % GA damage | # NAMA adults | % HYTR damage | # new stems | # old stems |
|------|-----------------|--------------|--------------|------------|---------------|-------------|-------------|---------------|---------------|-------------|-------------|
| June | Correlation     | -0.147 (a)   |              | -0.22      | -0.095        | -0.147      | -0.033      | -0.023        | -0.088        | -0.402(**)  | 0.031       |
|      | Sig. (2-tailed) | 0.293        |              | 0.114      | 0.501         | 0.294       | 0.812       | 0.871         | 0.529         | 0.003       | 0.826       |
|      | N               | 53           | 53           | 53         | 53            | 53          | 53          | 53            | 53            | 53          | 53          |
| July | Correlation     | -0.069       | 0.014 (a)    | (a)        | -0.153 (a)    |             | -0.049 (a)  |               | -0.179 (a)    |             | 0.184       |
|      | Sig. (2-tailed) | 0.628        | 0.921        |            | 0.284         |             | 0.732       |               | 0.21          |             | 0.196       |
|      | N               | 51           | 51           | 51         | 51            | 51          | 51          | 51            | 51            | 51          | 51          |

# new *L. salicaria* stems from June and July (104 quadrats) correlated with elevation is significant at the p=0.01 level – Pearson’s correlation r=-0.259, p=0.008.

**Correlations between these field variables and quadrat elevation were significant at at least the 0.05 level at this site:**

*June: # new L. salicaria stems and elevation*

*June and July together: # new L. salicaria stems and elevation*



## Buffered Distance Summaries:

In the following tables, variables measured during the field sampling are summarized for June and July by distance from the initial biocontrol release point. Shown are the average, minimum, and maximum values for measures of biocontrol agent presence and damage, along with the number of new and old purple loosestrife stems averaged over the total number of quadrats within each distance buffer (i.e. ring or donut) sampled in either the June or July period.

|      |         | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m | June    |                                  |   |                                    |                        |                           |                             |   |                                   |                        |                 |                      |                 |
|      | mean    |                                  |   |                                    |                        |                           | 2                           |   |                                   |                        | 5               | 79                   | 3               |
|      | st dev  |                                  |   |                                    |                        |                           | 3                           |   |                                   |                        | 8               | 41                   | 6               |
|      | min     |                                  |   |                                    |                        |                           | 0                           |   | 0                                 |                        | 0               | 14                   | 0               |
|      | max     |                                  |   |                                    |                        |                           | 10                          |   | 1                                 |                        | 22              | 152                  | 18              |
|      | proport | 0/13                             | 0/13                                    | 0/13                               | 0/13                   | 0/13                      | 6/13                        | 0   | 1/13                              | 2/13                   | 7/13            |                      | 5/13            |
| %    | 0       | 0                                | 0                                       | 0                                  | 0                      | 46                        | 0                           | 8   | 15                                | 54                     |                 | 38                   |                 |
| 25 m | mean    | 0                                |   |                                    | 1                      | 2                         | 1                           | 0   |                                   |                        | 8               | 87                   | 3               |
|      | st dev  | 0                                |   |                                    | 2                      | 4                         | 1                           | 0   |                                   |                        | 9               | 34                   | 6               |
|      | min     | 0                                |   |                                    | 0                      | 0                         | 0                           | 0   |                                   |                        | 0               | 14                   | 0               |
|      | max     | 1                                |   |                                    | 7                      | 14                        | 3                           | 1   |                                   |                        | 25              | 160                  | 23              |
|      | proport | 1/16                             | 0/16                                    | 0/16                               | 2/16                   | 4/16                      | 6/16                        | 1/16  | 0/16                              | 5/16                   | 10/16           |                      | 5/16            |
|      | %       | 6                                | 0                                       | 0                                  | 13                     | 25                        | 38                          | 6   | 0                                 | 31                     | 63              |                      | 31              |
| 50 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 4               | 81                   | 1               |
|      | st dev  | 0                                | 0                                       | 1                                  | 0                      | 1                         | 1                           | 0   | 0                                 |                        | 5               | 36                   | 1               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           | 0   | 0                                 |                        | 0               | 6                    | 0               |
|      | max     | 0                                | 0                                       | 3                                  | 0                      | 4                         | 2                           | 1   | 1                                 |                        | 14              | 174                  | 5               |
|      | proport | 0/24                             | 0/24                                    | 1/24                               | 0/24                   | 2/24                      | 4/24                        | 1/24  | 1/24                              | 3/24                   | 15/24           |                      | 3/24            |
|      | %       | 0                                | 0                                       | 4                                  | 0                      | 8                         | 17                          | 4   | 4                                 | 13                     | 63              |                      | 13              |

No quadrats fell in the 100 m buffer area during the June 2006 sampling.

|      | July    | <i>Galerucella pusilla</i> Adult | <i>Galerucella californiensis</i> Adult | <i>Galerucella nymphaeae</i> Adult | <i>Galerucella</i> Egg | <i>Galerucella</i> Larvae | % <i>Galerucella</i> Damage | % <i>Hylobius transversovittatus</i> Damage | <i>Nanophyes marmoratus</i> Adult | Other Herbivore Damage | New Stem Number | New Stem Length (cm) | Old Stem Number |
|------|---------|----------------------------------|---|------------------------------------|------------------------|---------------------------|-----------------------------|---|-----------------------------------|------------------------|-----------------|----------------------|-----------------|
| 10 m | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 2               | 83                   | 2               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 7               | 8                    | 6               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 70                   | 0               |
|      | max     | 0                                | 0                                       | 0                                  | 1                      | 0                         | 1                           |   |                                   |                        | 21              | 91                   | 20              |
|      | proport | 0/10                             | 0/10                                    | 0/10                               | 1/10                   | 0/10                      | 1/10                        | 0/10  | 0/10                              | 1/10                   | 1/10            |                      | 1/10            |
| 25 m | %       | 0                                | 0                                       | 0                                  | 10                     | 0                         | 10                          | 0   | 0                                 | 10                     | 10              |                      | 10              |
|      | mean    | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 4               | 139                  | 0               |
|      | st dev  | 0                                | 0                                       | 0                                  | 0                      | 0                         | 1                           |   |                                   |                        | 10              | 31                   | 1               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 77                   | 0               |
|      | max     | 0                                | 1                                       | 0                                  | 0                      | 0                         | 4                           |   |                                   |                        | 39              | 216                  | 2               |
| 50 m | proport | 0/16                             | 2/16                                    | 0/16                               | 0/16                   | 0/16                      | 3/16                        | 0/16  | 0/16                              | 4/16                   | 4/16            |                      | 1/16            |
|      | %       | 0                                | 13                                      | 0                                  | 0                      | 0                         | 19                          | 0   | 0                                 | 25                     | 25              |                      | 6               |
|      | mean    | 0                                | 0                                       | 0                                  | 1                      | 0                         | 1                           |   |                                   |                        | 4               | 113                  | 0               |
|      | st dev  | 1                                | 0                                       | 0                                  | 2                      | 0                         | 2                           |   |                                   |                        | 6               | 51                   | 0               |
|      | min     | 0                                | 0                                       | 0                                  | 0                      | 0                         | 0                           |   |                                   |                        | 0               | 11                   | 0               |
|      | max     | 4                                | 0                                       | 0                                  | 7                      | 0                         | 5                           |   |                                   |                        | 19              | 200                  | 2               |
|      | proport | 2/25                             | 0/25                                    | 0/25                               | 5/25                   | 0/25                      | 8/25                        | 0/25  | 0/25                              | 9/25                   | 14/25           |                      | 2/25            |
|      | %       | 8                                | 0                                       | 0                                  | 20                     | 0                         | 32                          | 0   | 0                                 | 36                     | 56              |                      | 8               |

No quadrats fell in the 100 m buffer area during the July 2006 sampling.

## Tide Summary

| NAVD88, meters |                      | June | July |
|----------------|----------------------|------|------|
| >3.2           | >Highest Tide        | 0    | 2    |
| 2.77 to 3.1    | MHHW to Highest Tide | 37.7 | 41.2 |
| 1.55 to 2.76   | MSL to MHHW          | 62.3 | 56.9 |
| 0.22 to 1.54   | MLLW to MSL          | 0    | 0    |
| -0.33 to 0.21  | Lowest to MLLW       | 0    | 0    |
| <-0.34         | <Lowest Tide         | 0    | 0    |

The table above presents the percentage of quadrats sampled during June or July that have elevations that are either above the highest tide water level, between MHHW and the highest tide, between MSL and MHHW, between MLLW and MSL, between MSL and the lowest tide water level, and below the water level of the lowest tide. The majority of quadrats are above MSL, roughly 1.5 m NAVD88.

| Knappa Slough | Tide Level (zero is MLLW) | Cumulative Percentage of Time | Elevation (NAVD88) |
|---------------|---------------------------|-------------------------------|--------------------|
| >MHHW         | >8.3 ft                   | 3.2%                          | >9.0 ft            |
| >MSL          | >4.3 ft                   | 48.3%                         | >5.1 ft            |
| >MLLW         | >0 ft                     | 94%                           | >0.7 ft            |
| <MLLW         | <0 ft                     | 94.7-100%                     | <0.7 ft            |

The table above reports the percentage of time water levels at the tide gauge nearest the study site were above MHHW, above MSL, above MLLW, and below MLLW. Calculations are based on tidal values from every hour of every day between June 1, 2005 – December 31, 2006 at the nearest tidal gauge station of Knappa Slough; calculating the number of number of hours where the hourly tide level was in a given category (i.e. >MSL, >MLLW, etc.).<sup>2</sup> The elevations presented in the column marked “NAVD88” are equivalent to the tide levels in the second column but are simply converted from the MLLW to the NAVD88 tidal datum. This table indicates that only 3% of the time water levels are above the MHHW mark (8.3 ft MLLW) at this site. Forty-eight percent of the time water levels exceed MSL (4.3 ft), 94% of the time water levels exceed MLLW, and 95-100% of the time areas below MLLW (0 ft elevation) are under water.

## Site Photos



View northeast toward biocontrol release point (left), purple loosestrife (*Lythrum salicaria*) at water's edge (right). June, 2006.

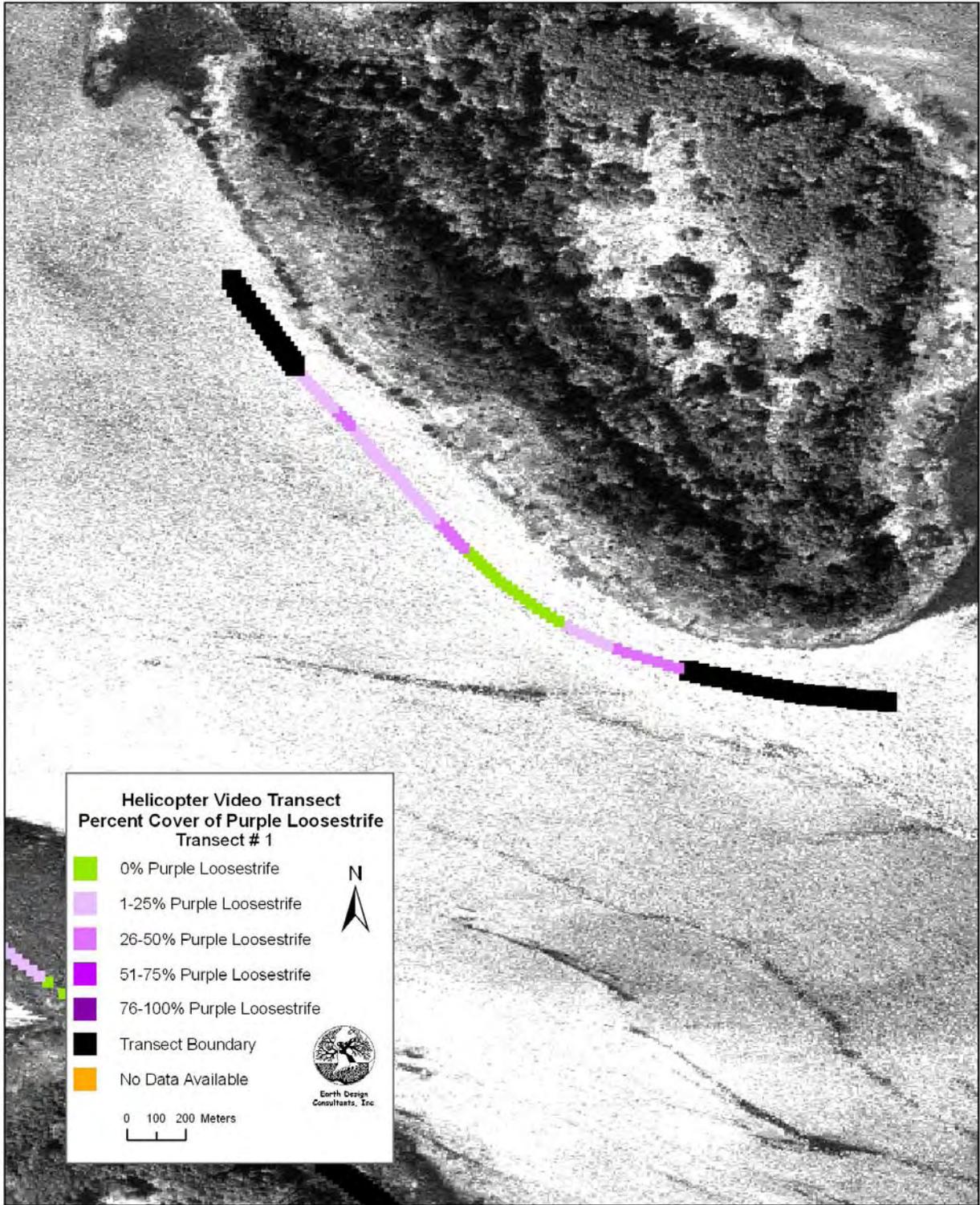
<sup>2</sup> Nobeltec Tides and Currents software was used to generate tidal values and allows for the prediction of future tide levels. No adjustment was made for the distance of the biocontrol release point from the tidal gauge station because the effect due to distance is unknown and likely insignificant at the scale of the release points from one another.

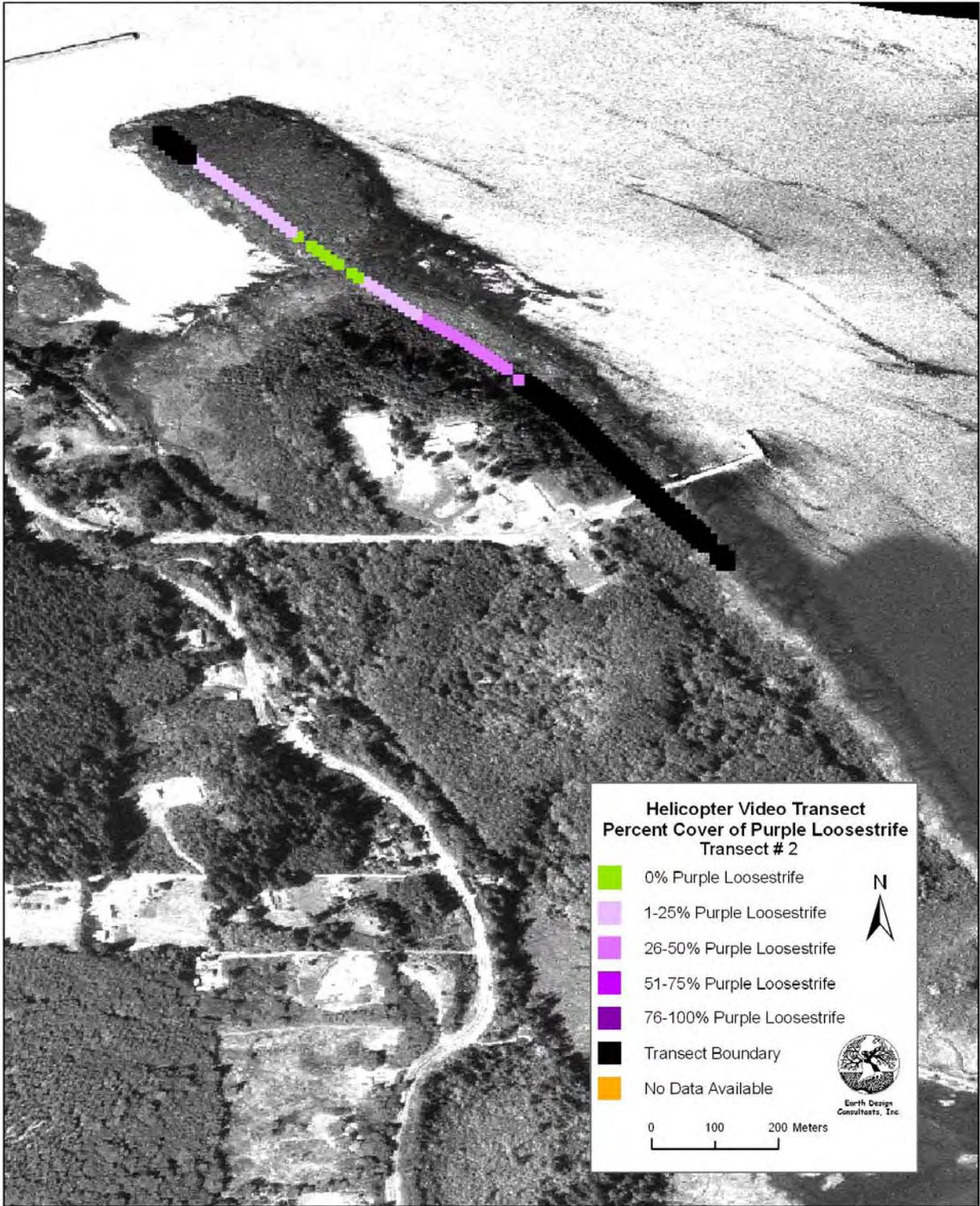
## **Appendix II – Helicopter Transects**

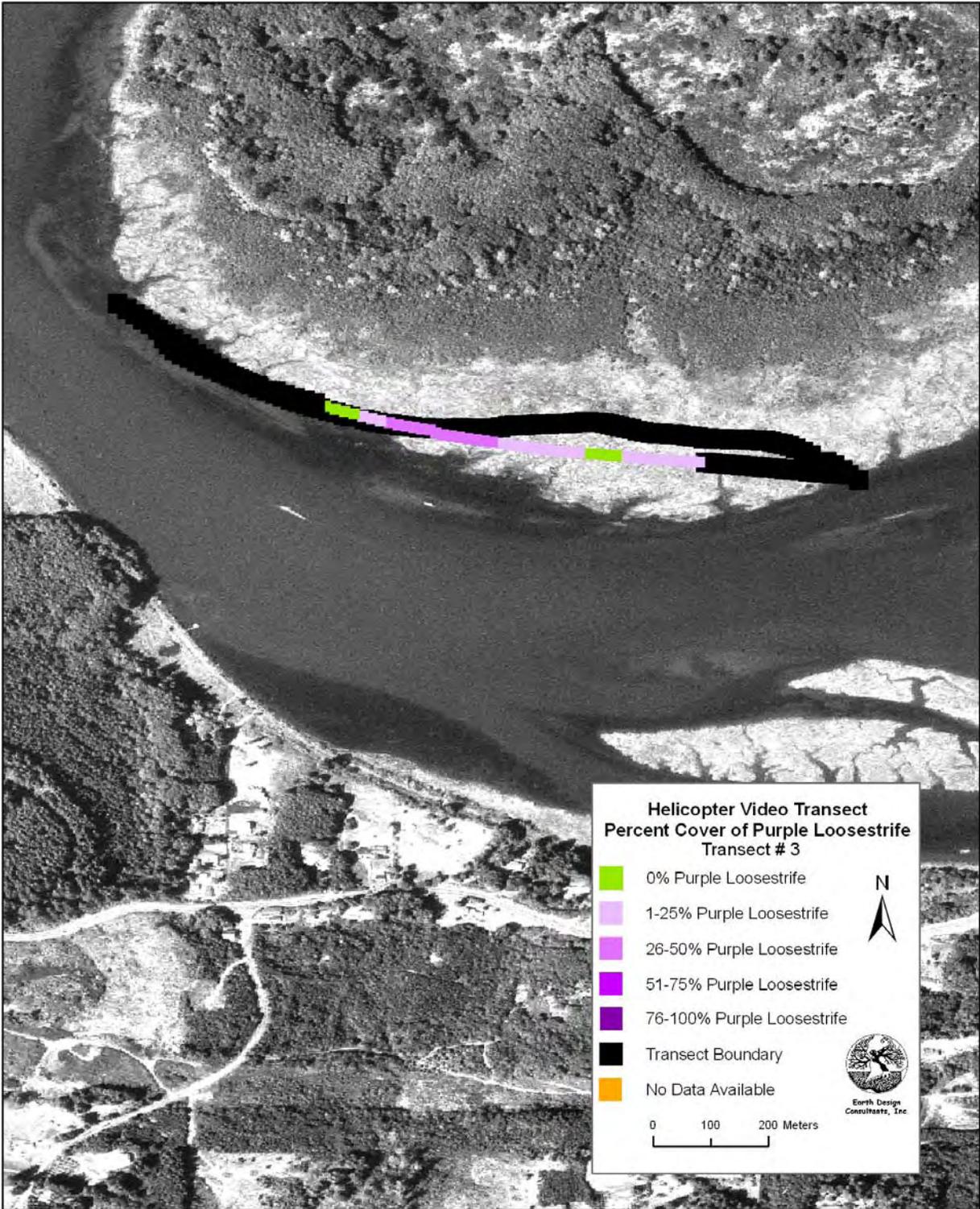
We collected airborne digital video imagery from 35 transects on July 19-20, 2006. Each transect was approximately 1500ft long and 20ft wide. Transect locations were predetermined by USACE and distributed across shoreline and islands within the Lower Columbia River. We measured *Lythrum* cover along each video transect. Shown are densities of *Lythrum*, as percent cover, on black and white digital ortho quarter quads (DOQQ)<sup>1</sup>. See main report for more details.

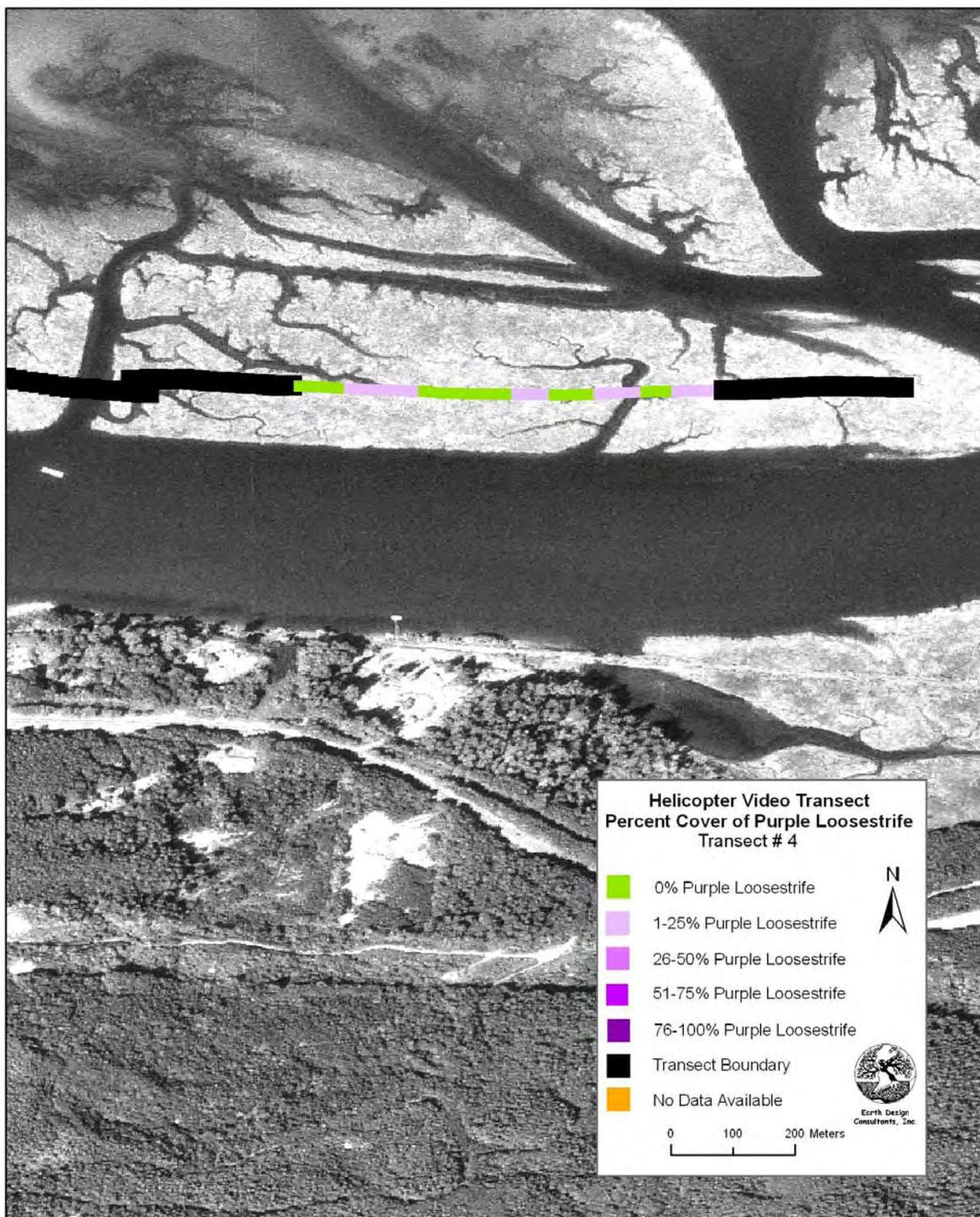
---

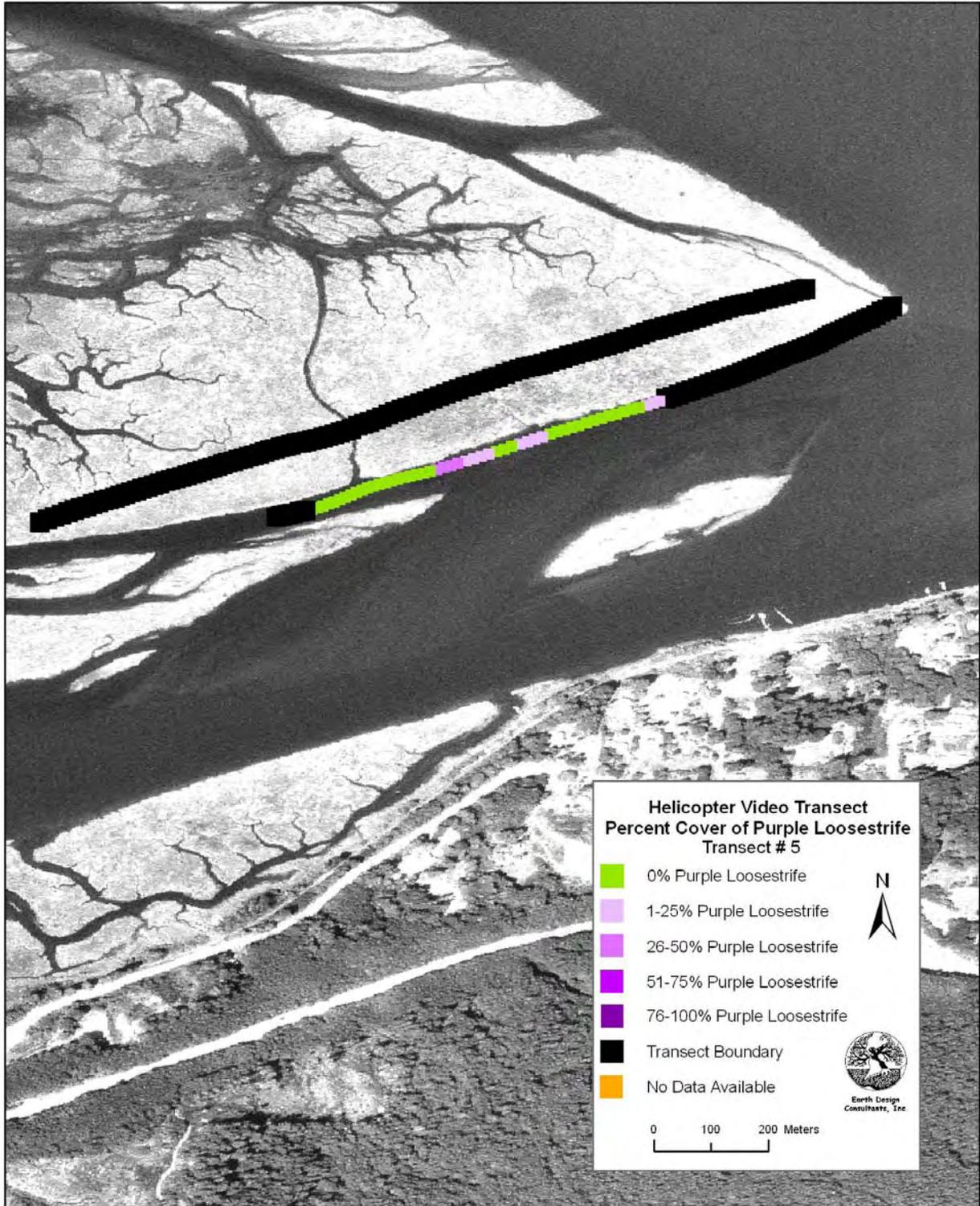
<sup>1</sup> Minor differences in projections between video transect shapefiles and DOQQs result in some of the transects appearing over open water instead of the nearby island on which they were actually located.

