ORIGINS OF JUVENILE CHINOOK IN SAN JUAN COUNTY, WASHINGTON

Final Report to the
San Juan County Marine Resources Committee

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Final Project Report

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The San Juan Archipelago is the oceanographic crossroads of the Salish Sea, daily washed by the Fraser River and by tides from Puget Sound and the Gulf of Georgia. Not surprisingly, a SRFB-funded study found large numbers of juvenile Chinook, chum, pink, and coho in San Juan County nearshore waters from early spring through late summer (Barsh and Wyllie-Echeverria 2006). The largest aggregations were observed along the beaches of Waldron Island and President Channel; the beaches of south Lopez; and rocky shorelines of north San Juan Island.

Juvenile salmon use of coarser, higher-energy beaches distinguishes the San Juan Islands from most of Puget Sound, where smolts congregate preferentially in much more protected delta environments and pocket estuaries (Beamer et al. 2003; Fresh et al. 2006). It is not yet certain that all juvenile salmon shift to higher-energy nearshore habitats as they move seaward; or what prey attract them to higher-energy environments. First, it is necessary to determine the origins of juvenile Chinook utilizing San Juan County waters, so that we connect their foraging behavior in the islands with their behavior in their natal streams, deltas and estuaries. This report is a first step in that direction.

With over four hundred miles of shoreline, furthermore, San Juan County must set priorities for protection and restoration that have the highest likelihood of contributing to the recovery of ESA-listed salmon. Identifying the habitats used by ESA-listed stocks as opposed to juvenile Pacific salmon generally will help focus county action.

Partners

This study was originally planned as collaborative effort of KWIÁHT; Paul Moran and his salmon genetics team at the NOAA Northwest Fisheries Science Center, Seattle; and Terry Beacham and colleagues at the Canadian Department of Fisheries and Oceans Pacific Research Station, Nanaimo. The Moran and Beacham labs are founding members of the genetics consortium recently formed under the auspices of the Chinook Technical Committee of the Pacific Salmon Commission. KWIÁHT is working towards certification, with the assistance of the Moran lab; and had agreed to use this study to help the Moran lab test a new "ladder" designed to simplify and speed the process of genotyping samples of Chinook tissue (described under Methods, below). After the project got underway, the Beacham lab advised us that other obligations made it impossible for them to participate.

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Previous research

The importance of the San Juan Islands to inbound adult Pacific salmon has been known to fishermen for centuries, as evidenced by the antiquity of Native American reef-net sites and the great value placed on them by Native communities throughout the Salish Sea (Barsh 2005; Suttles 1974). Salmon migration paths through the islands were first investigated using acoustic tags more than 30 years ago (Stasko et al. 1976), but were not pursued further systematically, nor did they determine what resources adult migrants used in the archipelago.

A 1985 State tag-and-recapture study found 16 coho and 5 Chinook stocks among salmon recaptured in the San Juan Islands (Stohr and McGowan 1987), including three ESA-listed Chinook stocks (Nooksack, Lower Skagit, Dungeness River). More recent unpublished data from the Pacific States Marine Fisheries Commission is set out in the WRIA2 *Handbook of Salmon Recovery in San Juan County* (June 2004), Table 2, 19-20. Coded wire tag recoveries in the San Juan Islands included coho and Chinook stocks from the Fraser River, Georgia Strait, the west side of Vancouver Island, the Strait of Juan de Fuca, Hood Canal, all parts of Puget Sound, and much of the Columbia River. It is certain that adult salmon linger in the San Juan Islands each summer, but it remains unclear whether they feed, and if they do, what prey they target and where.[3]

Juvenile salmonids are also present in the archipelago throughout the year (Rice et al. 2004; Barsh and Wyllie-Echeverria 2006). Juvenile chum, juvenile pinks, and adult Chinook were amongst the ten species most commonly found in beach seine collections made by students at Friday Harbor Laboratories in the San Juan Islands (Miller et al. 1977). Data from several decades of FHL student projects are of limited value, however, because the methods, sampling locations, and times of year have varied from year to year (Moulton 2004). A more comprehensive multi-year approach is essential to ascertain, not only which WRIA2 beaches juvenile Chinook utilize, but also where these fish originate, since WRIA2 has no natal Chinook stocks of its own.[4]

