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EVALUATION OF MIGRATION AND SURVIVAL OF JUVENILE SALMONIDS FOLLOWING TRANSPORTATION

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Draft Annual Report for 1997

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EXECUTIVE SUMMARY

✱Most radiotagged yearling chinook migrated to a monitoring station 86-90 miles downstream in 27-85 hours, consistent with a sustained velocity of 1-3 miles per hour. Most fish appeared to reach the estuary two to three days following release.

✱Migration speed in the lower Columbia River appeared to be influenced by both river flows and fish condition. Yearling run-of-river chinook migrated faster than barged chinook released at the same time under identical flow conditions; this difference in travel time must be the result of some difference in fish condition . An increase in travel time of barged chinook was observed in the middle of May, simultaneous with a brief drop in flows. A regression analysis suggested that river discharge and level of smoltification accounted for 87% of the variability in travel time.

✱We observed that 74% to 97% of radiotagged barged chinook and 77% to 91% of run-of-river chinook successfully reached the estuary. More barged fish reached the estuary on the last release date (1 June) but there was no difference between groups of two previous releases.

✱Approximately 3-27% of radiotagged fish reaching the estuary were later found in colonies of piscivorous birds, suggesting that bird predation may be a significant source of mortality of juvenile salmonids passing through the estuary. There was no difference in observed mortality of barged and run-of-river fish.

✱Radiotagged chinook often were found in or near the shipping channel in the upper estuary (river miles 25-60). Conversely, in the lower estuary many individuals tracked by aircraft were found in the relatively shallow central portion of the estuary; most individuals tracked by boat were also found to cross this area.

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- Movement of radiotagged juvenile chinook in the lower estuary was influenced by the tide, with individuals moving downstream on the ebb tide and holding or moving upstream on the flood tide.

- During the peak of the outmigration it appears likely that yearling chinook were moderately to highly stressed at the time of release, as judged by plasma cortisol levels. Plasma cortisol levels were weakly, but significantly correlated with barge loading density ($p=0.01$, $R^2=7\%$).

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OBJECTIVES

The goal of this study is to obtain information that will allow us to make recommendations concerning how the fish transportation program may be managed to minimize the severe loss of fish in the estuary.

Specific objectives of the 1997 project year were as follows:

1) Document migratory behavior and survival of transported and run-of-the-river yearling
spring chinook in the lower Columbia River and estuary to the ocean.

2) Determine how the development and health status of migrants collected at Snake River dams and transported relates to their behavior and survival in the Columbia River estuary; relate fish quality and performance of barged fish to performance of run-of-the-river fish.

3) Establish the relationship between fish behavior and physiological indicators of fish quality so that monitoring of fish may be predictive of successful ocean entry after release from barges.

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INTRODUCTION

The success of transportation is determined by the performance of the transported fish following release. Post-release performance of the fish is a function of the quality of the fish at release, which is itself determined by both the condition of the fish at collection, and the effect of transportation. The condition of fish at collection may be extremely important in affecting success of the program. Condition of fish when they reach the dam is extremely variable in terms of their general quality and health. There is not only variation over the course of the run, but also between individuals collected at any one time. We suspect that this variation in fish quality is reflected in the ability of juvenile salmonids to perform various tasks following transportation, such as migration through the lower Columbia River, and successful passage through the estuary.

In spring of 1996 we found that 10-30% of radiotagged juvenile chinook salmon were taken by piscivorous birds in the Columbia River estuary. If this percentage extends to all migrants, than the total number of Columbia River yearling spring chinook taken by birds near the mouth of the river is enormous. It is not known what factors determine the vulnerability of migrating juvenile salmonids to bird predators, although fish behavior in the estuary clearly has the potential to affect the likelihood of being eaten. For example, those individuals who swim higher in the water column, or linger in areas containing many birds, may be more at risk. A number of factors relating to fish health and development (smoltification) have been shown to influence the behavior of juvenile salmonids, and by extension, survival.

At present we have very limited information concerning large-scale migration behavior of juvenile chinook salmon in the estuary near the river's mouth, and no information whatsoever concerning detailed behavior. Increased understanding of smolt behavior in the estuary is needed to determine what may be done to minimize avian predation.

