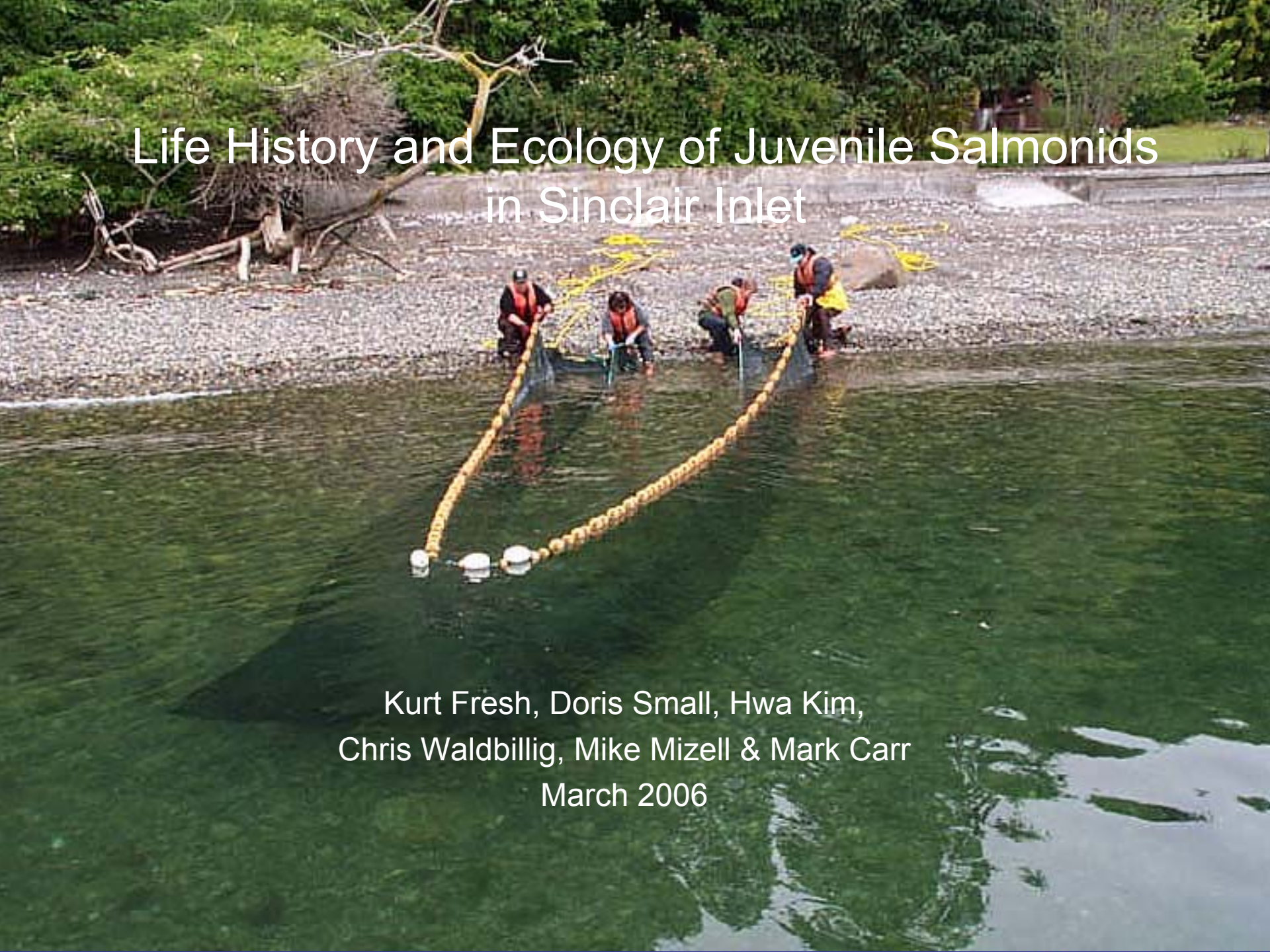
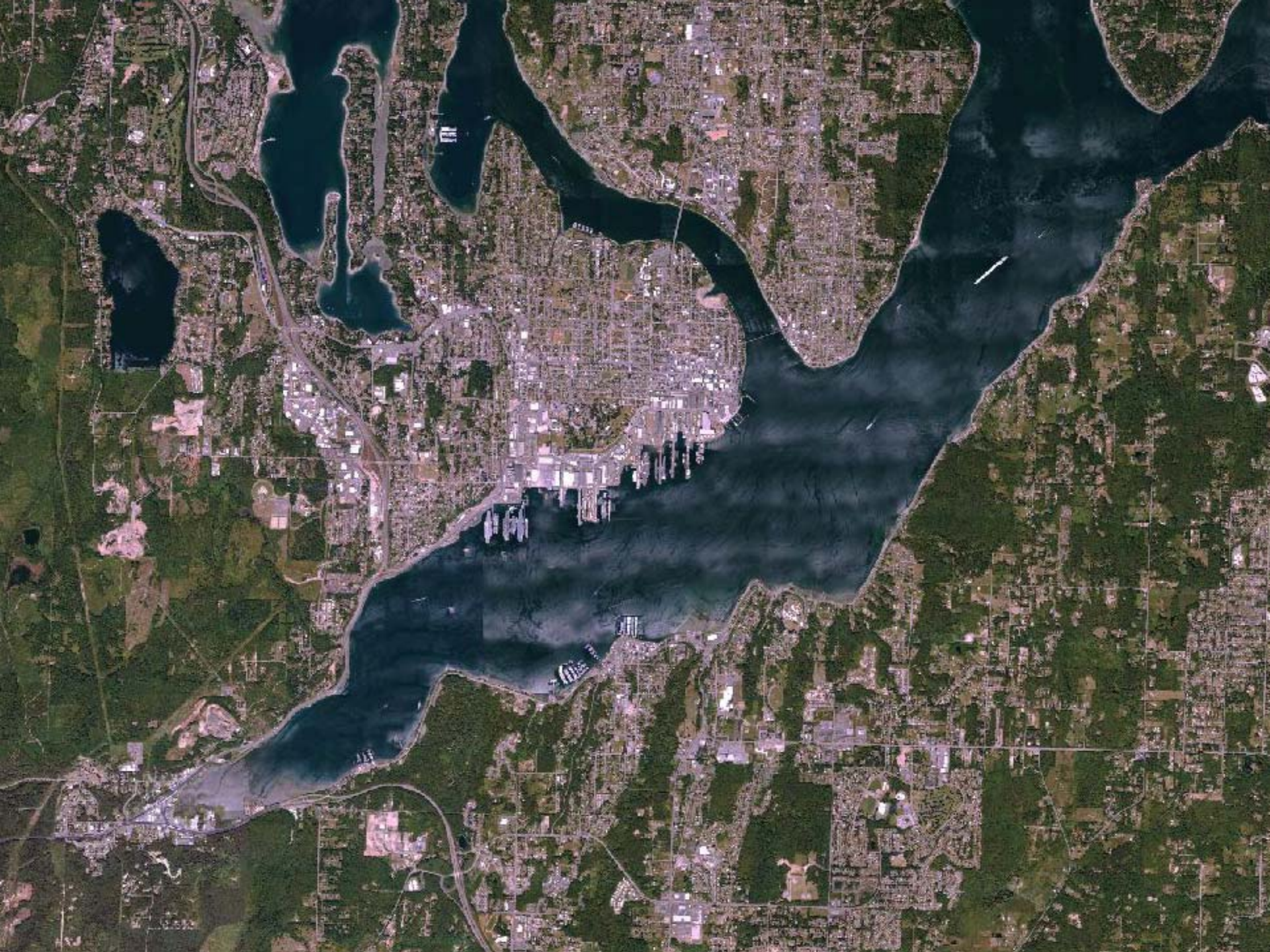


Life History and Ecology of Juvenile Salmonids in Sinclair Inlet

Kurt Fresh, Doris Small, Hwa Kim,
Chris Waldbillig, Mike Mizell & Mark Carr

March 2006

WDFW RESEARCH
WASHINGTON DEPARTMENT OF
FISH AND WILDLIFE



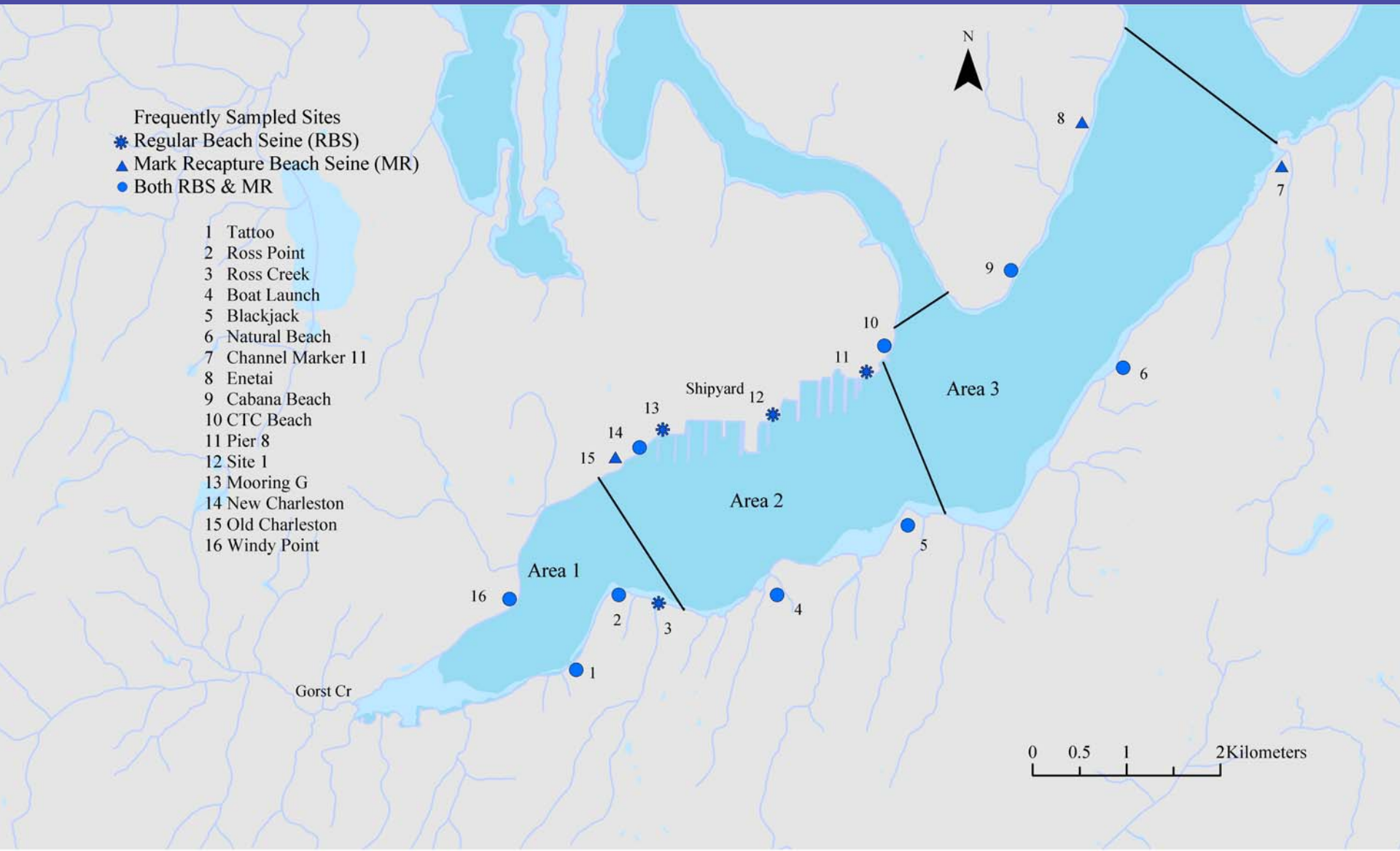
GOALS

- Increase understanding of behavior of juvenile Chinook salmon in Sinclair Inlet
- Improve design for habitat restoration for nearshore projects in Sinclair Inlet