Determining stock origins is crucial for public policy insofar as ESA-listed stocks must be given priority under federal and state management plans. To the extent that there are stock-specific preferences regarding habitat types or prey selection, moreover, greater focus can be given to local protection and restoration measures. For example, if juvenile Chinook from a particular endangered ESU are found feeding on smelt eggs on President Channel beaches, there is far more than a theoretical basis for protecting and enhancing smelt sands in that part of the county.

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[3] In August 2003 we analyzed the stomach contents of 10 sockeye taken by purse seined on the west side of San Juan Island. Seven stomachs contained prey items including insects, euphausiids, hypollytid shrimp, isopods, fish scales, and octopus, which suggest both pelagic and nearshore feeding within 24 hours of their capture (consistent with Higgs et al 1995, for sockeye harvested in Georgia Strait).

[4] A study currently underway by Barsh and Glasgow (Wild Fish Conservancy) has, thus far, identified five WRIA2 streams with native cutthroat populations and two with chum and coho. Chinook are produced in great numbers by the Glenwood Springs hatchery on East Sound, Orcas Island, operated by Long Live the Kings, but these tagged fish have not been found in any of the present authors' beach seine or tow samples.

Methods

1. Sampling strategy

We began with 16 tissue specimens collected by beach seine at various locations in San Juan County in 2005, mainly in the two "hot spots" where we had observed very large seasonal aggregations of juvenile salmon, including Chinook, for several years. We felt that it was most important to understand these large aggregations: are they relatively homogeneous, or composed of a wide variety of stocks; and from where?

Ideally, we would have sampled the two "hot spots" frequently over the course of several years, to capture seasonal and inter-annual variation. This was not possible given the time and financial constraints of our contract, which was approved in mid-August for completion by June the following year: that is, from the end of the 2006 juvenile Chinook migration to the beginning of the 2007 juvenile Chinook migration. Contract constraints therefore left us with two small time windows to collect fish. In previous studies we had used beach seines to sample fish populations in shallow water in different habitat types, but rarely brought more than 2-3 juvenile Chinook to hand together. To achieve a larger sample in such a very short time, we decided to use a larger net in deeper water where we believed we would be able to collect larger and more representative samples. However, it was conceivable that different salmon stocks frequent shallower and deeper waters in the San Juan Islands, so that beach seines and tow-nets might produce different results.

2. Beach seine sampling

Our beach seine sampling followed the method of Beamer et al. (2003). An 80-foot seine is deployed by hand in 1-4 feet of water from a floating tub or dinghy, and then pulled ashore by a crew of four. Three successive seine sets are carried out at each site as replicates, typically at the speed of one set every 15-20 minutes, moving up the current to minimize catching the same fish. Processing the catch from each set may take an hour or longer depending on the number of fish landed, which in our experience may include over a thousand chum or pink salmon, but rarely more than a few Chinook.

The beach-seined Chinook in our genetic sample were brought to hand in 2005 and 2006 in the course of our earlier exploratory study aimed at identifying the kinds of shoreline habitats most attractive to juvenile salmon (Barsh and Wyllie-Echeverria 2006). More than 20 exposed and more sheltered beaches in WRIA2 were seined at least once in the course of the study; those where salmon were found were seined repeatedly in spring and summer to determine the timing of different Pacific salmon species and their overlap with other seasonal fish populations such as herring, surf smelt, and shiner perch. This is an "opportunity sample" in the sense that it was not collected for the present study and is not ideal for the purposes of identifying all of the Chinook stocks that may seasonally use WRIA2 shorelines.