We postulate that the quality of migrants reaching the lower Columbia River (either by barge or in-river migration) relates to subsequent behavior and avoidance of predation. Fish quality may particularly relate to delays in seawater entry in the Columbia

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estuary. Such delays could result in more predation by increasing the amount of time the migrants spend in the freshwater lens, where the fish are exposed to large concentrations of birds and may be easier to catch due to the relatively shallow nature of the freshwater lens. Smoltification, disease, and stress status may all influence the amount of time a fish might be "trapped" in the freshwater lens. Although physiological condition influences behavior, the exact relationship between fish quality indices and behavior is not always intuitive. It has been demonstrated that seawater entry behavior may lag weeks behind physiological readiness to enter seawater as determined by saltwater challenge tests; such tests may be deceptive in that they measure the ability of smolts to tolerate seawater, but not the likelihood that they will actually choose to enter seawater. Once the linkages between fish quality and behavior are understood, the opportunity exists to manage the migration of juvenile salmonids through the Columbia Basin hydropower system to maximize downstream survival.

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METHODS

Task 1. Document migratory behavior and survival of transported and run-of-the river yearling spring chinook in the lower Columbia River and estuary to the ocean.

The migration behavior of yearling spring chinook in the lower Columbia River downstream of Bonneville Dam was documented using radiotelemetry. We examined migration of both barged fish collected at Lower Granite Dam on the Snake River and run-of-river yearling chinook collected at Bonneville Dam. Radio transmitters were purchased from Advanced Telemetry Systems (ATS-Isanti, Minnesota) and operated on the 148-149 megahertz bandwidth. They weighed approximately 1.2 g in air and were designed to transmit continuously for 7 days. Two tags were placed on each frequency, and were distinguished by different beeping rates (approximately 40 and 60 beeps per minute). This strategy allowed us to cut in half the number of frequencies to be scanned during tracking. Before use, all tags were checked for proper functioning following a 24 h immersion in water. To avoid compromising the performance of the fish, only individuals 20 g in weight (approximately 12.5 cm fork length) or greater were tagged.

Fish to be released from barges were collected from the fish separator at the Lower Granite Dam Juvenile Fish Facility. Individuals were anesthetized in 50 mg/l MS222 buffered with 100 mg/l $NaHCO_3$, after which the transmitter was implanted into the stomach (Ward and Miller, 1988). Following tagging, 6-7 fish were placed in each of six 33 gal live wells and allowed to recover. On the first release date the livewells were secured in the stern barge holds the night before the start of the trip. Tagged fish were held in the livewells for approximately 12-16 h to monitor for regurgitation of the transmitters or other problems, then released into the barge compartment shortly before the barge departed Lower Granite. This has been our usual procedure in previous years. For the remaining releases the livewells were placed on the barge dock overnight because the barge was unable to dock at the fish facility due high flows in the tailrace. In the morning, spill was temporarily reduced to allow the barge to dock at the Fish Facility and the livewells were secured in the barge compartments. The livewells remained

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secured aboard the barge until arrival at the Little Goose Juvenile Fish Facility, where the fish were released into the barge compartments. This gave the fish an additional 4 hours or more to recover from any disturbance resulting from moving the livewells. As the barge reached Bonneville Dam, an observer was placed on board to verify that all tags were transmitting and to record the release time and location. Up to 40 fish were tagged on each of six dates over the 1996 outmigration in order to sample the various components of the spring run (Figure 1). A more detailed description of the circumstances of each barge trip and release of radiotagged fish is contained in Tables 1 and 2.

Later in the migration season releases of run-of-river fish were paired with concurrent releases of barged fish. Fish radiotagged at Bonneville Dam were released on three dates in May and early June of 1997. Timing of these releases was designed to coincide with peak passage of Snake River juvenile salmonids past Bonneville Dam, so that we could obtain the highest proportion of Snake River fish for tagging. On the dates we tagged, Snake River hatchery chinook were demonstrated to be passing the dam via pit tag detections (Figure 2), but the exact place of origin of any given individual implanted with a radiotag is unknown. A detailed description of the circumstances of the Bonneville Dam releases is given in Table 3.