OBJECTIVES

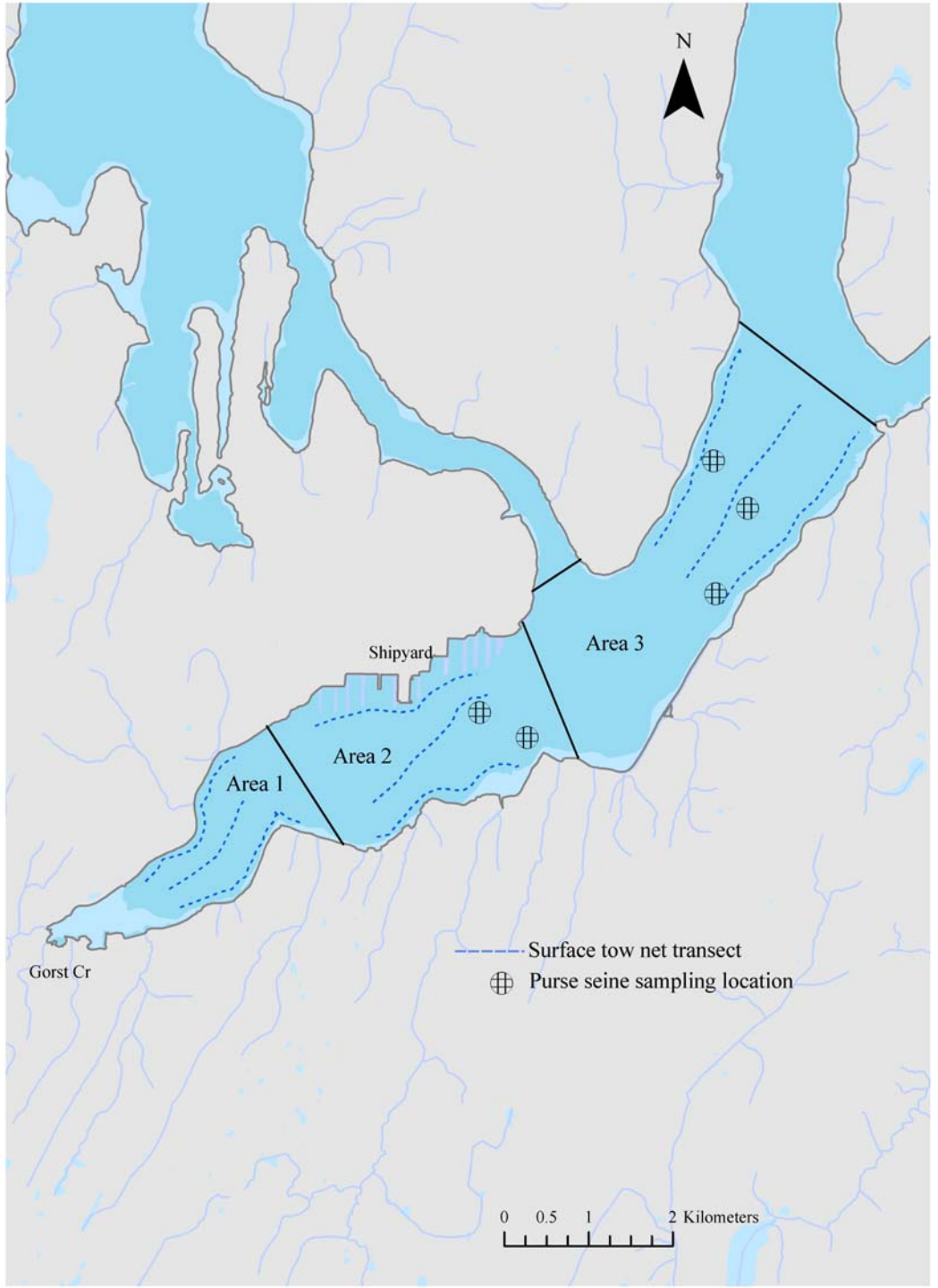
- Determine spatial and temporal use of nearshore habitats by salmonids
- Determine use of offshore habitats
- Determine residence time of juvenile Chinook salmon in Sinclair Inlet
- Examine the diet of juvenile Chinook salmon in Sinclair Inlet

Sinclair Inlet Beach Seine Sites



WDFW RESEARCH

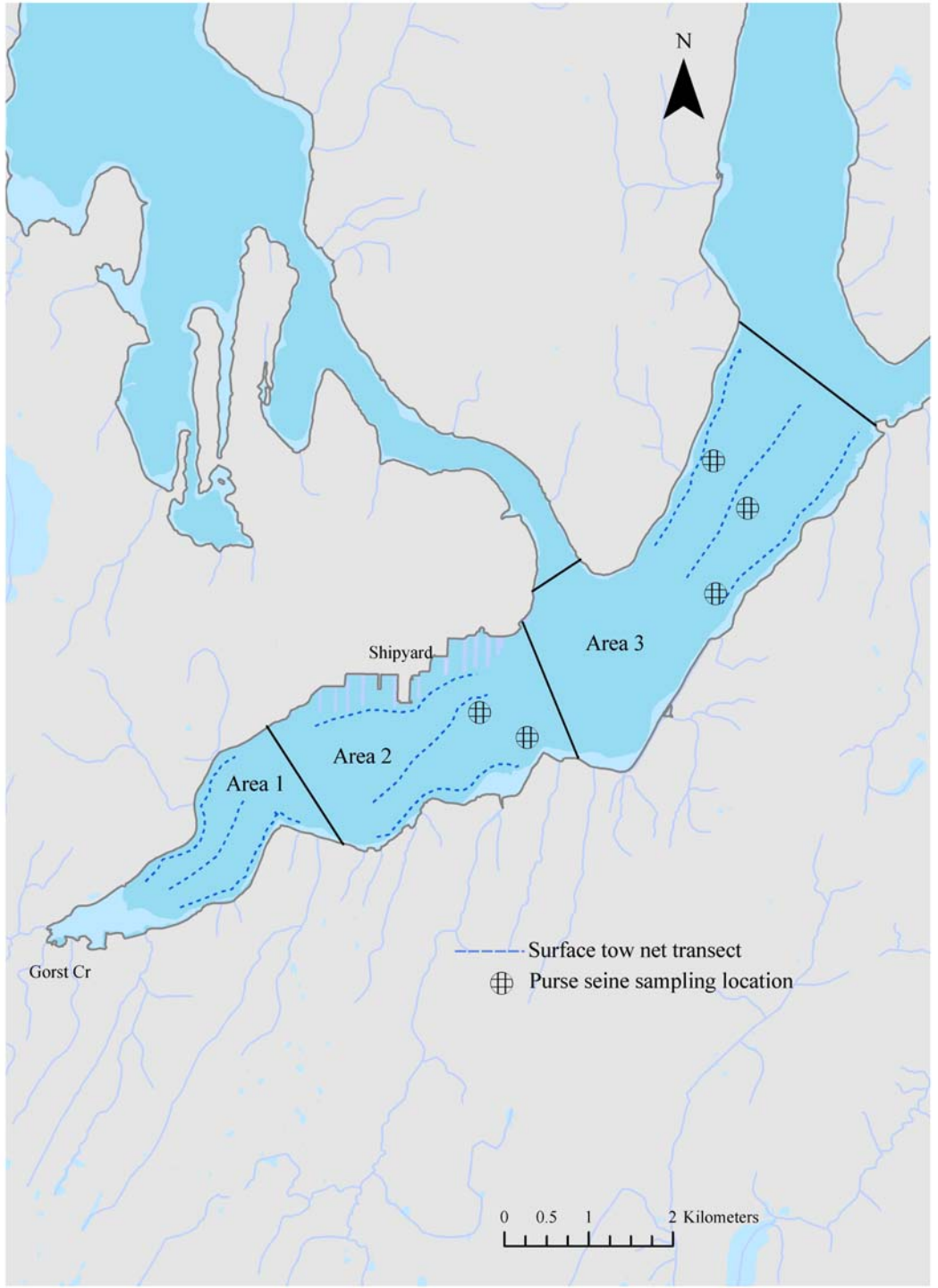
Sinclair Inlet Surface Tow Net Sampling Sites

