Entrainment of Crab in the Columbia River Estuary: Preliminary Results of Summer 02 Studies

Walter H. Pearson and G. D. Williams
Marine Sciences Laboratory
Pacific Northwest National Laboratory

John R. Skalski
University of Washington

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Topics Today

- Short Background on Modified DIM and Direct Entrainment Measurements
- Statistical Design of Field Sampling
- Preliminary Entrainment Results from Studies for Channel Improvement Project
- Status of MCR Entrainment Study
- Salinity Influence on Crab Distribution (Preliminary)
- Next Steps

Modified Dredge Impact Model (DIM) and Direct Entrainment Measurements

- Approach is hybrid of DIM with entrainment rate data from direct observations on dredge
- Extrapolate to Adult Equivalent Loss (AEL) at Midwinter Age 2+ and Midwinter Age 3+, and Loss to Fishery
- Compare Loss to Fishery with historic landings

Modified DIM Steps

- Entrainment rates (crabs per cy) directly measured on dredge (no need to reference trawl density)
- Entrainment rates times dredged volumes give crabs entrained
- Post-entrainment mortality rates from Wainwright et al. (1992) give immediate losses
- Natural survival curves from Wainwright et al. (1992) give Adult Equivalent Loss to midwinter Age 2+; subsequent survival to midwinter Age 3+ assumed to be 45% (Armstrong et al. 1991)
- Natural survival curves (Wainwright et al. 1992), sex ratio, and harvest rate (70%) give Lost Recruits
- Statistical sampling design enables calculation of error rates on AEL and Lost Recruits
- Lost Recruits vs. landings (WDFW and ODFW) gives perspective

Statistical Analysis to Develop Sampling Design for JUN02 Entrainment Pilot Study

- Examined raw data from Larson (1993)
- Identified variance components
  - Day to day
  - Load to load within a day
  - Basket sample to basket sample within a load
- Day to day variation proved to be the dominant variance component
- Therefore, recommended sampling all days of dredging sequence (over 5 to 6 days of dredging)

Statistical Analysis to Develop Sampling Design for JUN02 Entrainment Pilot Study

- Coefficient of Variation (CV) for selecting different rates of basket samples and load samples
- To be within +/- 25% of true value, we desire a CV of 0.125
- Recommended sampling at random half the loads within a day
- Recommended sampling loads at rate of 10 basket samples per load

Samples per Load	CV	
	All Loads	1/2 Loads
2	0.139	0.221
3	0.113	0.187
4	0.098	0.167
5	0.088	0.154
6	0.08	0.144
7	0.074	0.137
8	0.07	0.131
9	0.066	0.127
10	0.062	0.123

Results JUN02 Entrainment Pilot Study – CV Calculations for Selecting Sample Size

- Sample size of 2 basket samples per load yields CV <0.125 for age 1+ and 2+ crabs

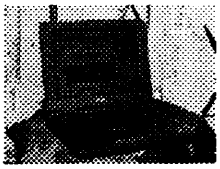
Number of Basket Samples	Coefficient of Variation (CV) by Age Class			
	0+*	1+	2+	3+
1	0.185	0.064	0.151	0.268
2	0.149	0.049	0.103	0.24
3	0.135	0.043	0.086	0.23
4	0.127	0.04	0.076	0.224
5	0.122	0.038	0.07	0.221

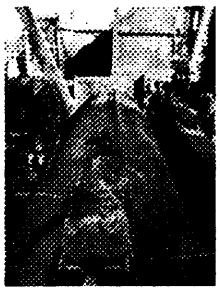
Statistical Design for Summer 02 Entrainment Measurements

- Statistical Sampling Design
  - Random sample of half the loads dredged
  - Rate of 3 basket samples per load
  - Assumes sampling about 350 loads from 8 JUL through OCT 02
- Location: Mouth of Columbia River primarily with some dredging upriver of RM3

Measurement of Flow into Basket Sampler

- Specialized flowmeter mounted on *Essayons* measured fluid velocity and fluid depth.





Measurement of Flow into Basket Sampler

- Flow into basket sampler as proportion of total flow coming onboard was **0.26 +/- 0.03 (95% CI)**
- No evidence to reject the value of 0.25 based on piping schematics used by Larson 1993
- All calculations of entrainment rates use factor of 0.25

Entrainment Sampling Upriver from RM3

- Entrainment Sampling on Essayons

- Locations and Dates:

•Desdemona Shoals	11 to 15 JUN 02	RM +4 to +7
•Desdemona Shoals	17 SEP 02	RM +4 to +7
•Upper Sands	23 SEP 02	RM +16
•Miller Sands	1 to 8 OCT 02	RM +21 to +24

Entrainment Sampling Upriver from RM3

- Location Desdemona Shoals JUN 02

Total Dredged Volume (cy)	186,737
Total loads dredged	33
Total loads sampled	17
Total basket samples	169

Entrainment Sampling Upriver from RM3

- Location Desdemona Shoals SEP 02

- Total Dredged Volume (cy) 30,012
- Total loads dredged 6
- Total loads sampled 4
- Total basket samples 12

Entrainment Sampling Upriver from RM3

- Location Upper Sands SEP 02

- Total Dredged Volume (cy) 54,036
- Total loads dredged 9
- Total loads sampled 9
- Total basket samples 27

Entrainment Sampling Upriver from RM3

- Location Miller Sands OCT 02

- Total Dredged Volume (cy) 443,563
- Total loads dredged 75
- Total loads sampled 36
- Total basket samples 140

Preliminary Entrainment Rates (crabs/cy) for Locations Upriver of RM3

	Age Class			
Location	0+	1+	2+	3+
Desdemona	0.005	0.193	0.024	0.001
Desdemona	0.000	0.022	0.065	0.033
Upper Sands	0.010	0.010	0.000	0.000
Miller Sands	0.000	0.000	0.000	0.000

Note: Uses factor of 0.25 to calculate volume in basket sample

Contribution by Age Class to Adult Equivalent Loss (Age 2+)* - Dredge Volumes Completed

	Age Class				
	0+	1+	2+	3+	Total
Desdemona JUN					
Male	<1	1,757	1,899	71	3,728
Female	<1	1,707	633	71	2,412
Desdemona SEP					
Male	0	31	546	421	998
Female	0	31	546	421	998
Upper Sands					
Male	<1	26	0	0	27
Female	<1	26	0	0	27
Miller Sands	0	0	0	0	0

* (To midwinter (Feb) of Age 2+)

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Contribution by Age Class to Adult Equivalent Loss (Age 3+)* - Dredge Volumes Completed

	Age Class				
	0+	1+	2+	3+	Total
Desdemona JUN					
Male	<1	790	855	32	1,679
Female	<1	768	285	32	1,086
Desdemona SEP					
Male	0	14	245	189	449
Female	0	14	245	189	449
Upper Sands					
Male	<1	12	0	0	12
Female	<1	12	0	0	12
Miller Sands	0	0	0	0	0

* (To midwinter (Feb) of Age 3+)

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Total Crabs Entrained (E) and 95% Confidence Limits

Total (all age classes) E for 186,737 cu yd at Desdemona for JUN 02

E = 41,759 +/- 4,099 crabs entrained (CV = 5%)

Goal of having CV less than 12.5% was achieved.

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Total Adult Equivalent Loss (AEL) and 95% Confidence Limits

Total (all age classes) AEL for 186,737 cu yd at Desdemona for JUN 02

AEL at 2+ = 6,140 +/- 821 crabs (CV = 6.8%)

AEL at 3+ = 2,763 +/- 370 crabs (CV = 6.8%)

Goal of having CV less than 12.5% was achieved.

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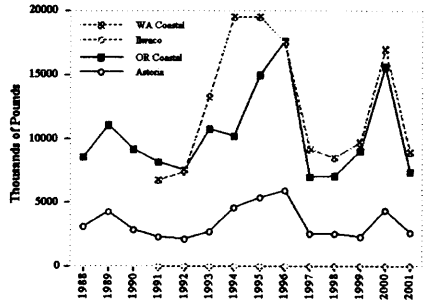
Loss to Fishery and 95% Confidence Limits

Loss to Fishery =
1174 +/- 259 crabs (CV = 11.2%)

– based on 186,737 yd^3 dredged

In Columbia River areas, average annual catch is 5.3 million crab

Background: Commercial Crab Landings by Year



Summary of Projected Entrainment, Adult Equivalent Loss, and Fishery Loss

Location: Desdemona (Using JUN 02 Rates)

Planned Volume	Deepening (411,042 cy)	M&O (585,070 cy)
AEL 2+	13,516	19,239
AEL 3+	6,082	8,657
Fishery Loss	2,129	3,030

Summary of Projected Entrainment, Adult Equivalent Loss, and Lost Recruits

Location: Desdemona (Using SEP 02 Rates)

Planned Volume	Deepening (411,042 cy)	M&O (585,070 cy)
AEL 2+	27,330	38,901
AEL 3+	12,299	17,505
Fishery Loss	4,304	6,127

Note: 2+ and 3+ crab entrainment higher in SEP than in JUN

Summary of Projected Entrainment, Adult Equivalent Loss, and Lost Recruits

Location: Upper Sands (Using SEP 02 Rates)