Run-of-river yearling chinook to be radiotagged were obtained at Bonneville Dam First Powerhouse DSM and Second Powerhouse FERL as part of the daily sample collected by NMFS personnel for smolt monitoring purposes. The tagging procedure was identical to that used for barged fish. At release, fish were placed back into the first powerhouse juvenile bypass system. In an effort to standardize the arrival time of barged and run-of-river migrants in the estuary (which might influence risk of predation from birds), releases at Bonneville Dam were made after the transport barge carrying the paired release group of radiotagged fish had passed the Bonneville Navigation Lock. Since we have found that run-of-river migrants often travel through the lower river faster than barged migrants, particularly earlier in the season, run-of-river fish were released approximately 5 h after the barge locked through on 16 May, 3 h later on 24 May, and at approximately the same time on 1 June.

Following release the locations of radiotagged individuals were monitored from an aircraft using ATS challenger 2000 radio receivers. Location data was collected daily for a period of 2-4 days starting on the second day following release. The movement of the fish was

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monitored from the vicinity of Longview, Washington to the mouth of the Columbia River (Figure 3); as the fish moved downstream the portion of the river covered by aircraft was also shifted downstream to allow us to observe the lead fish until it reached the ocean. When fish were passing through the estuary downstream of river mile 30, we flew twice a day when feasible to collect more detailed data concerning movement speed and migration patterns in the estuary.

Aircraft used for tracking were equipped with two ATS receivers connected to 4-element YAGI antennas mounted on either wing strut. Flights were conducted at an altitude of 500 ft and air speed of approximately 100-110 miles per hour. Once a radio signal was heard, the plane circled until its precise location could be determined. The effective distance at which we could detect the tag ranged from approximately 0.25 miles to 1 mile. During each flight the study area was covered twice: once with the aircraft flying the main channel and a second time flying over side channels. In areas with no side channels, we flew closer to the Oregon shore on one pass, and closer to the Washington shore on the next pass. Due to the extreme width of the river in the estuary we changed the search pattern to a series of north/south transects spaced at 0.5 mile intervals. The transects were used from the mouth of the river up to about river mile 30, at which point the river divides into channels that are narrow enough to eliminate the need for transects.

The progress of radiotagged individuals was also recorded at a fixed monitoring station located upstream at river mile 55.5, near the community of Bunker Hill, Washington. At this location the river makes a wide bend and the shipping channel abuts a series of cliffs on the Washington shoreline. It has been our experience that juvenile chinook often are located in or near the shipping channel, and thus can be expected to pass near the Washington shore at this location. Three 6 ft YAGI antennas were placed approximately 100 ft above river level on top of a cliff that dropped directly to the water. The antennas were pointed directly to the far side of the river, and were each connected to an ATS receiver. The same list of frequencies were loaded into each receiver, but scanning was staggered between the receivers so that the effective time to scan all the frequencies was reduced. This technique also allowed us to have two receivers scanning at all times while the third one could be used to listen to a passing fish. The monitoring station was staffed 24 hours a day during periods when fish were migrating past. Of all fish observed in the estuary, 76-95% of barged fish and 77-100% of run-of-river fish were detected at the monitoring station.

Detailed behavior of individual migrants was also examined. Boats were used to continuously monitor the behavior of individuals as they traversed the estuary; these included both radiotagged fish that were released upstream from barges or at Bonneville as part of our regular release groups, or fish that had been equipped with sonic telemetry tags and released in the estuary by us. Once tracking began we attempted to keep the boat close to the fish at all times, and used a GPS (geographic positioning) unit to obtain the location of the boat at approximately 10 minute intervals. Typically, tracking began in the morning and continued until (1) the fish entered seawater, (2) the fish could not be followed because of shallow water or the signal was otherwise lost, or (3) weather or other factors made continued tracking unsafe.

Water quality data was also collected during tracking in order to determine the immediate environmental conditions associated with the fish. A Hydrolab Corporation datasonde IV and a YSI model 85 D.O/salinity meter were used to measure water quality parameters such as salinity, temperature, and dissolved oxygen at several depths. We are not able to report these data because a malfunction of the Hydrolab resulted in the loss of most of this information.