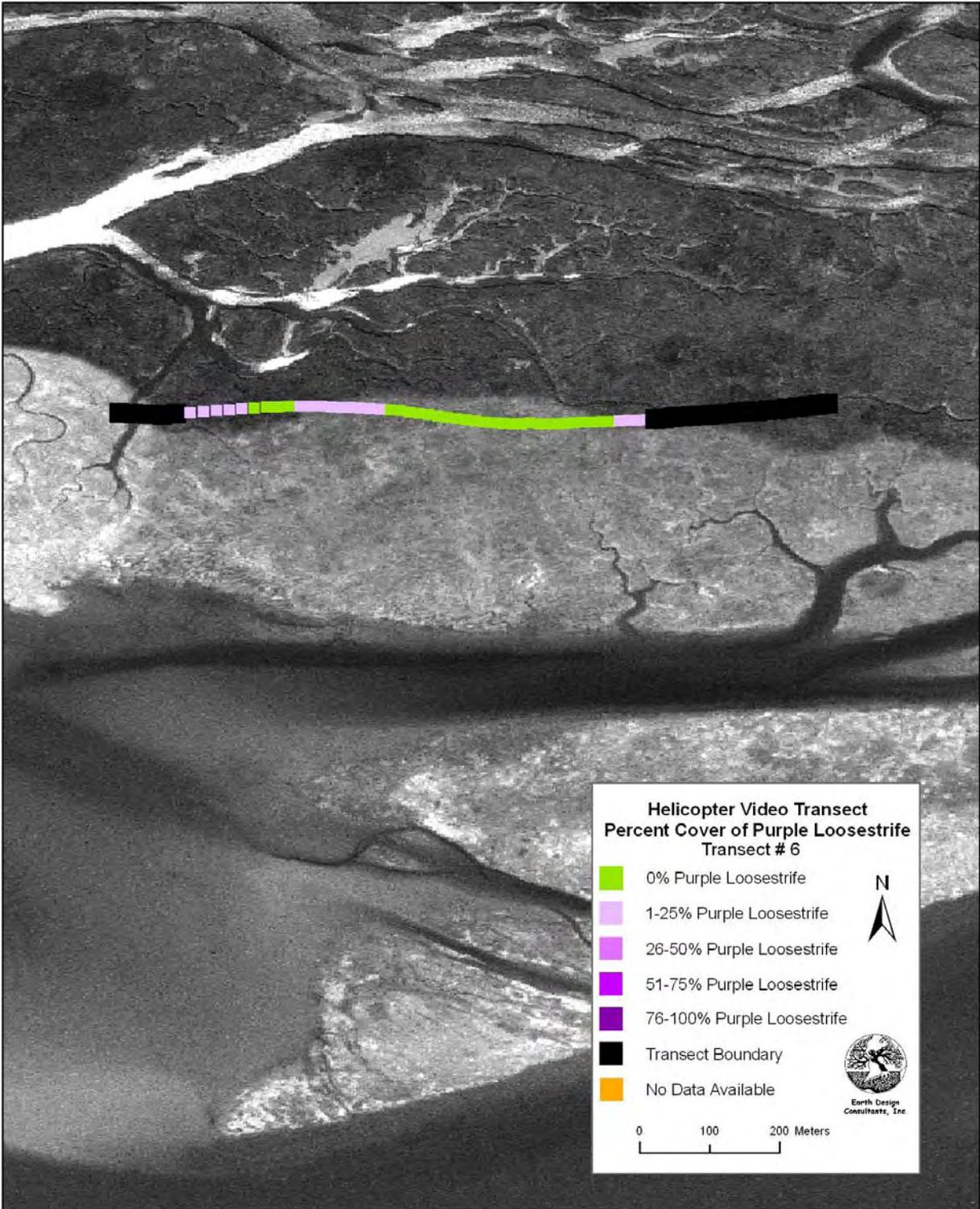


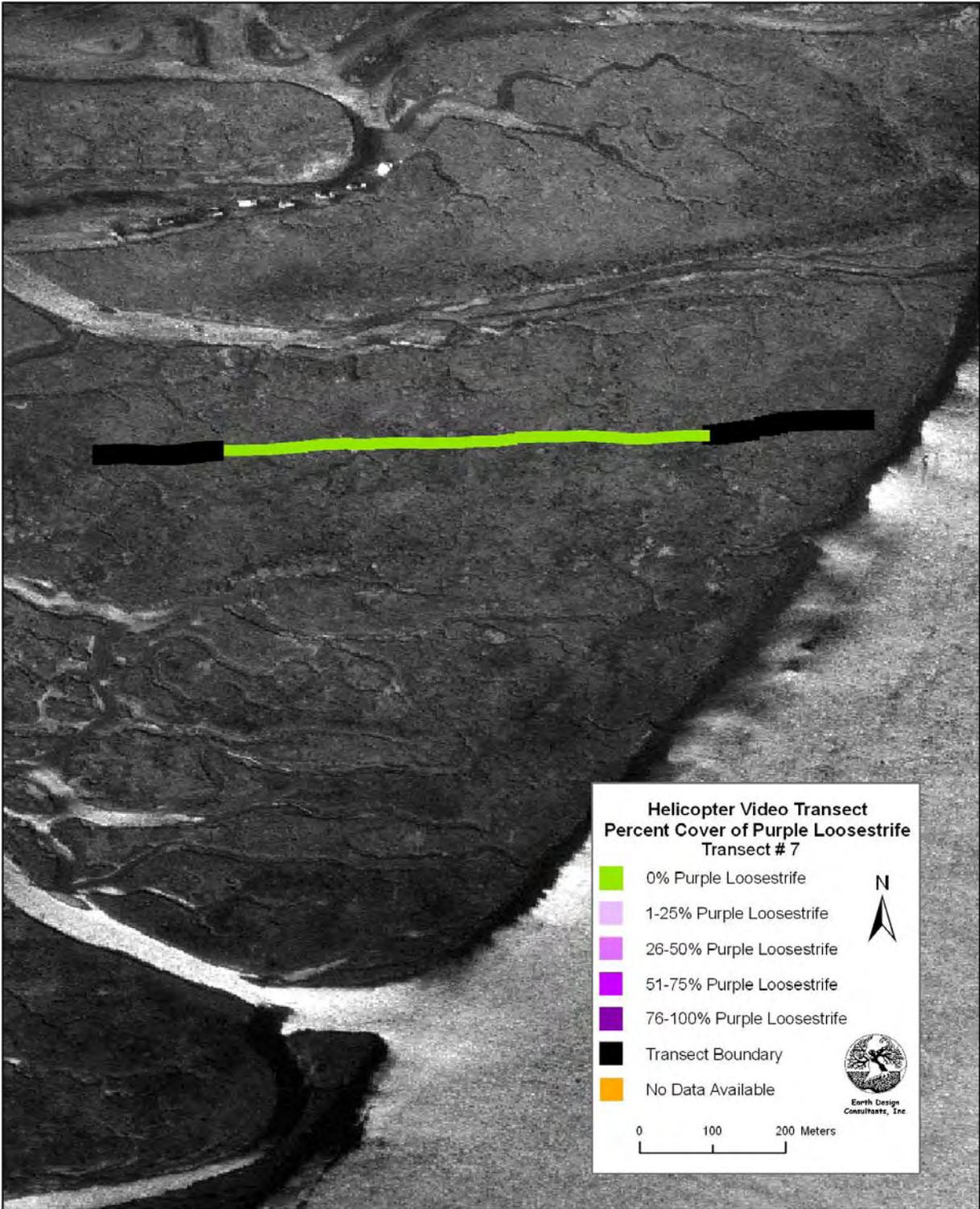


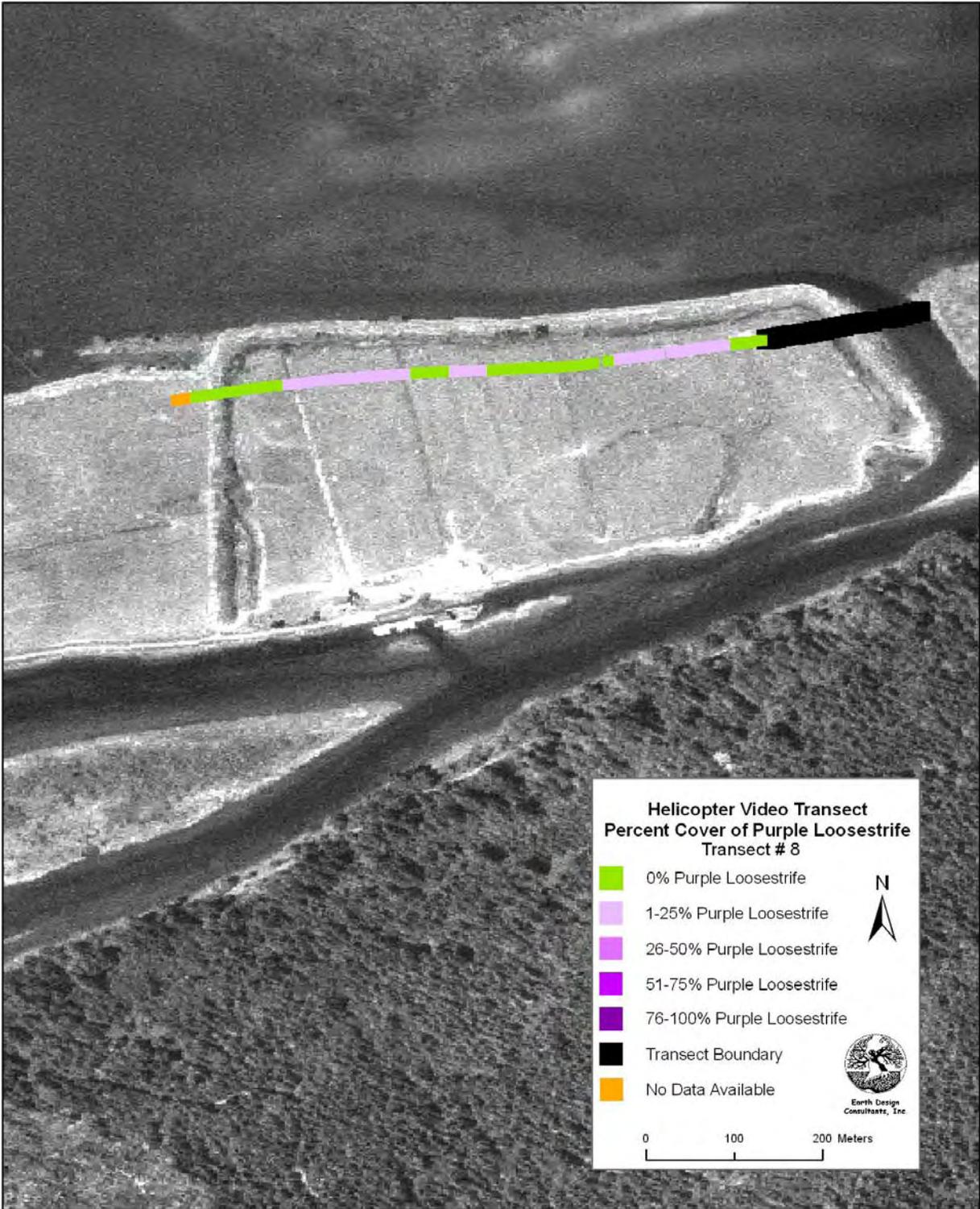


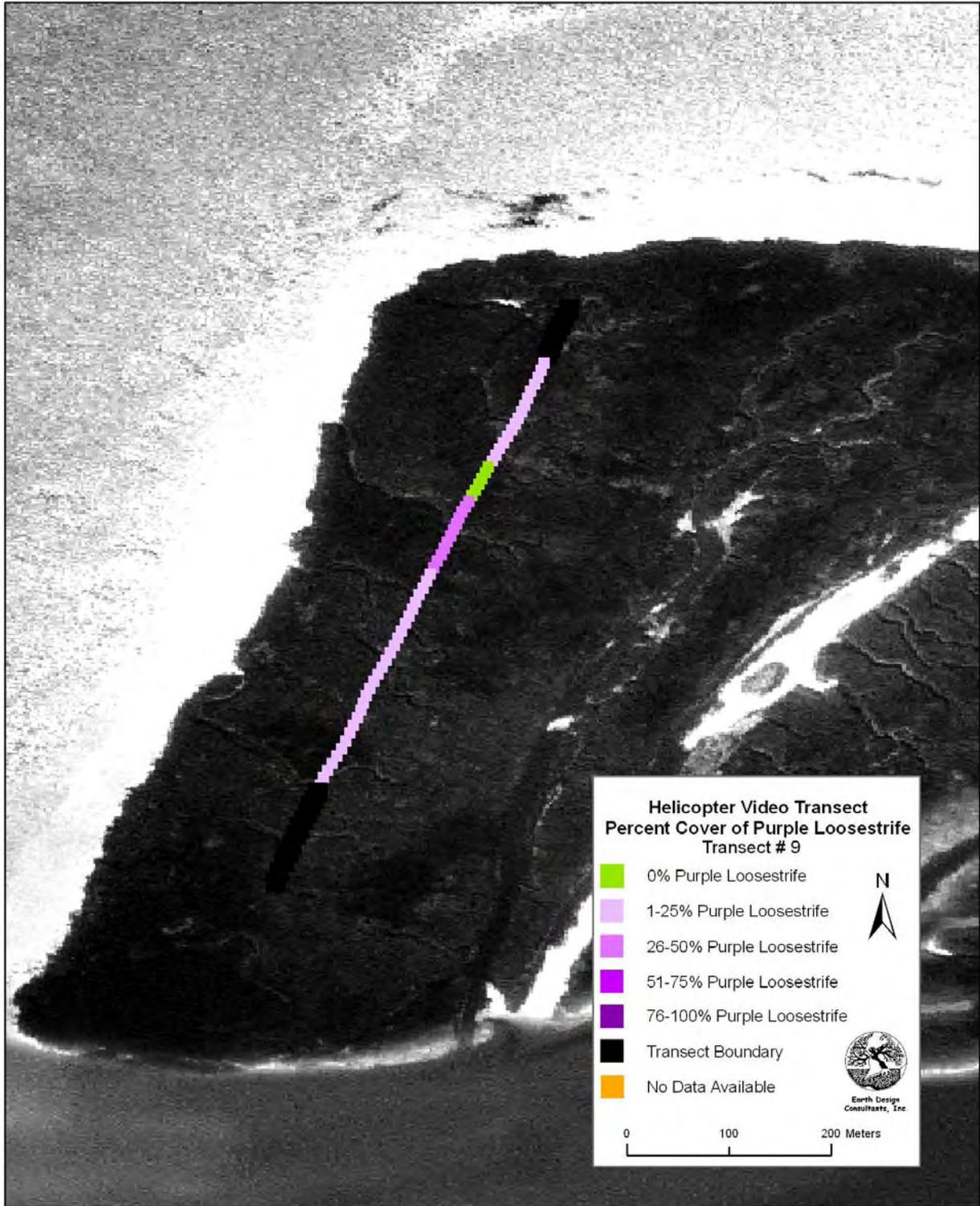


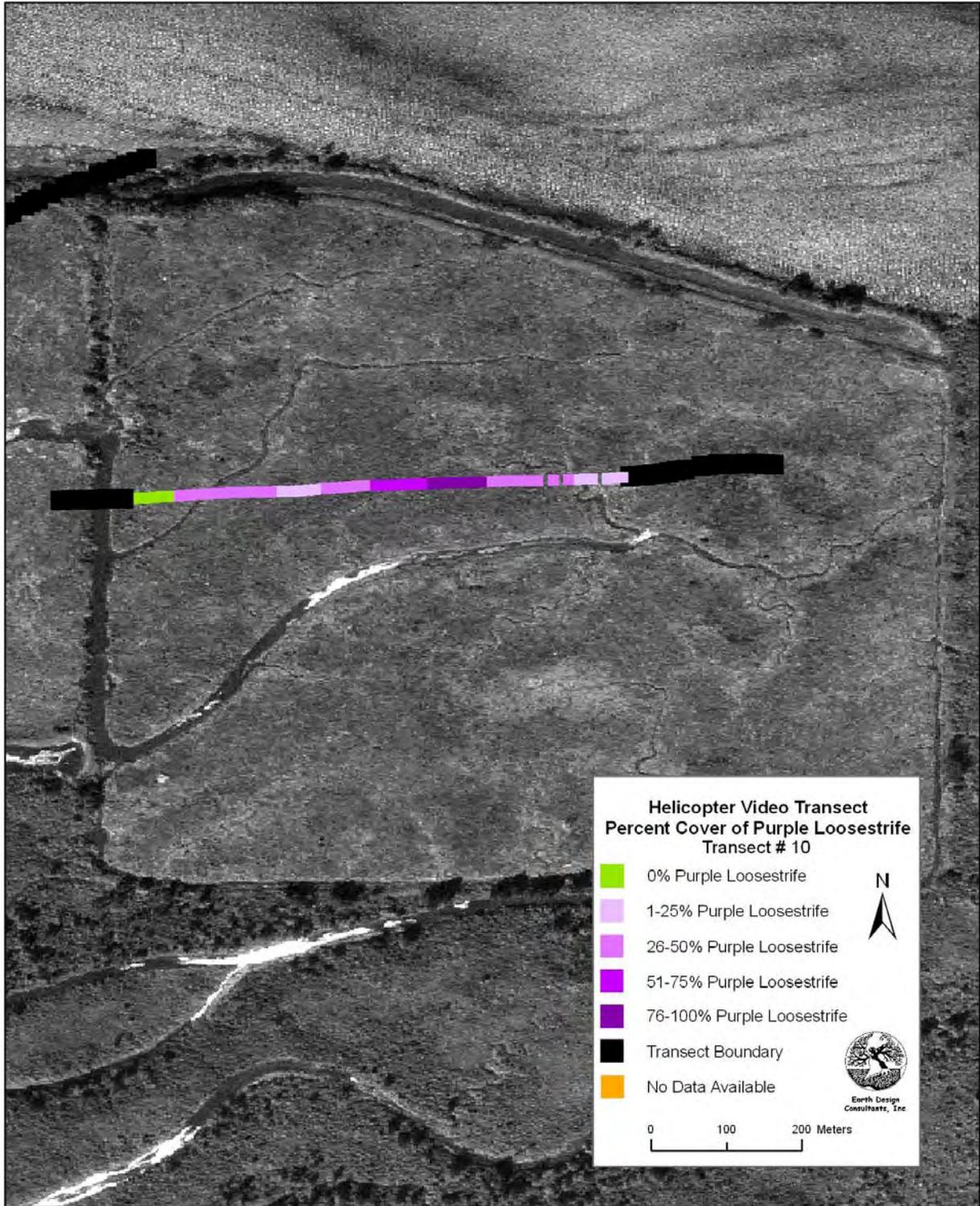


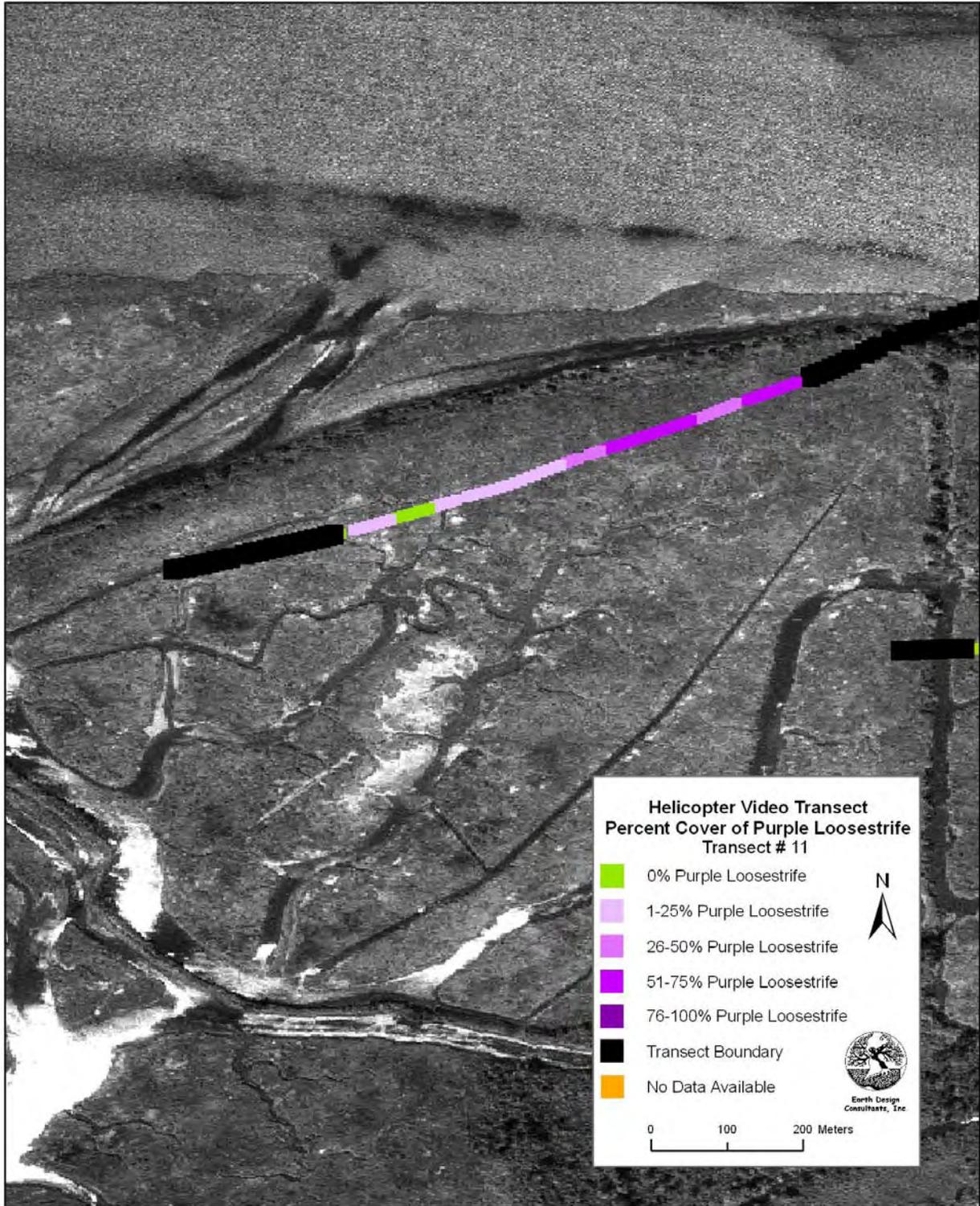


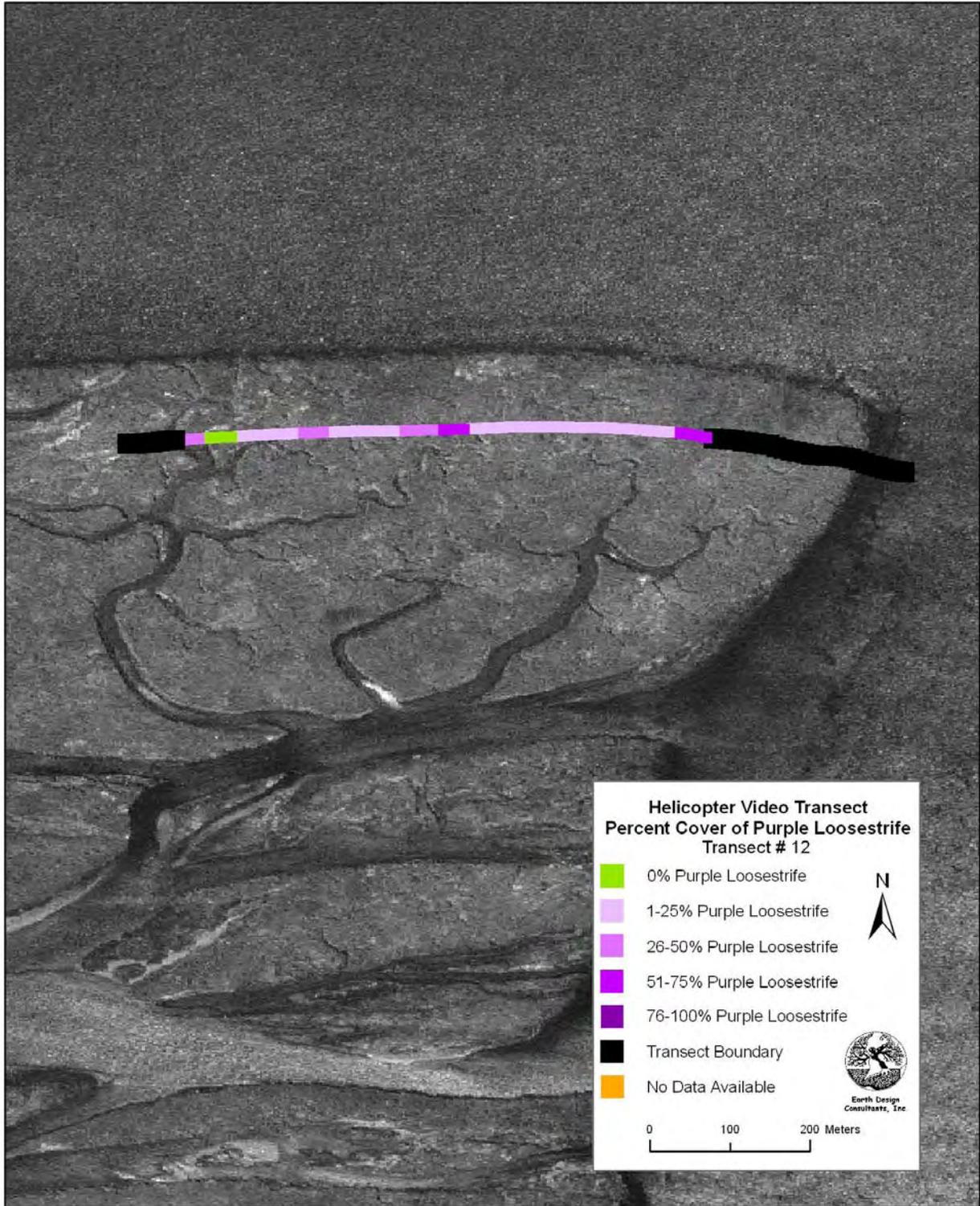


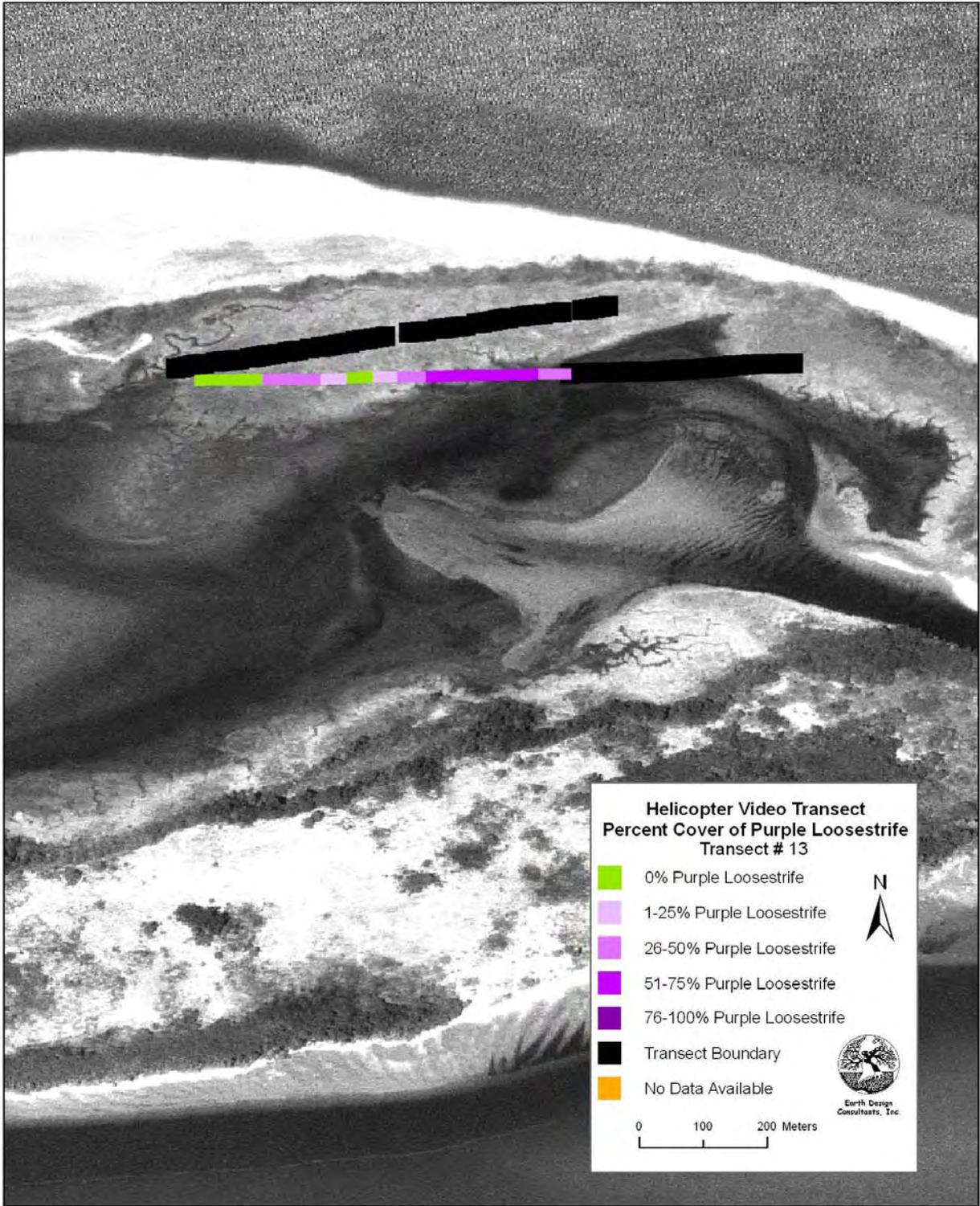


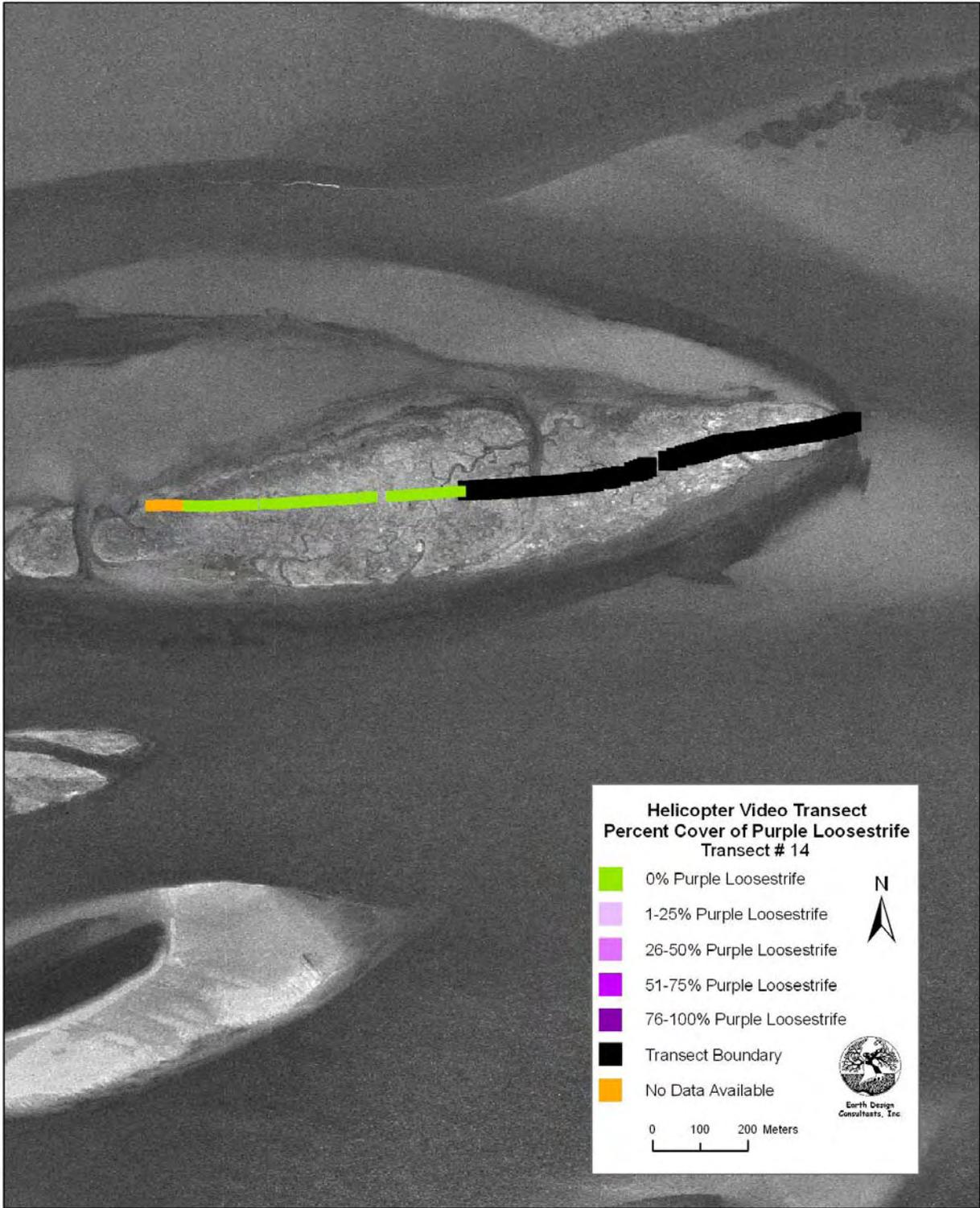


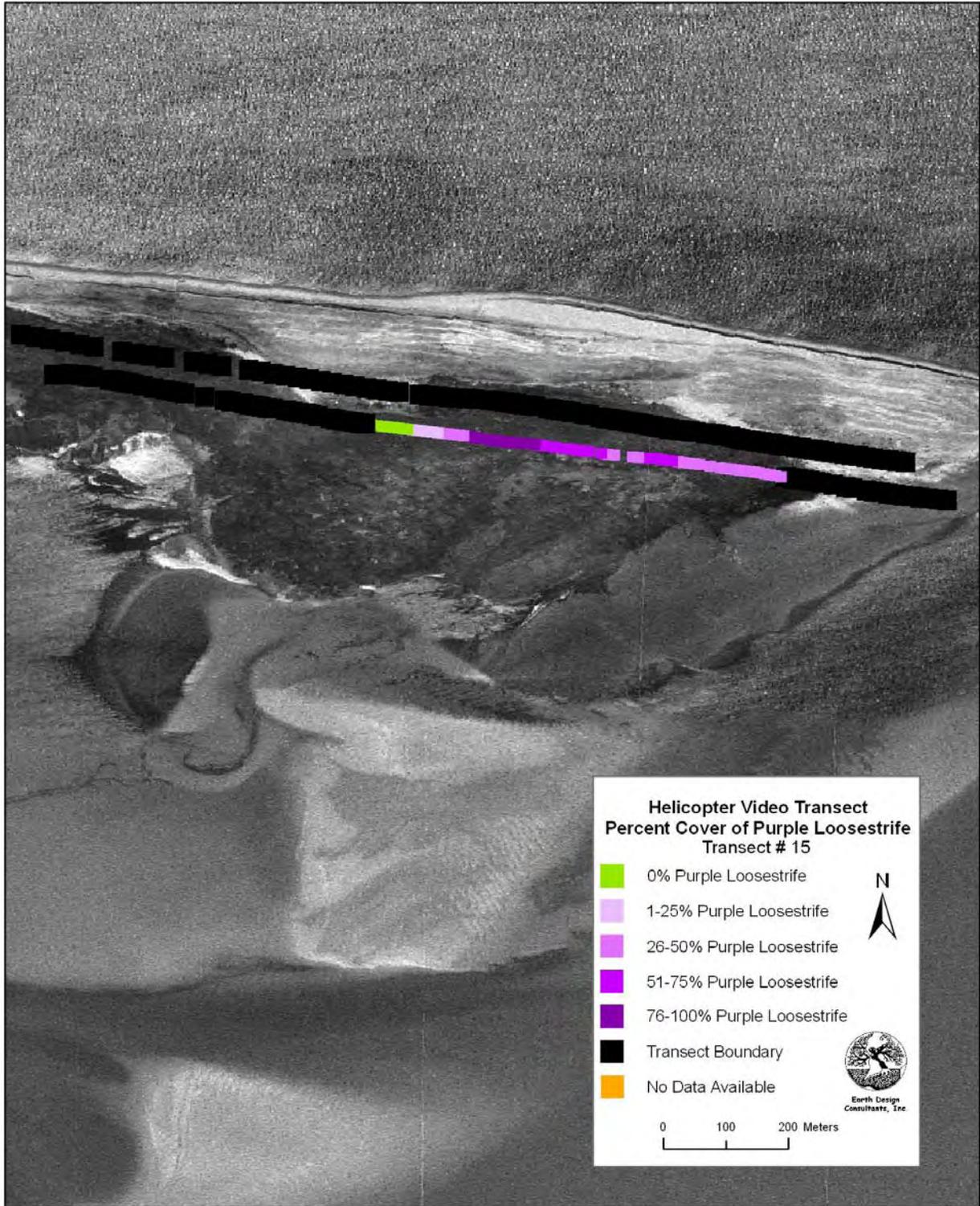


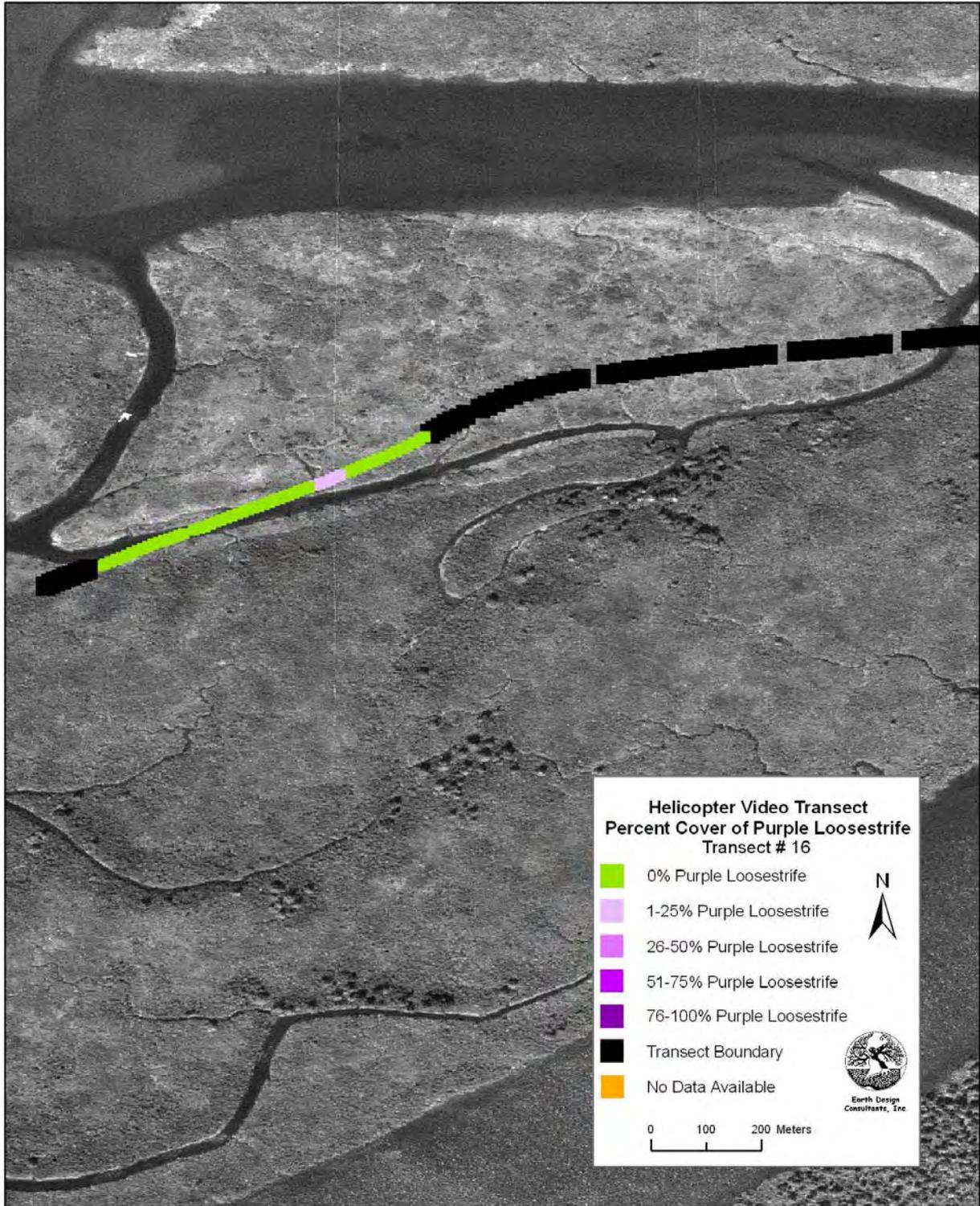


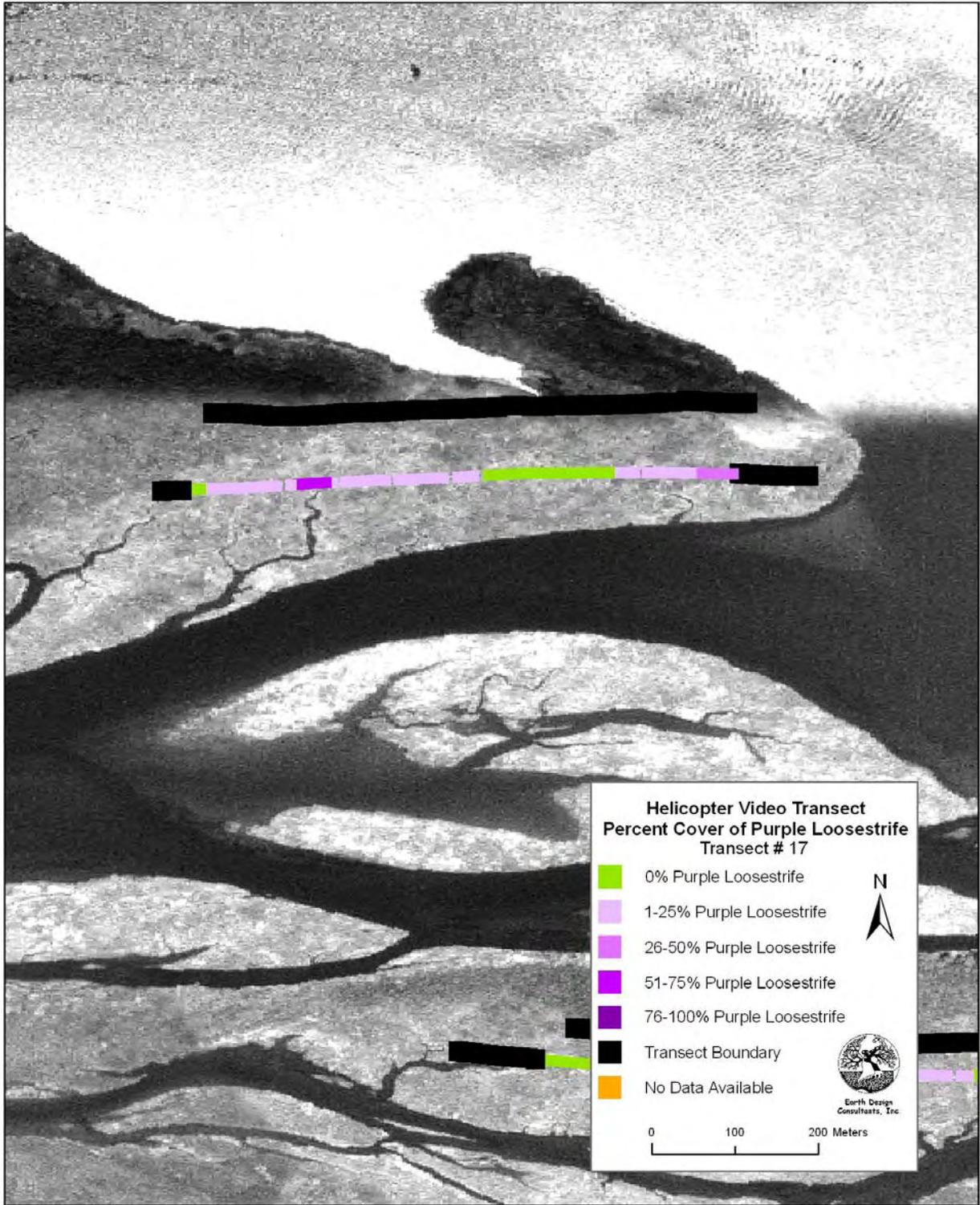


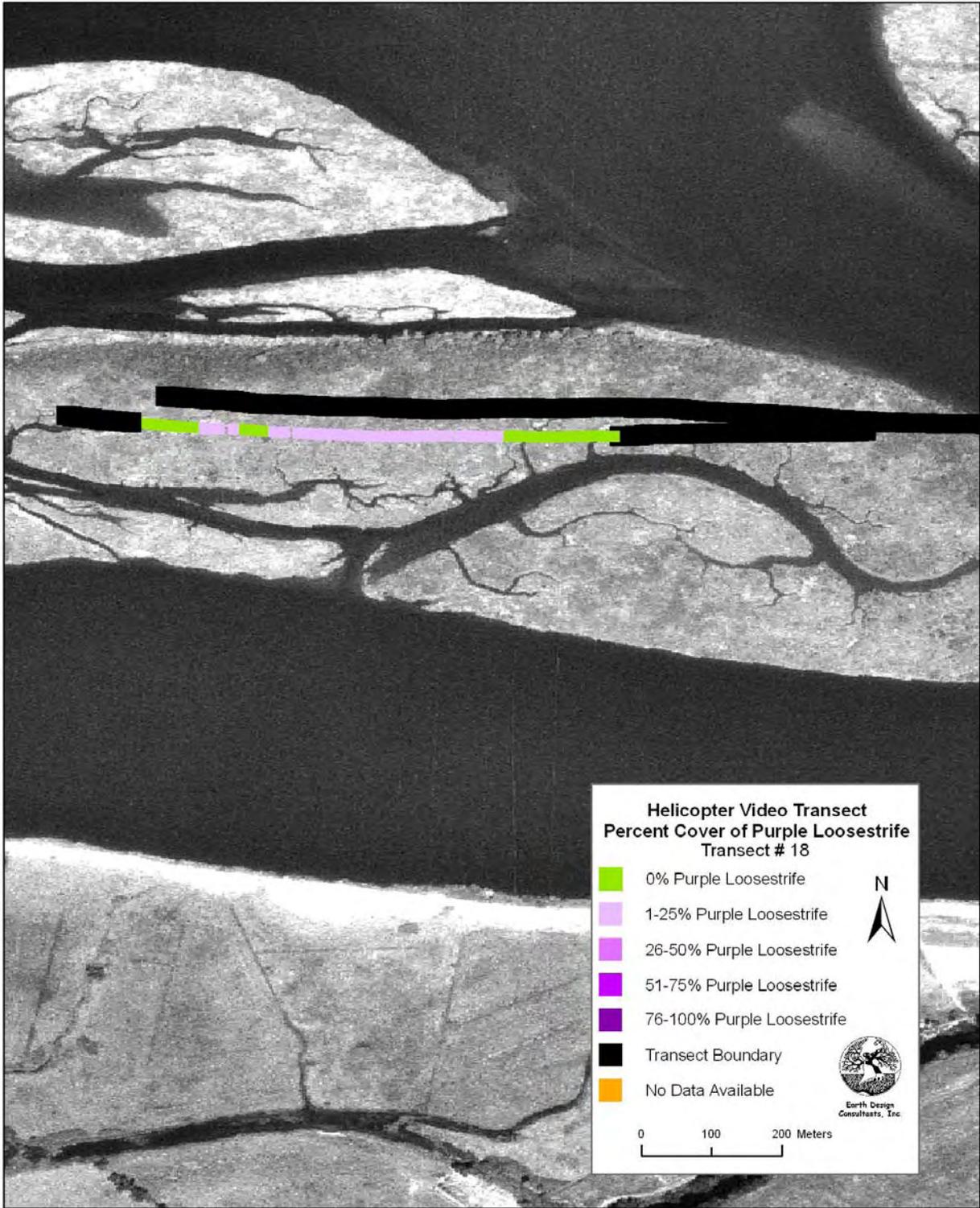


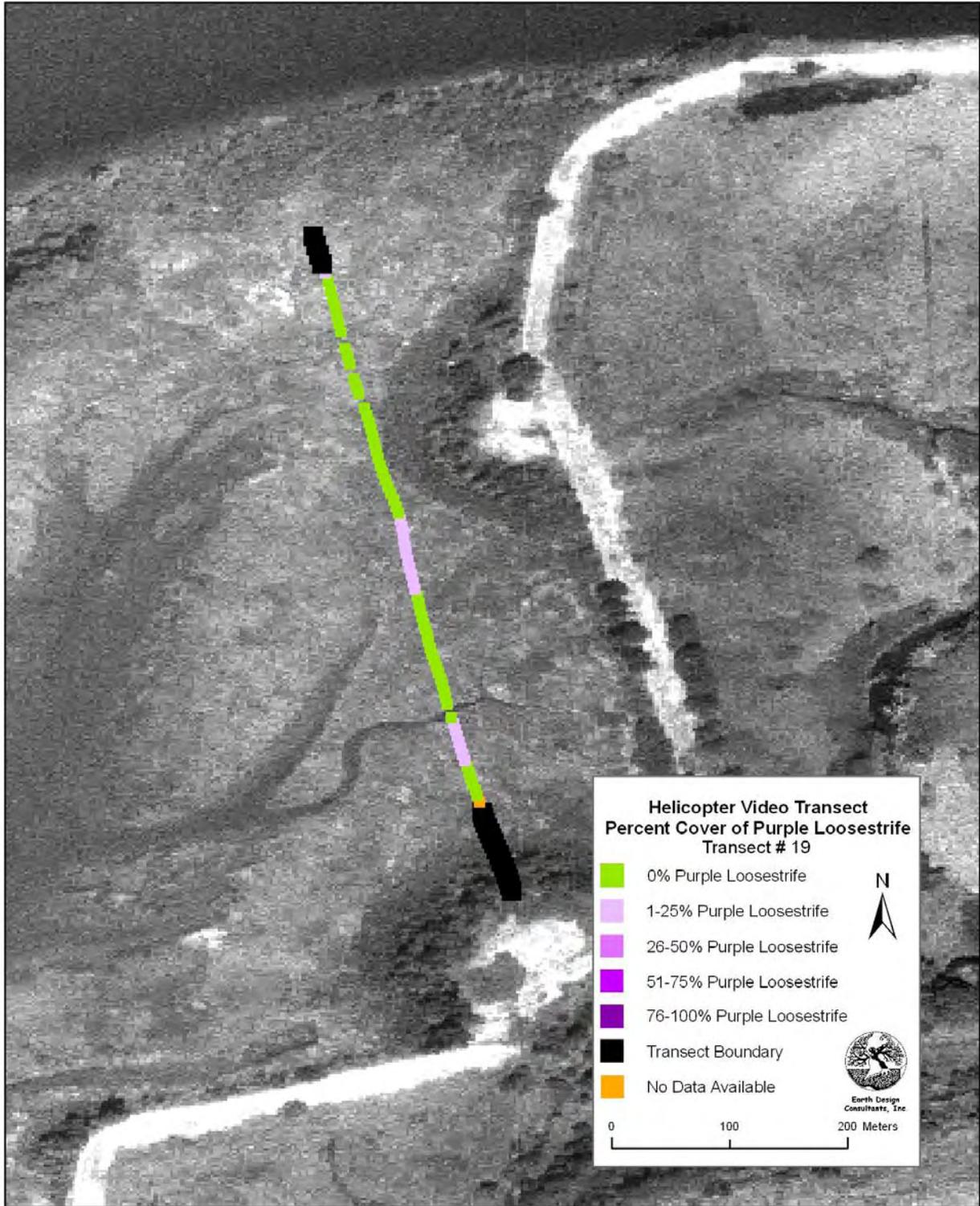