	Deepening (858,622cy)	M&O (154,087cy)
Planned Volume		
AEL 2+	853	153
AEL 3+	384	69
Fishery Loss	134	24

Status of MCR Sampling as of 15 OCT 02

- Days in MCR 64
- Days Sampled in MCR 57
- Total loads in MCR 489
- Loads sampled in MCR 215
- Total basket samples 644

- Notes:
  - Changes in dredge schedule
  - Salinities generally above 30 o/oo

Preliminary Entrainment Rates (crabs/cy) for MCR Summer 02

	Age Class			
Location	0+	1+	2+	3+
MCR	0.003	0.014	0.032	0.010

R for all age classes = 0.059 crabs per cy

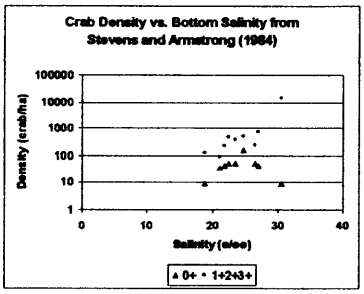
Note: Uses factor of 0.25 to calculate volume in basket sample

Crabs and Salinity: Preliminary Analyses

- Salinity-Crab Density Model
- Salinity in the Columbia River Estuary
- Scenarios of Salinity Intrusion
  - Extremes from Jay and Smith (1990) data on salinity intrusions
  - Median low flow salinity from Jay and Smith (1990)
  - May and September 2002 CORIE/ELCIRC forecasts
- Summer 02 Salinity Data

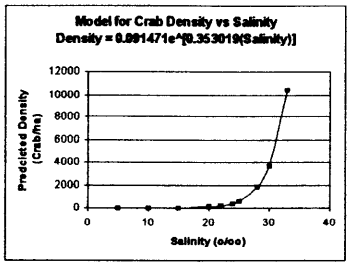
Crab Density : Bottom Salinity Relationship

- Density of 1+ and older crabs falls logarithmically as bottom salinity decreases
- 0+ crab have complex relationship with bottom salinity
- Data from Stevens and Armstrong (1984)



Crab Density : Bottom Salinity Relationship

- Equation from regression analysis of data from Stevens and Armstrong (1984)
- Equation is for 1+ and older crab
- Predicted density at 20 o/oo is about 1% of that at 32 o/oo



Crab and Salinity

- Salinity Intrusion in Columbia River is Complex Compared to Other Estuaries
- Large freshwater flows through a shallow estuary
- Two channels
  - Tidal exchange dominates in North Channel, which is saltier
  - River flow dominates in South Channel, which is less salty
- River flow levels and neap-spring tide transitions interact to produce greatest salinity intrusion at neap tides during low flows

Salinity Intrusion in the Columbia River Varies by River Flow AND Tidal Regime

Conditions			Within Isohaline at Position					
Flow	Tide	Max/Min	RM0	RM5	RM10	RM15	RM18	RM20
Low Flow	Neap	Minimum	25	20	5	5	5	5
Low Flow	Neap	Maximum	32	32	25	25	25	20
Low Flow	Spring	Minimum	15	15	5	1	0	0
Low Flow	Spring	Maximum	33	32	30	25	20	15
High Flow	Spring	Minimum	0	0	0	0	0	0
High Flow	Spring	Maximum	33	33	30	10	0	0

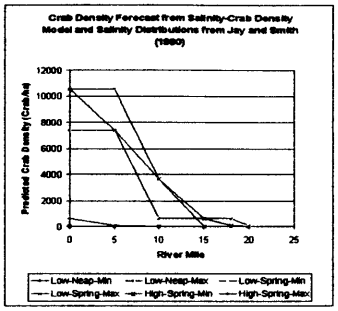
- Data from Jay and Smith (1990) for South Channel of Columbia River
- Low Flow 120 to 150 Kcfs
- High Flow 535 to 570 Kcfs

Crab Density Forecasts Under Different Scenarios

- Using the 6 conditions from Jay and Smith (1990) that cover extremes of flow and salinity intrusion
- Using the median of low flow conditions from Jay and Smith (1990)
- Using CORIE/ELCIRC forecasts of bottom salinity for May and September of 2002

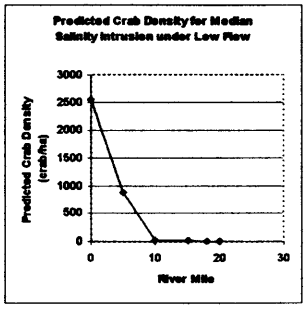
Under Most Salinity Intrusions, Modeling Shows Highest Crab Densities Are Seaward of RM10

- Using salinity intrusions from Jay and Smith (1990)
- Using Salinity-Crab Density Model derived from Stevens and Armstrong (1984)
- Highest upstream crab densities are for maximum intrusion under low flow and neap tides

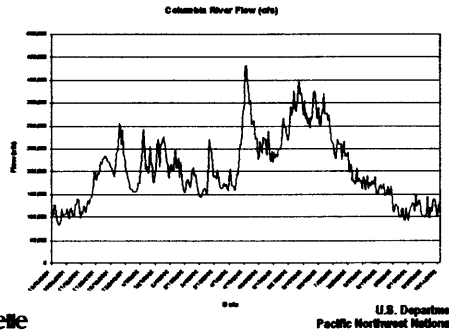


Using Median of Low Flow Salinity Intrusions, Modeling Shows Low Crab Densities At and Above RM10

- Using median for salinity intrusions under low flow from Jay and Smith (1990)
- Using Salinity-Crab Density Model derived from Stevens and Armstrong (1984)

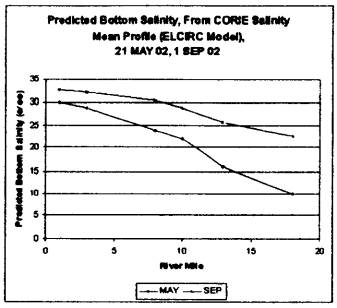


2001/2002 Flow in Columbia River



Bottom Salinities Forecast by CORIE/ELCIRC for 21 MAY and 1 SEP 02

- From CORIE Salinity Mean Profile for 21 May and 1 SEP 02
- Under lower river flow in SEP, bottom salinities at RM18 were predicted to be about 23 o/oo
- At RM18, predicted salinity in MAY was 10 o/oo



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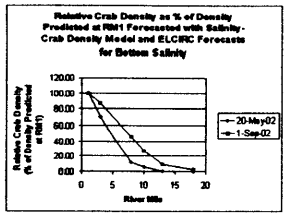
Under 2002 Flows, Modeling Shows Low Crab Densities At and Above RM10

- 21 May 02 flow: 356Kcfs
- 1 Sep 02 flow: 133Kcfs
- Predicted crab density at RM13 as % of density at RM1
  - May 02: <1%
  - Sep 02: 9%



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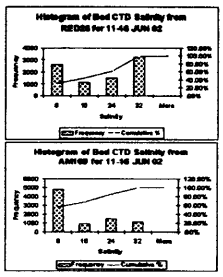
Salinity Regimes in Columbia River JUN02

- Salinity measurements from bed CTD at CORIE stations RED26 (RM3) and AM169 (RM13) for 11-16 JUN 02
- Near Desdemona 62% of the bottom salinity measurements were above 24 o/oo
- CR Flow: 300-350Kcfs



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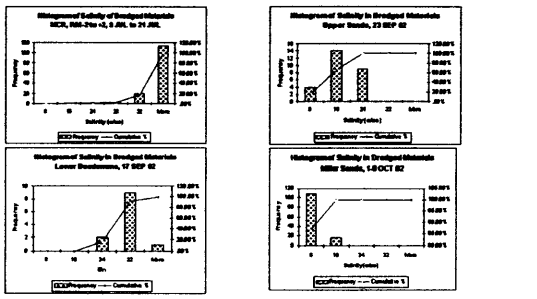
Salinity Regimes in Columbia River Summer 02



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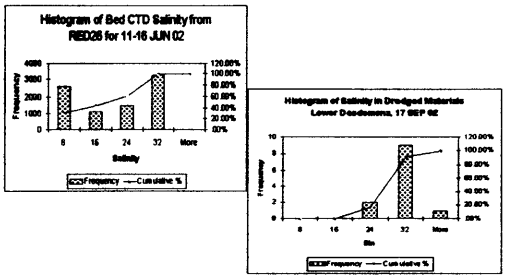
Salinity near and at Desdemona JUN vs. SEP



Relationship Between Preliminary Entrainment Rate (crabs/cy) and Salinity

	Entrainment Rate	Salinity (o/oo) %>32	%<16
MCR	0.059	96	<1
Desdemona JUN	0.224	38	16
Desdemona SEP	0.119	83	0
Upper Sands	0.021	0	67
Miller Sands	0.000	0	100

Regressions Between Preliminary Entrainment Rates (crabs/cy) and Salinity

	Entrainment Rate		
Salinity (o/oo)	**All crab**	**Age 1+**	**Age 2-3+**
%>32	p=0.25	p=0.51	p=0.02* (r^2=0.81)
%<16	p=0.03* (r^2 =0.86)	p=0.15	p=0.01* (r^2 =0.91)