Early in the season yearling chinook tagged with sonic transmitters were tracked by boat. The use of sonic tags was intended to provide data concerning fine-scale movement patterns of migrants as they made the transition from freshwater to saltwater, where radiotags are unusable due to attenuation of the radio signal. Releases of these fish were made at various locations ranging from river mile 34 to river mile 20, with tracking beginning immediately after release. The very short range of the tag (200m) made it imperative to maintain constant contact with the fish because it was unlikely that a fish could be found once the signal was lost. Since our objective was to follow these individuals into saltwater, releases were made in the estuary to make it possible for a boat crew to follow the fish into seawater within a reasonable time frame.

The sonic tags used were obtained from Sonotronics, Tucson, AZ. They were 8 mm in diameter, 20 mm long, weighed 2.4 g in air and had a battery life of 15 days. Transmitting at a frequency of 70-79 kHz, these tags had a range of approximately 200 m. Fish to be tagged were collected from the fish separator at the Lower Granite Dam Juvenile Fish Facility and anesthetized in 50 mg/l MS222 buffered with 100 mg/l $NaHCO_3$. The transmitter was then

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surgically implanted into the body cavity. Due to the relatively large size of the tag, no fish under 15 cm (fork length) were tagged. Following tagging, 1 sonic tagged fish, 1radiotagged fish, and 5-6 untagged fish were placed in each of three 33 gal live wells and allowed to recover. The addition of untagged fish was intended to reduce stress in tagged fish that might be result from isolation. Among salmonids, juvenile chinook are relatively gregarious and often form schools (Kelsey, 1996). The livewells were secured on the barge or placed on the barge dock as described above. These livewells were submerged in the middle or forward barge compartments and remained on the barge until it reached Bonneville Dam. Here the livewells were removed, held at Bonneville First Powerhouse DSM overnight, and transported to the estuary the following day where the livewells were secured next to docks in the river. At various times fish were held at the towns of Cathlamet, Skamokowa, and Astoria. Fish from a single livewell were released each day starting the next morning.

Concerns about holding conditions of these fish led us to shift our approach to using radiotagged fish that had been released from barges or at Bonneville. It was felt that tagged fish who could successfully migrate 100 miles or more downstream to the estuary might be more representative of the population of migrants in the estuary than the sonic tagged fish we were releasing. (Many of these sonic tagged fish were observed to migrate only a short distance before stopping, after which some were believed to be taken by predators.) In addition, the advantage of using sonic tags was lost because there was very little saltwater intrusion past the Columbia River mouth, a result of high flows. We did not have the boats available to safely navigate the Columbia River bar and track fish offshore.

During the course of data analysis, three individuals of 304 released were censored (i.e. removed) from the data set due to nonsensical sets of observations (Tables 1, 3). A fish was censored when it was observed in two widely separated locations at approximately the same time and there was no clear indication of operator error, or conflict with radiotags on similar frequencies released by other researchers. Additionally, two other individuals were removed from the data set because of failure of the tag.

Task 2. Determine how the development and health status of migrants collected at Snake River dams and transported relates to their behavior and survival in the Columbia River estuary; relate fish quality and performance of barged fish to performance of run-of-the-river fish.

Health status and smoltification were determined in juvenile chinook salmon migrants collected at the same time and place as radiotagged fish described in task 1. Yearling chinook were collected from the Lower Granite Fish Facility and from the barge shortly before release which made it possible to compare the quality of fish before and after transportation. At Lower Granite fish were dipnetted from the flume immediately downstream of the separator. Our original plan was to collect fish from the gatewell in order to obtain data from fish that had minimal exposure to the collection system, but we were unable to capture any fish here using a lift-net. Recently installed extended-length bypass screens caused significantly more upwelling of water into the gatewell than in previous years, making the gatewell much more turbulent and possibly reducing the holding time of migrants (Tim Wik, personal communication). The post-transport sample was collected form the barge while it was in the navigation lock at Bonneville Dam, approximately 1 hour before release. Fish were obtained on the barge by pulling a lift net in the same compartments that held radiotagged fish. A description of fish collected for physiological sampling can be found in Table 4.

Fish were immediately anesthetized in 200 mg/l tricane methanesulfonate (MS222) buffered with 500 mg/l $NaHCO_3$. Length, weight, and the presence of fin clips was then recorded for each fish. The fish were bled by severing the caudal peduncle, after which whole blood was collected into ammonium-heparinized capillary tubes. Whole blood was centrifuged, and the plasma removed and immediately frozen on dry ice. Plasma was stored at -20 ^{o}C.