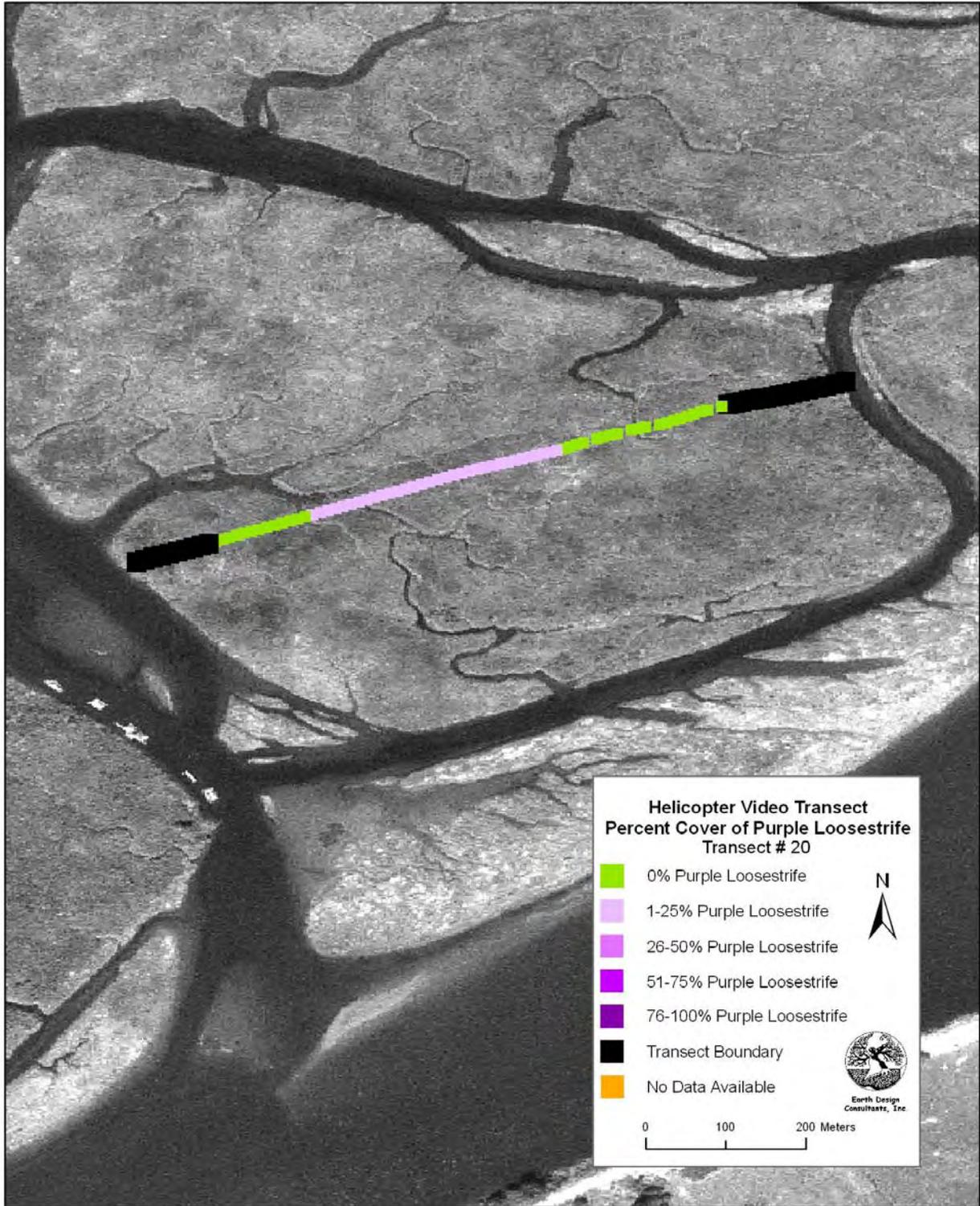


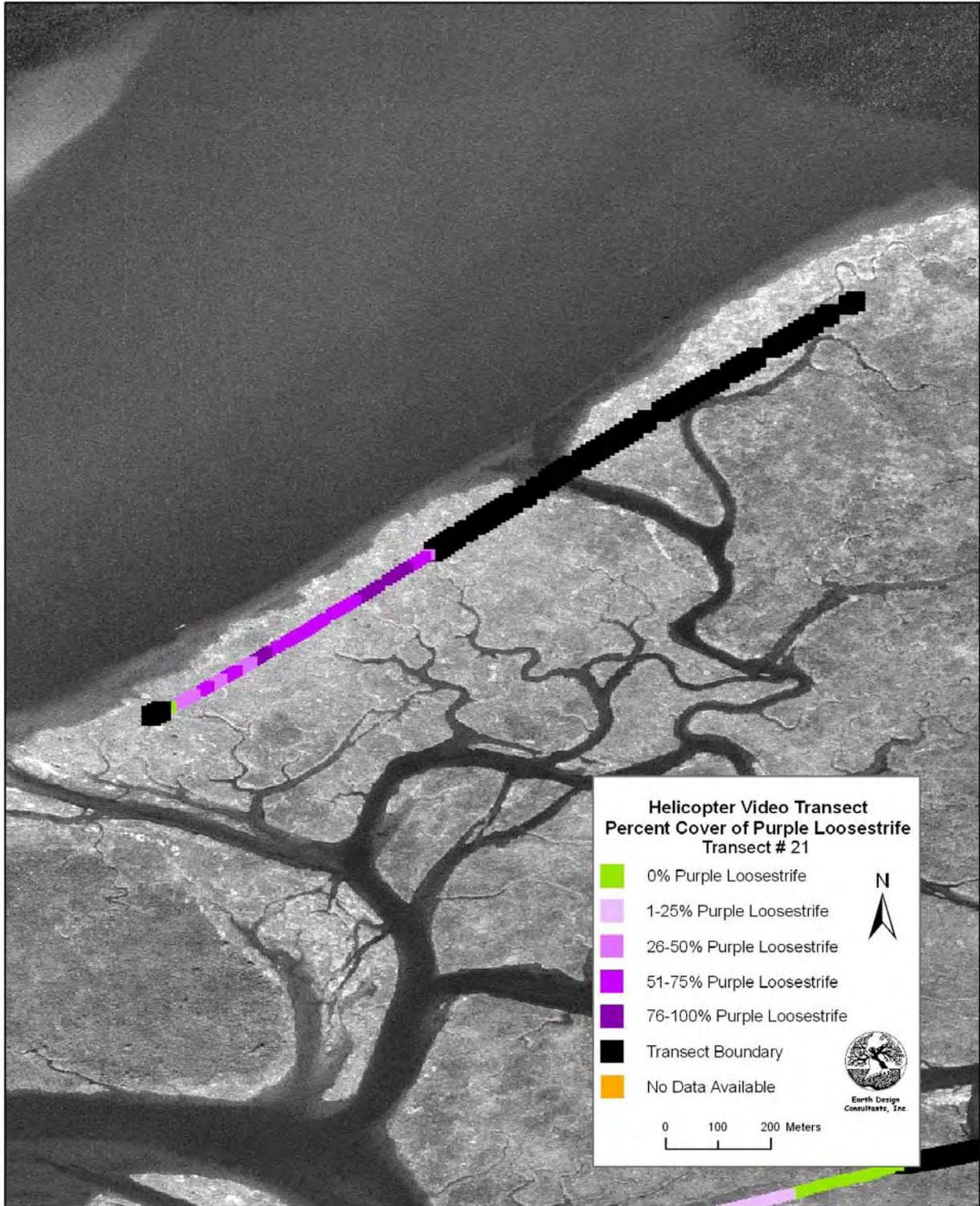


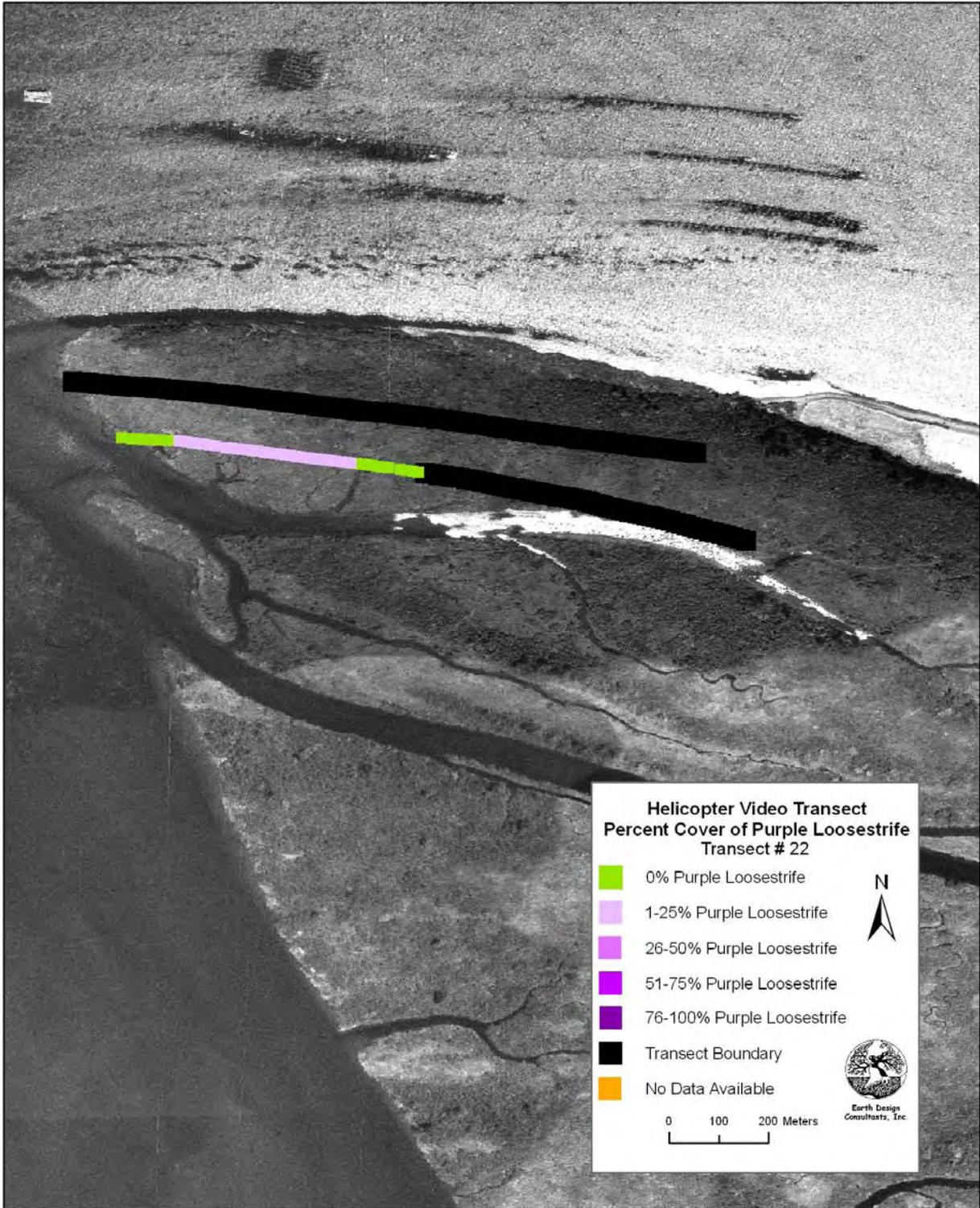


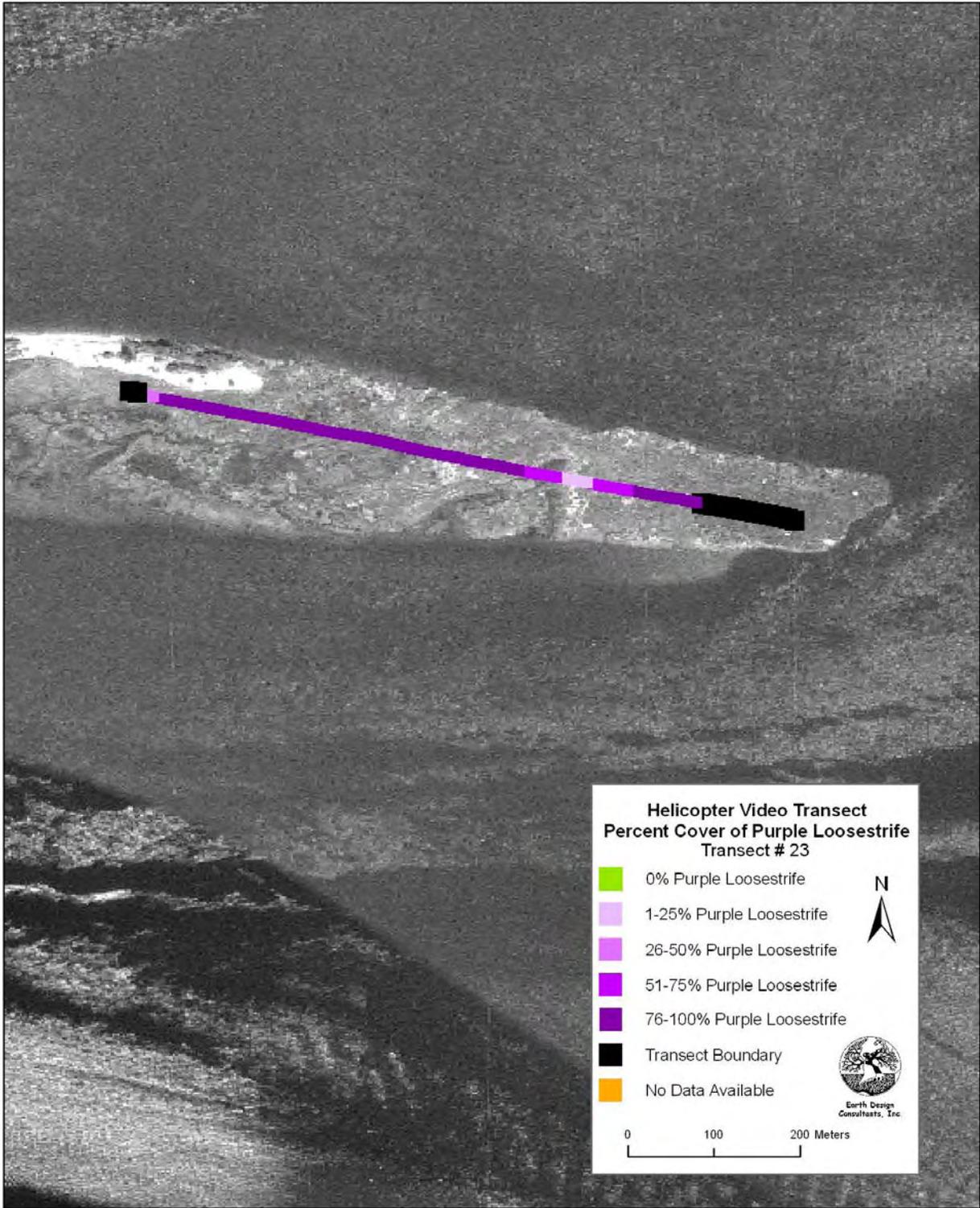


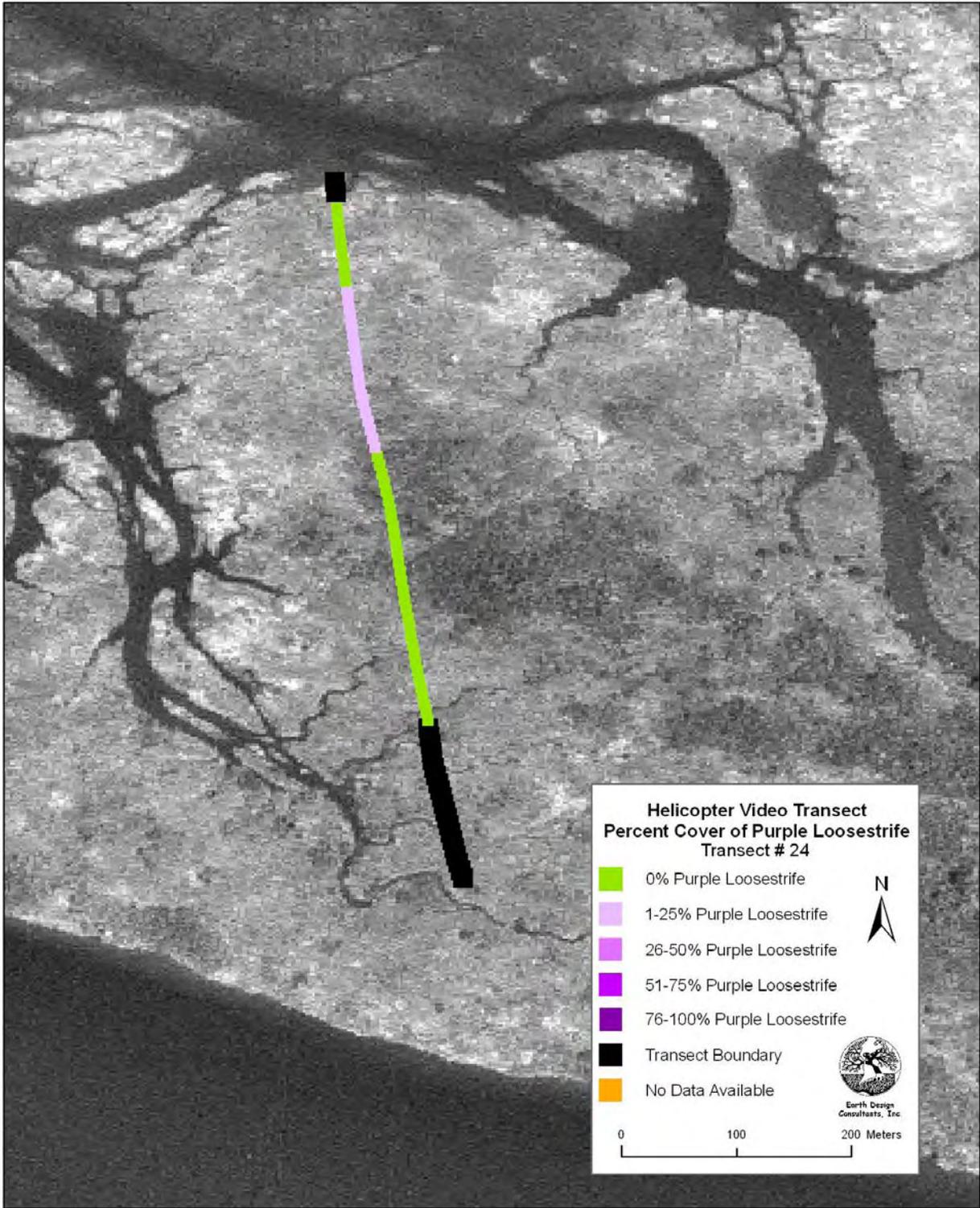


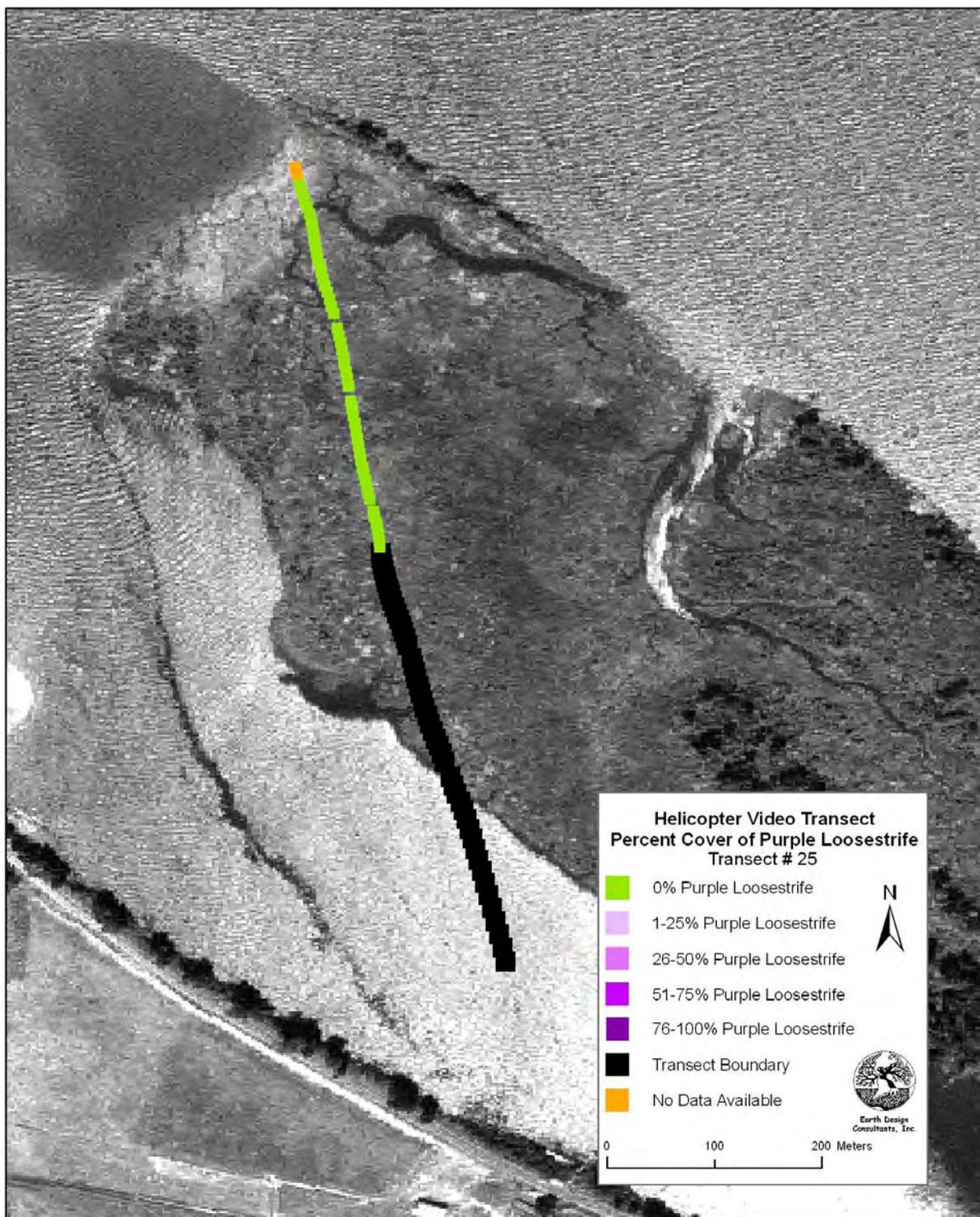


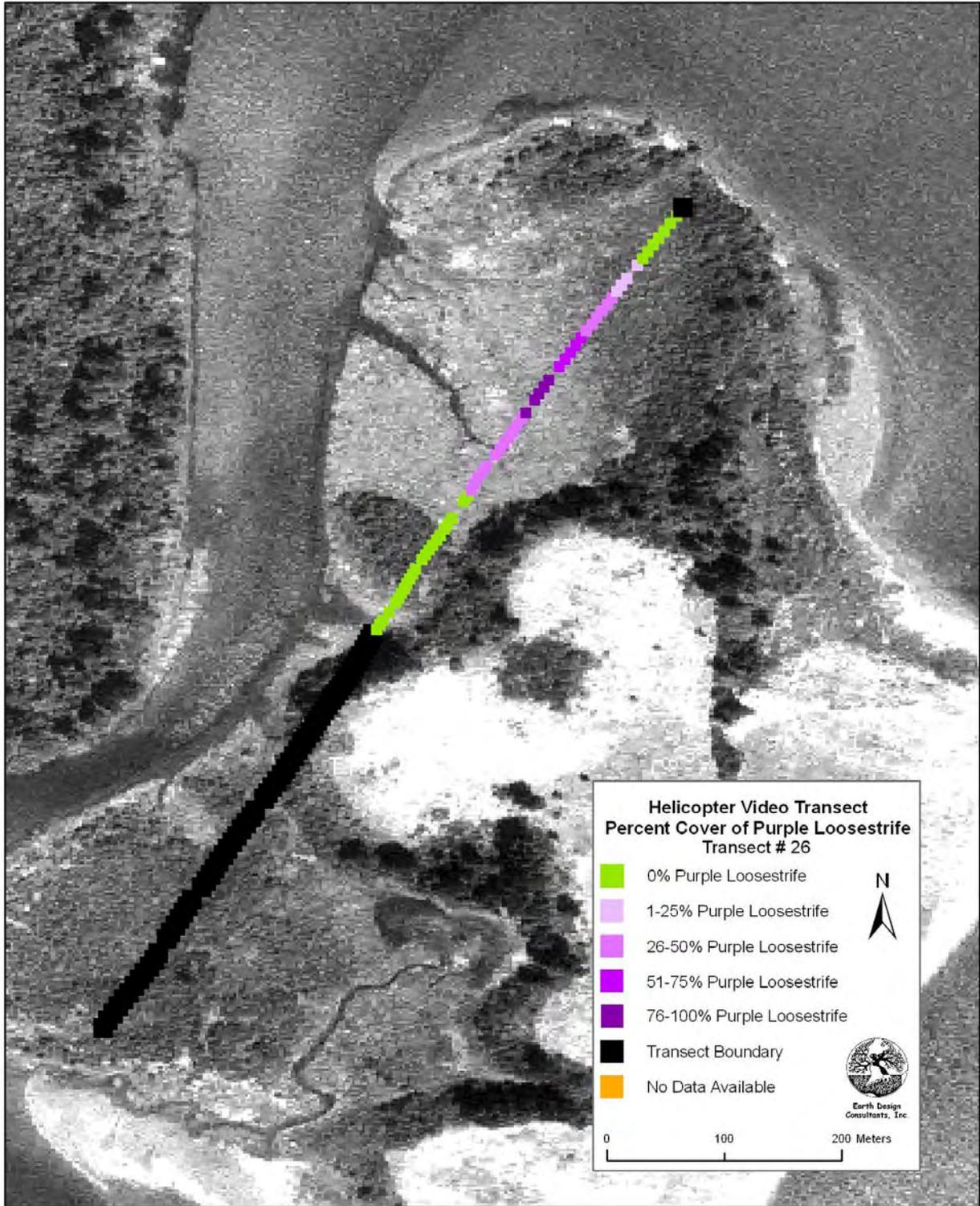


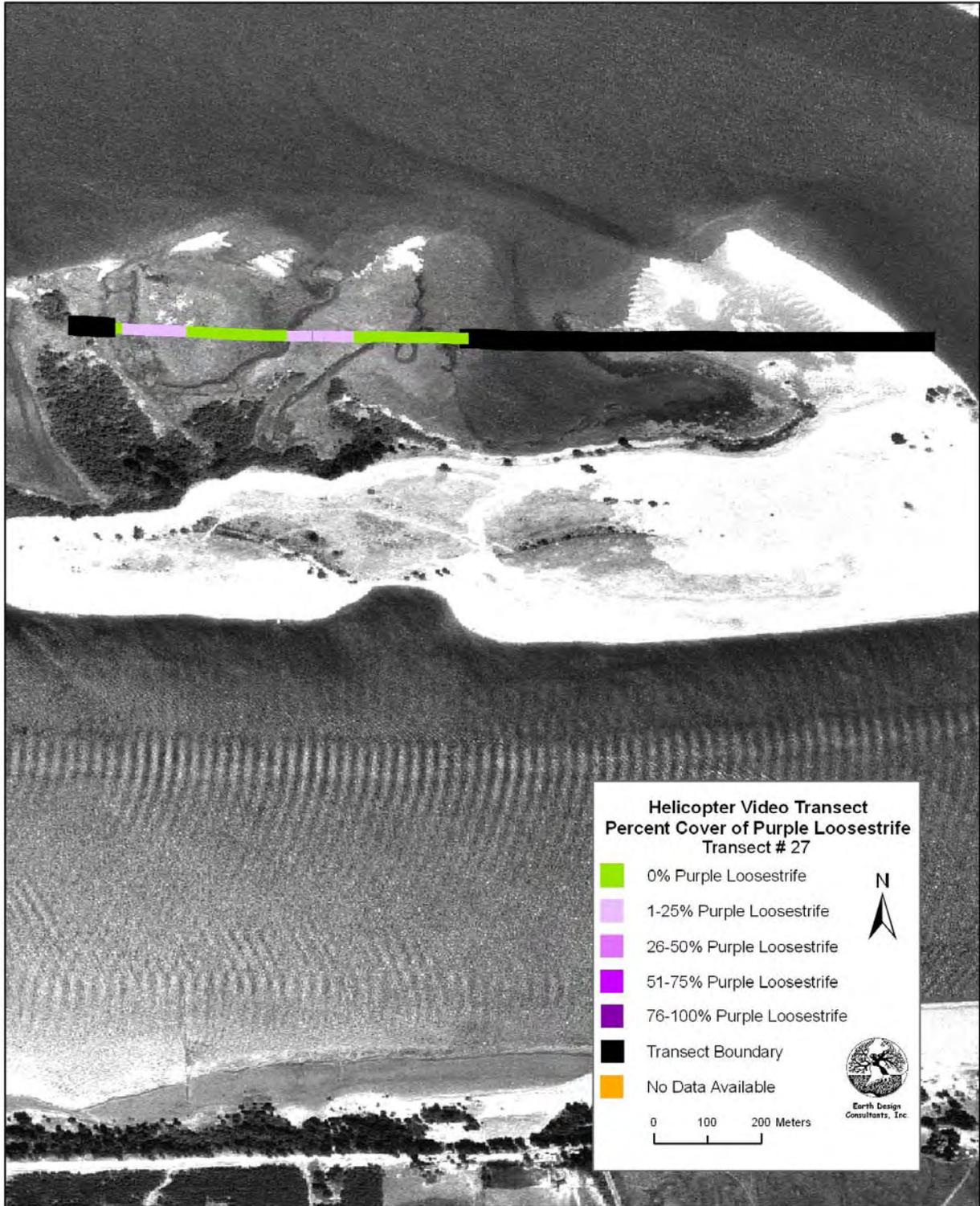


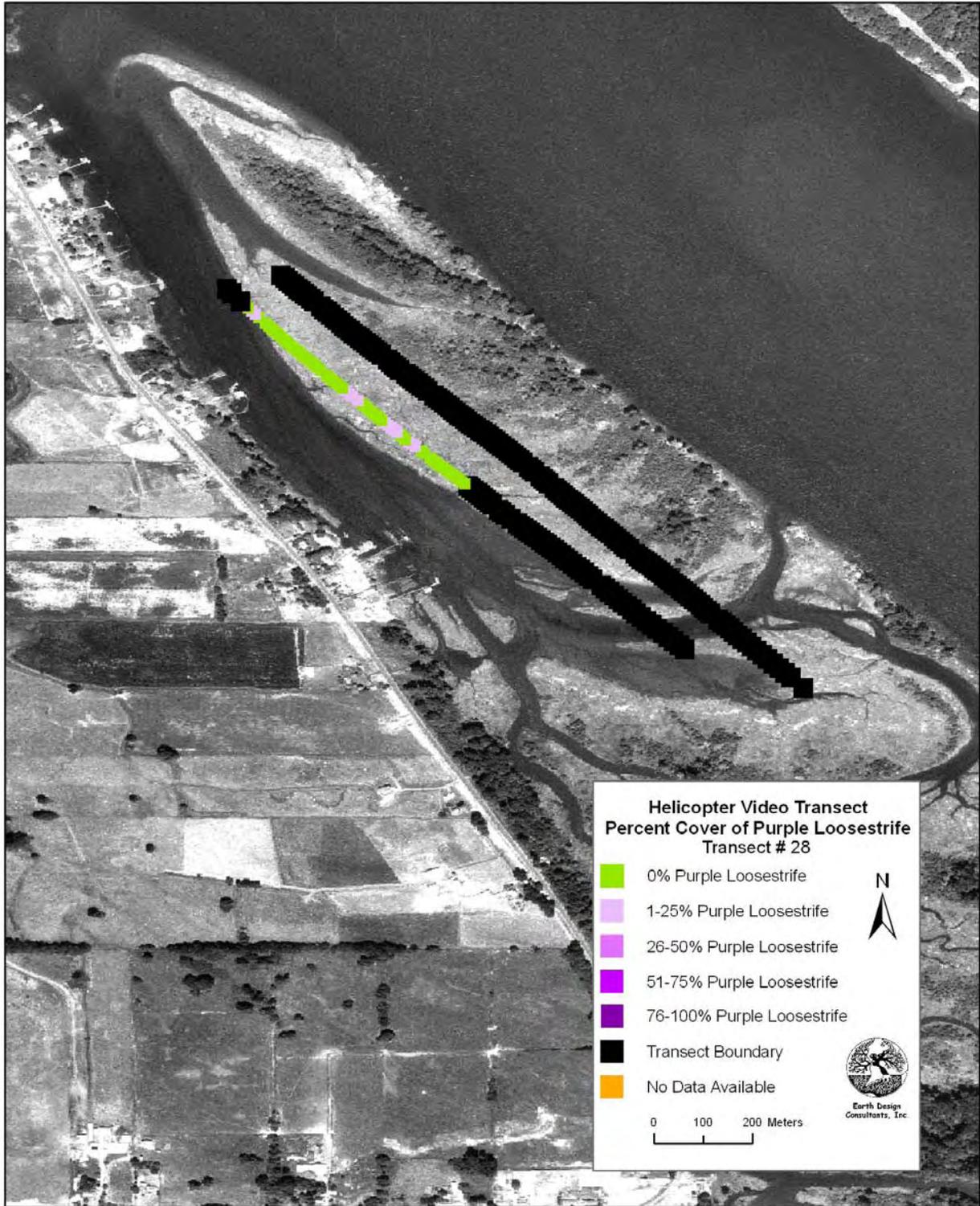


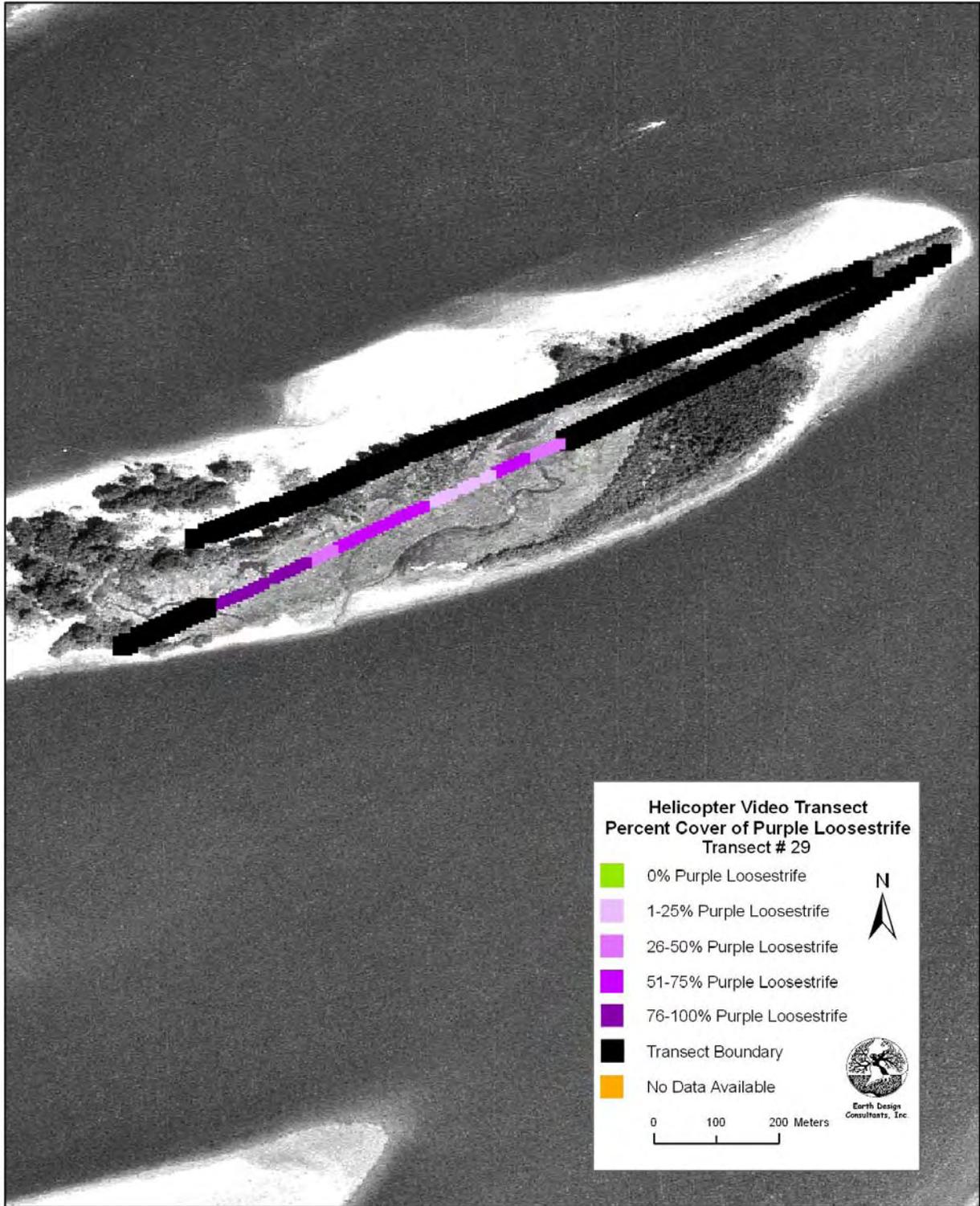


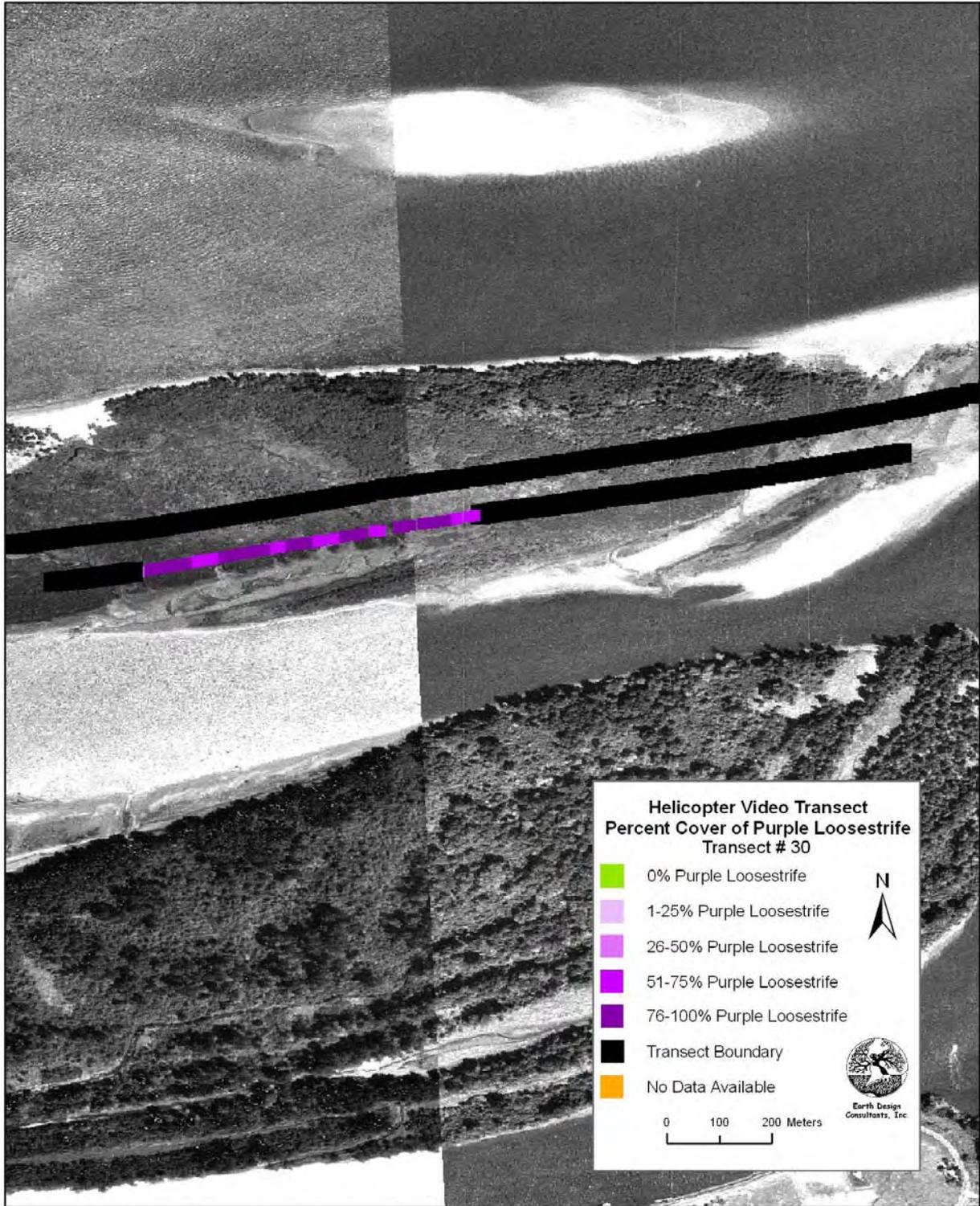


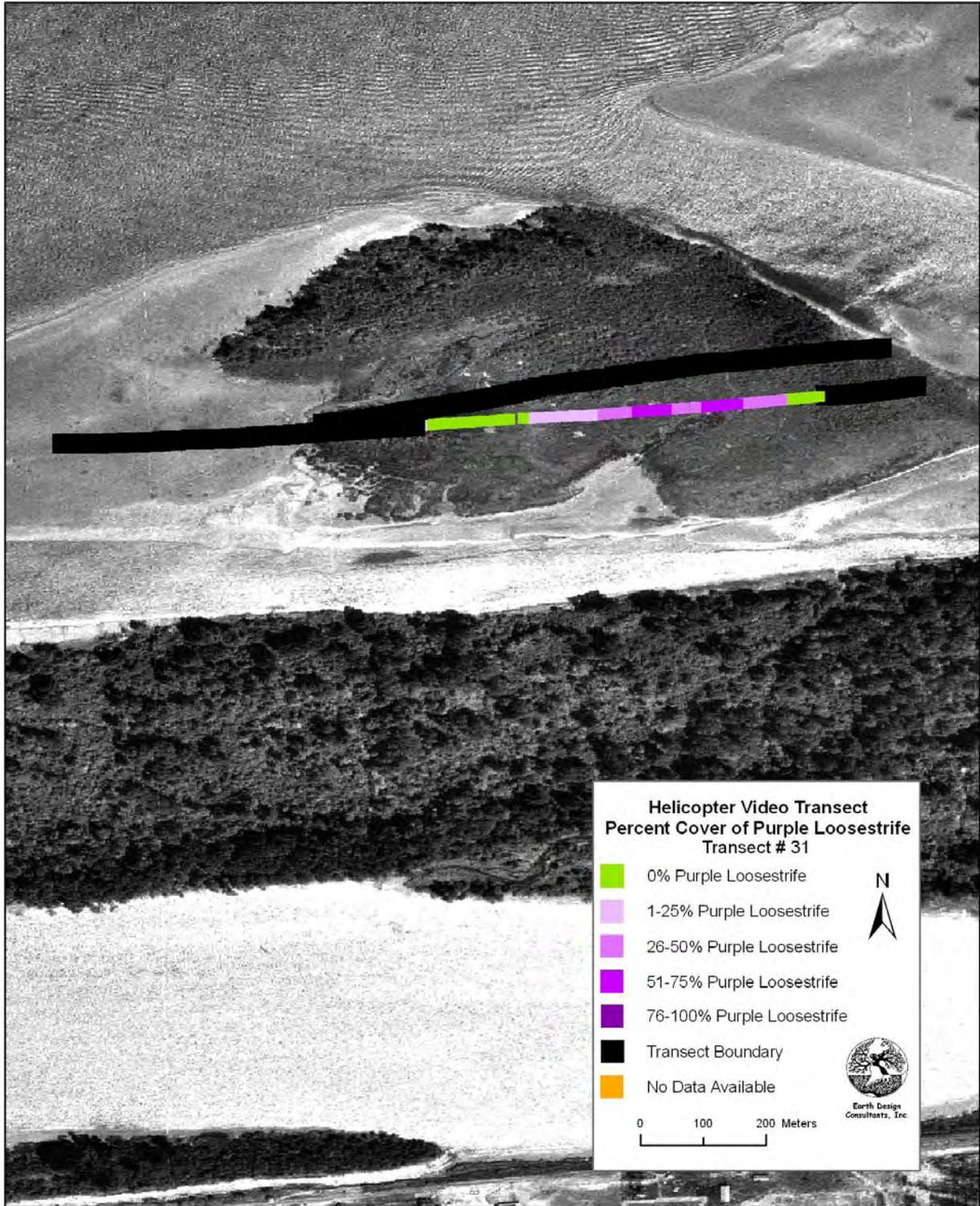


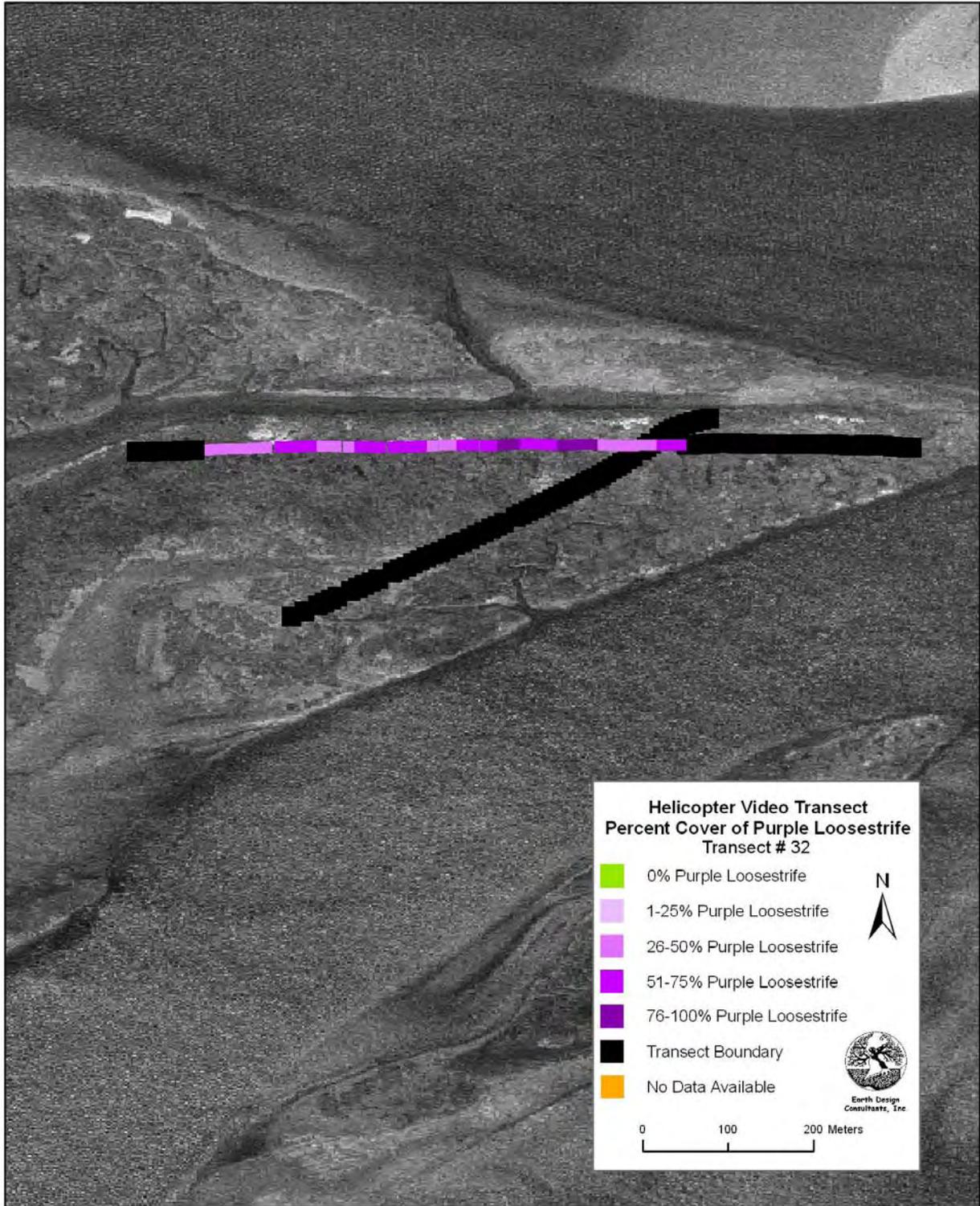


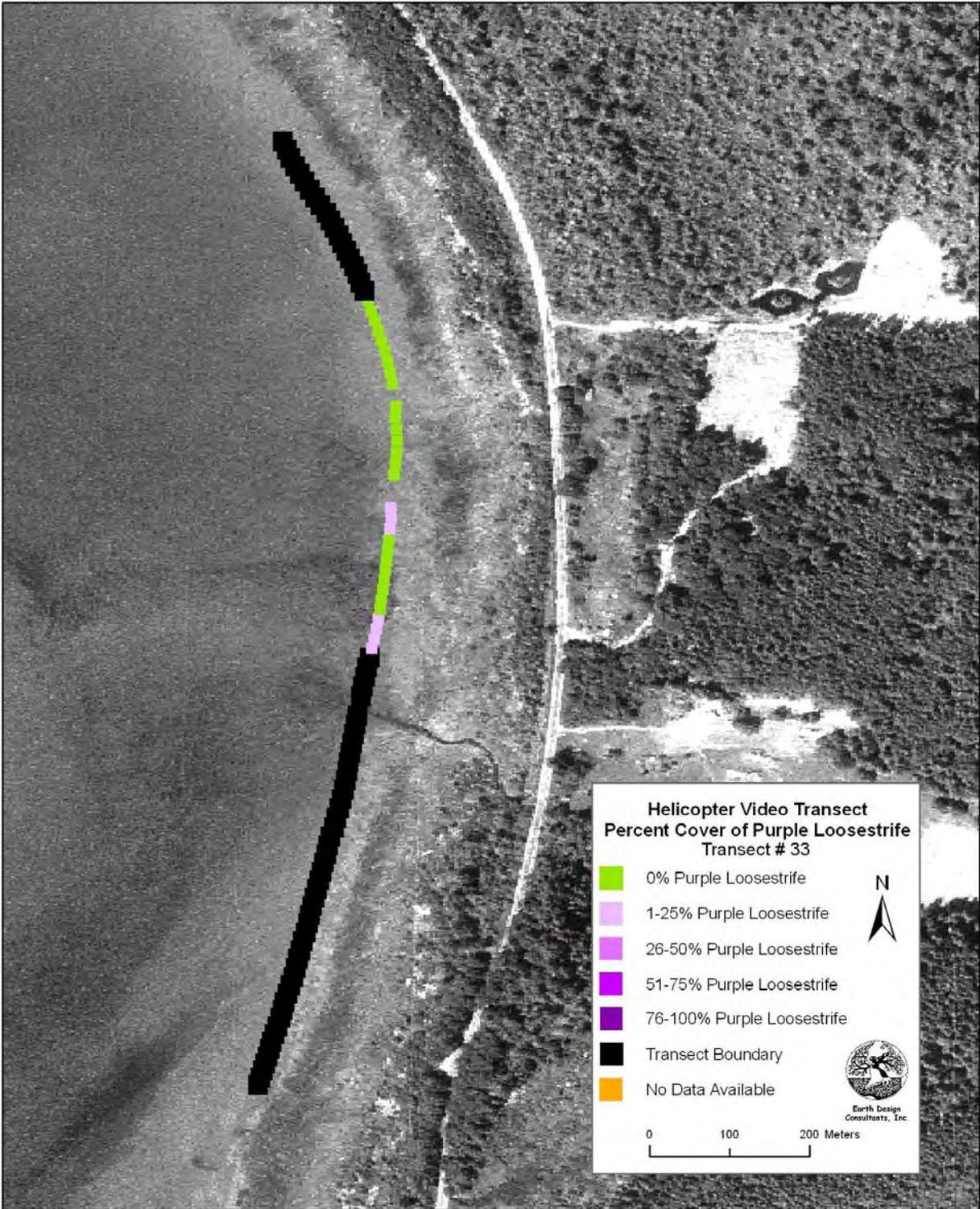