Crab Entrainment and Salinity: Preliminary Summary

- For all age classes, entrainment rates are significantly related to % of salinity observations less than 16o/oo
- For 1+ crabs, entrainment rates are not significantly related to salinity measurements
- For 2+ and 3+ crab, entrainment rates are significantly related to % of salinity measurements greater than 32o/oo and less than 16o/oo
- % of salinity measurements less than 16o/oo explains more of the variation

Summary Findings from Columbia River Crab Studies 2002

- Statistically rigorous sampling design yields precise crab entrainment rates; coefficient of variation <12.5%
- Directly measuring entrainment is a powerful approach; 281 loads and 992 basket samples collected from June – October 2002
- Issues related to sample volume were resolved; flow rates to crab sampler confirmed at 25%

Summary Findings from Columbia River Crab Studies 2002

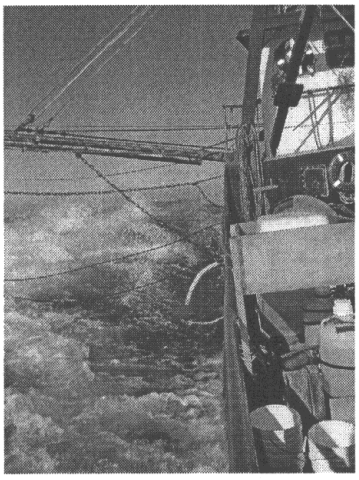
- Adult equivalent loss (AEL) and losses to fishery were estimated from summer 2002 entrainment rates; losses were also estimated based on projected deepening volumes
- Bottom salinity affects crab entrainment, especially for age 2-3+

Next Steps

- Elaborate the Salinity-Crab Density Model
- Final analysis of entrainment data in OCT 02
- Report in late NOV 02

MCR Ocean Disposal Sites

Preliminary Results on 2002 Surveys
MEC Analytical Systems, SAIC and EHI
28-29 Oct 2002

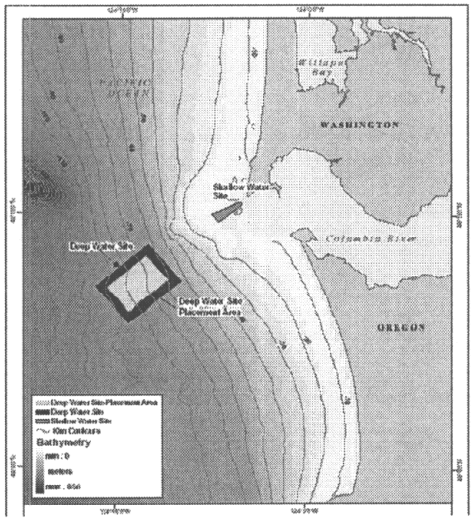


Presentation Objectives

- Overview of study objectives
- Overview of sampling activities
- Preliminary data results

Study Objectives

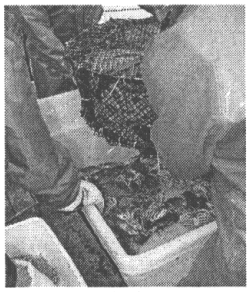
- Evaluate The RELATIVE Abundance Of Fishery And Ecological Resources WITHIN AND BETWEEN Alternative Disposal Sites.



SAMPLING OBJECTIVES

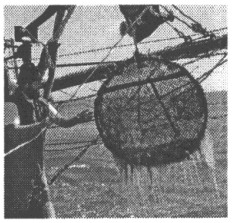
SHALLOW WATER DISPOSAL SITE

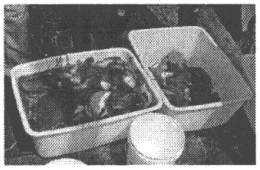
- Trappable Dungeness Crab Assessment Using Modified Commercial Crab Pots
- Demersal Fish and Invertebrate Assessment Using a Modified Willis Otter Trawl

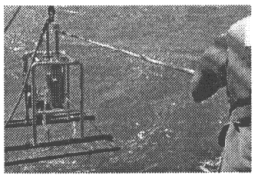


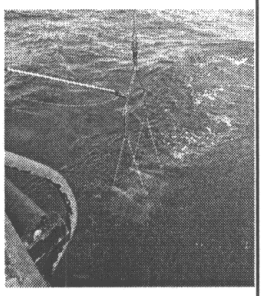
SAMPLING OBJECTIVES
DEEP WATER DISPOSAL SITE

- Trappable Dungeness Crab Assessment Using Modified Commercial Crab Pots
- Demersal Fish and Invertebrate Assessment Using a Modified Willis Otter Trawl
- Distinguish Benthic Habitat Types Using Sediment Profile Imaging (SPI)
- Compare Benthic Community Structure and Function Within Deep Water Habitat Types Using Benthic Grab Samplers (Modified Double Van Veen Grabs)

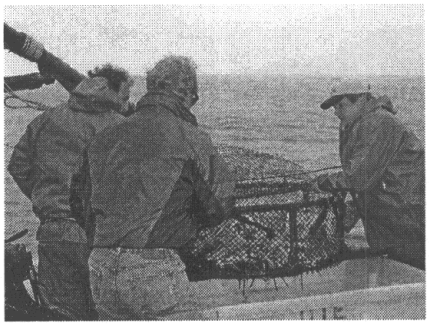






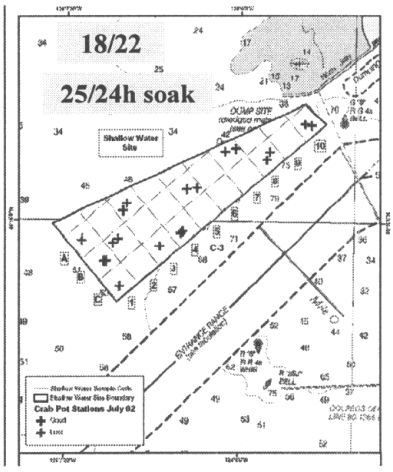


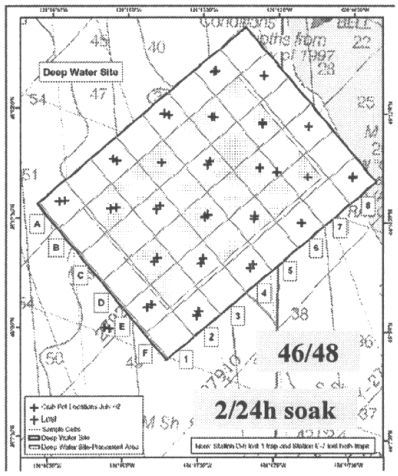
MODIFIED COMMERCIAL CRAB POT SURVEYS



CRAB POT SURVEY LOCATIONS

(Late Spring/Early Summer 2002)





CRAB POT DATA SUMMARY

Late Spring/Early Summer 2002

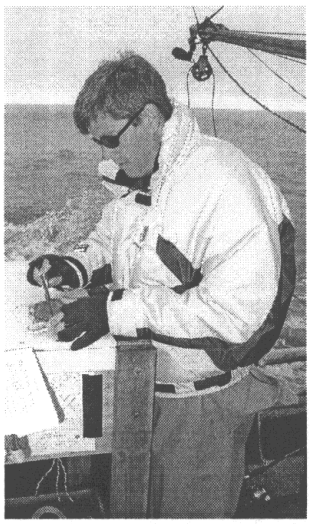
Shallow Water Site

- <77 Crab/24 hour soak
- 18/22 deployments recovered
- 451 crab recovered = ~25/pot/24 h soak
- Average carapace length = 5.1 inch
  - Maximum Size – 7.2" and 6.7"
  - Minimum Size – 2.8" and 3.4"
- Majority were female (~75%) and < legal size
- Majority were relatively soft (merus deflection with slight pressure)

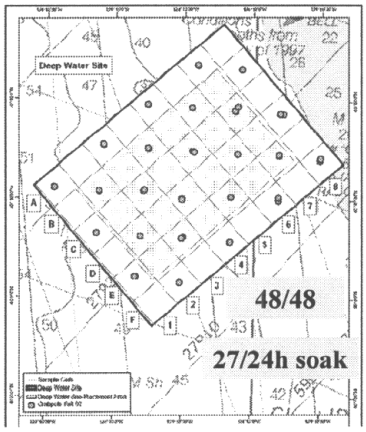
Deep Water Site

- <10 crab in one 24 hour soak
- 46/48 deployments recovered
- 82 crab recovered = <2/pot/24 h soak
- Average carapace length – 5.5 inch
  - Maximum Size – 7.4" and 6.3"
  - Minimum Size – 4.0" and 4.6"
- Majority were female (~80%)
- Majority were hard

Deep water crab were harder and larger but much fewer (>10-fold)



CRAB POT SURVEY LOCATIONS (Fall 2002)