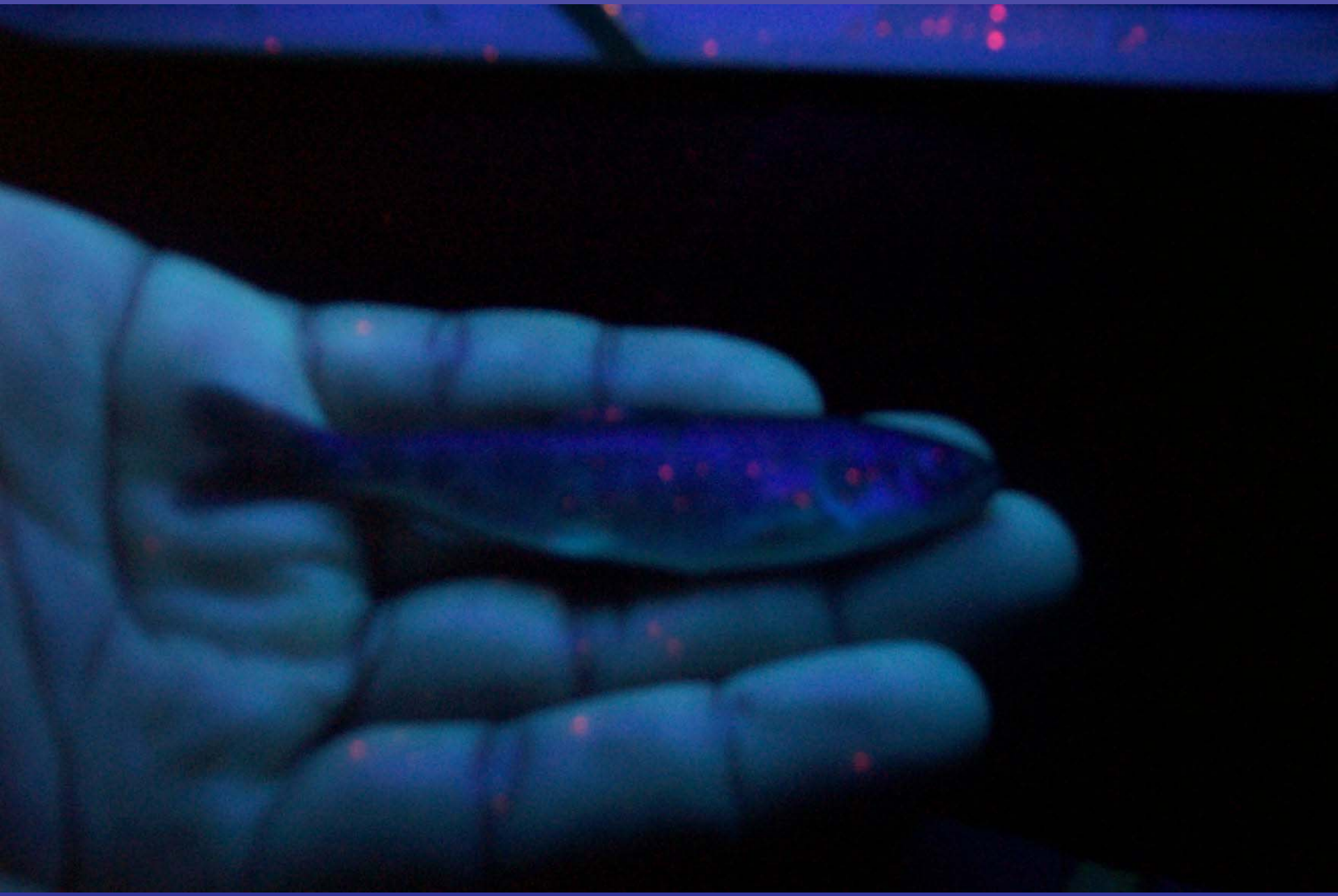


RESEARCH

Sinclair Inlet Purse Seine Sampling Sites

June 2002





Habitat characteristics of Sinclair Inlet shorelines

7. 30. 2001

Results

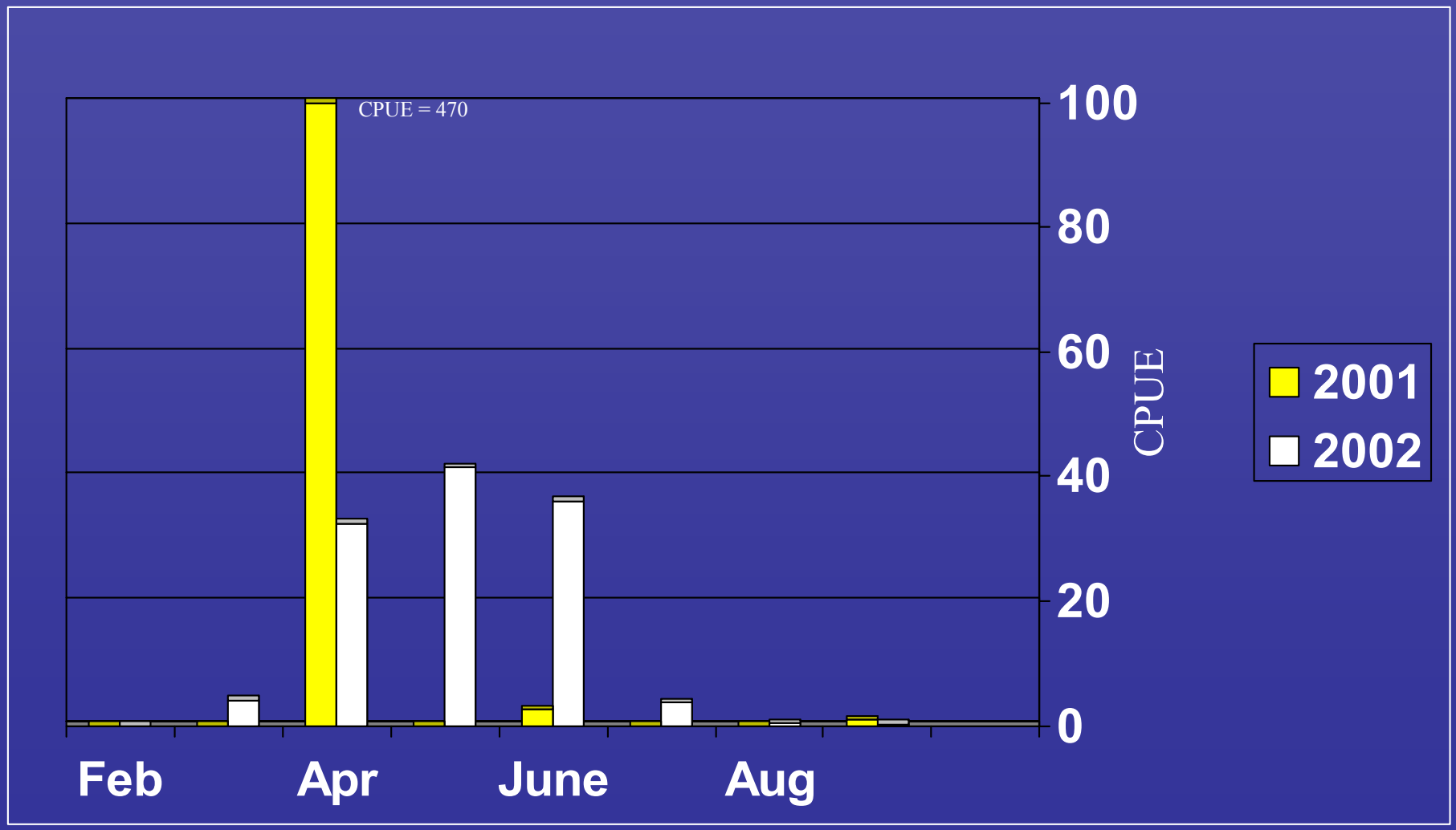
- Species composition
- Abundance patterns
- Size distribution
- Residence time
- CWT recovery
- Diet of salmonids

- Shiner perch most abundant
- Chum salmon most abundant
- Diverse nearshore fish community
- Schooling fish

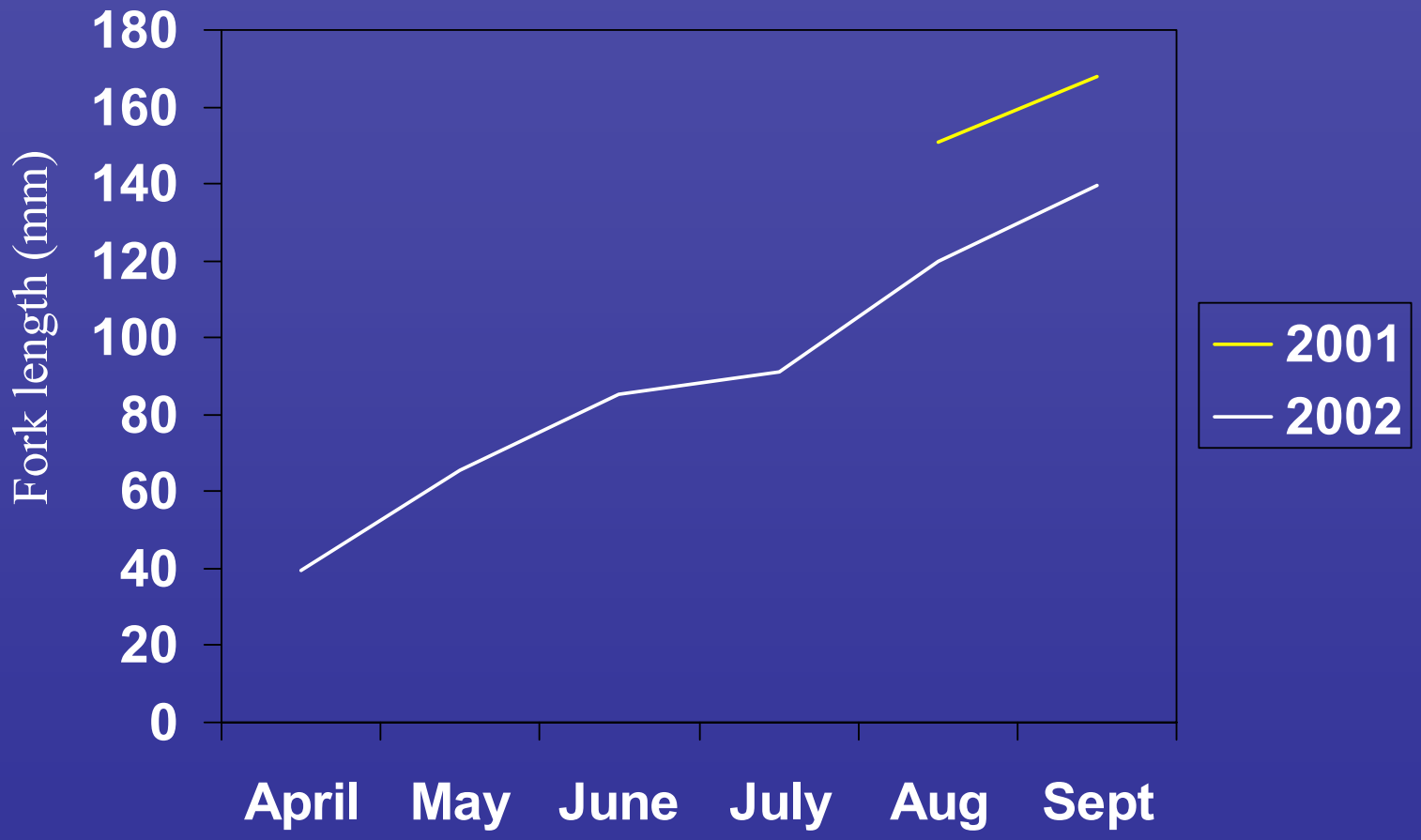
Common Name	2001	2002 RBS	2002 MR
Chinook salmon	732	798	3672
Coho salmon	7	266	25
Chum salmon	5,713	4,090	1931
Cutthroat trout	78	177	190
Steelhead trout		1	
Big skate	1	4	
Pacific herring	539	386	1
Surf smelt	1,294	383	306
Plainfin midshipman	121	8	2
Three spine stickleback	19	1,180	2
Tubesnout	7	4	
Bay pipefish	10	11	11
misc. greenling	7	5	
Staghorn sculpin	864	412	268
Buffalo sculpin	2	125	17
Tadpole sculpin	0		
Irish lord	0		
misc. sculpins	223	1,029	361
Shiner perch	12,960	11,982	3509
Striped perch	260	88	36
Pile perch	194	1,011	26
misc. perch	4		
Snake prickleback	169	543	29
Crescent gunnel	8	30	
Penpoint gunnel	9	11	2
Saddleback gunnel	2	50	
misc. gunnel	44	60	94
Pacific sandlance	231	10,017	2
misc. forage fish	70		
Pacific sanddab		17	
Starry flounder	187	415	44
Rock sole	7	56	3
English sole	9	11	1
Sand sole	9	14	
CO turbot	0	18	
misc. flatfish	172	29	50
juvenile tidepool fish	7		
# fish from infrequent sites	*5200*	*641*	
Total	29159	33,872	10,584
species	29	29	20
effort	95	176	96