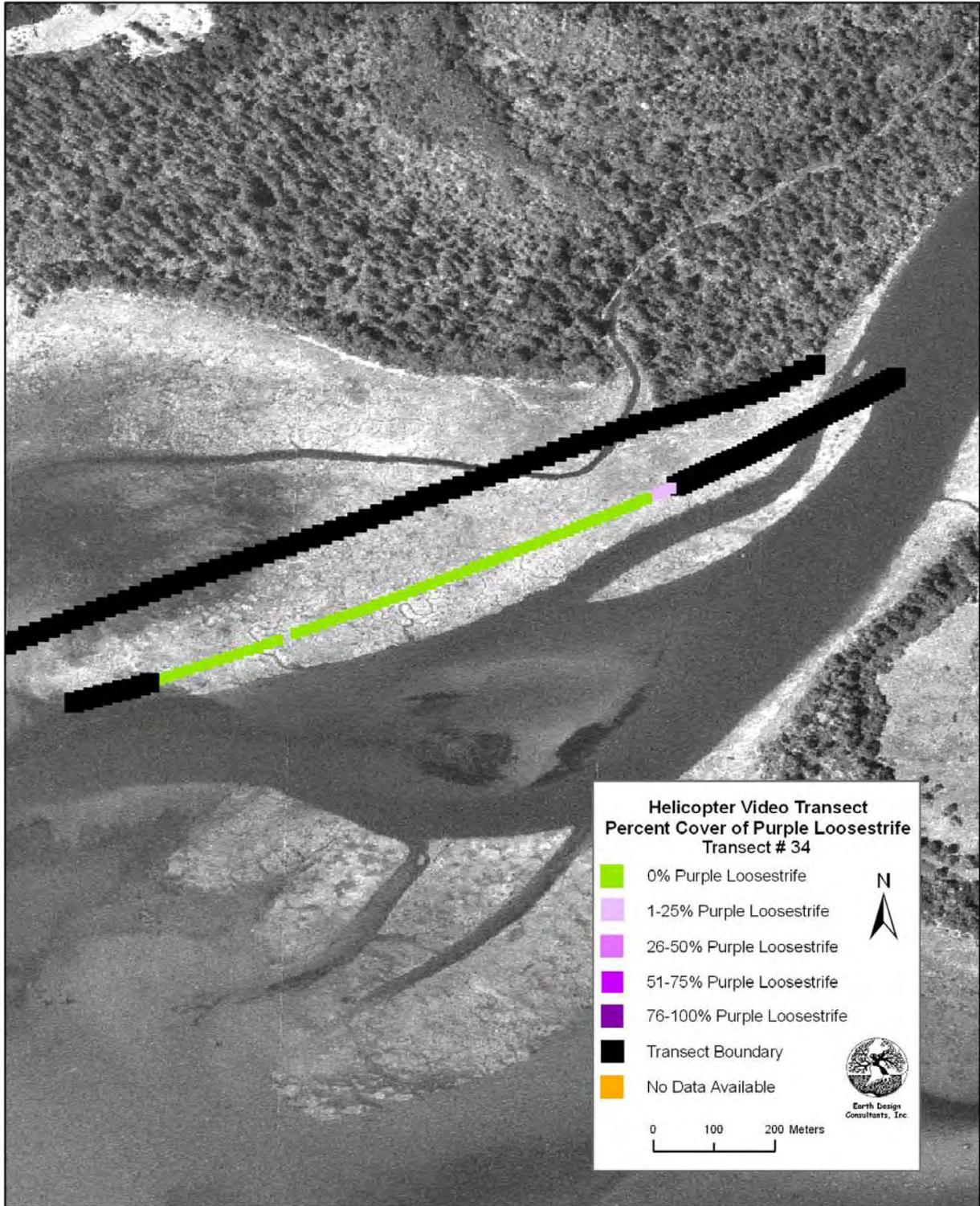


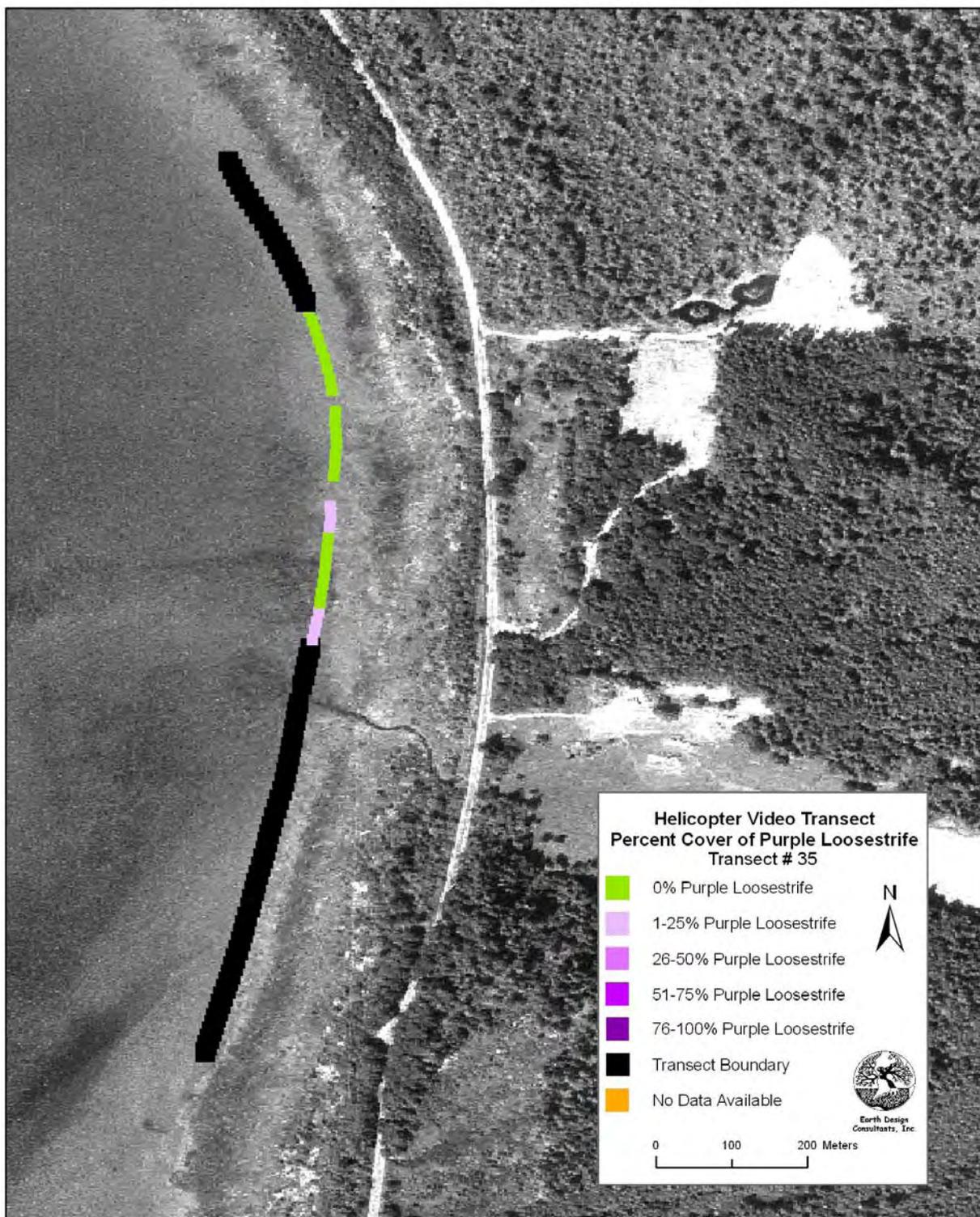










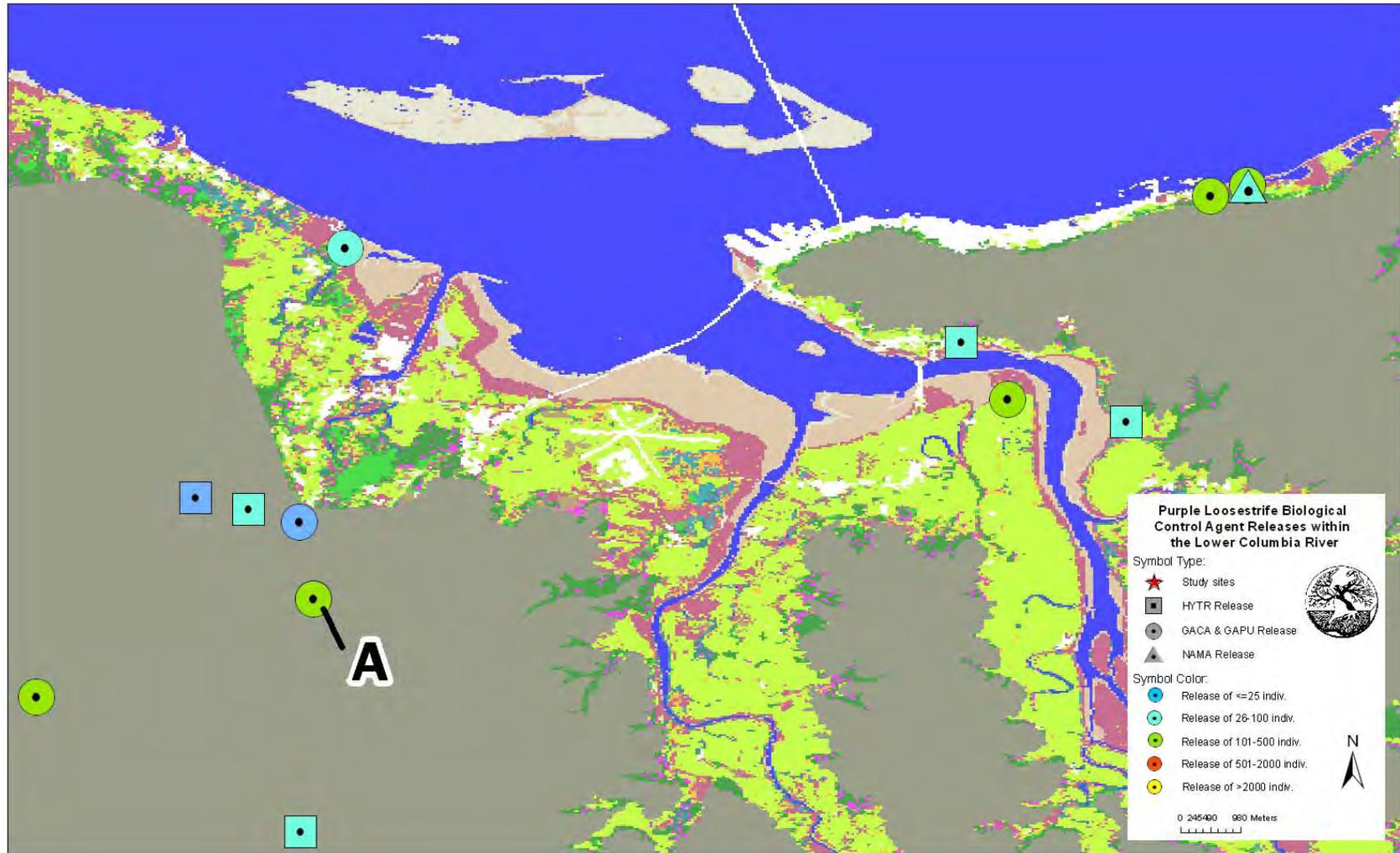


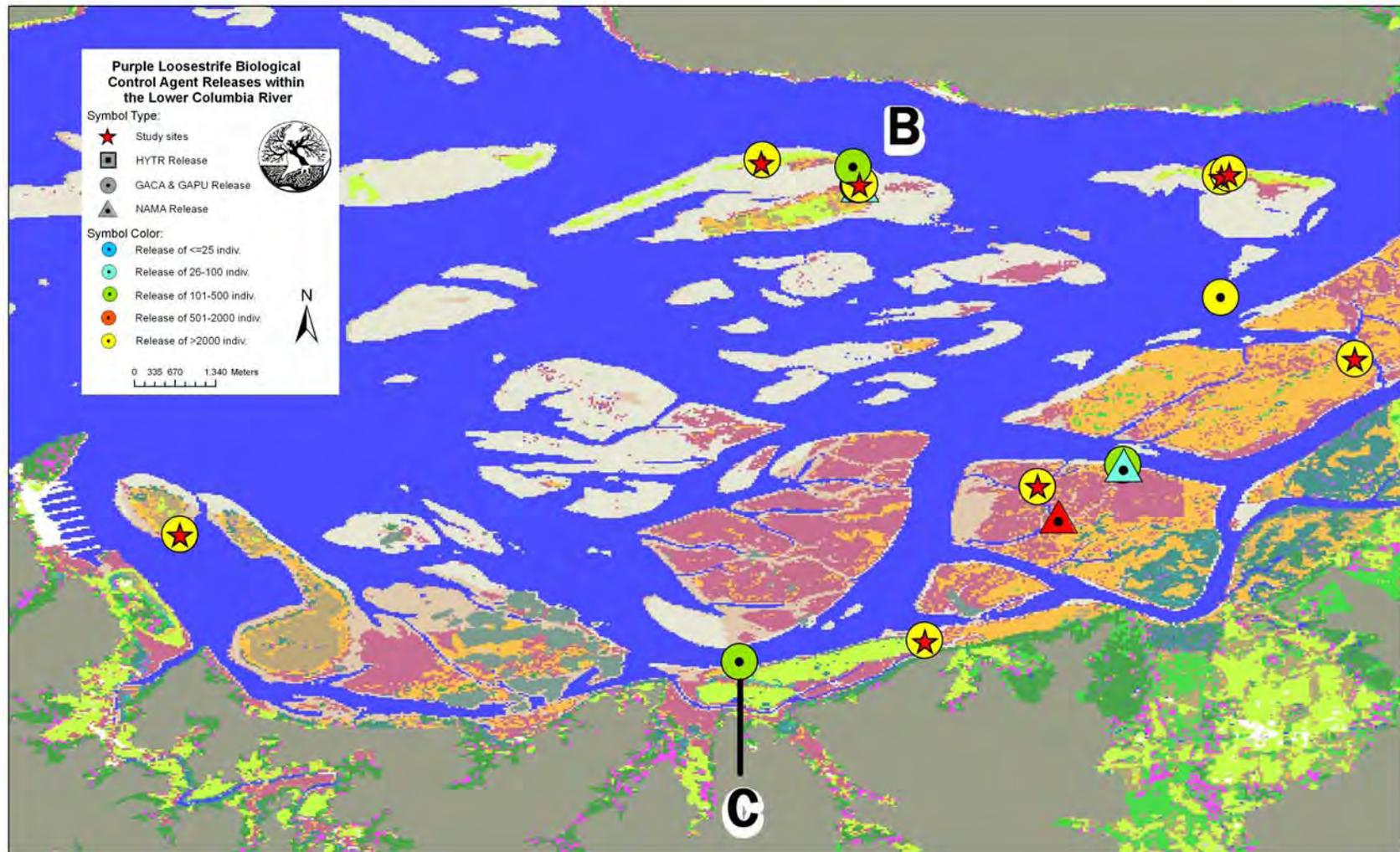
## Appendix III – Other Known Release Sites

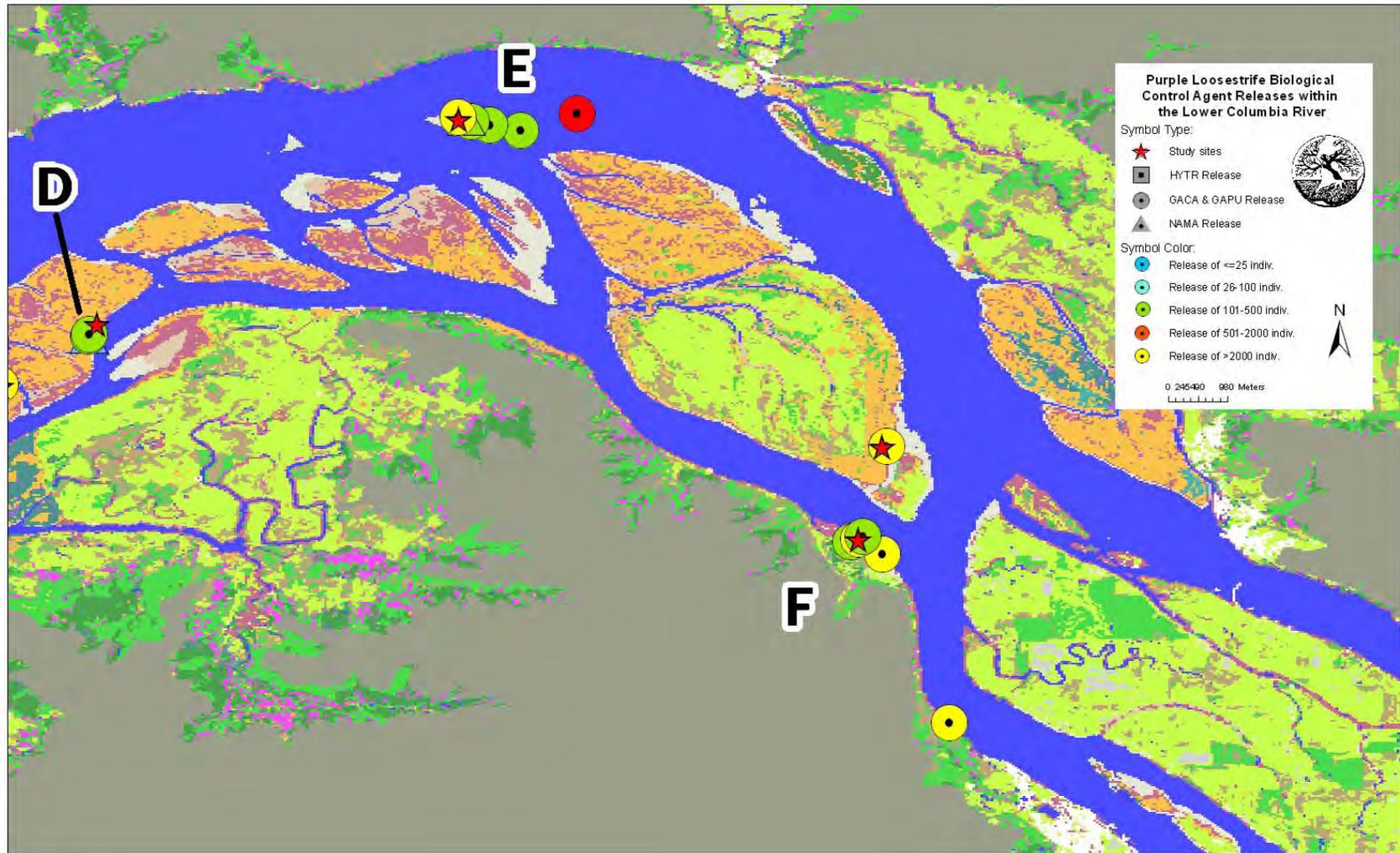
Biocontrol agent releases made by various groups within the Lower Columbia Estuary. Shown are location, year, organism, number of individuals, and agency for each release for which records were available. Locations of agent releases are shown on the following images. There are release sites east of Wallace Island that are not shown in the following images because they fall outside of our study area. Organisms released abbreviations are as follows: GACA=*Galerucella californiensis*, GAPU=*Galerucella pusilla*, GA spp.=*Galerucella* species released, indicating exact species is unknown or unspecified in release documentation; HYTR=*Hylobius transversovittatus*; and NAMA=*Nanophyes marmoratus*. Releasing agency abbreviations are: ODA=Oregon Department of Agriculture; LCRWC=Lower Columbia River Watershed Council; COE=Army Corp of Engineers, Portland Office; and EDC=Earth Design Consultants.