CRAB POT DATA SUMMARY Fall 2002

Shallow Water Site

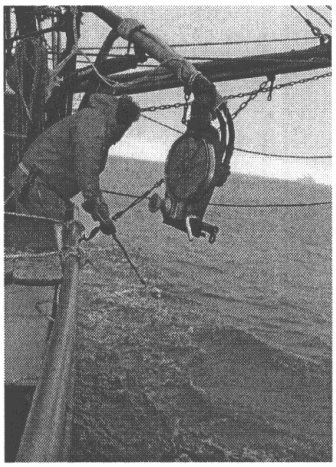
- 13-75 Crab/24 hour soak
- 22/24 deployments recovered
- 852 crab recovered = ~39/pot/24 h soak
- Average carapace length = 5.9 inch (0.8" increase)
  - Maximum Size – 8.4" and 7.5" (<1.2" increase)
  - Minimum Size – 4.2" and 2.2"
- Majority were female (69%)
- Majority were hard (89%) (merus deflection with slight pressure)

Deep Water Site

- 0-64 crab in one 24 hour soak
- 48/48 deployments recovered
- 1313 crab recovered = ~27/pot/24 h soak
- Average carapace length – 5.9" inch (0.5" increase)
  - Maximum Size – 7.9" and 7.2" (<0.9" increase)
  - Minimum Size – 2.1" and 2.5"
- Majority were male (90%)
- Majority were soft (80%)

All Crab were more abundant in Fall

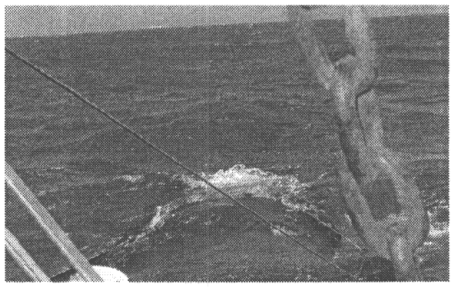
Deep water crab were fewer than shallow water, of equivalent size to the shallow water crab but were significantly softer

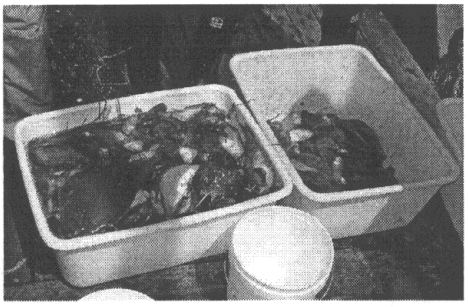


Summary of Crab Pot Collections in Late Spring and Fall 2002

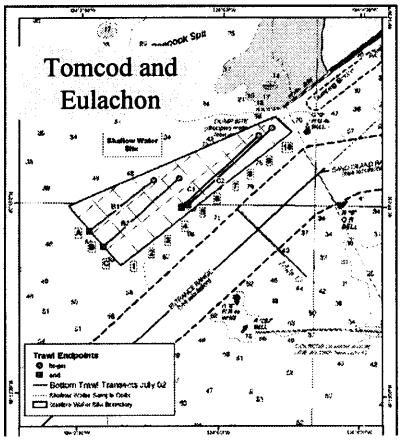
- Late Spring/Early Summer - Trappable shallow water crab are more abundant (~10-fold) but smaller than deep water crab (average of ½" smaller).
- All crab were more abundant and larger during Fall (0.5to ~1")
- Fall – Trappable shallow water crab were more abundant, harder and of equivalent size to deeper water crab populations.
- Fall crab were on average 0.5 to 1.0 inches larger than late spring early summer crab.

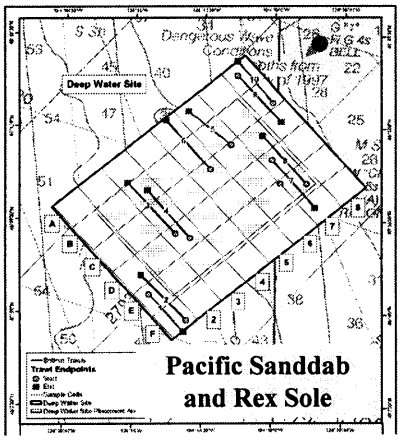
MODIFIED OTTER TRAWL SURVEYS



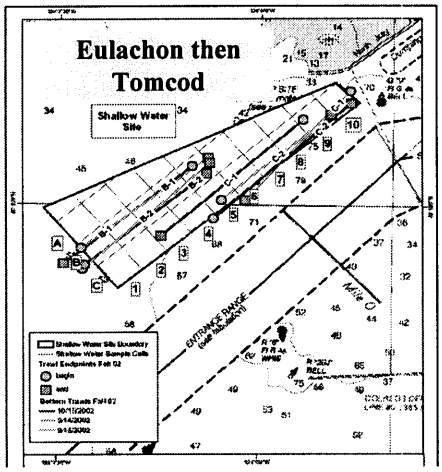


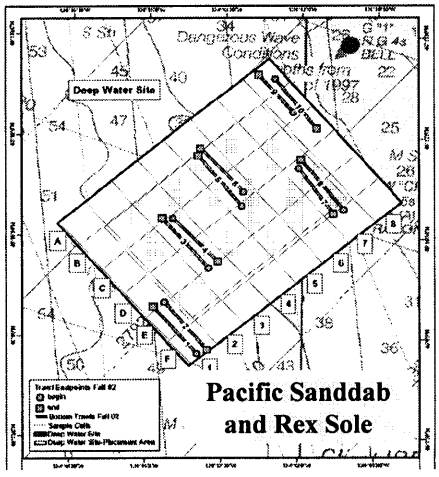
MODIFIED OTTER TRAWL SURVEYS – Late Spring/Early Summer 2002



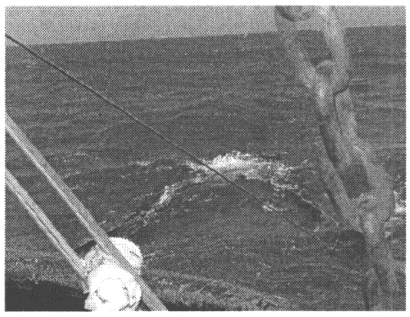


MODIFIED OTTER TRAWL SURVEYS – Fall 2002





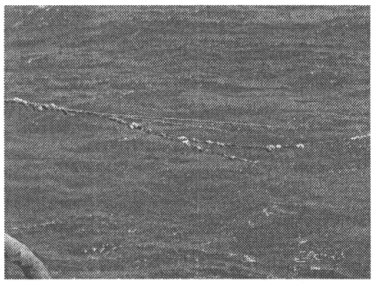
MODIFIED OTTER TRAWL SUMMARY OF SURVEYS
Fish - Late Spring/Early Summer 2002



Summary of Fish Catch (Late Spring/Early Summer2002)				
Characteristic	Shallow Water		Deep Water	
	Min	Max	Min	Max
No of Species	1	14	5	11
Abundance	5	762	43	1179
Most Abundant				
Tom Cod	<228			
Eulachon	<356			
Pacific Sanddab				<1072
Rex Sole				<168
Biomass (kg)	<1	<78	2	52
Big Skate	<48			
Pacific Sanddab				<34
Diversity	0	1.96	1.4	1.8
Tumor Incidence				
English Sole	<10%			
Rex Sole				<15%

MODIFIED OTTER TRAWL SUMMARY OF SURVEYS
Invertebrates - Late Spring/Early Summer 2002

Summary of Invertebrate Catch (Late Spring/Early Summe 2002				
Characteristic	Shallow Water		Deep Water	
	Min	Max	Min	Max
No of Species	1	5	5	12
Abundance	82	149	12	140
Most Abundant				
Luidia			<37	
Biomass (kg)	<50		<5	
Echinoderm/Sea Anemone			<1.5	



MODIFIED OTTER TRAWL SUMMARY OF SURVEYS
Late Summer 2002 Survey

Summary of Fish Catch (Summer2002)				
Characteristic	Shallow Water		Deep Water	
	Min	Max	Min	Max
No of Species	5	10	7	9
Abundance	28	865	64	479
Most Abundant				
Eulachon	788		na	
Pacific Tomcod	45		na	
Pacific Sandab			249	
Rex Sole			228	
Biomass (kg)	6	11	6	47
Starry Flounder	5.11		na	
Sand Sole	4.9		na	
Pacific Sanddab	na		31	
Dover Sole	na		19	
Tumor Incidence				
English Sole	~10%			
Rex Sole			~15%	

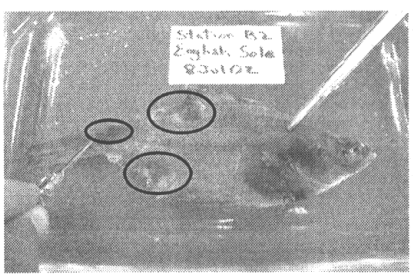
MODIFIED OTTER TRAWL SUMMARY OF SURVEYS
Summer 2002 Survey