We measured plasma cortisol concentration as an index of stress. Plasma cortisol is a widely accepted measure of the primary (neuroendocrine) response to stress (Mazeaud et al., 1977). Thawed plasma samples were assayed for cortisol using a radioimmunoassay (Foster and

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Dunn, 1974) as modified for use with salmonid plasma (Redding et al., 1984). Degree of smoltification was estimated by measuring gill Na^+/K^+ ATPase. Gill filaments were collected into a buffer solution (Zaugg, 1982) and frozen on dry ice. The samples were then sent to Dr. Alec Maule (USGS-BRD Northwest Science Center, Columbia River Field Station) for analysis. The kidney tissue of each fish was removed, frozen, and sent to Dr. Ron Pascho (USGS-BRD Northwest Science Center, Seattle) to test for the presence of bacterial kidney disease. Presence and severity of infection was measured using the technique of Pascho et al. (1991).

We collected yearling spring chinook on all six barge trips in which radiotagged groups were released. In addition to documenting the health condition for each cohort of radiotagged fish, this also allowed us to measure differences in the response to transportation over the migration season. Conditions within the barges on each sampling date are summarized in Table 2. Health and smoltification indicators were compared to migration behavior (primarily migration speed) and survival of the corresponding radiotagged groups in a effort to determine if these indicators are predictive of post-release performance.

Task 3. Establish the relationship between fish behavior and physiological indicators of fish quality so that monitoring of fish may be predictive of successful ocean entry after release from barges.

A system for testing salinity preference in a vertical salinity gradient was developed. The experimental setup consists of 760 L rectangular fiberglass tanks (1.83 x 0.66 x 0.60 m) with acrylic windows in front that are placed in a quiet room and visually isolated by black plastic curtains. The tanks are exposed to a diffused 20W flourescent light which provides even light intensity over the surface of each tank, with photoperiod adjusted to ambient conditions. During acclimation flow-through well water is supplied to the tanks. At the start of a test approximately 380 L of saltwater (Instant Ocean™, 30 ppt) is introduced to the bottom of the tank over a period of approximately 1 hour to establish a salinity gradient. The window of each test tank is marked to show the final dividing line between fresh and saltwater.

Fish to be used for testing are transported to Oregon State University's Oak Creek Laboratory, and 13 fish are placed in each test tank and allowed to acclimate for 48h. Following acclimation position of fish in the water column is observed for 15 minutes, then saltwater introduced. The position of fish is noted every five minutes thereafter for the next 90 minutes. Fish position and behavior are noted once more after 24 hours and salinity is measured at the top, middle and bottom of the test tanks.

We examined the feasibility of conducting salinity preference tests in the field using fish obtained from barges. The smolt evaluation facilities at both powerhouses at Bonneville Dam were examined as locations for conducting these tests, but it was determined that the noise level in these areas could impact behavior of the fish. As an alternative, fish will be brought to Oregon State University where tests can be conducted under more controlled conditions. This system was used successfully to examine juvenile chinook salmon reared in net pens in Young's Bay, Oregon by the Port of Astoria. Fish were transported to Corvallis, allowed to acclimate for two days, and tested as above.

Tests are currently in progress to examine the effects of bacterial kidney disease infection and smoltification on saltwater preference.

RESULTS

Following release radiotagged yearling chinook migrated 86-90 miles downstream to the monitoring station in 27-85 hours, consistent with a sustained velocity of approximately 1-3 miles per hour (Figures 4, 5). Migration speed in the lower Columbia River appeared to be influenced by both river flows and fish condition. Yearling run-of-river chinook migrated faster than barged chinook released at the same time under identical flow conditions on two of three release dates (Fig. 5); this difference in travel time must be the result of some difference in fish condition. Travel time decreased over the course of the migration season in both barged fish ($p<0.0001$, ANOVA) and in run-of-river fish ($p=0.01$, ANOVA). Flows generally increased over this period, but discharge at Bonneville was high throughout the migration season, with flows typically between 400 kcfs and 500 kcfs (Figure 6). An increase in travel time of barged chinook

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was observed for the 8 May release group that was simultaneous with a brief drop in flows (Fig. 4).