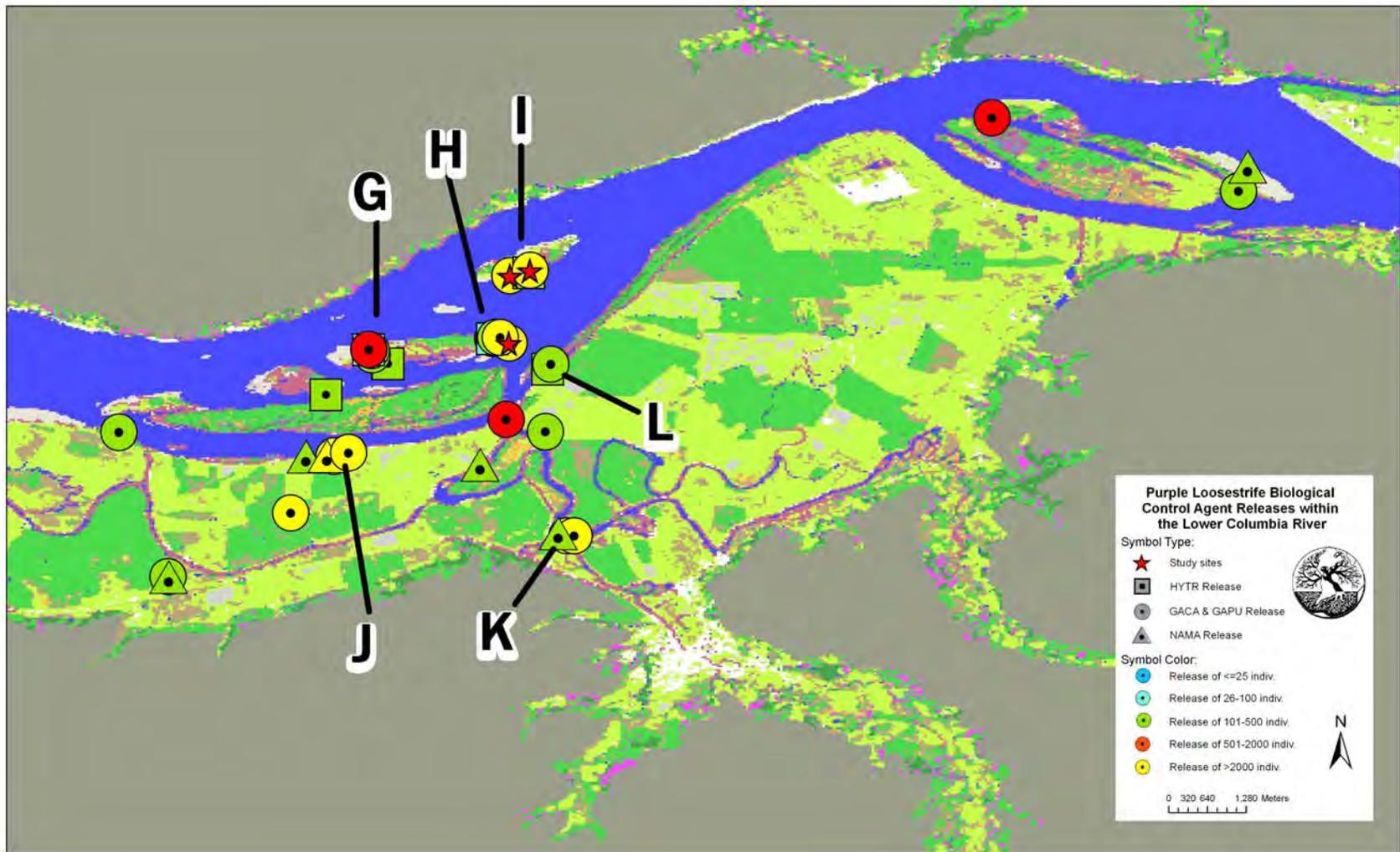
| <b>Biocontrol Releases Made in the Lower Columbia River Estuary</b> |                             |                 |                 |                         |
|---|-----------------------------|-----------------|-----------------|-------------------------|
| Letter - Corresponding Site Name                                    | Release History Information |                 |                 |                         |
| <b>A - Smith Lake</b>   | <b>Year</b>                 | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
| 1   | 1997                        | GAPU            | 200             | ODA                     |
| 2   | 1997                        | GAPU            | 200             | ODA                     |
| <b>B - Miller Sands East</b>  | <b>Year</b>                 | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
| 1   | 2005                        | GAPU            | 1000            | COE                     |
| 2   | 2004                        | NAMA            | 60              | ODA                     |
| 3   | 2004                        | GACA & GAPU     | 300             | ODA                     |
| 4   | 2002                        | GAPU            | 200             | ODA                     |
| <b>C - Svensen West</b>   | <b>Year</b>                 | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
| 1   | 1997                        | GAPU            | 200             | ODA                     |
| 2   | 1997                        | GAPU            | 200             | ODA                     |
| <b>D - Devil's Elbow (Horseshoe Island)</b>                         | <b>Year</b>                 | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
| 1   | 2004                        | NAMA            | 80              | ODA                     |
| 2   | 2004                        | GACA & GAPU     | 300             | ODA                     |
| 3   | 2004                        | GACA & GAPU     | 300             | ODA                     |
| <b>E - Fitzpatrick</b>  | <b>Year</b>                 | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
| 1   | 2005                        | GAPU            | 1000            | COE                     |
| 2   | 2004                        | GACA & GAPU     | 480             | ODA                     |
| 3   | 2002                        | NAMA            | 500             | ODA                     |
| 4   | 2001                        | GAPU            | 400             | ODA                     |
| 5   | 2001                        | GAPU            | 400             | ODA                     |
| 6   | 2001                        | GAPU            | 3500            | ODA                     |

| <b>Biocontrol Releases Made in the Lower Columbia River Estuary</b> |   |                                    |                 |                 |                         |
|---|---|------------------------------------|-----------------|-----------------|-------------------------|
| <b>Letter - Corresponding Site Name</b>                             |   | <b>Release History Information</b> |                 |                 |                         |
| <b>F - Dry Dock</b>   |   | <b>Year</b>                        | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
|   | 1 | 2005                               | GAPU            | 1000            | COE                     |
|   | 2 | 2004                               | GA spp.         | 600             | LCRWC                   |
|   | 3 | 2002                               | GACA            | 500             | ODA                     |
|   | 4 | 2001                               | GAPU            | 300             | ODA                     |
| <b>G - Wallace West</b>   |   | <b>Year</b>                        | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
|   | 1 | 2002                               | HYTR            | 50              | ODA                     |
|   | 2 | 2002                               | HYTR            | 200             | ODA                     |
|   | 3 | 2002                               | GAPU            | 500             | ODA                     |
|   | 4 | 2002                               | GAPU            | 2000            | ODA                     |
|   | 5 | 2001                               | GAPU            | 400             | ODA                     |
|   | 6 | 2001                               | GAPU            | 400             | ODA                     |
|   | 7 | 2001                               | HYTR            | 70              | ODA                     |
|   | 8 | 2001                               | GAPU            | 6000            | ODA                     |
| <b>H - Wallace East</b>   |   | <b>Year</b>                        | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
|   | 1 | 2006                               | HYTR            | 175             | EDC                     |
|   | 2 | 2005                               | GAPU            | 1000            | COE                     |
|   | 3 | 2004                               | GACA & GAPU     | 500             | ODA                     |
|   | 4 | 2002                               | GACA            | 600             | ODA                     |
|   | 5 | 2001                               | GAPU            | 3800            | ODA                     |
|   | 6 | 2001                               | HYTR            | 75              | ODA                     |
| <b>I - Eureka Bar</b>   |   | <b>Year</b>                        | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
|   | 1 | 2006                               | HYTR            | 175             | EDC                     |
|   | 2 | 2005                               | GAPU            | 1000            | COE                     |
|   | 3 | 2002                               | HYTR            | 200             | ODA                     |
|   | 4 | 2005                               | GAPU            | 1000            | COE                     |
| <b>J - Mainland, near Wallace Island</b>                            |   | <b>Year</b>                        | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
|   | 1 | 2004                               | NAMA            | 530             | ODA                     |
|   | 2 | 2002                               | NAMA            | 300             | ODA                     |
|   | 3 | 2002                               | GAPU            | 600             | ODA                     |
|   | 4 | 2002                               | GACA            | 600             | ODA                     |
| <b>K - Mainland, near Wallace Island</b>                            |   | <b>Year</b>                        | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
|   | 1 | 2004                               | GA spp.         | 800             | LCRWC                   |
|   | 2 | 2002                               | GACA            | 600             | ODA                     |
|   | 3 | 2001                               | NAMA            | 400             | ODA                     |
| <b>L - Mainland, near Wallace Island</b>                            |   | <b>Year</b>                        | <b>Organism</b> | <b>Quantity</b> | <b>Releasing Agency</b> |
|   | 1 | 2002                               | HYTR            | 200             | ODA                     |
|   | 2 | 2001                               | GAPU            | 350             | ODA                     |



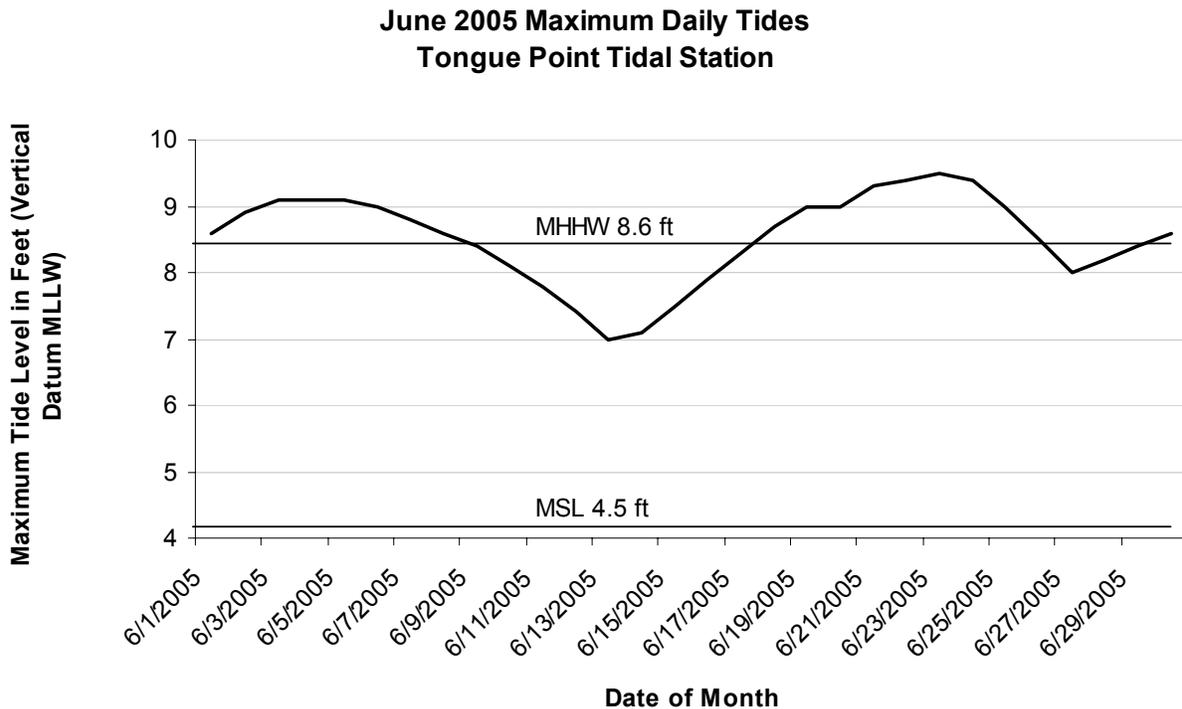




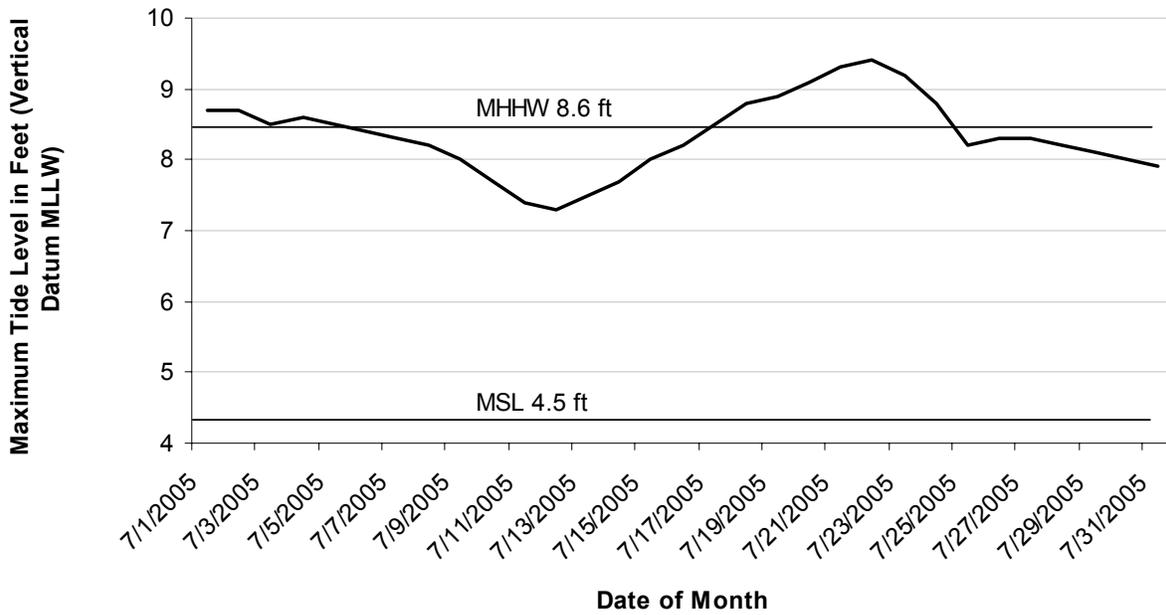


## Appendix IV – Daily High Tides

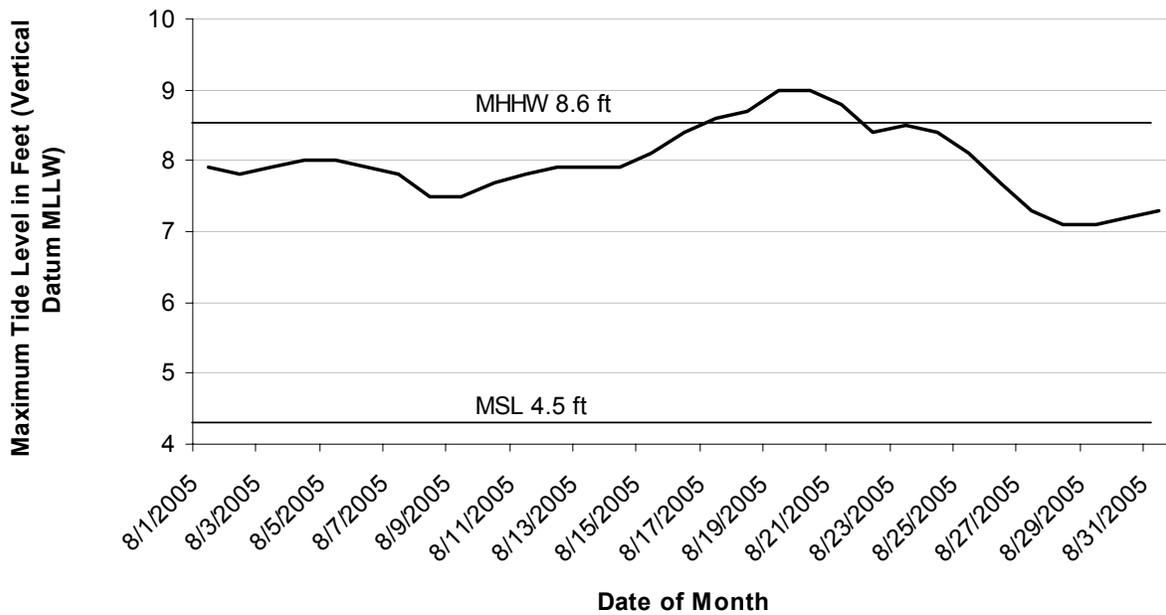
Graphs of daily high tides for each month beginning June 2005 through December 2006. Daily maximum tide levels were obtained using Nobeltec Tides and Currents software. Tidal heights are based upon Tongue Point and Knappa Slough tidal gauge stations in vertical datum MLLW. Knappa Slough values are based on Tongue Point but adjusted for the distance between them. Mott Island, Miller Sands Upstream and Downstream, Pillar Island Upstream and Downstream, and Fitzpatrick Island study sites tidal patterns are likely similar to Tongue Point. All other study sites (Devil's Elbow, Dry Dock, Eureka Bar Upstream and Downstream, Karlson, Marsh, Svensen Tenasillahe, Wallace) are probably similar to Knappa Slough tidal patterns. Lines designating the level of MHHW and MSL are shown in each graph. First, Tongue Point Tidal Station daily high tides are presented by month below, followed by Knappa Slough.



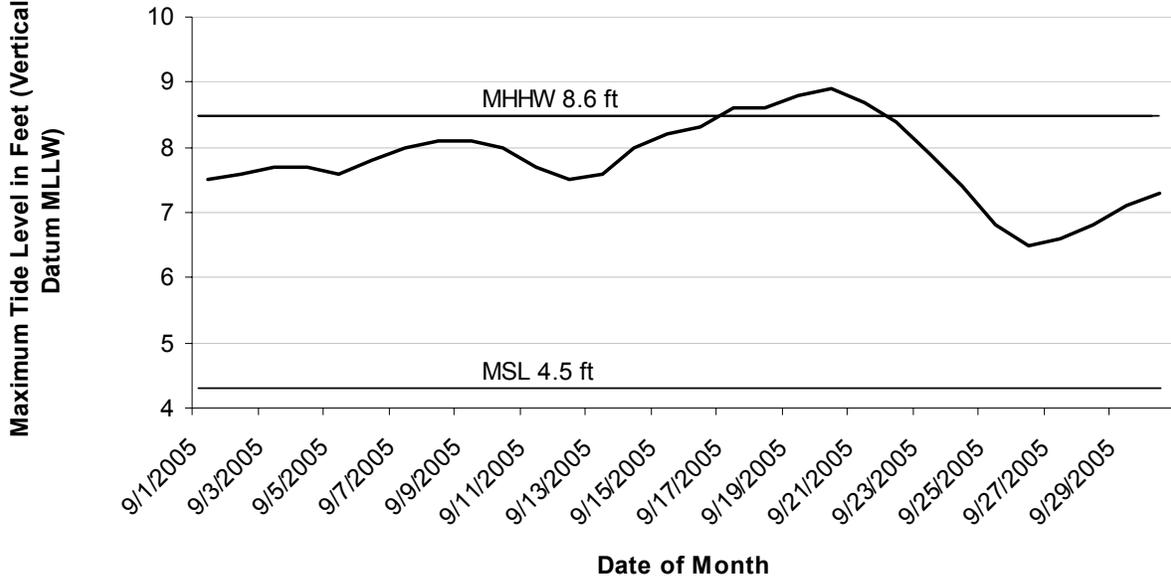
**July 2005 Maximum Daily Tides  
Tongue Point Tidal Station**



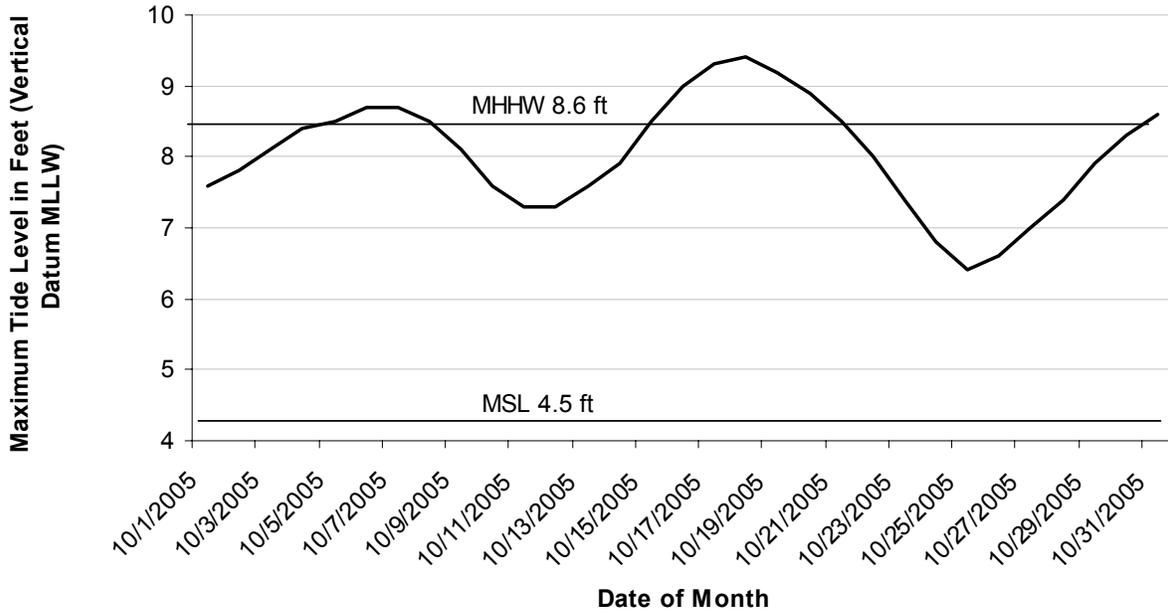
**August 2005 Maximum Daily Tides  
Tongue Point Tidal Station**



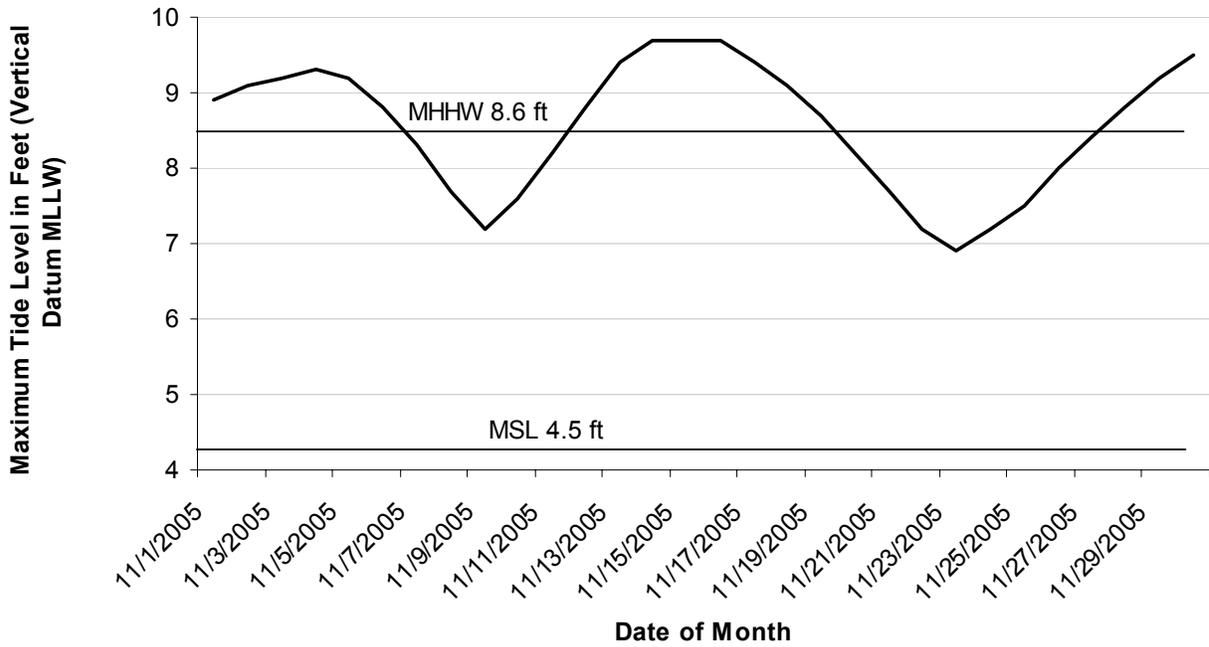
**September 2005 Maximum Daily Tides  
Tongue Point Tidal Station**



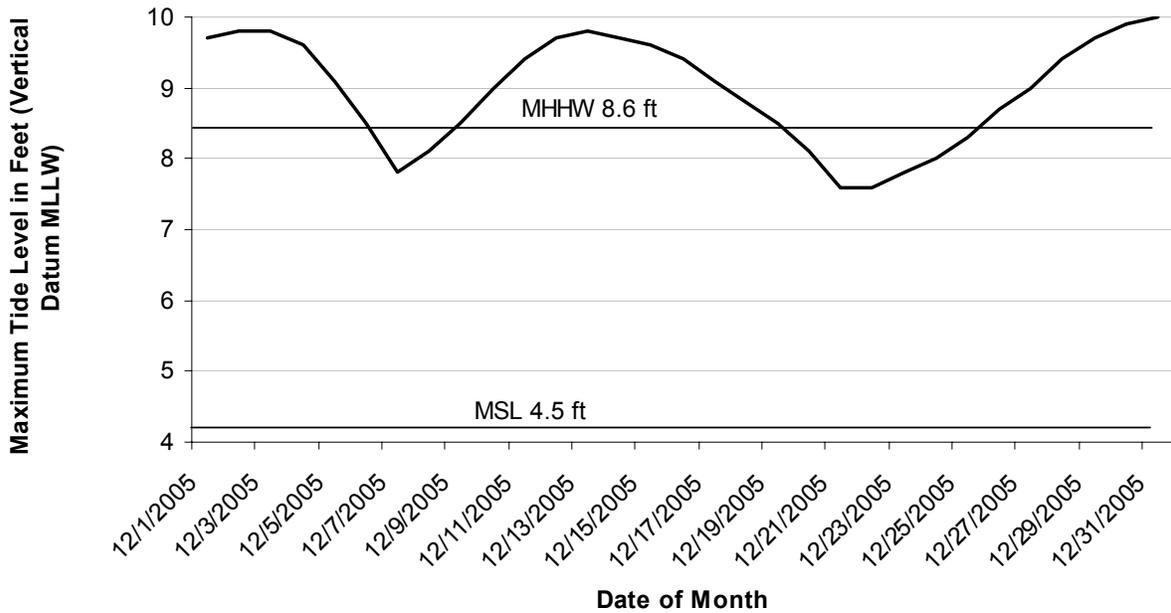
**October 2005 Maximum Daily Tides  
Tongue Point Tidal Station**



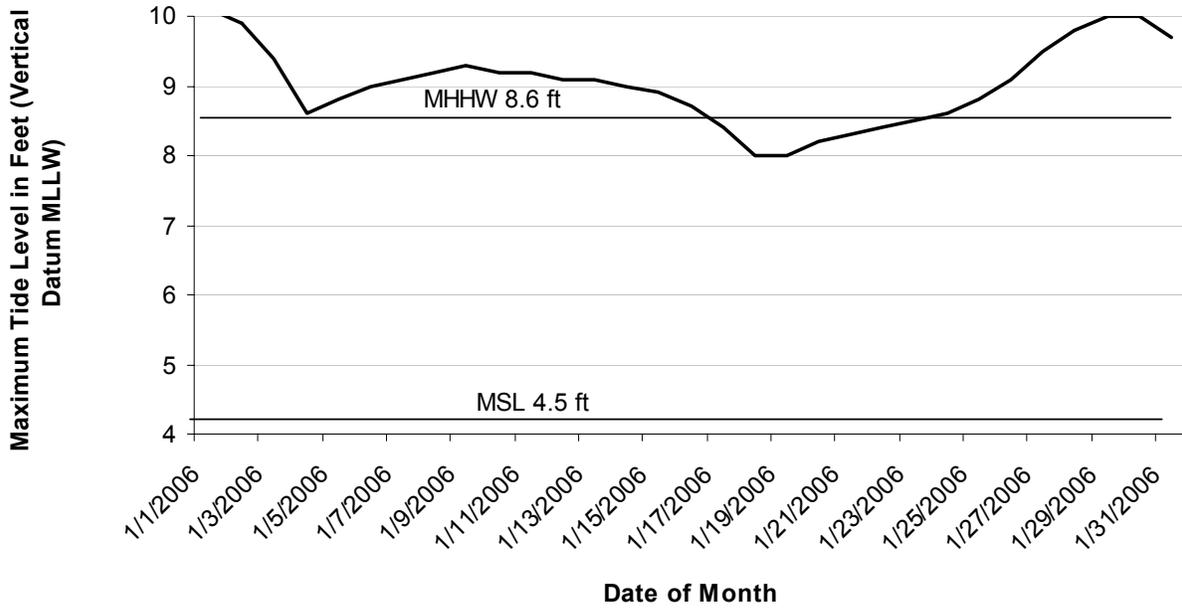
**November 2005 Maximum Daily Tides  
Tongue Point Tidal Station**



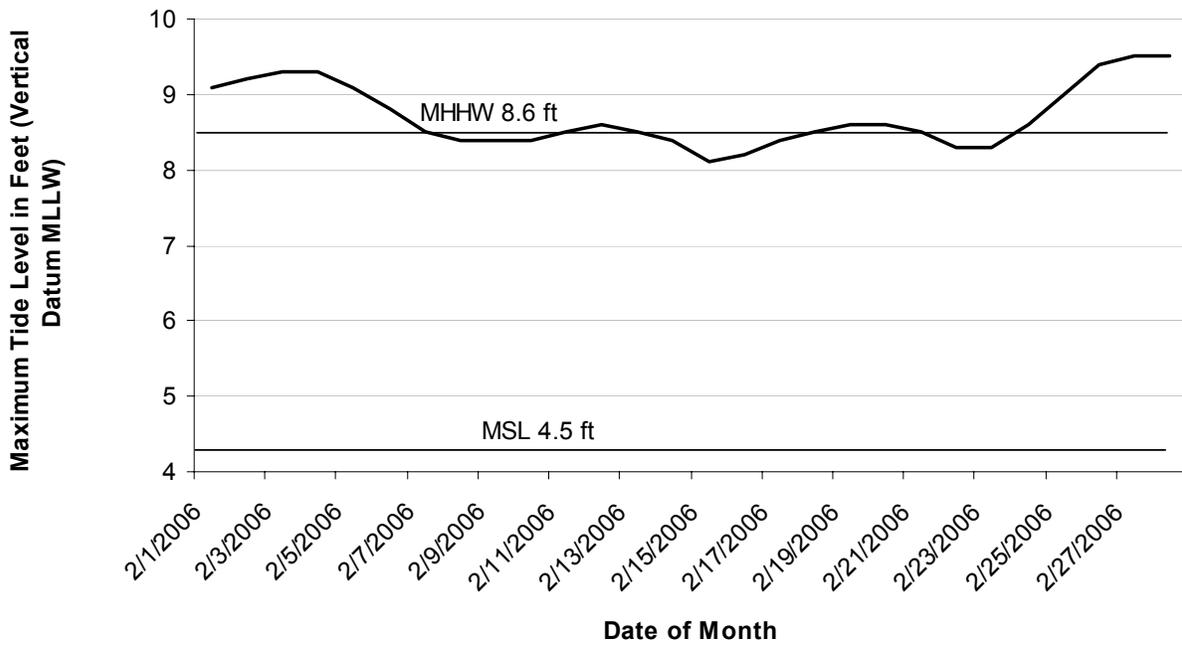
**December 2005 Maximum Daily Tides  
Tongue Point Tidal Station**



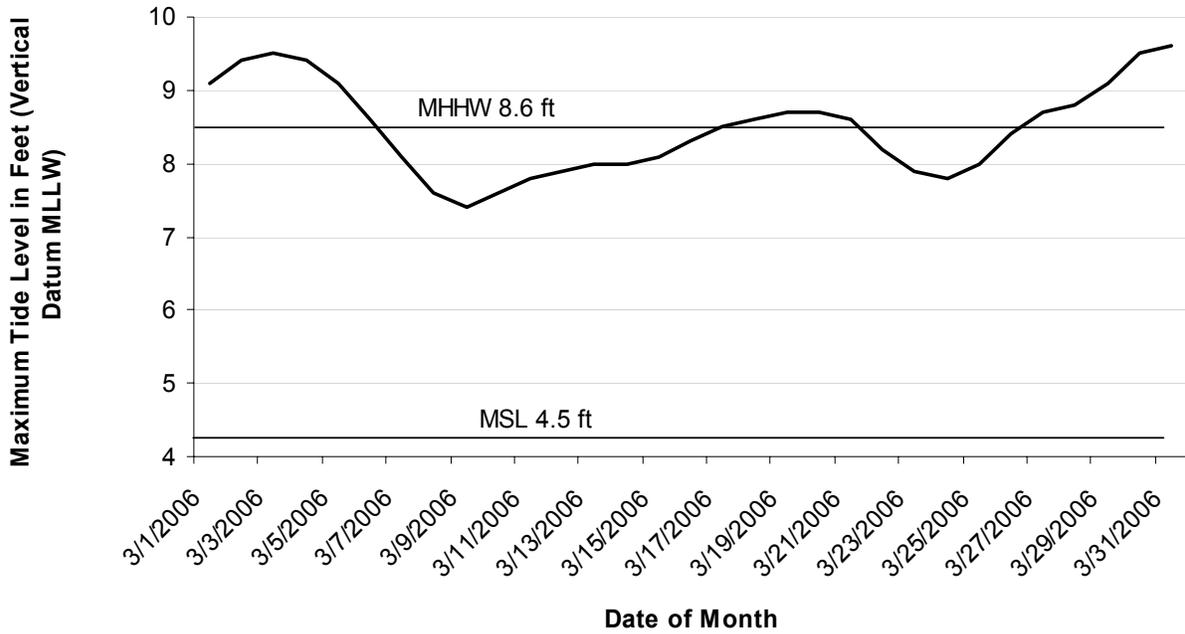
**January 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