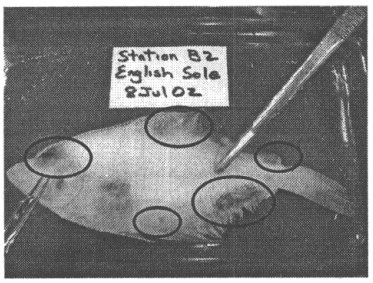
Summary of Invertebrate Catch (Summer2002)				
Characteristic	Shallow Water		Deep Water	
	Min	Max	Min	Max
No of Species	3	4	2	4
Abundance	158	222	7	43
Most Abundant				
Luidia	na		67	
Biomass (kg)	49		24	
Metridium	na		2.5	

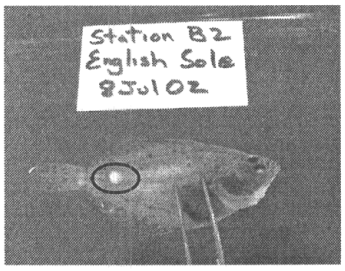
MODIFIED OTTER TRAWL SUMMARY OF SURVEYS
Fall 2002

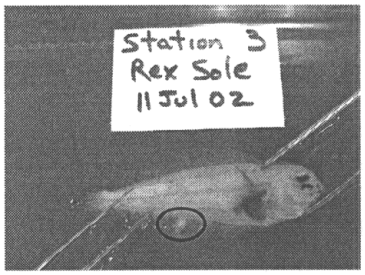
Summary of Fish Catch (Fall 2002)		
Characteristic	Shallow Water	
	Min	Max
No of Species	10	15
Abundance	201	1088
Most Abundant		
Pacific Herring	84	
Biomass (kg)	8.8	13.2
Big Skate	11.4	
Tumor Incidence		
English Sole	nm	
Rex Sole		

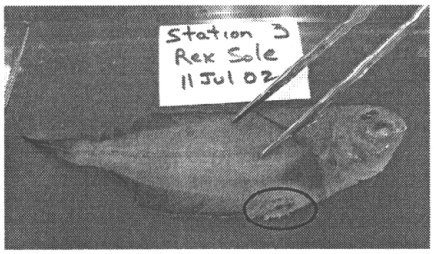
Characteristic	Shallow Water	
	Min	Max
No of Species	0	3
Abundance	0	132
Most Abundant		
Biomass (kg)	10.2	20.8

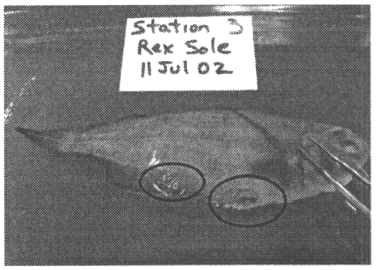


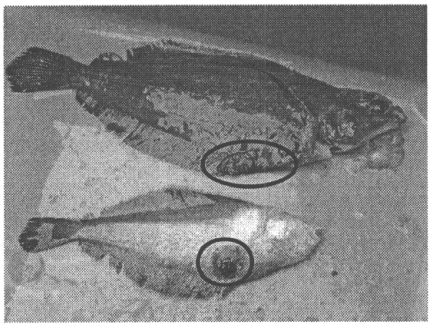




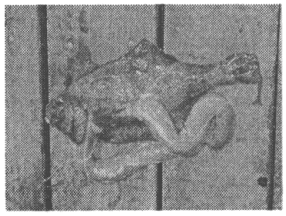


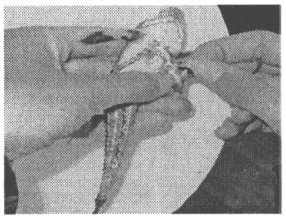


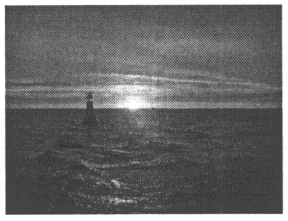




Examples of Catch







Trawl Summary
Late Spring/Early Summer 2002

- Late Spring trawlable shallow water fish were predominantly roundfish (Tomcod or Eulachon)
- Late Spring trawlable deep water fish were predominantly flatfish (Pacific Sanddab or Rex Sole)
- Shallow water trawlable fish are slightly less abundant than deep water fish
- Dungeness Crab were present at both locations with shallow water hauls having more (factor of ~10)
- Both shallow water (English Sole) and deep water flatfish (Rex Sole) had a tumor incidence of 10-15%)

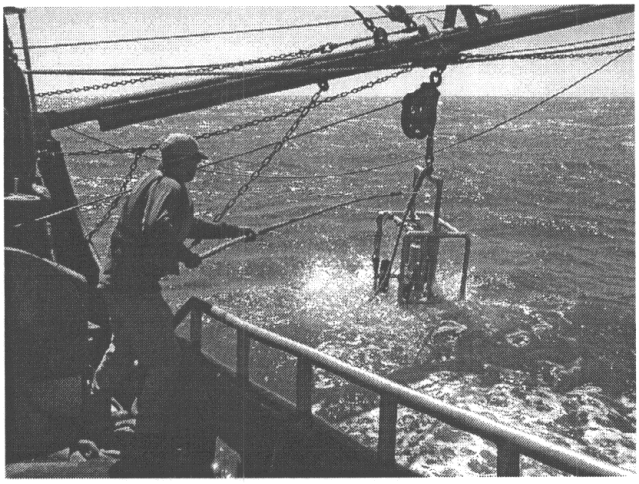
Trawl Summary
Summer 2002

- Late Spring trawlable shallow water fish were predominantly Eulachon
- Late Spring trawlable deep water fish were predominantly flatfish (Pacific Sanddab or Rex Sole)
- Shallow water trawlable fish are less abundant than deep water fish, especially if Eulachon are absent
- Dungeness Crab were present at both locations with shallow water hauls having more (factor of ~5)
- Both shallow water (English Sole) and deep water flatfish (Rex Sole) had a tumor incidence of 10-15%)

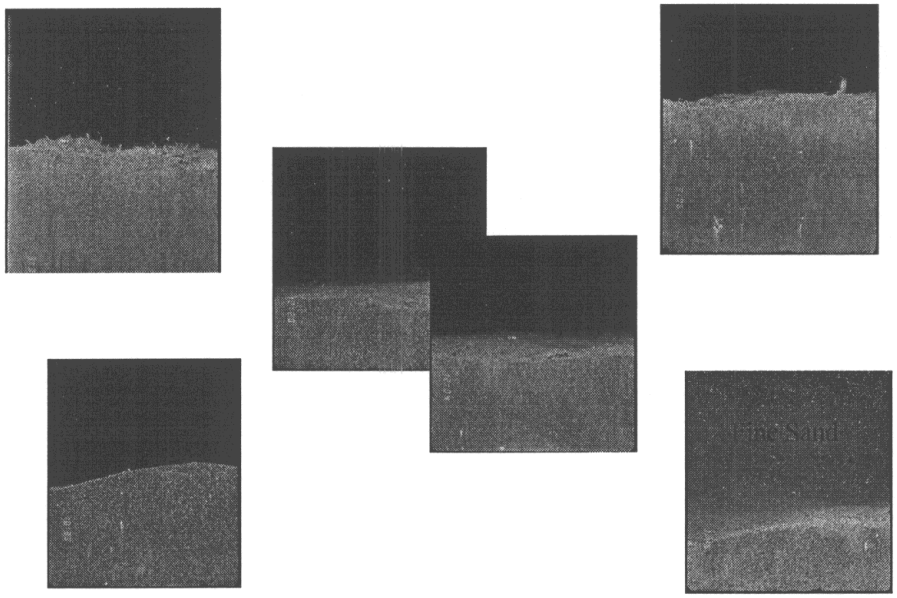
Trawl Summary
Fall 2002

- Late Spring trawlable shallow water fish were predominantly Tomcod that were ovigerous, crab appeared to be feeding on Tomcod eggs.
- Crab were abundant, hard and very large.
- English sole were not abundant enough to detect a 10% incidence of tumors.