Large portions of both barged and run-of-river chinook successfully migrated to the estuary: 74% to 97% of radiotagged barged chinook and 77% to 91% of run-of-river chinook were observed at or downstream of the exit monitoring station at river mile 55.5 (Figures 7, 8). There was a significant difference in the proportion of the fish reaching the estuary between all four dates (p=0.02, Chi-square test) but this difference was not consistent over the migration season. There was no difference between the first two dates and the last two dates (p=0.94, Fig. 7). There was no significant difference between barged and run-of-river groups in the proportion of the fish reaching the estuary for groups released on 16 May (p=0.97, Chi-square test) and 24 May (p=0.21), but more barged fish were observed to reach the estuary on 1 June (p=0.009). A total of 84% of all barged fish and 84% of run-of-river fish were known to have passed the monitoring station.

Radiotagged fish that were never observed accounted for 3-26% of barged fish and 9-23% of run-of-river fish. All tags were known to be functioning immediately before release, so these missing fish must be the result of: (1) radiotags that were regurgitated during the barge trip and sank out of radio range when the barge was emptied, (2) fish that were dead at release and sank out of radio range, (3) fish that were taken by predators after release and whose remains were deposited out of radio range, (4) individuals that migrated successfully but went undetected. As described in 1996, we believe that tag regurgitation probably explains many of these observations. Regardless of the reason certain individuals were never observed, it was assumed that all tags were inside fish and transmitting radio signals and could be detected by the radio receivers. If this assumption is false, then the true sample size of observable radiotagged fish is reduced and the relative proportion of fish reaching the estuary is higher than reported.

Of the radiotagged chinook that were observed downstream of the exit monitoring site, 3% to 18% of barged fish and 4% to 16% of run-of-river radiotagged fish were observed two or more times in colonies of piscivorous birds on Rice Island or once on East Sand Island and were considered "probably dead" (Figure 9, 10). An additional 0% to 14% of barged fish and 3% to 12% of run-of-river fish were observed on Rice Island once (Fig. 9) and were considered "possibly dead" because it is unclear if these observations represent individuals that were eaten

but whose tag was deposited away from the colony, or whether these fish were alive and in the water adjacent to the island. Any radio signals observed on East Sand Island were assumed to represent mortalities since it is unlikely radio signals would be detected from living fish near the island due to the presence of saltwater. The proportion of barged fish found in bird colonies (both of the above categories combined) did not change over the course of the outmigration; ($p=0.32$, Chi-square). Mortality of barged fish was higher than run-of-river fish on 1 June ($p=0.04$, Chi-square) but there was no difference on 24 May ($p=0.25$) or 16 May ($p=0.78$), or when all three dates were pooled ($p=0.70$). Out of all observations of both barged and run-of-river chinook, 13% of all fish known to have reached the estuary (27 individuals) were "probably dead" and 7.8% were "possibly dead", to give a total potential mortality of 21%.

At this time we do not know what influences the level of predation on migrating salmonids in the estuary, but such factors must fall into two general categories: (1) conditions that influence fishing pressure from birds, and (2) phenomena that change the vulnerability of salmonid migrants to predation. The fishing pressure exerted by piscivorous birds is the result of conditions such as population size and availability of alternate prey. Vulnerability of salmonid migrants could be increased by delay in seawater entry (increasing the exposure time to high concentrations of predators in the estuary), swimming higher in the water column, or other behavior that causes them to be more accessible to birds.

We did not observe any relationship between travel time to the monitoring station and predation; there was no difference in the travel times of fish that were eaten versus not eaten (Figure 11). This might suggest that whatever factors influence travel time are not necessarily related to predation risk in the estuary. Conversely, travel time of migrants could conceivably influence survival in the estuary by determining the time of arrival of fish in areas were birds forage. If migrants were to reach the lower estuary on an ebb tide during hours of darkness, they may traverse many of the areas of highest predation pressure when birds are not foraging. Unfortunately, data collected in 1997 does not allow us to test this hypothesis since estimated arrival times in the lower estuary were predominantly during daylight hours.