Chum salmon in Sinclair Inlet

CPUE for chum salmon in beach seines



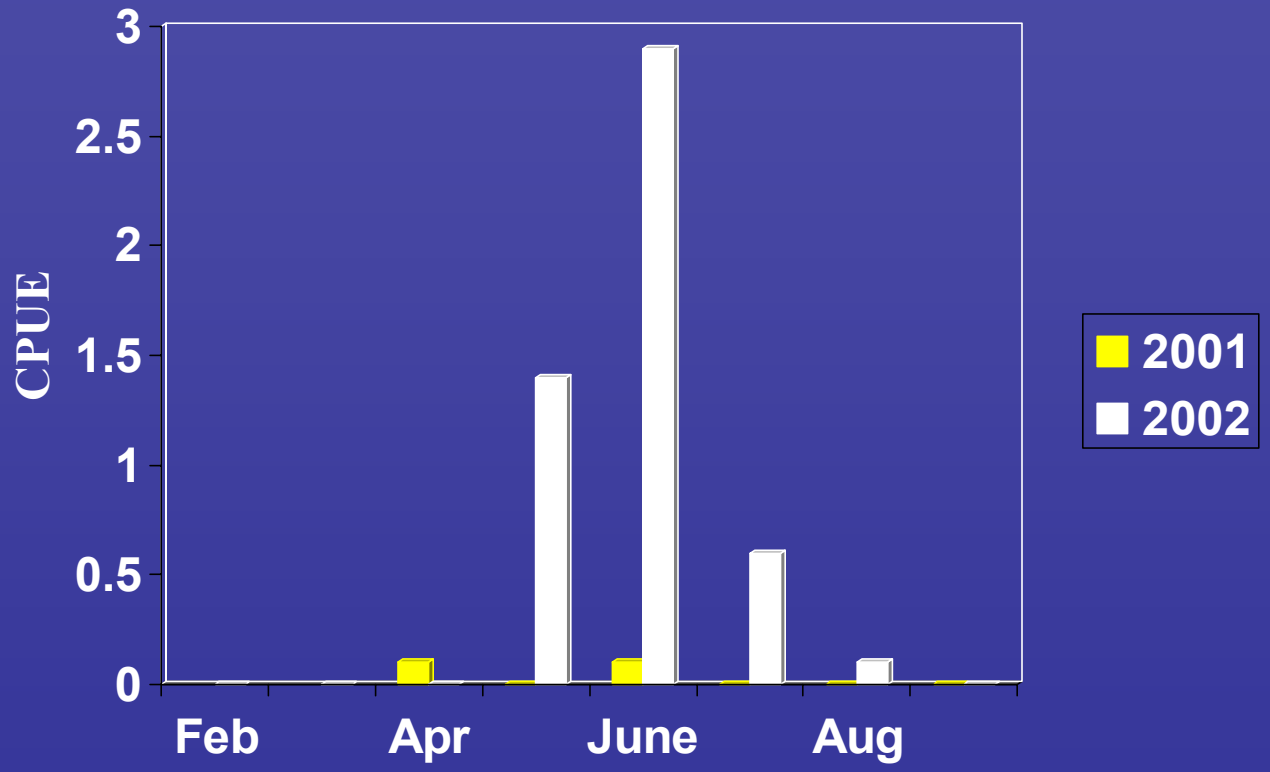
Chum size in beach seines



Subyearling coho

Yearling coho

Coho salmon CPUE in beach seines



6.14.2001

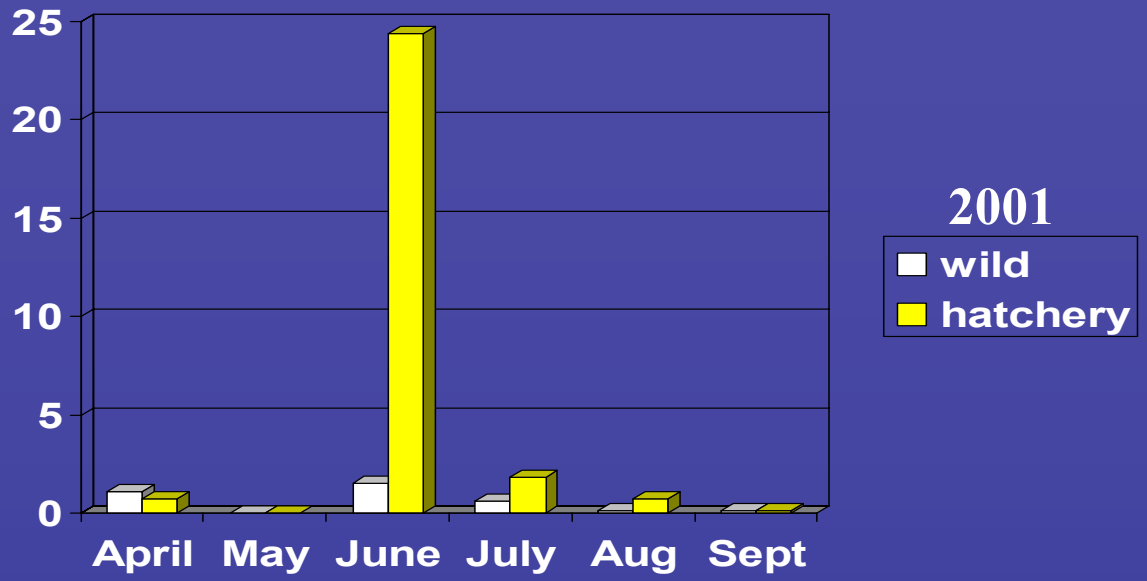
Juvenile Chinook Salmon

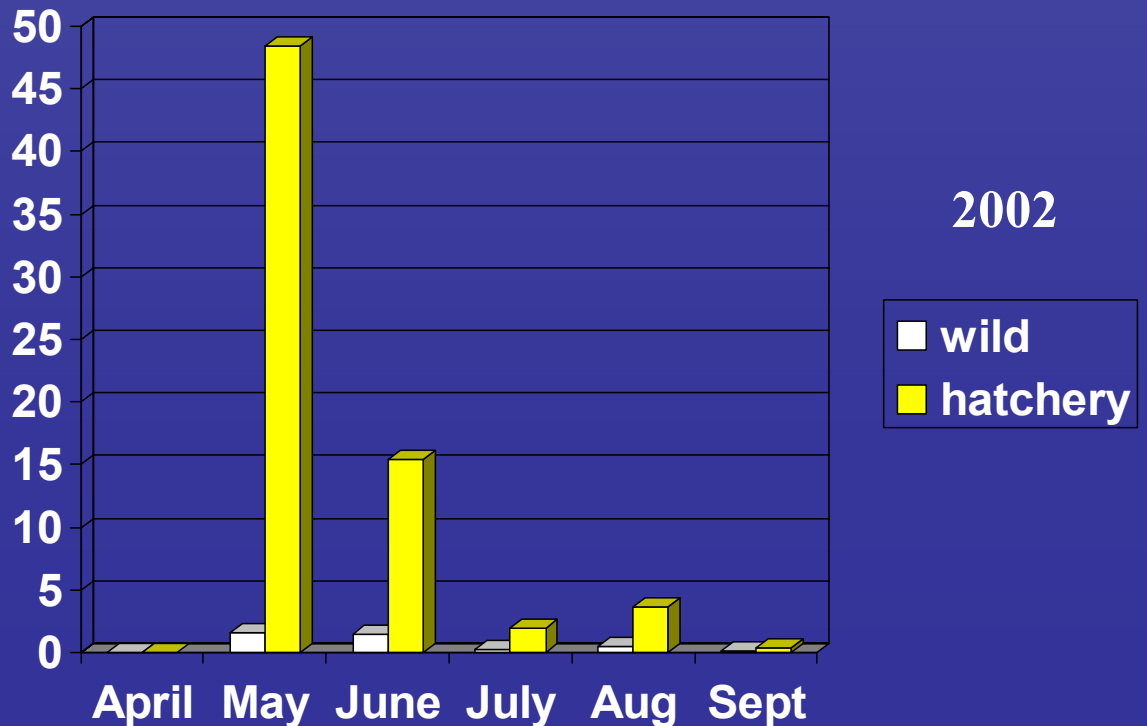
WDFW Habitat Program

Hatchery / “Wild” Chinook Salmon

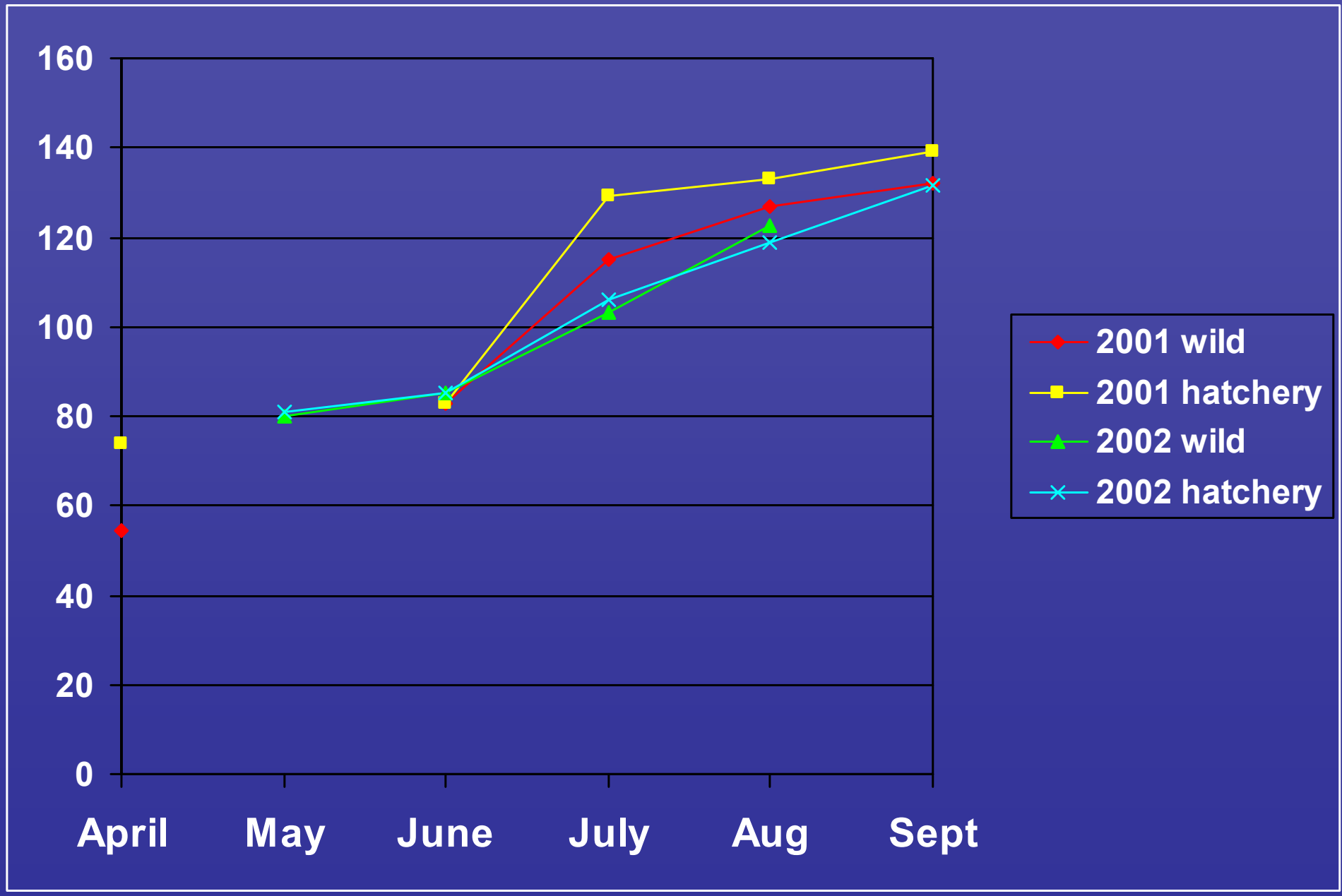
Total # Chinook	**732**	**798**	**3674**
“wild”	**89**	**75**	**421**
hatchery	**605**	**717**	**3253**
adult	**38**	**6**	**0**
CPUE			
“wild”	**0.9**	**0.4**	**4.4**
hatchery	**6.4**	**4.1**	**33.9**
Effort	***95***	***176***	***96***