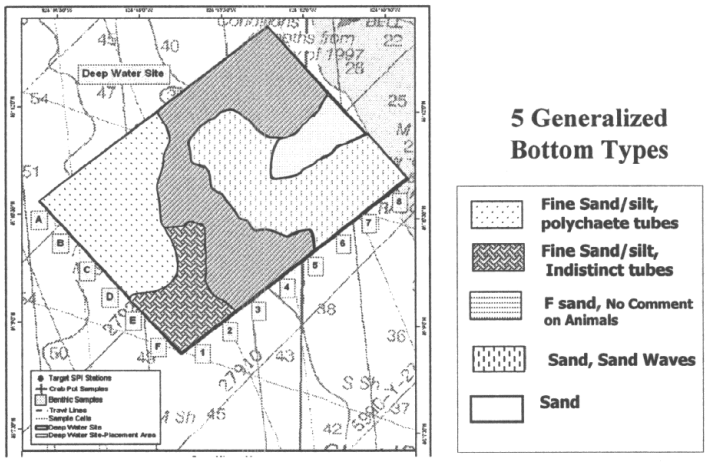
BENTHIC HABITAT TYPES USING SEDIMENT PROFILE IMAGING (SPI)



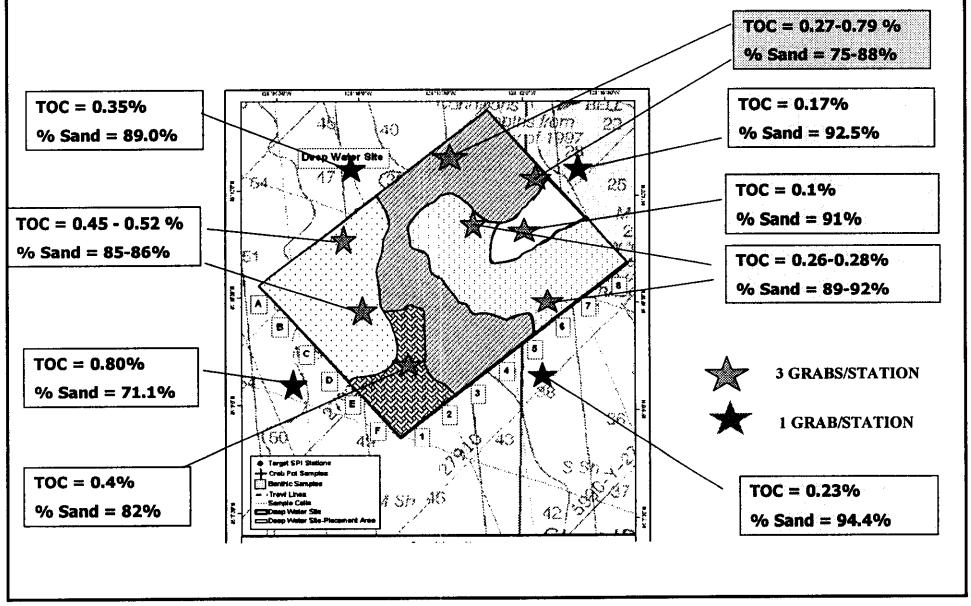
SPI COMMUNITY TYPES

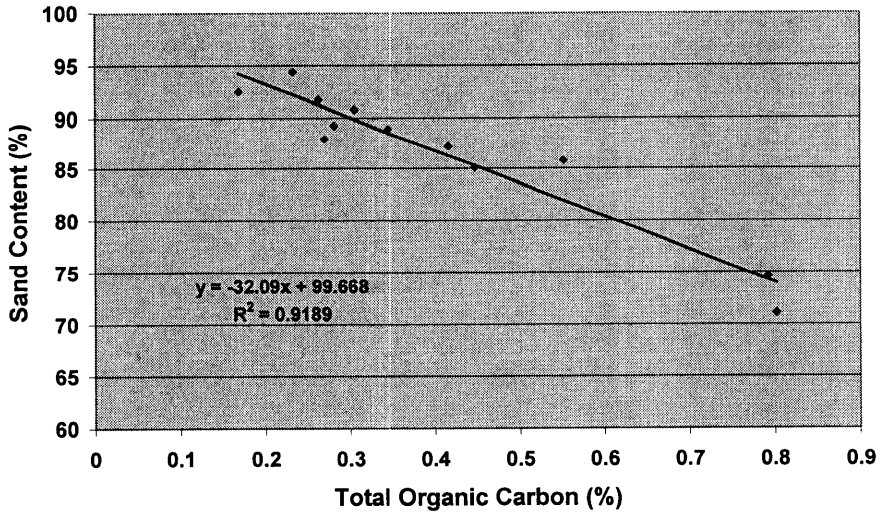


BENTHIC HABITAT TYPES USING SEDIMENT PROFILE IMAGING (SPI)
Late Spring/Early Summer 2002



SPI SELECTION FOR BENTHIC SAMPLING – Late Spring/Early Summer 2002





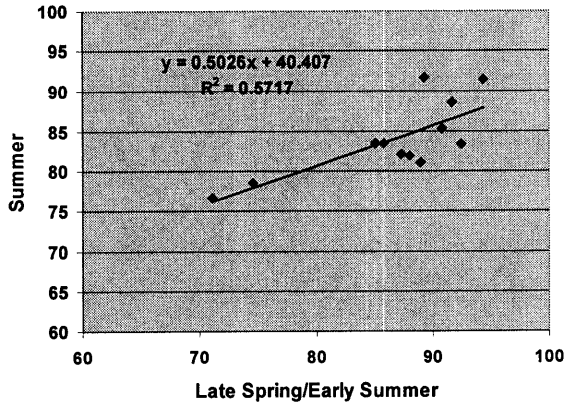
Late Spring/Early Summer SPI Observations

- 5 general bottom types were observed
- 3 covered relatively large areas; 2 stations with 3 replicates each were sampled in each of these areas; 1 station with 3 replicates each in the smaller areas and 1 sample each at the margins of the proposed disposal site.
- **In general, the TOC and grain size matched these area descriptions well.**

Summary Information on Sediment Characteristics

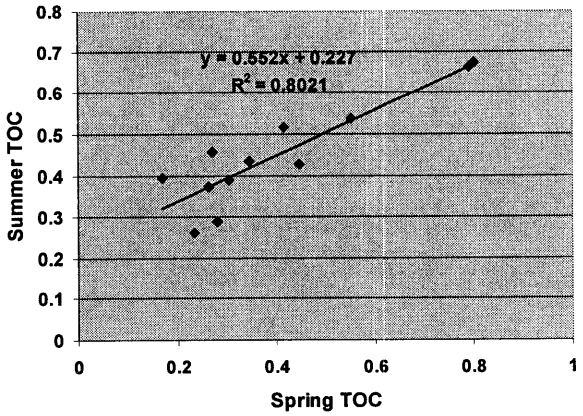
STATION	Late Spring/Summer 2002			Summer 2002		
	TOC	% SAND	Abundance	Abundance	TOC	%SAND
EAST	0.17	92.5	138	341	0.4	83.3
SOUTH	0.23	94.4	229	569	0.26	91.5
F6	0.26	91.7	132	280	0.37	88.5
C8	0.27	88	200	285	0.46	81.8
C6	0.28	89.3	207	313	0.29	91.7
D7	0.31	90.8	156	379	0.39	85.3
NORTH	0.35	88.98	270	654	0.43	81
E2	0.42	87.3	398	735	0.52	82.1
A3	0.45	85.1	425	575	0.43	83.5
C2	0.55	85.8	491	598	0.54	83.5
A7	0.79	74.6	176	503	0.67	78.5
WEST	0.8	71.1	372	380	0.67	76.7

Comparison of Spring and Summer % Sand



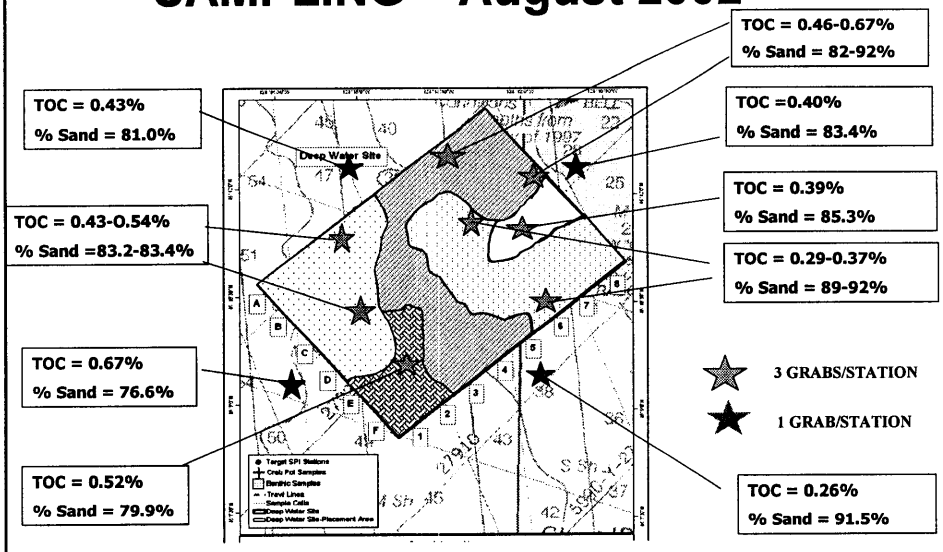
- On average Summer concentrations of % Sand or coarser was less in late spring/early summer

Comparison of Spring and Summer TOC Sediment Concentrations



- On average, summer TOC is higher than late spring/early summer

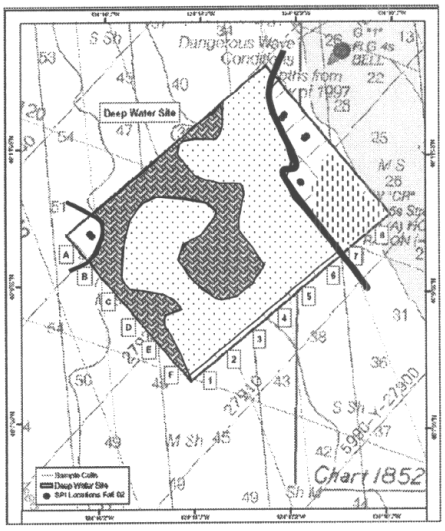
SPI SELECTION FOR BENTHIC SAMPLING – August 2002