Migrating radiotagged chinook observed from the air were often found in or near the shipping channel, especially in the upper estuary (river miles 30-60; Figures 12, 13). In the lower estuary (downstream of river mile 30) limited use of side channels was observed, and

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compared to previous years many fish were found in the central portion of the estuary, away from the shipping channel. This was somewhat unexpected, since most of this area is quite shallow (5 ft deep or less at low tide) and contains a relatively small proportion of the total river flow. As in previous years the fish did not appear to reside in the estuary for any great length of time; individuals observed in the estuary on one day were rarely seen in the estuary the next day.

Detailed migration behavior as monitored by boat revealed a more complicated pattern of movement than the data obtained from aircraft suggested. Movement of fish through the lower estuary appeared to be strongly influenced by the tide, with fish moving downstream at rates up to 5-6 miles/h on the outgoing tide and slowing down or holding on the incoming tide (Figure 14). Individuals located in relatively shallow water at the low tide tended to hold over the flood tide, while fish located in the deeper water of the navigation channels in some cases actually moved upstream. In addition, the majority of individuals tracked by boat left the main shipping channel downstream of Rice Island and crossed over to the northern shore of the estuary. Fish moving across the shallow tidal flats that comprise much of the central portion of the estuary appeared to use small channels that traversed the flats. These channels typically had a depth of 2-4 ft at low tide, and were 10 to 30 feet wide.

Task 2. Determine how the development and health status of migrants collected at Snake River dams and transported relates to their behavior and survival in the Columbia River estuary; relate fish quality and performance of barged fish to performance of run-of-the-river fish.

Plasma cortisol levels of yearling chinook collected at the Lower Granite Juvenile Fish Facility did not change significantly over the course of the migration season, but remained at levels characteristic of moderate stress (Figure 15). This is in contrast to samples collected by us from 1992 to 1994 in which fish sampled from this location invariably showed high levels of plasma cortisol (in the range of 150 ng/ml), indicating that collection was quite stressful. It is unclear if collection was less stressful in 1997, or if individuals reached the Fish Facility before having time to reach peak levels of cortisol elevation, which often requires an hour or more. In 1997 the

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fish may have reached the fish facility much faster due to reduced holding time in the gatewell, associated with installation of extended-length fish diversion screens as described earlier.

Cortisol levels of migrants collected at the end of the barge trip were highest during the peak of the outmigration season, and were elevated above pre-trip values at the end of April and first week of May (Figure 16). During the peak of the outmigration it appears likely that yearling chinook were moderately to highly stressed at the time of release. Individual post-transportation cortisol levels were positively correlated with loading density on the barge ($p=0.01$) but loading density explained only 7% of the variability in the cortisol data ($R^2=0.07$; Figure 16).

Gill Na^+/K^+ ATPase increased significantly over the course of the migration season (Figure 17), indicating that the degree of smoltification in migrating fish increased during the outmigration season. There was no change in gill Na^+/K^+ ATPase over the course of the barge trip, so samples collected from the same cohort of fish were pooled for analysis. Elevated gill Na^+/K^+ ATPase may be associated with reduced travel times in the lower Columbia. Median gill ATPase of barged fish explained 56% of the variation in travel time of radiotagged fish transported on the same trip, although the p value was high ($p=0.09$, Figure 18). When ATPase was combined with an indicator of river flow (total discharge at Bonneville Dam) in a multiple regression, the r-squared was elevated to 87% with $p=0.045$.

Prevalence of bacterial kidney disease was high throughout the season, with 77-100% of all fish having detectable levels of infection (Figure 19). Most individuals had low levels of infection, with only 4-18% of fish showing moderate to high levels of infection.

Fish condition as reflected in the level of descaling did not appear to affect survival of radiotagged chinook (Table 5). Due to low numbers of fish with 10% or more descaling, all release groups were pooled; no difference was observed between barged and run-of-river fish in the proportion of fish descaled over 10% or more of the total body surface ($p=0.10$, chi-square). Individuals with more than 10% descaling reached the estuary in the same proportions as fish with less than 10% descaling ($p=0.82$, chi-square). The rate of mortality within the estuary was also the same for descaled and non-descaled fish ($p=0.48$).

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Task 3. Establish the relationship between fish behavior and physiological indicators of fish quality so that monitoring of fish may be predictive of successful ocean entry after release from barges.

Tests are currently in progress to examine the effects of bacterial kidney disease infection and smoltification on saltwater preference.

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