Chinook salmon CPUE in beach seines





Chinook salmon size in beach seines



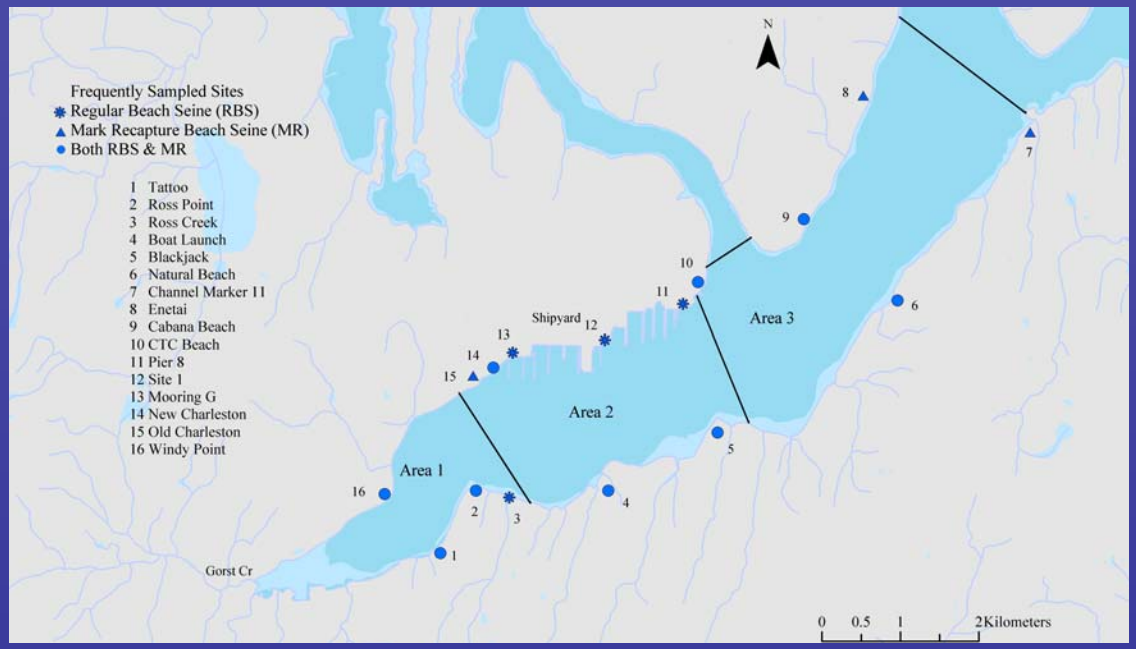
Chinook salmon distribution & growth

Effect of time of day
- day / night

Effect of tides
- flood / ebb
- low slack

Effect of shoreline
- north / south

Effect of habitat type
- substrate, slope, vegetation, shoreline armor, Area



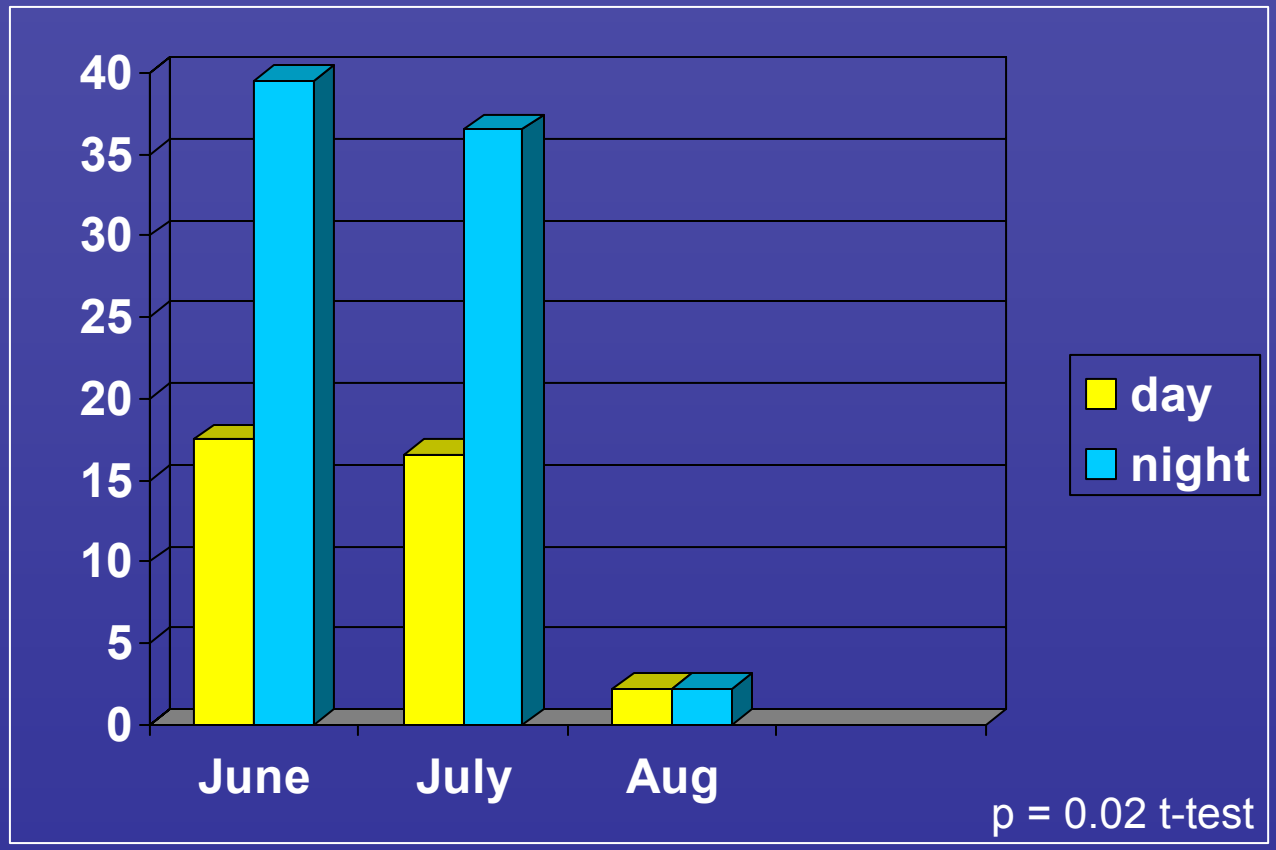
Surface Tow Net Catch

Common Name	Scientific Name	Total	Wild	Hatchery
Chinook salmon	*Oncorhynchus tshawytscha*	1892	188	1704
Coho salmon	*Oncorhynchus kisutch*	19	15	4
Chum salmon	*Oncorhynchus keta*	504		
Cutthroat trout	*Oncorhynchus clarki*	1		
Steelhead trout	*Oncorhynchus gairdneri*	2		
Atlantic salmon	*Salmo salar*	1		
Big skate	*Raja binoculata*	1		
Pacific herring	*Clupea pallasii*	89		
Surf smelt	*Hypomesus pretiosus*	15		
Plainfin midshipman	*Porichthys notatus*	198		
Three spine stickleback	*Gasterosteus aculeatus*	683		
Bay pipefish	*Syngnathus leptorhynchus*	15		
Pacific staghorn sculpin	*Leptocottus armatus*	2		
misc. sculpin	misc. Cottidae	4		
Shiner perch	*Cymatogaster aggregata*	159		
Snake prickleback	*Lumpenus sagitta*	17		
Crescent gunnel	*Pholis schultzi*	4		
Saddleback gunnel	*Pholis ornata*	66		
misc. gunnel	misc. Pholidae	4		
Pacific sandlance	*Ammodytes hexapterus*	83		
misc. forage fish		23		
Starry flounder	*Platichthys stellatus*	5		
English sole	*Pleuronectes vetulus*	1		
Total	20 species	3788		

Surface Tow Net

Area	Shore	Effort	"wild" Chinook	Hatchery Chinook	Chum	Coho
1	center	12	0	5	6	1
1	north	15	5	79	60	2
1	south	11	16	128	53	1
2	center	22	25	253	19	1
2	north	19	33	377	50	6
2	south	20	45	247	18	0
3	center	17	25	336	125	2
3	north	8	9	94	110	2
3	south	20	30	186	63	4

Surface Tow Net Day/Night hatchery Chinook salmon CPUE



Size difference

Larger at night * $p<0.0001$

Purse Seine Catch

Common Name	Scientific Name	Total	Wild	Hatchery
Chinook salmon	*Oncorhynchus tshawytscha*	663	49	614
Coho salmon	*Oncorhynchus kisutch*	46	31	15
Chum salmon	*Oncorhynchus keta*	708		
Steelhead trout	*Oncorhynchus gairdneri*	1		
Pacific herring	*Clupea pallasii*	20		
Surf smelt	*Hypomesus pretiosus*	11		
Three spine stickleback	*Gasterosteus aculeatus*	30		

Total	1479

Sinclair Inlet habitat survey

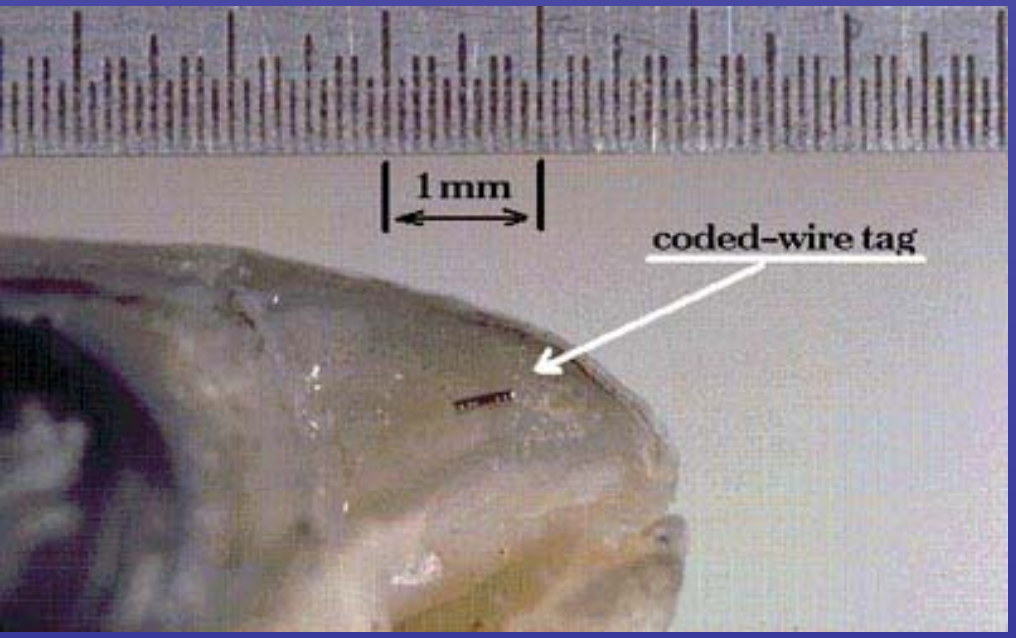
Substrate	**Area 1, South shoreline (west to Anderson Cr)**	**Area 2, South shoreline Annapolis to Natural Beach**	**Area 3, South shoreline (Natural Beach to Waterman)**	**Area 3, North shoreline (Manette to Enetai)**
Mud	73.9%			
Sand mixed with Gravel	5.1%	14.5%	15.4%	26%
Sand	0.1%	65.8%	31.3%	13.7%
Mixed Fines			10.9%	
Gravel	17%		5.1%	32%
Bedrock/Boulder	2.8%		17.3%	
Mixed Coarse			5.8%	26%
Large Rock		0.2%		1.6%
Cobble		18.5%	14.2%	
Sand w/ large rock		1%	0.1%	0.2%
Marsh Vegetation	1.1%			
Total area field surveyed	**95,343 m^2**	**207,332 m^2**	**121,639 m^2**	**222,541 m^2**
% of shoreline armoring				
Sloping riprap	49.9	93.4	42.1	5.7
Concrete/cement	29.8	1.9	19.8	64
Wood	8.3			1.3
Vertical rock riprap	2.8			
Unmodified/natural	9.2	4.7	38.1	29
Surveyed shoreline length	**2035 m**	**2668 m**	**3081 m**	**2568 m**
Total shoreline length	**4800 m**	**3470 m**	**3900 m**	**6210 m**