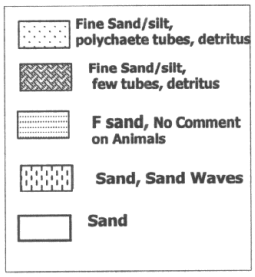


Benthic Sediment Conditions Early Summer and Summer

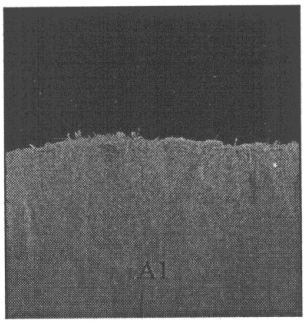
- Grain Size – Finer in summer than late spring/early summer
- TOC – Higher in summer than in late spring/early summer
- SPI images indicate a similar relationship (more surface detrital materials observed)

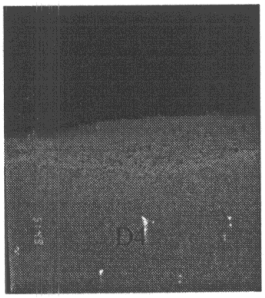
BENTHIC HABITAT TYPES USING SEDIMENT PROFILE IMAGING (SPI) August 2002

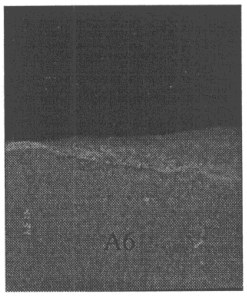


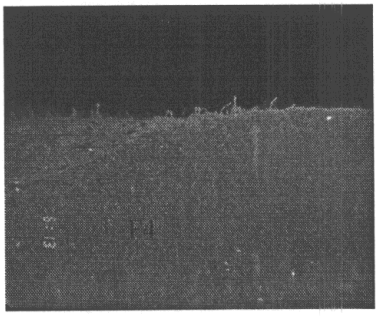


SPI COMMUNITY TYPES – Fall 2002

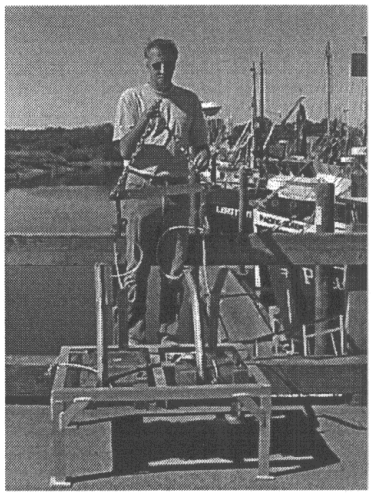


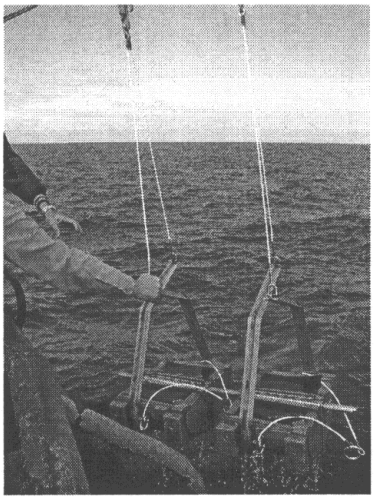




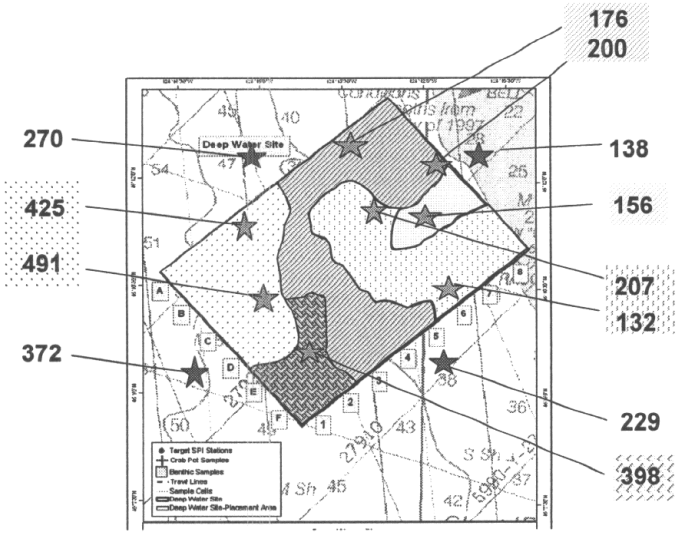


BENTHIC INFAUNA

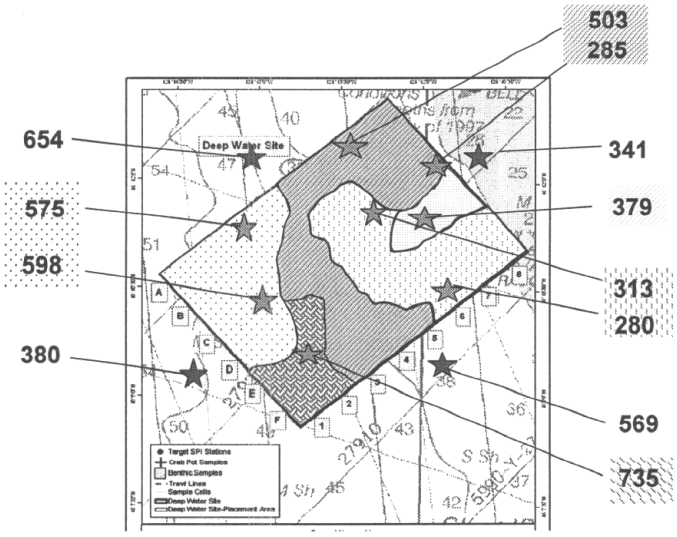




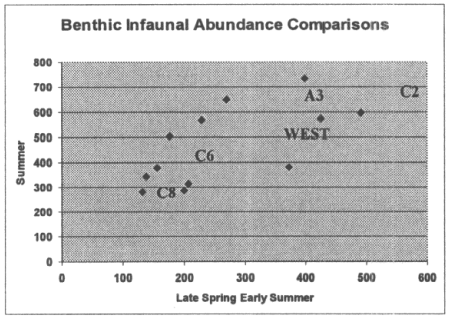
BENTHIC INFAUNA ABUNDANCE
Late Spring/Early Summer 2002

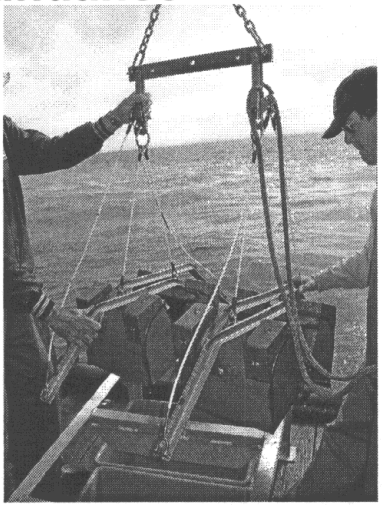


BENTHIC INFAUNA ABUNDANCE
Summer 2002

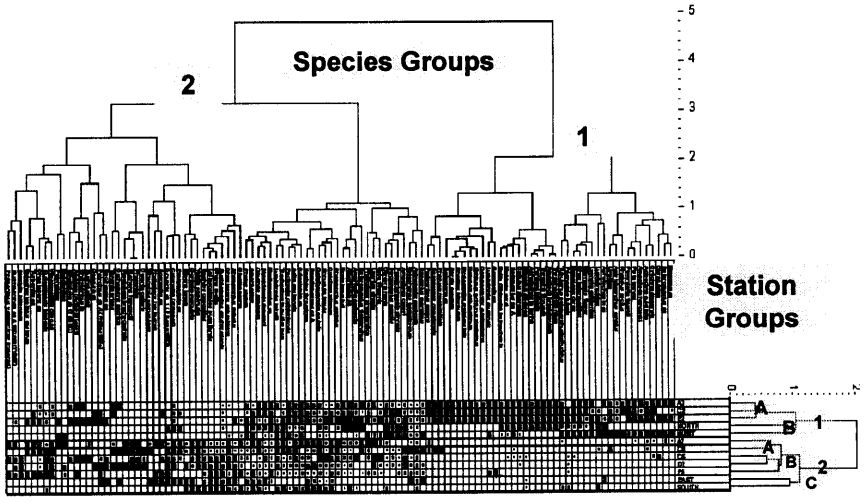


Spring Summer Comparison of Benthic Abundance





Benthic Invertebrate Cluster Analysis



Species within Clusters

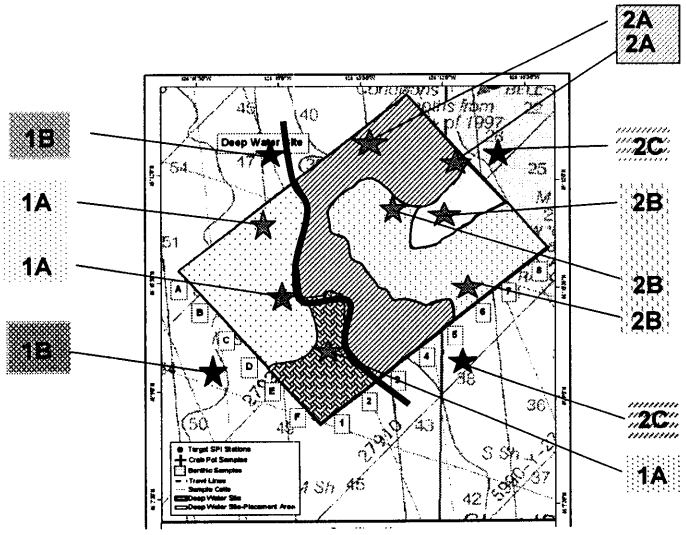
Group 1

Magelona cerae
Maldane sarsi
Syllis heterochaeta
Notomastus
Sternaspis fossar
Pista basei
Ampelisca brevisimulata
Ampelisca hancocki
Tubulanus polymorphus/pellucidis
Cadulus aberrans
Acteocina culcitella
Cylichna diegensis
Macoma calcarea and Macoma sp
Pandora billirata
Thyasira flexulosa
Thysanocardia nigra
Lyonsia californica
Chaetodermatidae