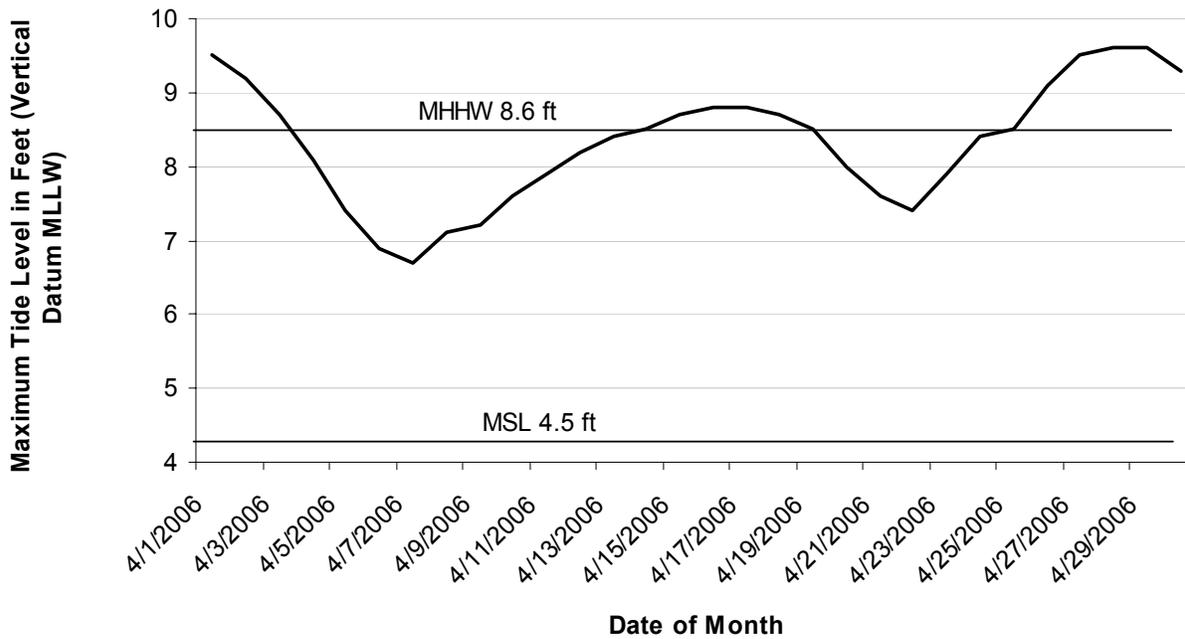
**February 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



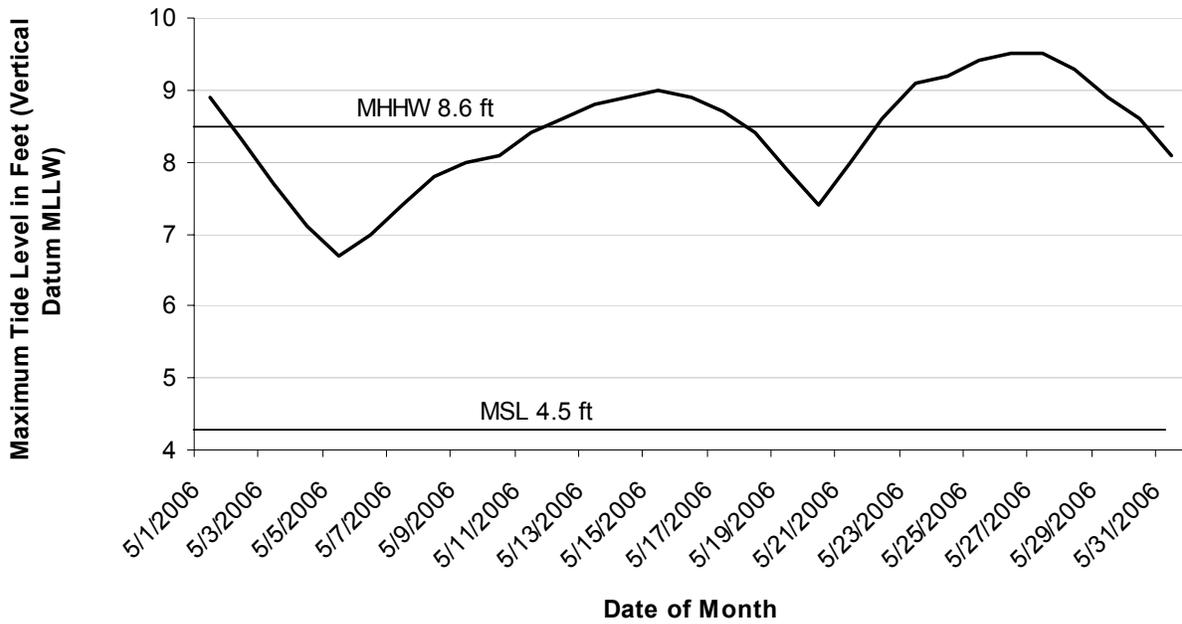
**March 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



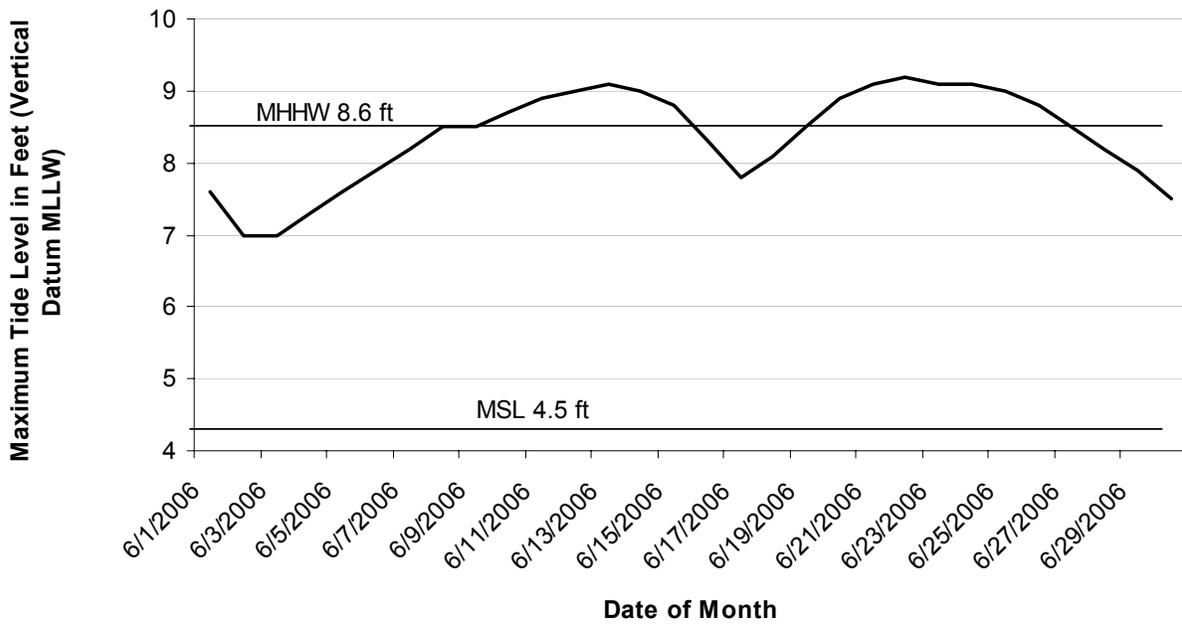
**April 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



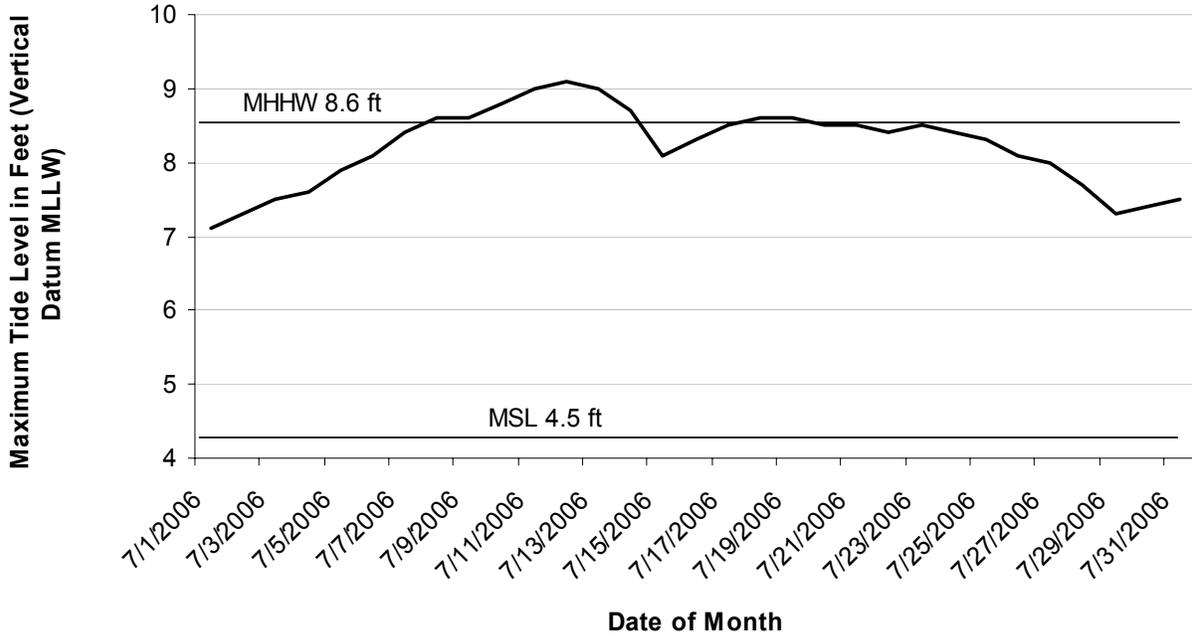
**May 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



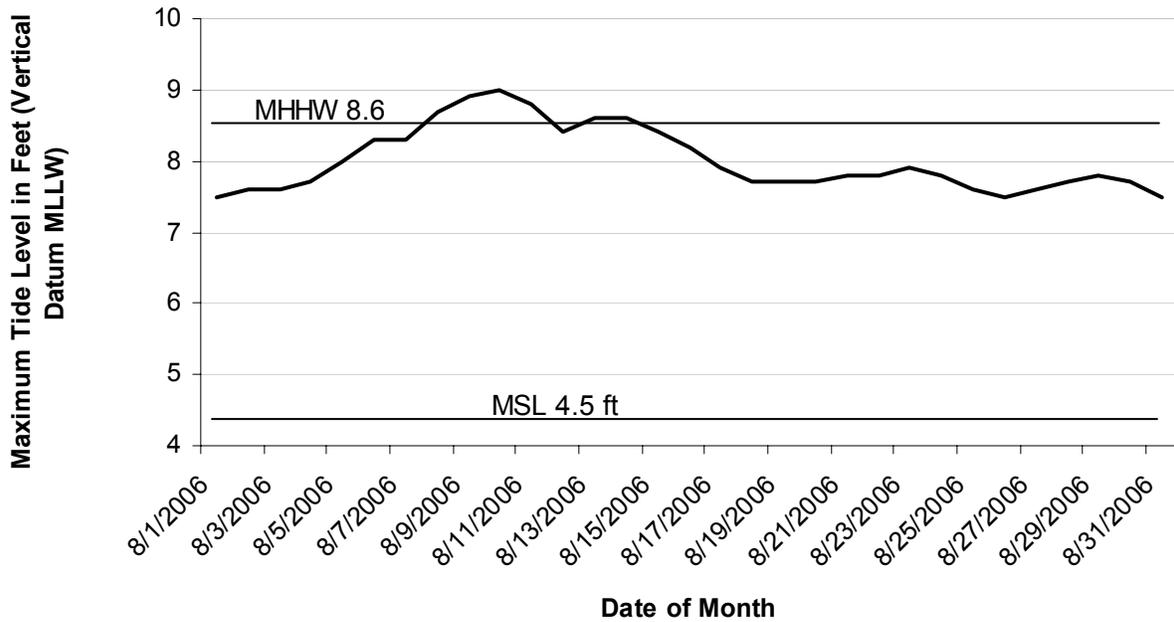
**June 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



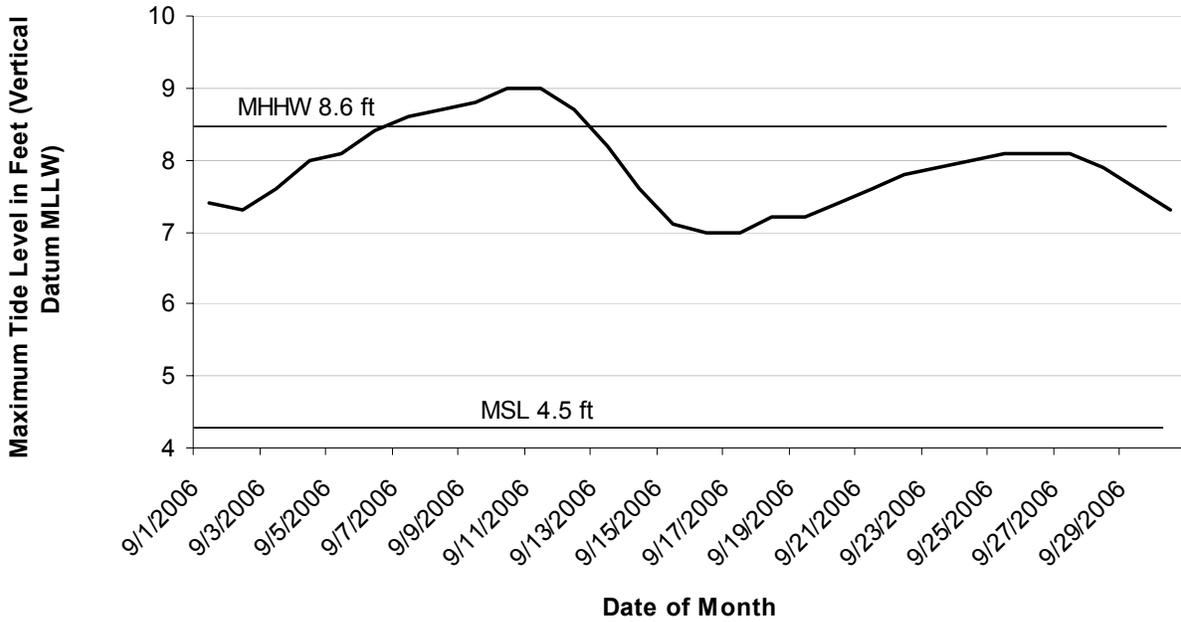
**July 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



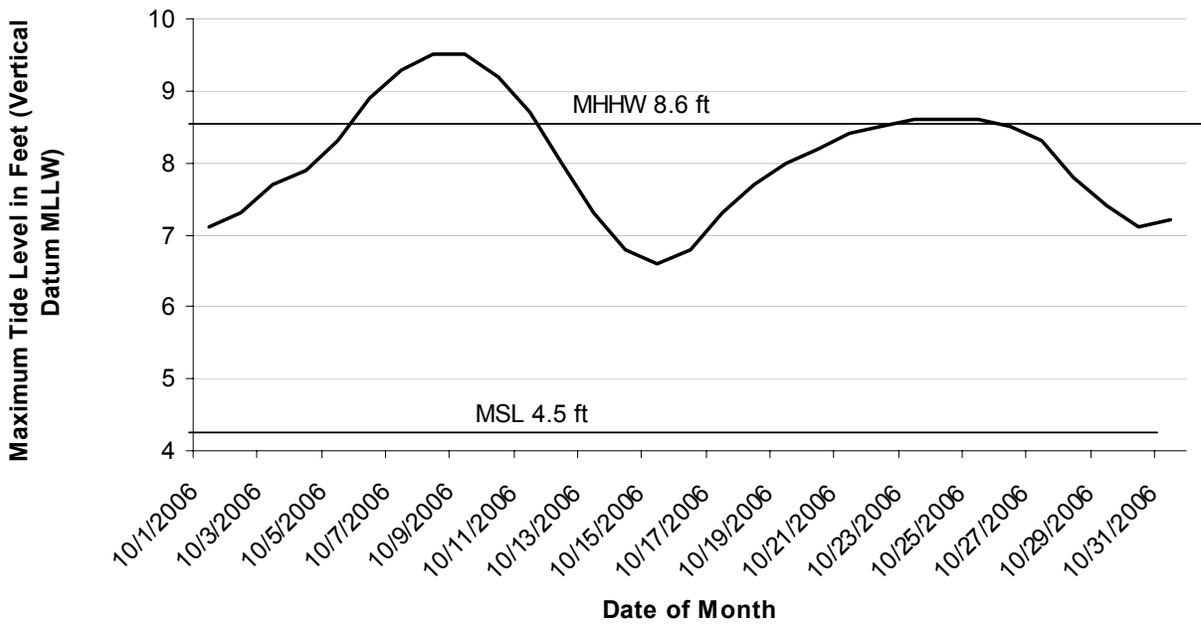
**August 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



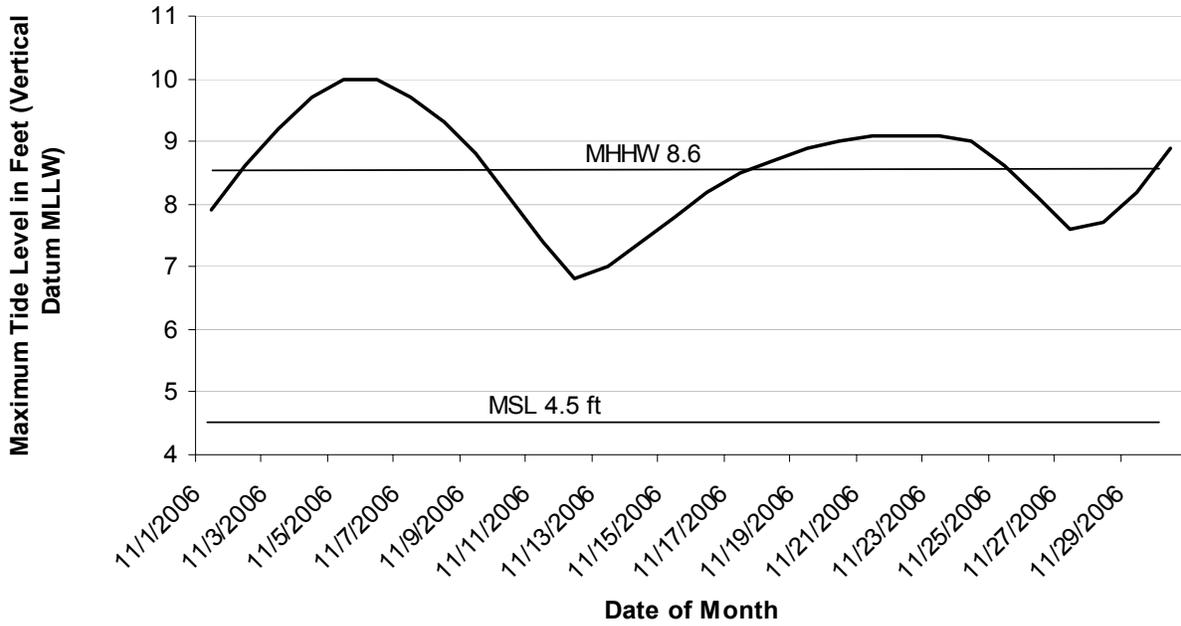
**September 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



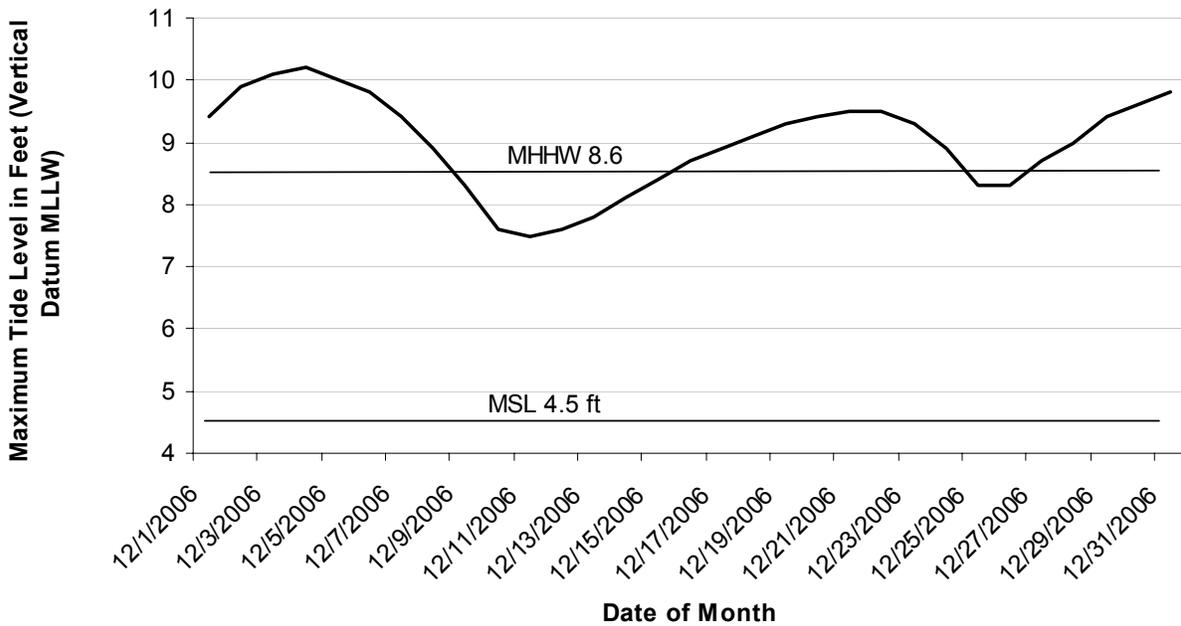
**October 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



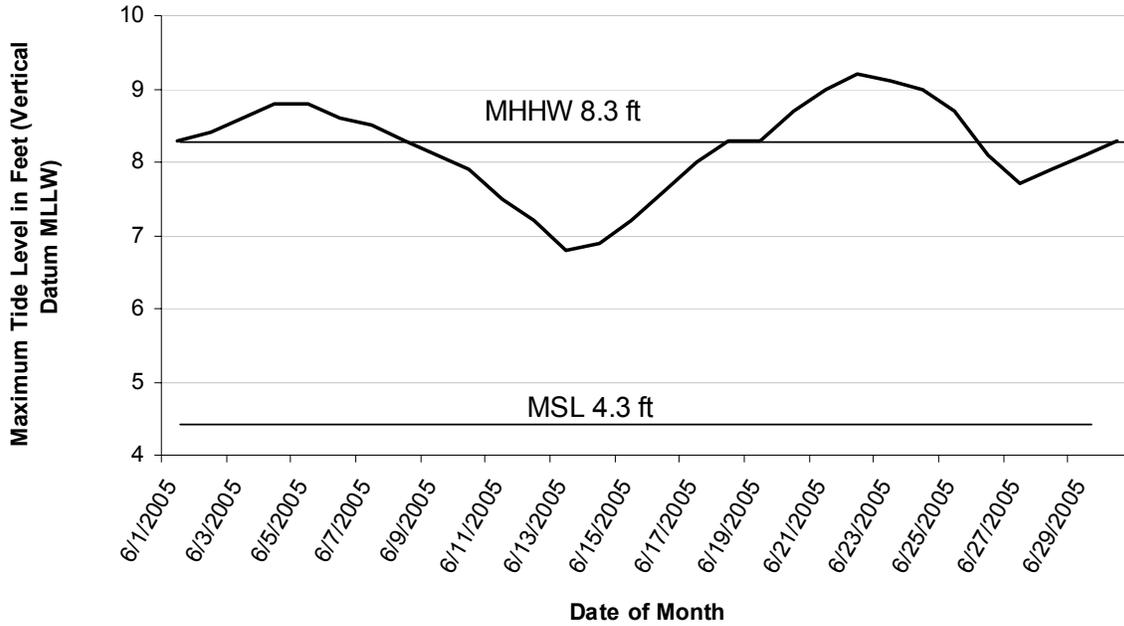
**November 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



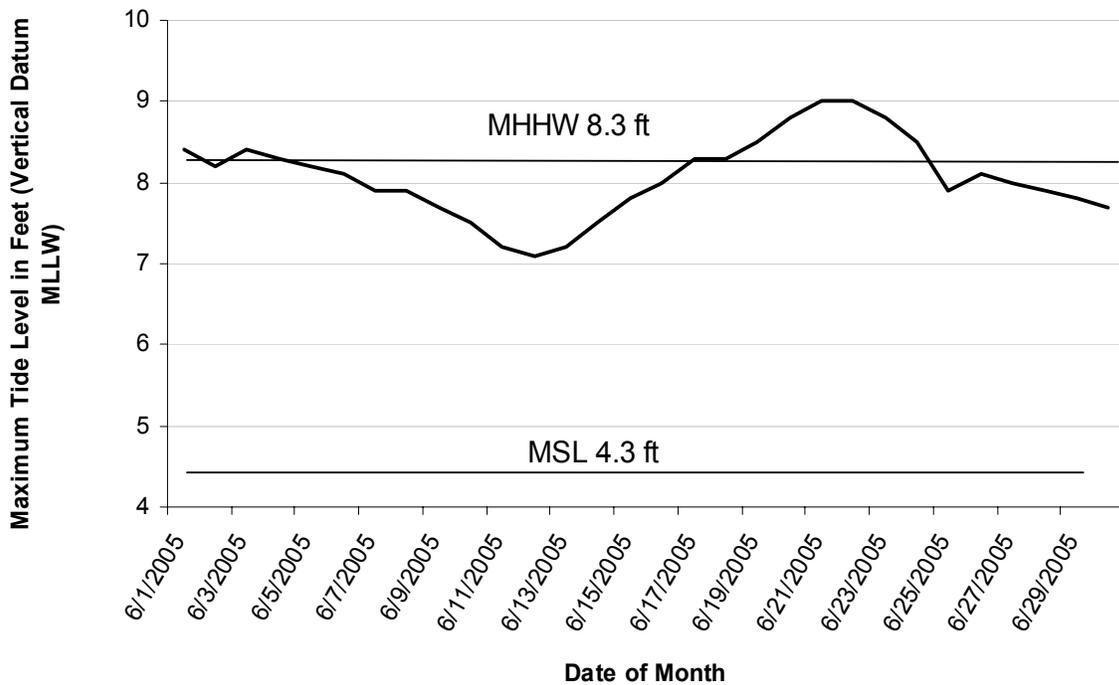
**December 2006 Maximum Daily Tides  
Tongue Point Tidal Station**



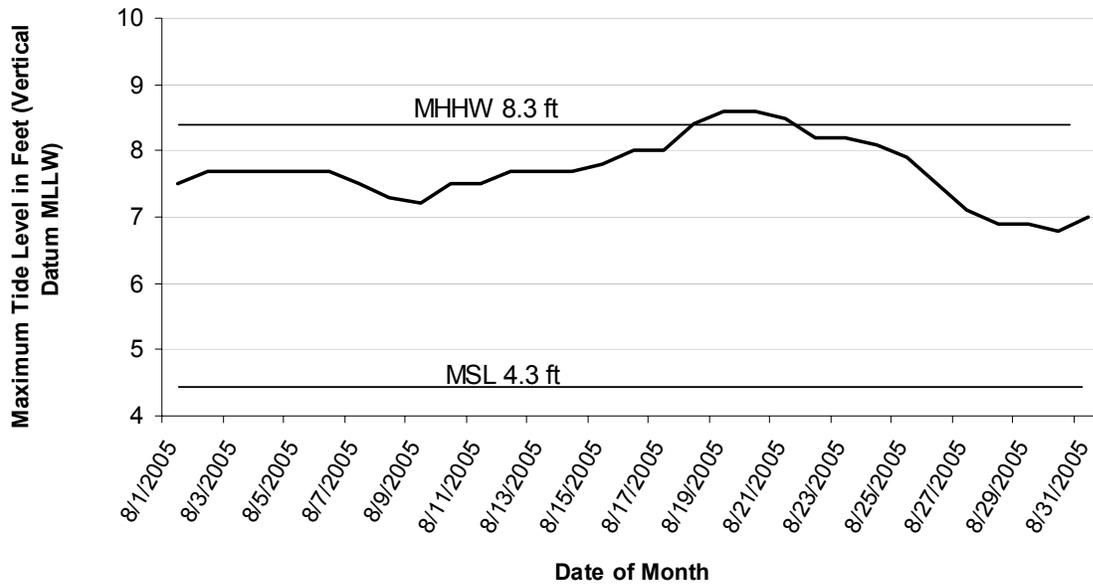
**June 2005 Maximum Daily High Tides  
Knappa Slough Tide Station**



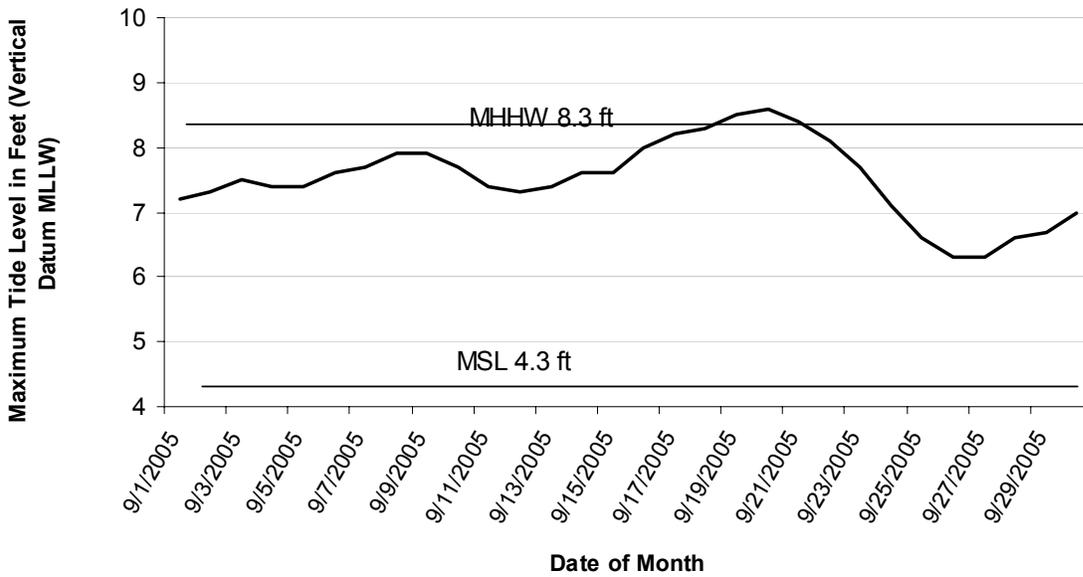
**July 2005 Maximum Daily High Tides  
Knappa Slough Tide Station**