Residence time in Sinclair Inlet

Pigment marking

Residence time in Sinclair Inlet

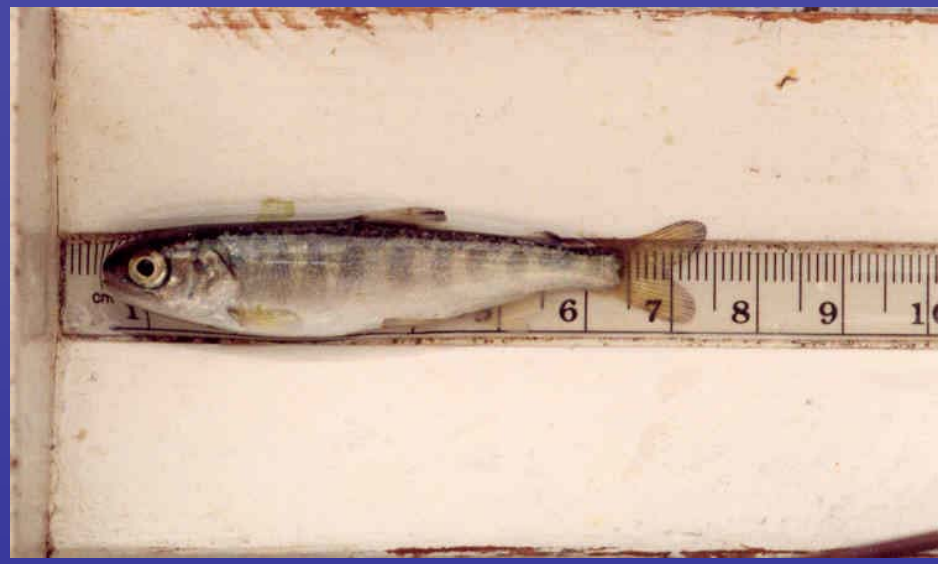
Coded Wire Tag Marks



Fin Clip Mark

Chinook residence time in Sinclair Inlet

2.2 million chinook at Gorst Creek
released late May / early June



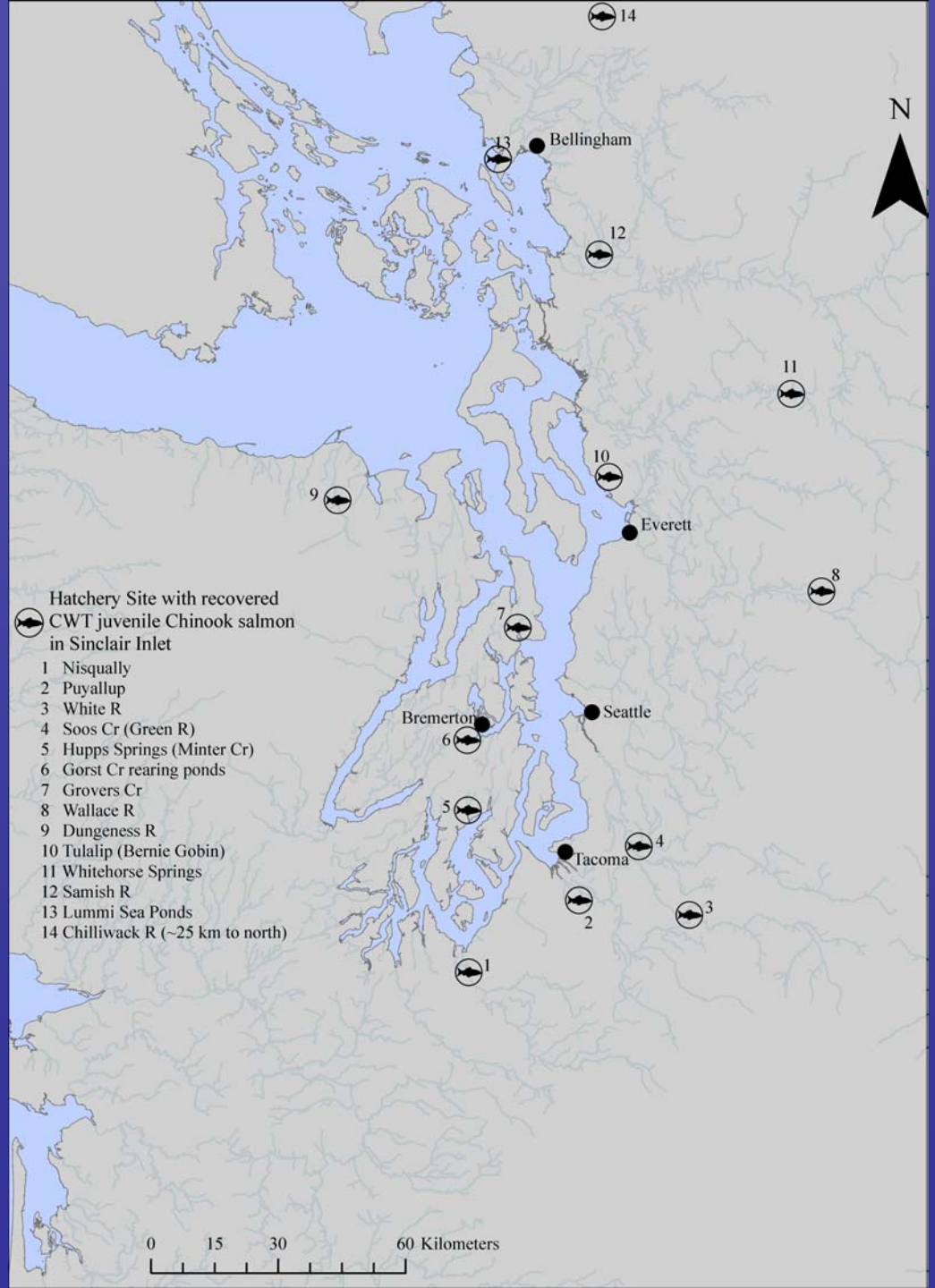
- Spray marked fish
  - 49,000 chartreuse
  - 10,830 red only
  - 24,700 red with CWT
- CWT fish
  - 106,000 Gorst control
  - 103,000 Gorst NATUREs

Chinook salmon residence time in Sinclair Inlet

	Mark	Ave residence time
	Red	5.4
	Red w/CWT	7.2
	CWT Gorst raceway	5.5
Area 1		
	Chartreuse	7.2
	CWT Gorst control pond	6.3
	CWT Gorst experimental pond	7.6
	Red	9.1
	Red w/CWT	7.6
	CWT Gorst raceway	9.3
Area 2		
	Chartreuse	6.8
	CWT Gorst control pond	8.5
	CWT Gorst experimental pond	7.8

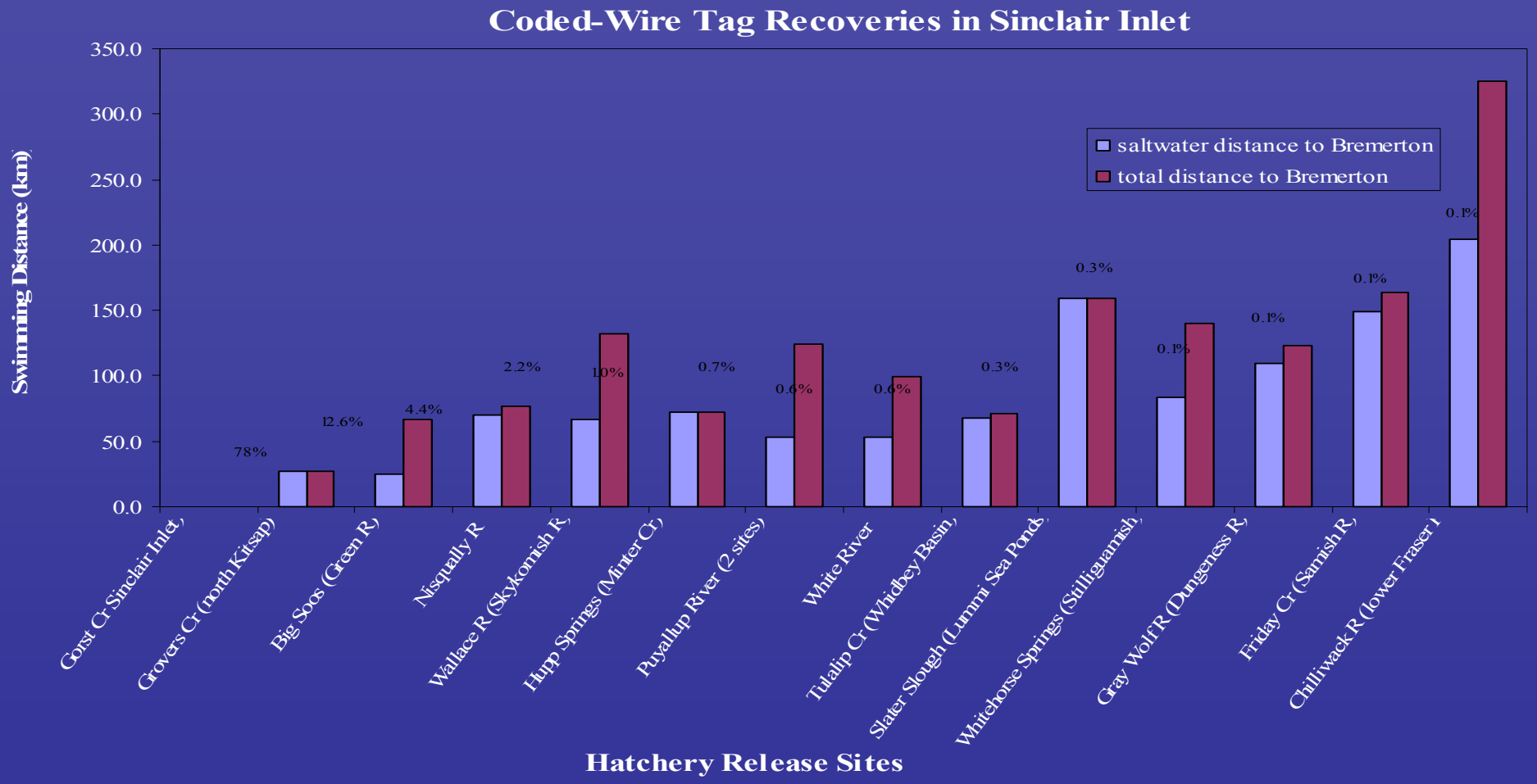
Coded Wire Tagged Juvenile Chinook Salmon Recovered in Sinclair Inlet

410 recoveries from
14 watersheds in Puget Sound



Chinook salmon CWT recoveries

Release sites	(Raw #)	(Adjusted for subsampling)	2002 Hatchery release dates
Gorst Cr rearing pond (control) (Sinclair Inlet)	104	234	5/20-6/21
Gorst Cr rearing pond (treatment)	101	330	5/20-6/21
Gorst Cr raceway (spray mark)	51	157	5/19
Grovers Cr (unclip) (north Kitsap)	38	77	5/20-5/29
Grovers Cr (ad clip)	31	41	5/20-5/29
Big Soos (2 codes) (Green R)	35	41	6/3-6/7
Nisqually R (6 codes)	16	21	5/7 – 6/4
Wallace R (2 codes) (Skykomish R)	8	9	6/15
Cowskull & Rushingwater Pond (Puyallup R)	5	5	6/14
Diru Cr (Puyallup R)	1	1	5/17-5/31
Hupp Springs (Minter Cr)	6	7	6/3
White River (subyearling)	5	5	5/29-5/31
White River (yearling)	1	2	4/
Slater Slough (Lummi Sea Ponds)	2	3	5/15-5/17
Tulalip Cr (Whidbey Basin)	2	3	5/14
Chilliwack R (lower Fraser R)	1	1	5/27-5/31
Friday Cr (Samish R)	1	1	5/24
Gray Wolf (Dungeness R)	1	1	5/28
Whitehorse Springs (Stilliguamish R)	1	1	5/20-5/24
Total	**410**	**940**	


Coded-Wire Tag Recoveries in Sinclair Inlet
Swimming Distance (km)
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
saltwater distance to Bremerton
total distance to Bremerton
78%
12.6%
4.4%
2.2%
1.0%
0.7%
0.6%
0.6%
0.3%
0.3%
0.1%
0.1%
0.1%
0.1%
Gorst Cr Sinclair Inlet
Grovers Cr (north Kitsap)
Big Soos (Green R)
Nisqually R
Wallace R (Skykomish R)
Hupp Springs (Minter Cr)
Puyallup River (2 sites)
White River
Tulalip Cr (Whidbey Basin)
Slater Slough (Lummi Sea Ponds)
Whitehorse Springs (Stilliguamish)
Gray Wolf R (Dungeness R)
Friday Cr (Samish R)
Chilliwack R (lower Fraser)
Hatchery Release Sites

Coho salmon CWT recoveries

Date	Recovery Location	Area	Capture Method	Release site	Release date
5/15/2002	CTC Beach	3	beach seine	Big Soos Cr 9.0072	4/6/02
5/16/2002	CTC Beach	3	beach seine	Issaquah Cr 8.0198	4/15/02
5/16/2002	CTC Beach	3	beach seine	Issaquah Cr 8.0198	4/15/02
5/16/2002	Enetai	3	beach seine	Issaquah Cr 8.0198	4/15/02
5/24/2002	West Marker 11	3	beach seine	Crisp Cr 9.0113	5/6 - 5/10/02
6/4/2002	Natural	3	beach seine	Agate Pass net pens	5/21/02
6/5/2002	Ross Point	1	beach seine	Voights Cr. 10.0414	4/29 - 5/06/02
6/6/2002	New Charleston	2	beach seine	Agate Pass net pens	5/21/02
6/6/2002	Boat launch	2	beach seine	Crisp Cr 9.0113	5/6 - 5/10/02
6/11/2002	Old Charleston	2	beach seine	Issaquah Cr 8.0198	4/15/02
6/12/2002	CTC Beach	3	beach seine	Big Soos Cr 9.0072	4/6/02
6/12/2002	West Marker 11	3	beach seine	Crisp Cr 9.0113	5/6 - 5/10/02
7/3/2002	Cabana	3	beach seine	Peale Passage	5/15 - 5/30/02
7/17/2002	Center 3	3	tow net	Rushingwater (Puyallup)	5/6 - 5/7/02

Conclusions

- The most abundant fish species in beach seines was shiner perch. Juvenile chum salmon was the most abundant salmonid.
- Juvenile chum salmon and forage fish were present from March through end of sampling (September). Chum salmon increased in size over time.
- We did not find juvenile pink salmon or bull trout during our study.
- Juvenile coho salmon were not caught in large numbers during the study.

Conclusions

- Juvenile Chinook salmon were caught from April through end of sampling (September). Peak catch was in June. Size of Chinook salmon increased over time.