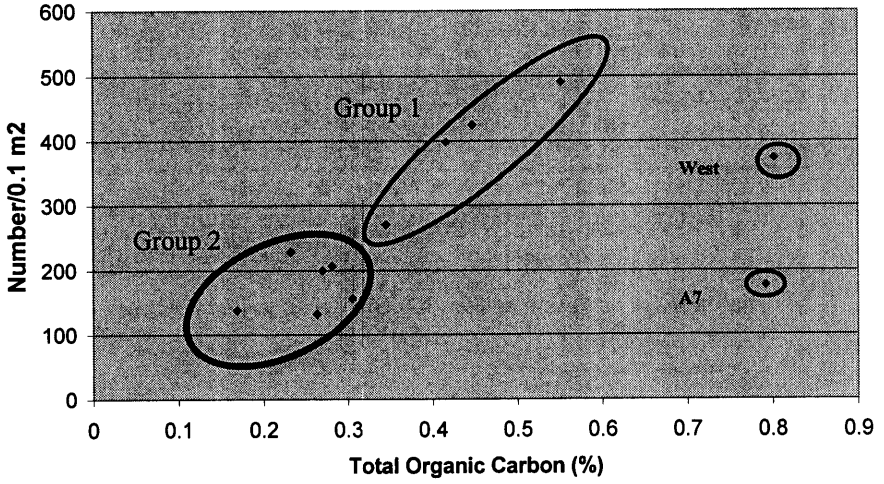
Group 2

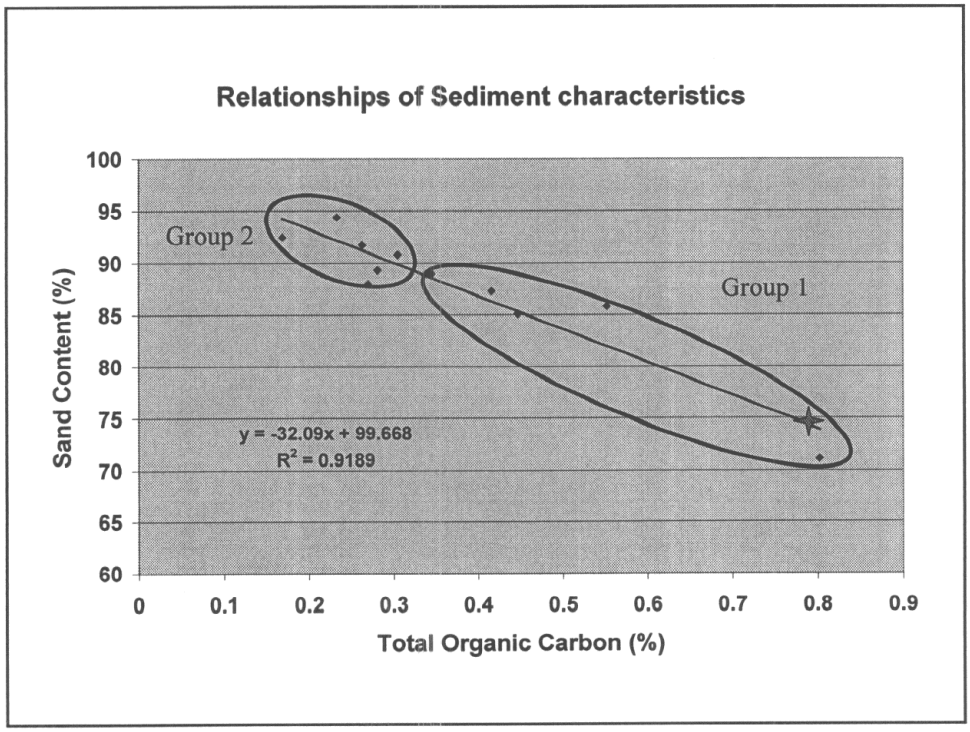
- *Euphilomedes carcharodonta*
- *Protomedia sp*
- *Westwoodilla caecula*
- *Eudorellopsis biplicata*
- Calanoida
- *Onuphis* sp 1
- *Chone mollis*
- *Leitoscoloplos pugettensis*
- *Nephtys caecoides*
- *Yoldia seminuda*
- *Goniada maculata*

BENTHIC INFAUNA STATION CLUSTER – Late Spring/Early Summer 2002



Relationship of Sediment Characteristics to Benthic Infauna

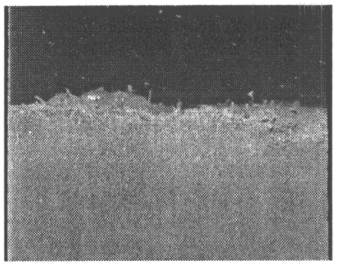


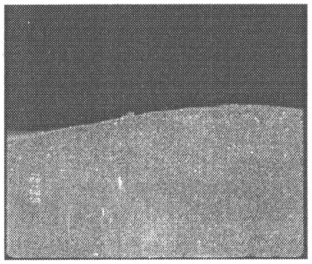


BENTHIC CONCLUSIONS ON Late Spring Early/Summer 2002

- **Group 1**
  - **TOC = 0.5±0.18%**
  - **Sand = 82.6±6.9%**
  - **>45 Meters**
  - ***Magelona* community**
- **Group 2**
  - **TOC = 0.21±0.07%**
  - **Sand = 91.2±2.35%**
  - **<45>25 Meters**
  - ***Euphilomedes* community**

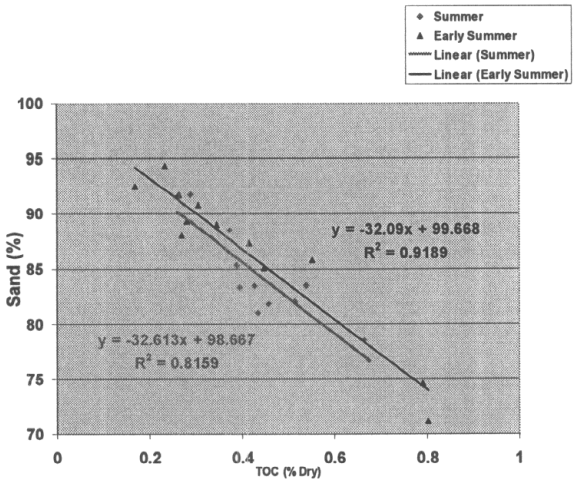
Major Bottom Types – LateSpring/Early Summer 2002



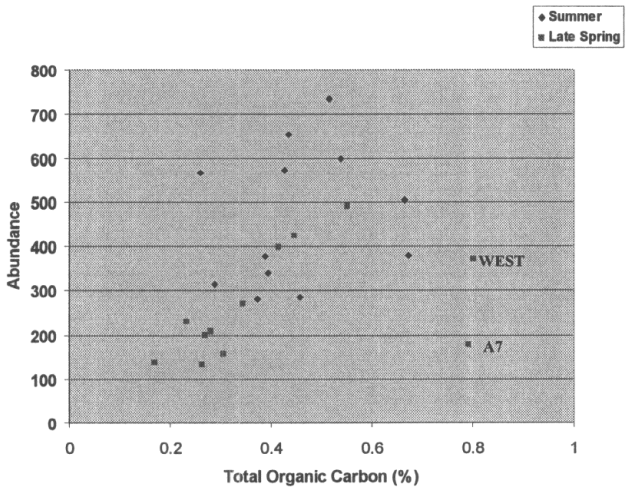


- Bottom Type 1 dominated by ***Magelona cerae, Maldane sarsi, Notomastus sp.***
- Bottom Type 2 dominated by ***Euphilomedes carcharodonta***

TOC and Percent Sand Relationships in Late Spring and Summer



Benthic Abundance and TOC



Benthic Community Conclusions

- As summer progressed the sediment became finer grained with higher TOC and the abundance of benthic infauna increased.
- SPI images also indicate that the percentage of fine grained materials at the surface of the sediment increased in shallower waters.