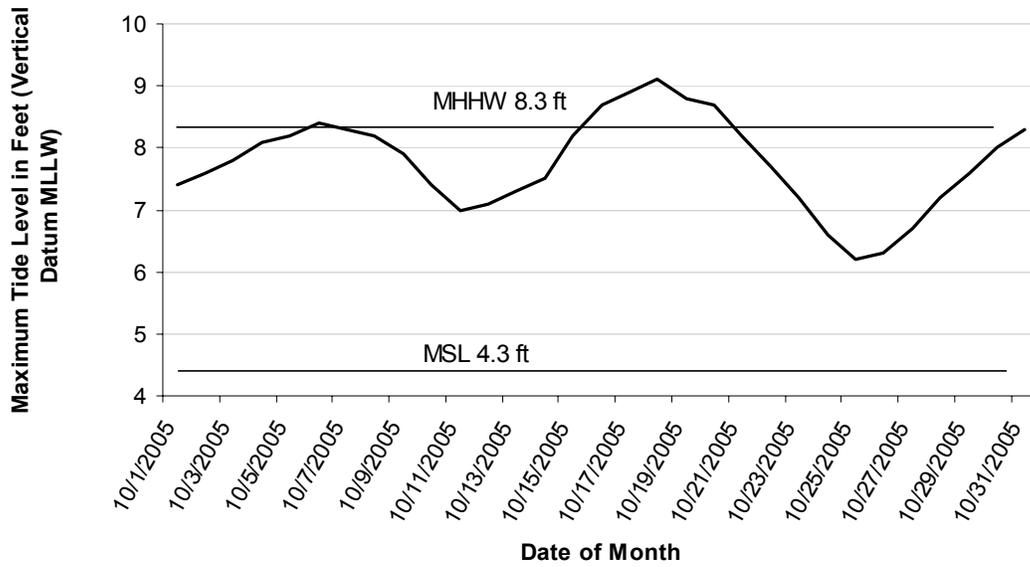
**August 2005 Maximum Daily High Tides  
Knappa Slough Tide Station**



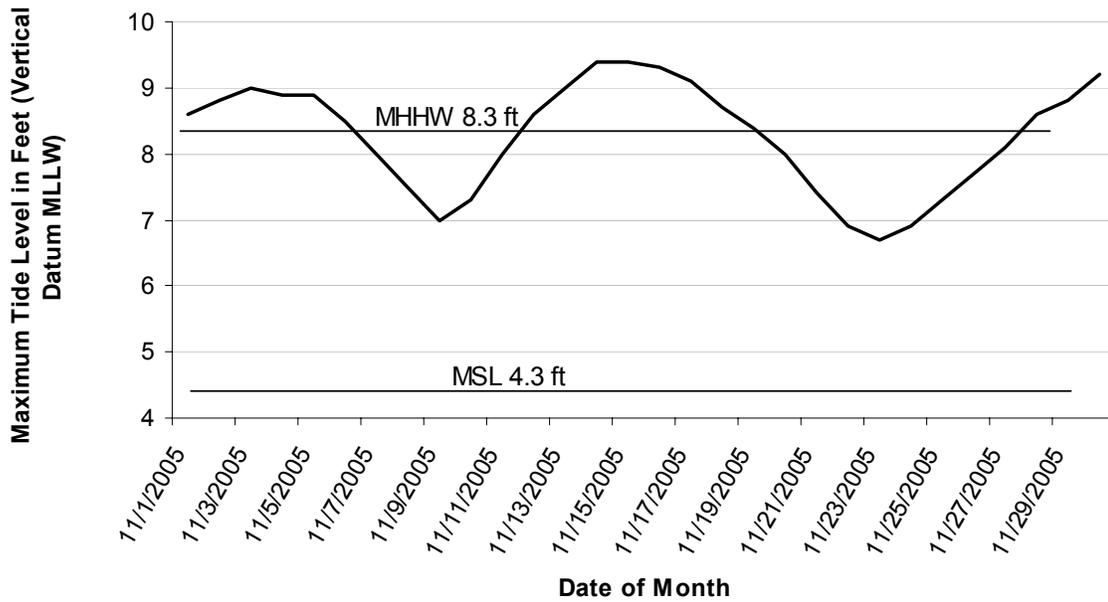
**September 2005 Maximum Daily High Tides  
Knappa Slough Tide Station**



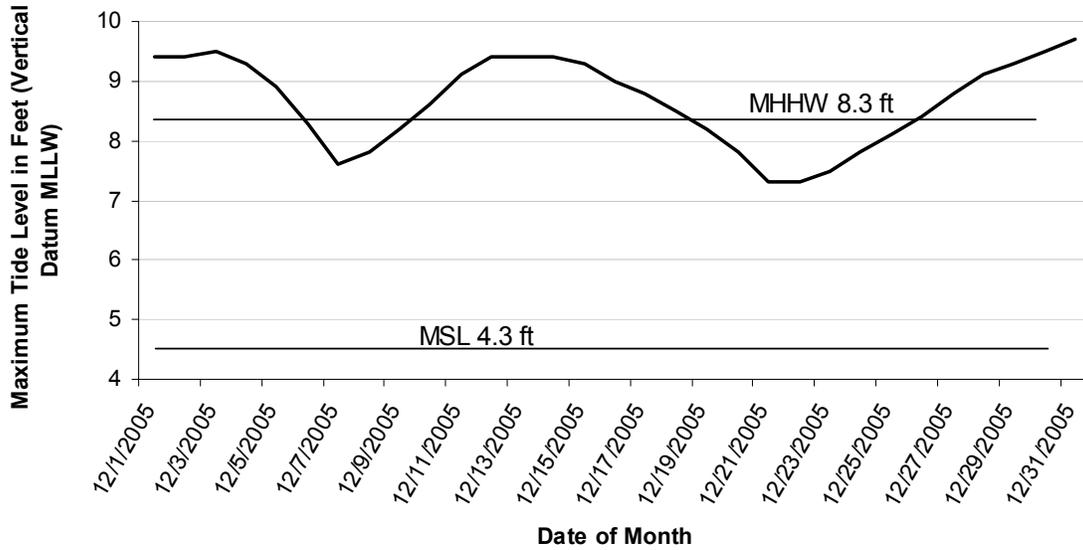
**October 2005 Maximum Daily High Tides  
Knappa Slough Tide Station**



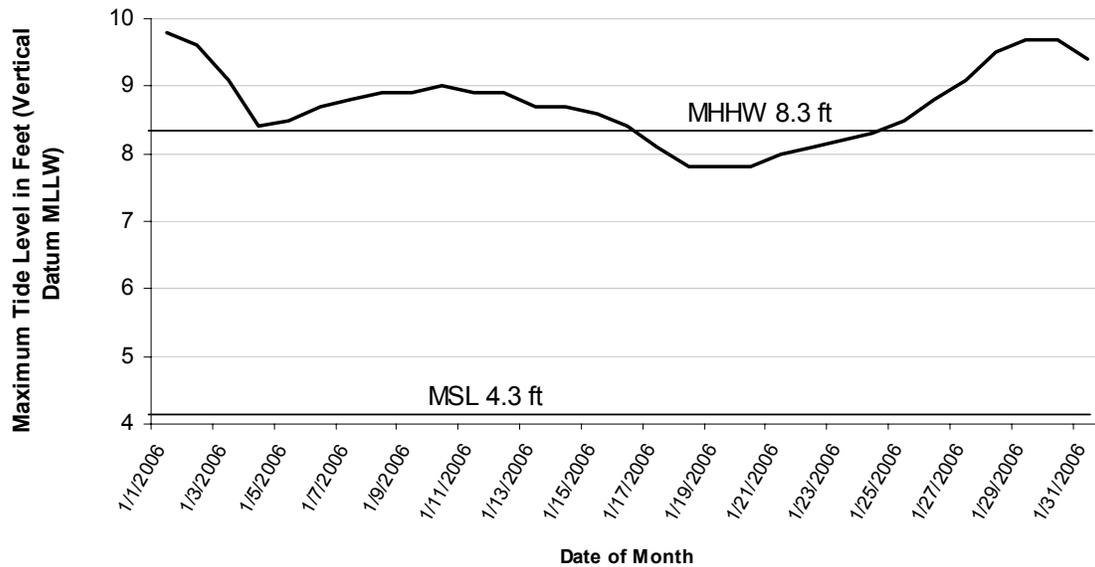
**November 2005 Maximum Daily High Tides  
Knappa Slough Tide Station**



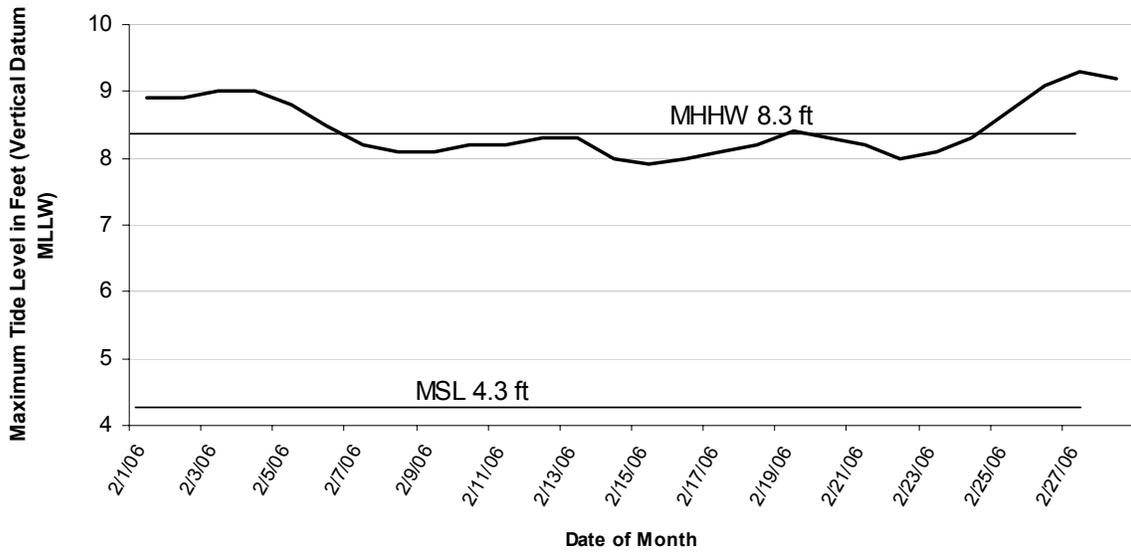
**December 2005 Maximum Daily High Tides  
Knappa Slough Tide Station**



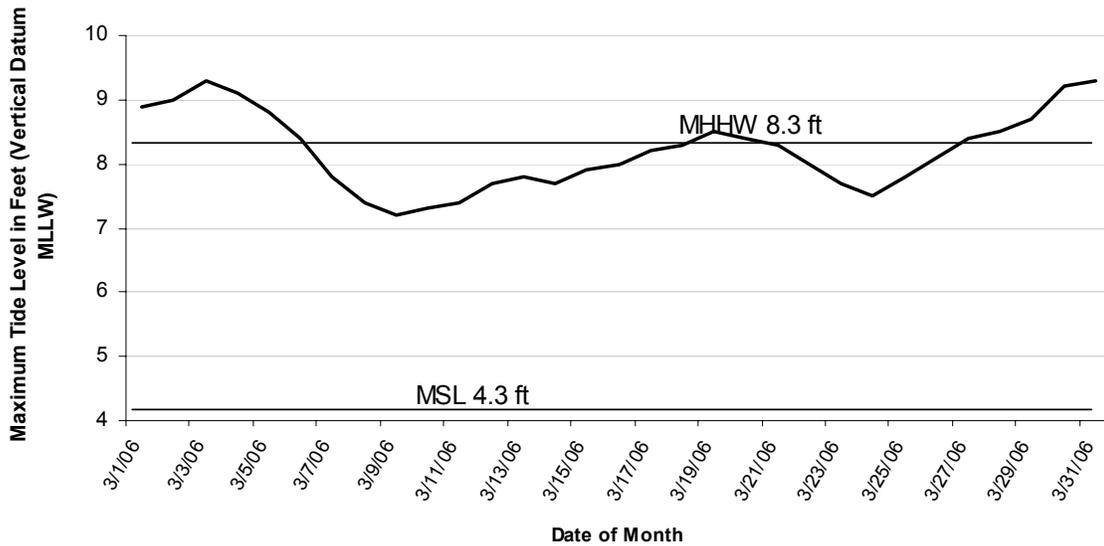
**January 2006 Maximum Daily High Tides  
Knappa Slough Tide Station**



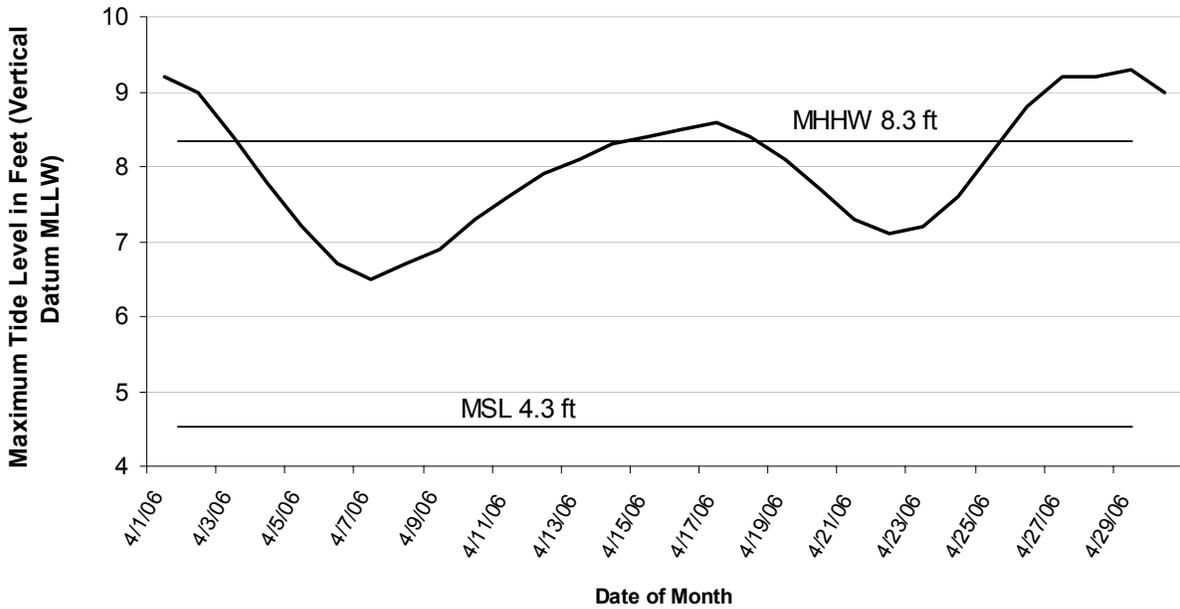
**February 2006 Maximum Daily High Tides  
Knappa Slough Tide Station**



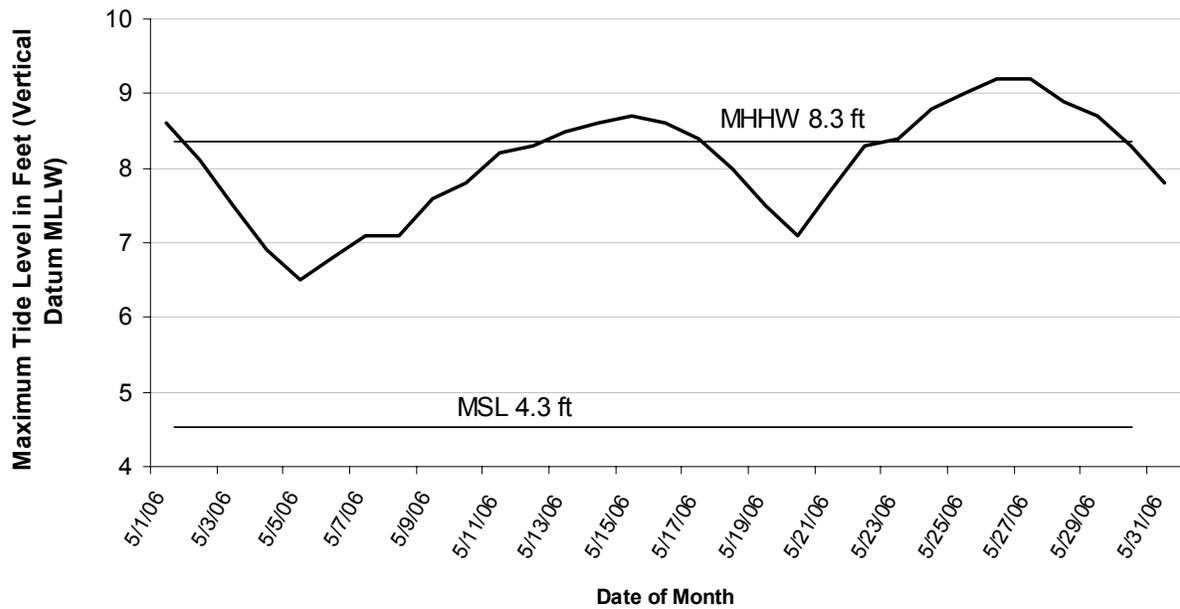
**March 2006 Maximum Daily High Tides  
Knappa Slough Tide Station**



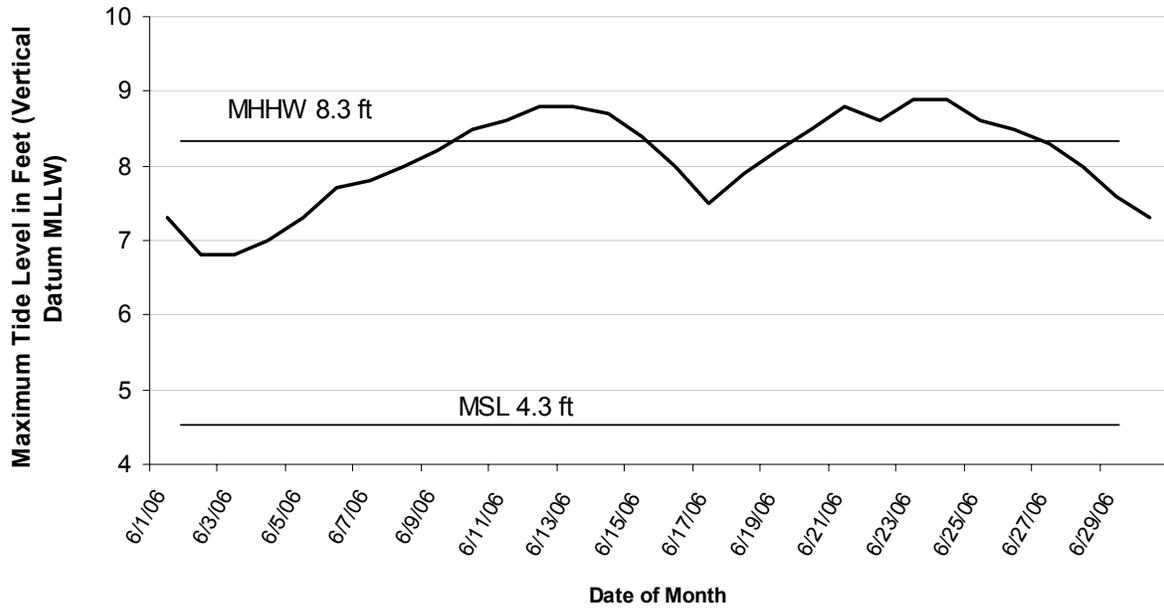
**April 2006 Maximum Daily High Tides  
Knappa Slough Tide Station**



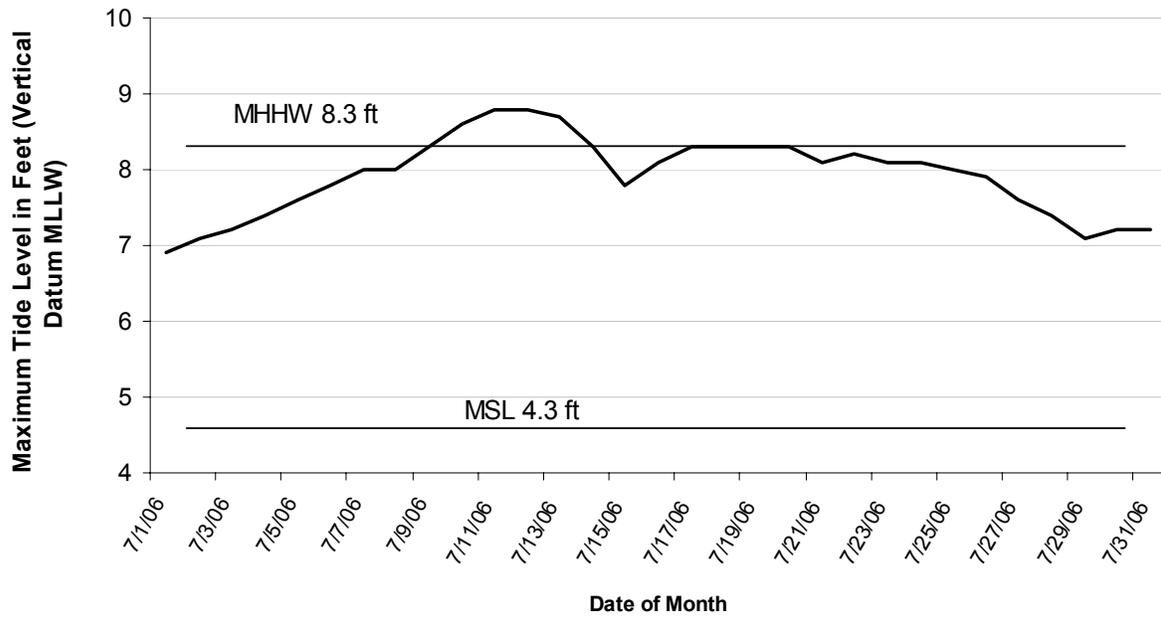
**May 2006 Maximum Daily High Tides  
Knappa Slough Tide Station**



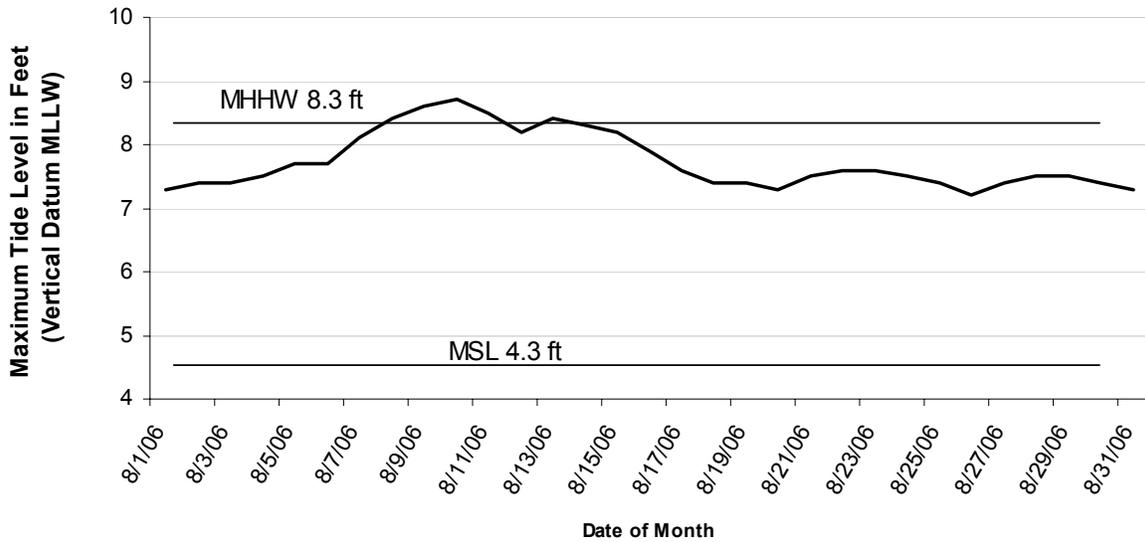
**June 2006 Maximum Daily High Tides  
Knappa Slough Tide Station**



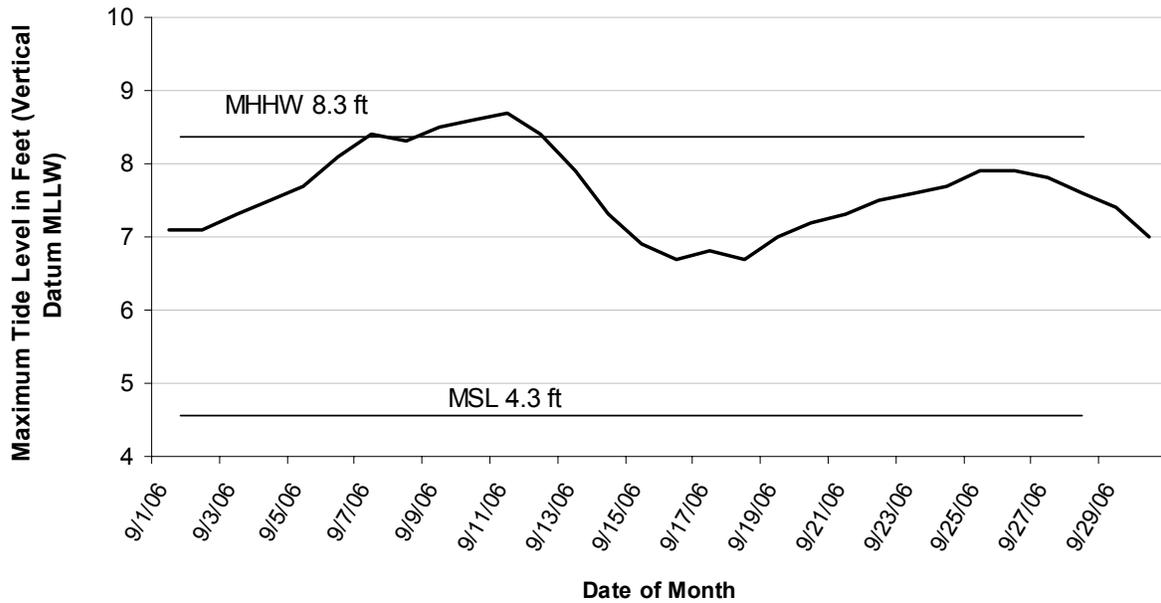
**July 2006 Maximum Daily High Tides  
Knappa Slough Tide Station**



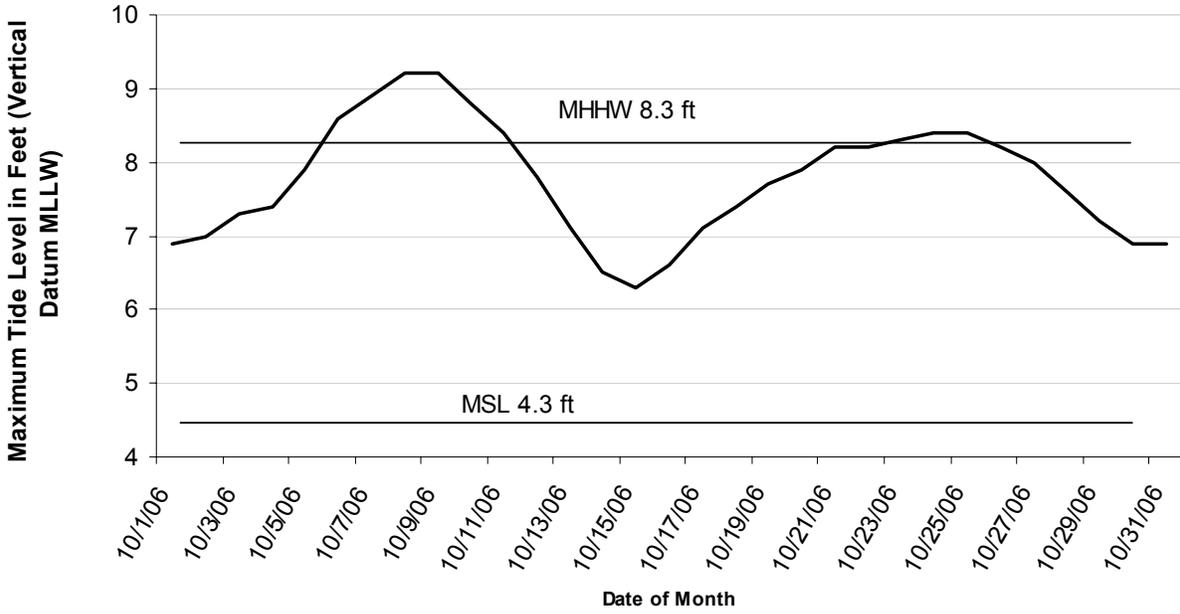
**August 2006 Maximum Daily High Tides  
Knappa Slough Tide Station**



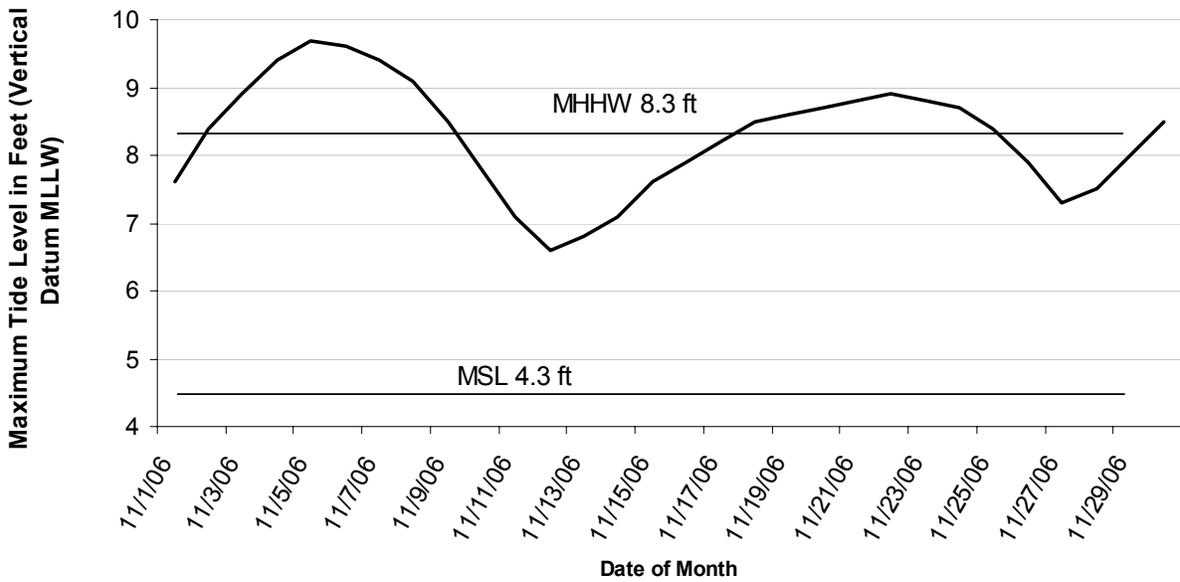
**September 2006 Maximum Daily High Tides  
Knappa Slough Tide Station**



**October 2006 Maximum Daily High Tides  
Knappa Slough Tide Station**



**November 2006 Maximum Daily High Tides  
Knappa Slough Tide Station**



December 2006 Maximum Daily High Tides  
Knappa Slough Tide Station