- About 10% of the Chinook collected by year & gear were unclipped subyearlings and may have been wild fish.

- Residence time for chinook in Sinclair Inlet is short.

- CWT hatchery chinook were recovered in Sinclair Inlet from 14 watersheds in Puget Sound. While 77% of the fish were from Gorst Creek, the percentage of these fish decreased after mid-summer. This suggests that fish from Gorst Creek leave and are replaced by non-natal fish that rear in Sinclair Inlet.

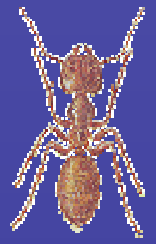
Conclusions

Three groups of juvenile Chinook salmon use Sinclair Inlet shorelines:

- Subyearling hatchery Chinook released into Sinclair Inlet
- Subyearling hatchery Chinook from outside the area
- Naturally produced Chinook salmon from local and distant systems

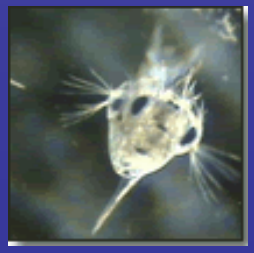
Diet of Juvenile Chinook in Sinclair Inlet Nearshore

Wide variety of food



Terrestrial insects
Water column prey (e.g. crab larvae, barnacle larvae)
Prey from the bottom (e.g. copepods, worms)

Few empty stomachs



7. 30. 2001

Diet Analysis

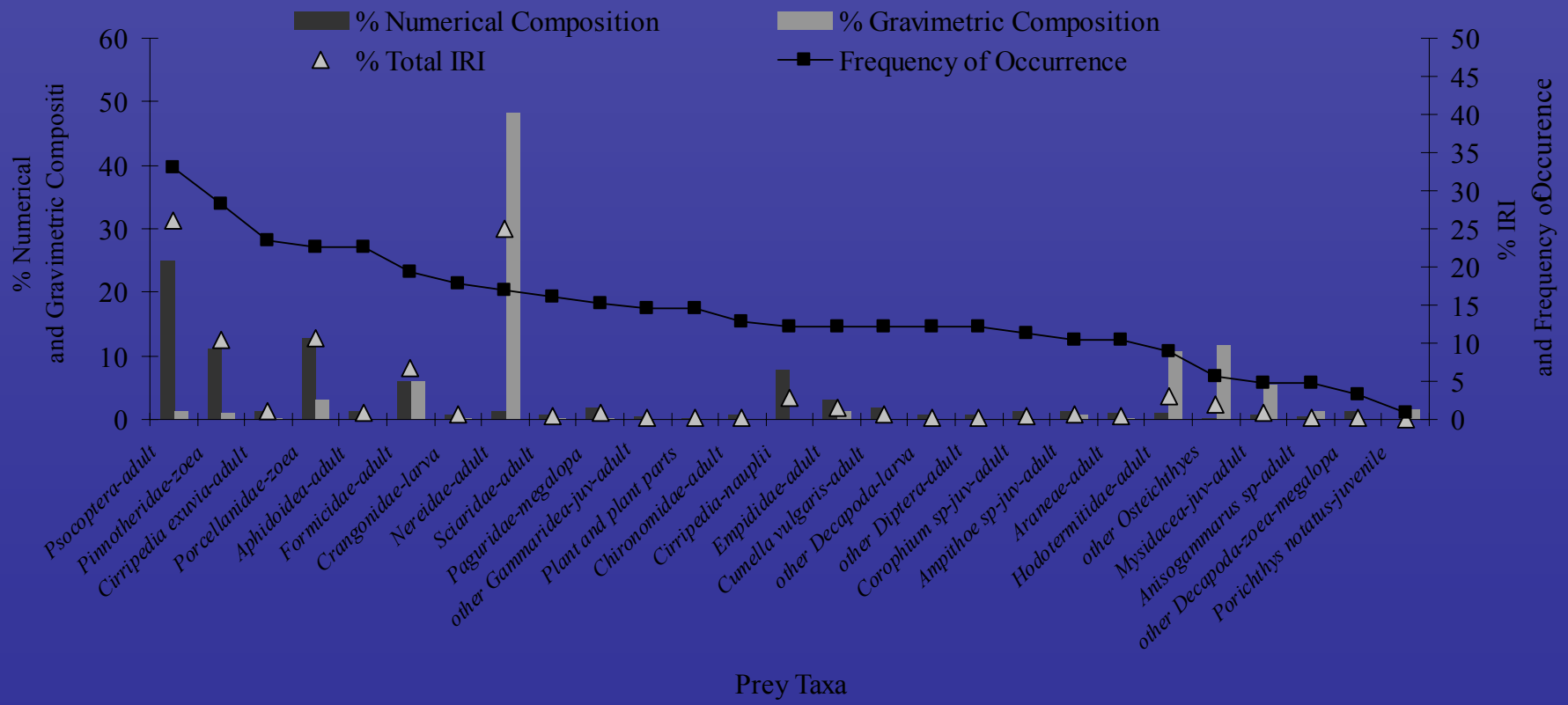
			Full Stomachs		Empty Stomachs	
Year	***Habitat***	***Species***	***n***	***Length (mm)***	***n***	***Length (mm)***
2001	Littoral	Chinook salmon	124	105.5	15	131.4
2002	Littoral	Chinook salmon	134	99.1	29	105.2
2002	Offshore	Chinook salmon	77	102.5	15	111.8
2001/02	Littoral	Chum salmon	41	73.7	5	115.2
2001/02	Littoral	Cutthroat Trout	34	244.3	11	237.7

Chinook diet summary

Ecological Prey Category	Major Taxa Represented
Terrestrial	Insects, spiders and mites
Marine Planktonic-Neritic	Decapod larva, hyperiid amphipods, calanoid copepods, fish and fish eggs
Marine Benthic-Epibenthic	Gammarid amphipods, polychaetes, harpacticoid copepods, cumaceans
Plant Matter	Aquatic and terrestrial plant matter
Other	Inorganic material, beach hoppers (Talitridae) and other supralittoral taxa