3. Tow net sampling

A long pursed net was towed behind the vessel *Coral Sea* with the assistance of a skiff in deeper waters of Cowlitz Bay (Waldron) and Hughes Bay (Lopez) on August 22 and August 24, 2006, and May 26 and June 18, 2007, using the methods of Fresh (1979) and Parr (1972). The duration of each tow was ten minutes, with the net maintained just below the surface, *i.e.*, in that portion of the water column where other studies suggested the greatest likelihood of encountering juvenile salmon. A single tow was also conducted in Shoal Bay (Lopez) on May 24, 2007 in connection with a different project, and yielded a single specimen for the present study.

Two days of towing in August 2006 yielded 46 juvenile Chinook—considerably more than we had been able to bring to hand by the beach seine method. We were not as successful in late May and June 2007, however: only 6 juvenile Chinook were brought to hand. It is conceivable that juvenile Chinook were simply late arriving in WRIA2 due to cooler and wetter than average spring weather. However, "leapers" were observed along WRIA2 shorelines during the same weeks that we deployed our tow net. As discussed in greater detail below, our poor early-summer tow results may also be due to previously unreported changes in juvenile salmon behavior during their summer residence in the San Juan Archipelago: more nearshore feeding in early summer when they are still relatively small, and more pelagic feeding as the summer continues and they grow larger.

We note that contractual constraints prevented us from repeating our late summer 2006 tows in 2007 in order to increase sample size and test the possibility of a seasonal shift in habitat use. Our study was approved on August 10, 2006, with a final reporting deadline of June 30, 2007, preventing us from towing at the same time for both summers as we originally had proposed.

4. Tissue preservation

After sedation in seawater dosed with Finquall (MS-222) juvenile Chinook were weighed, measured, and checked for marks and coded wire tags. A small part of anal fin tissue was then clipped with surgical scissors and transferred to an Eppendorf tube with 95% ethanol as a preservative and a waterproof paper slip with the site name, date, and a field number. At Friday Harbor Labs, tissue specimens larger than 5 mg were carefully divided (using sterilized disposable scalpels and trays to prevent cross-contamination) so that tissue not needed for DNA extraction could be preserved for future study. Extracted DNA not expended in microsattellite analysis (see below) was also preserved at Friday Harbor Laboratories by freezing at -80° Celsius.

5. DNA extraction

Chinook tissue samples were extracted using a DNAeasy Tissue and Blood Mini kit from QIAGEN. The tissue was rinsed in filtered TBE prior to extraction to remove any

residual alcohol. The extractions were eluted twice using 200µl of AE buffer, and the eluates were collected in separate microcentrifuge tubes. The concentration of DNA in a subset of six extractions (including two extractions that consisted of the second elution) was measured by spectrophotometer (absorbance at 260 nm). The concentrations varied from 7.5 ng/µl to 77.5 ng/µl with an average of 29.58 ng/µl. In most cases amplification was carried out on the first eluate.

6. Microsatellite analysis

We amplified 13 microsatellite loci from each sample—the so-called "CTC loci" as approved by the Chinook Technical Committee of the Pacific Salmon Commission (PSC) for determinations of Chinook origins—for comparison with the CTC database of Pacific Coast Chinook populations.

Microsatellites are small sequences of non-coding (*i.e.*, non-functional) DNA that are susceptible to relatively frequent duplication mutations called "short tandem repeats" or STRs (Banks et al. 1999; Nelson and Beacham 1999). Since they are non-coding, they are not subject to selection pressure to remove them from the population gene pool, hence they accumulate within populations, and reproductively isolated populations accumulate different patterns of greater or fewer repeats (different microsatellite alleles) that can be distinguished using DNA amplification (PCR), gel electrophoresis and fluorescent tags in a DNA sequencer. Patterns of microsatellite variations can be used to determine whether Chinook populations are reproductively distinct, and to assign individual fish to stocks of origin (e.g. Nelson et al. 2001). The fineness of scale of geographic distinctions, and the certainty or statistical power of the identification of individual specimens is a function of the number of microsatellites compared (Kim et al. 2004; Kinnison et al. 2002). The 13 CTC loci identify Chinook stocks to watersheds with 95+ percent confidence. (This is, coincidentally, the number of microsatellite loci used in human DNA "fingerprinting".) Several microsatellites are typically "multiplexed," *i.e.* tagged with different colors and run simultaneously on the same gel (Olsen et al. 1996).

As part of this project, the Moran lab and KWIAHT have tested the prototypes of a microsatellite "ladder" designed to reduce the time and expense of future genetic stock identification considerably, if its results are consistent with other methods. Multiplexing identifies 3 to 8 different microsatellite alleles per run by comparing each of them with a size standard, while ladders sort and identify any number of alleles by weight – thereby reducing several-fold the number of runs needed to identify a specimen. While ladders are already used in human "DNA fingerprinting," their use in salmon stock identification is novel, and San Juan County will have one of the first laboratories to use this new tool.

Samples were first amplified with 5'-end labled (6-FAM, HEX and NED) custom primers constructed for our use by Applied Biosystems, MGW DNA and Integrated DNA Technologies, as well as primers supplied by Paul Moran and Eric LaHood of the NOAA Northwest Fisheries Science Center in the form of a single amplification "cocktail". The Moran lab also provided us with the CTC primer sequences. The 13 primers amplify the

microsatellite loci of the CTC (Chinook Technical Committee) set standardized between 12 labs identifying Chinook (Moran et al 2005). Amplifications were performed using a Biometra thermal cycler in 10 μl reactions with 0.13-0.26 μl taq polymerase (Promega), 200uM dNTPs, 0.4uM labeled primer and 3μl sample or ladder or control.

Amplified loci were then run on an Applied Biosystems 377 automated slab gel sequencer. Fifty lanes were run on each gel, by loading with a paper membrane comb from The Gel Company (Toonen and Hughes, 2001). Where appropriate, PCR products with different colored labels were multiplexed by mixing prior to the addition of the size standard. 0.27-0.80μl of each PCR product was mixed with 0.9μl size standard-dye mix (2:1:6 ROX-500 size standard from Applied Biosystems comprising dextran blue EDTA: formamide); 1μl of this mix was loaded onto the comb using a loading tray from The Gel Company. Combs containing samples were loaded by filling the well with 5% ficoll + dextran blue and sliding the comb into it before filling the upper buffer chamber with 1x TBE. After the first few minutes of the run the membrane comb was removed, and the ficoll was rinsed out of the well. Each gel had a collection time of three hours. Two amplifications of an allele ladder (developed and provided by Eric LaHood) were run for each locus on each gel as well as two samples of known genotypes (also provided by Eric LaHood). Alleles were scored by comparison with the ladders and the control genotypes. STRand software developed by the University of California—Davis was used to identify alleles.

Paul Moran then analyzed the allele frequencies of our specimens, compared them with the genotypes of known source populations (Moran et al 2005) and assigned them to their stocks of origin.

Results

We have grouped stream-of-origin results by geographic domains and collection methods (Table). As noted above, Waldron and the south shores of Lopez form distinct "hot spots" where juvenile salmon congregate in the nearshore. We have also collected juvenile salmon in the corridor connecting the Waldron and Lopez hot spots—San Juan Channel—and have organized our data to see whether it attracts different populations of Chinook or simply functions as a migration route for fish using the Waldron and Lopez domains. We considered it prudent to compare beach seine and tow-net results, because these gears sample different albeit adjacent habitats: inter-tidal shorelines (beach seines) and the neritic zone beyond the deepest sub-tidal eelgrass meadows (tow-nets). Different stocks of Chinook may feed in the inter-tidal and neritic zones; or different size classes or life history stages of the same stocks; or the same stocks may simultaneous exploit both zones, following daily tides and currents.

Table 1: Origins of San Juan County juvenile Chinook determined by genotyping

Stream of origin	Collection location (N)				
	Waldron		SJ Channel	South Lopez	
	Seine ( )	Tow-net ( )	Seine ( )	Seine ( )	Tow-net ( )

When interpreting these data, it is important to bear in mind that juvenile Chinook tissue was collected over three seasons (2005-2007). Habitat choices may vary from year to year, especially if juvenile Chinook are attracted by the abundance of particular prey— rather than stock fidelity to particular shorelines or classes of shoreline morphology. Our current sample is too small to explore inter-annual variation in the habitat associations of different Chinook populations, but this question should be pursued in future studies.