Juvenile Chinook Salmon Diet

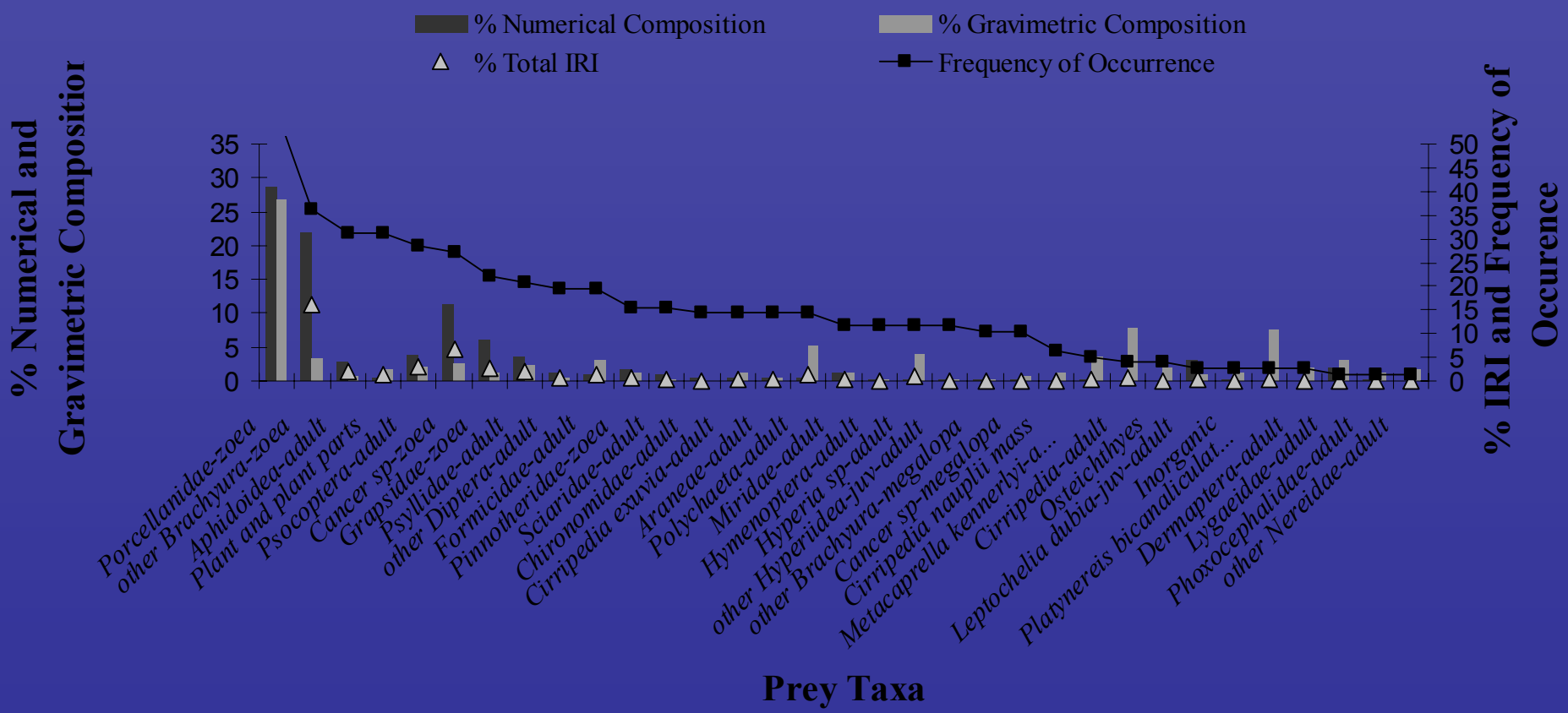
2001 nearshore



n=124, FL 58-185mm, mean 105.5mm

Juvenile Chinook Salmon Diet

2002 offshore



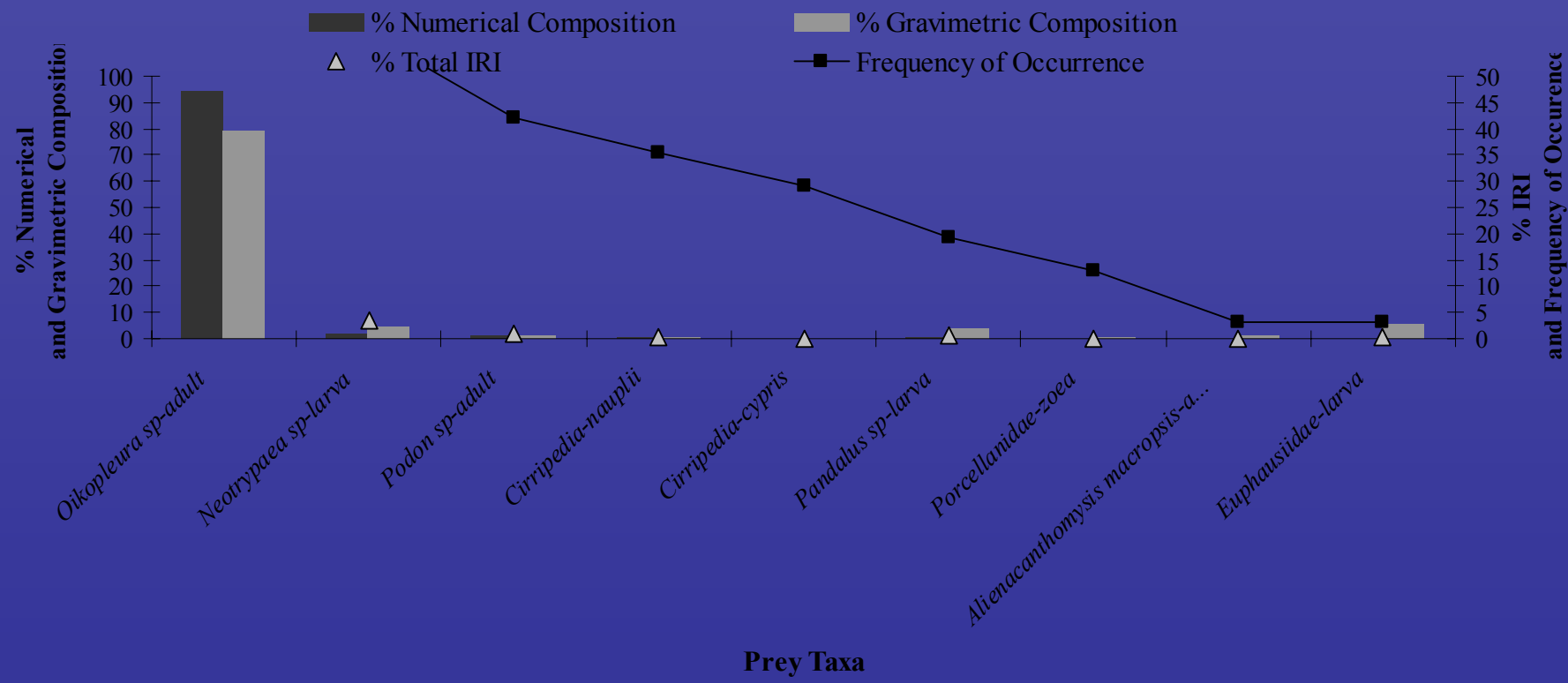
n=124, FL 58-185mm, mean 105.5mm

Juvenile Chinook diet in Sinclair Inlet

Category	Prey Taxa	2001 Littoral n=124			2002 Littoral n=134			2002 Offshore n=77		
		FO	NC	GC	FO	NC	GC	FO	NC	GC
Terrestrial										
	Araneae	10.5	0.9	0.2	8.1	0.4	0.2	14.3	0.4	0.5
	Psocoptera	33.1	25.0	1.4	15.6	1.5	0.3	28.6	3.7	2.1
	Sciaridae	16.1	0.9	0.1	8.9	0.5	0.1	15.6	1.0	0.2
	Hodotermitidae	8.9	0.9	10.8	-	-	-	-	-	-
	Hymenoptera	8.1	0.2	0	5.2	0.2	0.3	11.4	0.3	0.2
	Formicidae	19.4	5.9	5.9	6.7	4.6	4.0	19.5	0.8	3.0
	Psyilldae	9.7	0.4	0.1	2.2	0.1	0	20.9	3.4	2.3
	Aphipods	22.3	1.2	0.1	14.1	1.1	0.2	31.2	2.9	0.8
	Mirridae	3.2	0.1	0	8.9	0.3	0.3	11.7	1.1	1.2
	Other	-	7.1	1.8	-	4.9	5.7	-	6.8	9.1
	Total	**-**	**42.5**	**20.4**	**-**	**12.6**	**11.1**	**-**	**20.4**	**19.4**
Pelagic-Neustonic										
	Paguridae	15.3	1.7	0.4	5.2	0.8	0.3	2.6	0	0
	Pinnotheridae	33.1	12.1	1.2	33.6	2.7	1.5	16.9	1.7	1.5
	Brachyura	14.5	1.1	0.1	20.9	7.2	0.6	39.0	22.0	3.6
	Grapsidae	3.2	0.4	0	5.9	2.9	0.4	22.1	6.0	1.3
	Porcellanidae	22.6	12.3	3.2	37.8	20.2	7.9	58.0	28.6	26.9
	Cancer sp.	2.4	0.4	0.4	3.7	0.3	0	33.8	11.2	3.3
	Mysidacea	4.8	0.8	5.6	4.4	0.5	1.6	-	-	-
	Hyperiidae	2.4	0.3	0.5	2.9	0.2	0.3	18.1	0.6	4.4
	Cirripidea	30.6	9.8	0.6	31.3	6.8	0.7	20.8	0.7	10.2
	Fish	5.7	0.1	13.4	4.4	0.3	12.3	7.8	0.3	2.1
	Other	-	3.6	3.5	-	4.9	0.6	-	1.8	0.9
	Total	**-**	**42.6**	**25.7**	**-**	**46.8**	**26.2**	**-**	**72.9**	**54.2**
Benthic-Epibenthic										
	Polychaeta	9.7	0.5	0.7	6.7	0.3	7.4	14.5	0.5	12.6
	Nereidae	16.9	1.3	48.3	10.4	0.9	19.6	1.3	0.1	0.1
	Caprellidae	10.4	1.4	0.6	10.4	1.4	0.6	3.9	0	0.9
	Hippolytidae	2.1	0.1	0.4	1.5	2.2	16.0	-	-	-
	Gammaridea	31.4	4.6	2.8	29.1	23.5	10.3	24.7	0.3	0.7
	Cumacea	13.0	1.8	0.1	11.9	3.0	0.2	3.9	0	0
	Tanaidae	4.8	0.2	0	-	-	-	2.6	3.0	1.0
	Other	-	2.2	0.3	-	9.0	5.8	-	2.0	8.1
	Total	**-**	**12.1**	**53.2**	**-**	**40.3**	**59.9**	**-**	**5.9**	**23.4**
Plant										
	Plant Material	14.5	0.3	0.1	4.4	0.1	1.9	31.2	0.5	1.7

Juvenile Chum Salmon Diet

Nearshore 2001



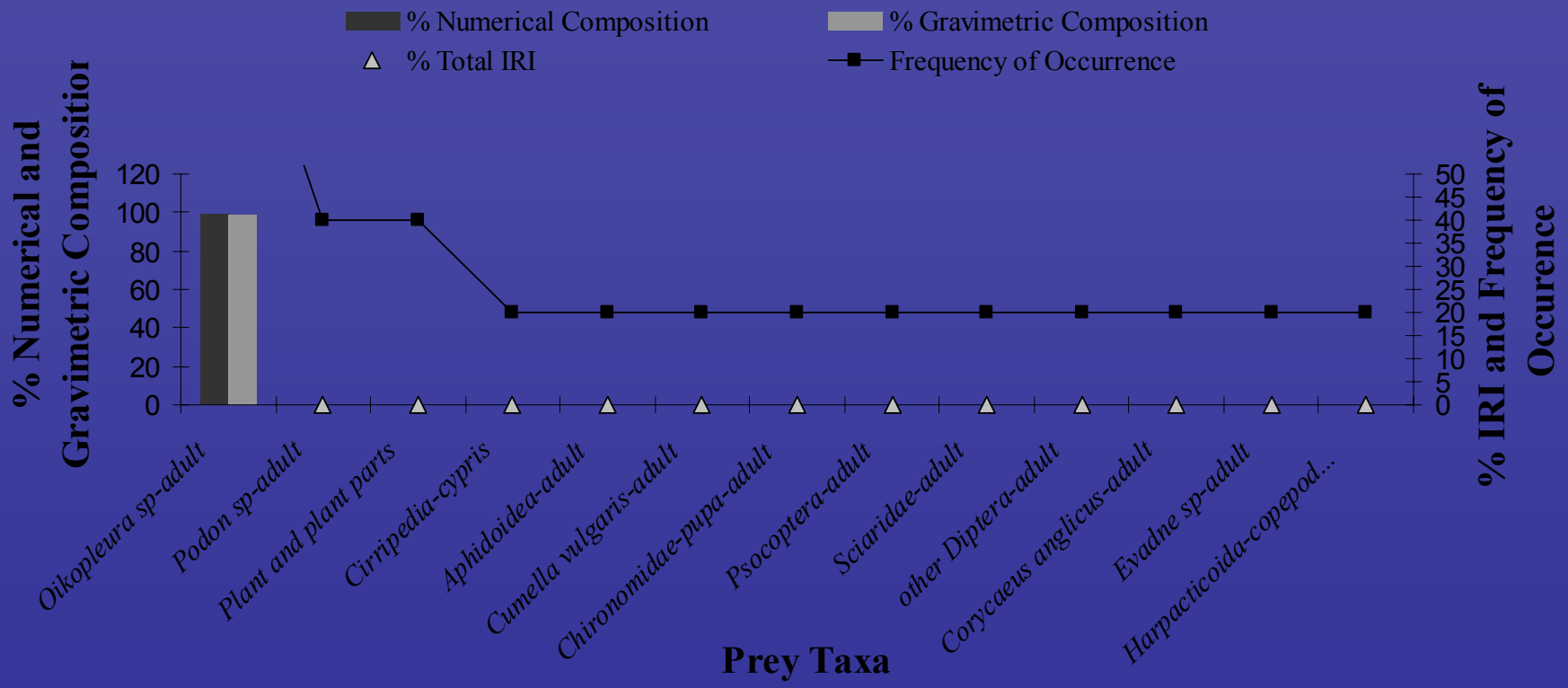
n=31, FL 64-86mm, mean 76.4mm

Chinook diet

- Low numbers of chironomids & *Corophium*
- Diet changes with size & month
  - Decapod larvae
  - Polychaetes

Juvenile Chum Salmon Diet

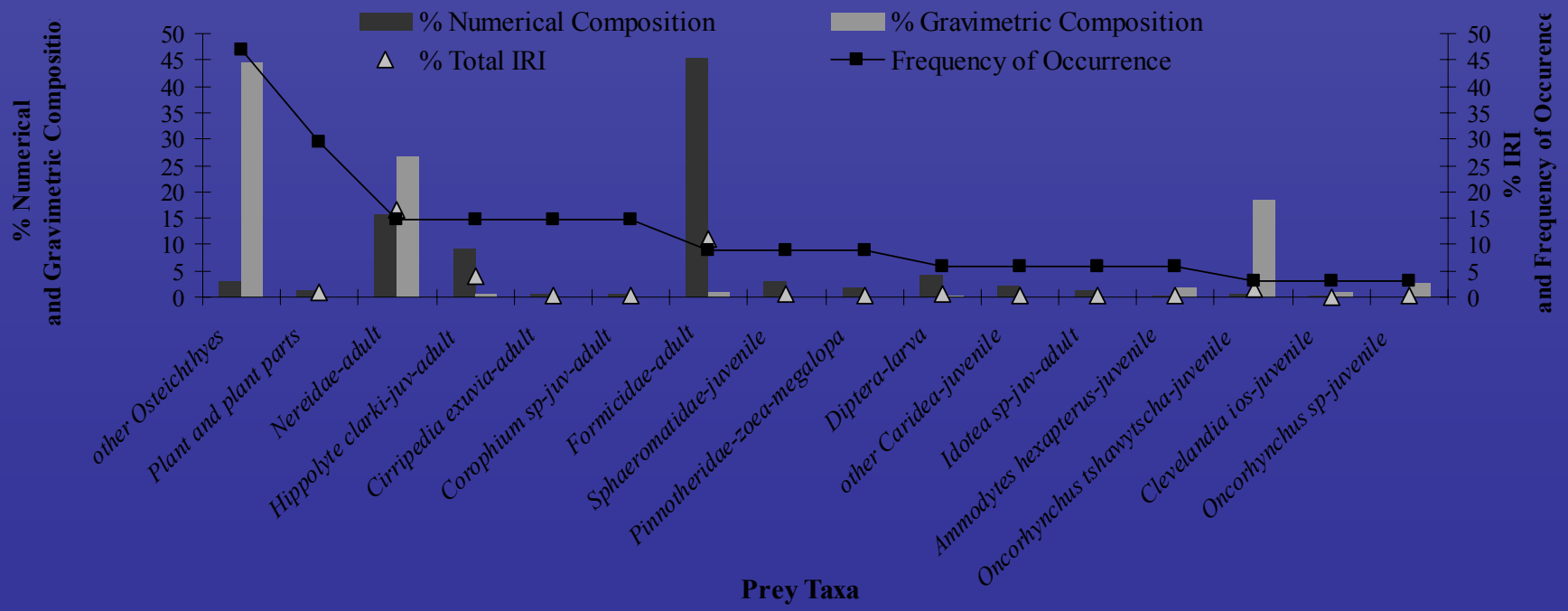
Offshore 2002



n=5, FL 62-72mm, mean 68.0mm

Cutthroat Trout diet

nearshore 2001



n=34, FL 130-450mm, mean 244.3mm

Conclusions

- Juvenile Chinook salmon have a diverse diet in Sinclair Inlet, including prey items from terrestrial sources.
- Juvenile chum salmon in Sinclair Inlet have a less diverse diet.
- The diverse diet of Chinook salmon suggests that they consume prey from a variety of microhabitats.