Furthermore, our sampling strategy was seriously constrained by the timing of our funding, as described above under Methods. We can say with confidence that the stocks identified in Table 1 were present in WRIA2—and, in the case of the beach seine sample, were feeding along WRIA2 shorelines—during the narrow time windows in which they were collected: May-August 2005 and 2006, and late May 2007. We cannot say with any confidence how representative these data may be of WRIA2 as a whole, year-round. The importance of conducting a more comprehensive, multi-year sampling exercise for stock identification cannot be over-emphasized.

Size (Fork Length) data did not reveal any clear size difference between juveniles caught in beach seines (chiefly in May and June) and juveniles caught in deeper water by our tow net in August. There was a greater range of size classes in shallower water, and the variance was quite high, as presented in Figure 2. The juveniles taken in Hughes Bay by tow-net were clearly smaller than those taken by tow-net in Waldron waters, however: a difference in means of 13 mm or 10 percent of the combined mean size of our tow-net sample. The two areas were towed within 48 hours of each other. Why were the juvenile Chinook in Hughes Bay smaller, and therefore presumably younger? Did they leave their natal streams for the islands at a younger age and smaller size? Or, had the Waldron fish arrived earlier in the season and grown more than a centimeter longer whilst residents in WRIA2? Differences in the lengths of local aggregations of juveniles in WRIA2 suggest differences in the role of WRIA2 in the life-history strategies of different Chinook stocks.

The seasonal difference between our beach seine and tow-net samples suggests an alternative possibility: as the summer progresses, juvenile Chinook feeding along WRIA2 shorelines either continue their seaward migration, or move to deeper WRIA2 waters and continue to feed on more pelagic prey. This predicts mixed stock aggregations of widely varying size along shorelines in the early summer, but relatively few juvenile Chinook in deeper WRIA2 waters until late summer, when only some Chinook stocks remain behind. Our poor tow-net results in late May and early June, during a time when shore observers on Waldron and Hughes Bay reported large numbers of "leapers", is consistent. In future studies it would be useful to pair beach seine and tow-net collections of juvenile Chinook during the summer months—or to maintain systematic shore observations for comparison with tow-net results.

Results from our 2007 tow net sampling are also suggestive, although the sample size is small and from different years, therefore non-comparable with 2006 data. Juvenile Chinook taken by our tow net in early summer 2007 were about 15 percent smaller (fork length) than juvenile Chinook taken by tow net in the same areas in late summer 2006. It is plausible that many juvenile Chinook spend the summer in the islands and grow by that much or more before continuing their seaward migration.

It should be noted that all juvenile Chinook included in this study were examined for external tags or marks and checked for coded wire tags with an electronic "wand." No marked or tagged individuals were found; hence in principle our sample consists entirely of wild fish, although there is always the possibility that some hatchery fish were released untagged.

Discussion

Adaptive genetic diversity has enabled Pacific salmon to survive the vagaries of a dynamic geology and volatile climate in the Pacific Northwest, marked by frequent rapid changes in the distribution of habitat patches and prey populations (Hutchings 2004). To help salmon survive the additional rapid changes brought about by industrialization of the Puget Trough, we must maintain habitat diversity and foraging options. Protecting only a part of the habitat mosaic collectively utilized by Pacific salmon would have a pernicious selective effect of selecting for particular life-history types and favoring genetically more homogenous populations. But first we must better understand the extent of the diversity of life histories and habitat uses of existing salmon stocks.

There is a growing body of evidence that juvenile salmon utilize a wide range of littoral and neritic habitats such as floodplains (Sommer et al. 2001), delta channels and pocket estuaries (Beamer et al 2003), and river plumes (Cooney et al. 2001; Fukuwaka and Suzuki 1998). A simple distinction between freshwater behavior and ocean behavior is no longer tenable. As Beamer emphasizes, salmon have evolved various complex life histories that involve different patterns of exploitation of the diverse aquatic ecosystems that lay along salmon migration paths. Nearshore habitats are probably a major factor in

the total life-span survival of Puget Sound Chinook and presumably other Pacific salmon (Beamish et al. 2004; Greene et al. 2005; Greene and Beechie 2004; Quinn et al. 2004).

Diversity of life histories implies some diversity in prey selection as well. On the Columbia River, juvenile coho and Chinook consistently prefer pigmented invertebrates, feasting on hyperiid amphipods, crab megalopae and euphausiids, as well as some larval and juvenile fish, with larger Chinook accounting for most of the fish consumption; small copepods dominate the zooplankton community but are a small part of the salmonid diet (Schabetsberger et al. 2003). Juvenile salmon are not passively opportunistic. Studies of pink and coho salmon have found that they are attracted to dense clouds of zooplankton (Willette 2001; Cooney et al. 2001), which they will attempt to exploit even if associated with dangerous conditions such as high temperatures (Birtwell et al. 2001).

Beamer et al. (2003) have shown important diversity in the life history strategies of wild fry migrant chinook of Skagit origin. Based on otolith data, they distinguish *fry migrants* (fry migrate directly into Skagit Bay); *tidal delta users* (fry remain in the tidal delta where they rear to c. 70 mm before proceeding into Skagit Bay); and *parr migrants* (fry remain in fresh water to c. 70 mm before proceeding into Skagit Bay). Once in the bay, furthermore, at least some juvenile Skagit Chinook congregate in "pocket estuaries" where they continue to grow for several weeks before migrating to deeper waters. What proportion of Chinook migrants utilize pocket estuaries, and where they go to feed after leaving Skagit Bay (perhaps to the San Juan Islands) was unclear until the present study.

Habitat use is at least partly a function of the prey preferences of salmon and the abundance of preferred prey in particular types of habitat. In an exhaustive review of the literature, Higgs et al (1995) reported that the prey items most frequently identified in juvenile Chinook whilst they are rearing in estuaries have been gammarid amphipods, calanoid copepods, euphausiids, mysids, and insects. As Chinook transition to marine habitats, they add juvenile fish (including other salmonids) and decapod larvae to their diet. Estuarine sockeye consumed insects, copepods, and larval fish, switching to fish larvae, euphausiids, cladocerans, hyperiid amphipods and calanoid copepods in marine waters. Estuarine chum targeted insects, harpaticoid copepods, gammarid amphipods, and cladocerans, switching to more planktonic crustaceans in the marine phase. These generalizations were derived from a wide variety of sources, methods, and geographical areas along the entire north Pacific range of Pacific salmon. They almost certainly do not represent the diversity of salmon prey; the relative importance of particular prey items to specific stocks of salmon; or the adaptive diversity of foraging strategies within stocks.

The same *caveat* may be applied to extant data on the foraging strategies and diets of juvenile salmon in Puget Sound waters. Simenstad et al (1979) and Miller et al (1980) found mainly epibenthic organisms such as harpacticoid copepods, gammarid amphipods, oniscoidean isopods, and cumaceans in the stomachs of coho, pinks, and to a lesser extent chinook; whilst planktonic organisms such as calanoid copepods and hyperiid amphipods dominated the stomach contents of juvenile chum and were also found in pinks. Decapod larvae and drift insects were frequently found in juvenile Chinook and sockeye. Larval and juvenile fish including herring and sand lance comprised a significant proportion of

the diets of juvenile coho and Chinook, and were also frequently seen in sockeye. On the whole, Chinook, chum and sockeye appeared to target more pelagic prey, whereas coho and pink salmon focused more on epibenthic prey (see also Brennan et al. 2004; Fresh 2006). Chinook and coho consumed the most fish, whereas other species relied more on crustaceans. Comparison at the level of species is inadequate for conservation, however, and data do not yet exist for finer scale analyses (*i.e.*, by stock or by nearshore habitat types). In particular, we still lack data on prey use by juveniles congregating in WRIA2, with its extensive beaches and rocky shorelines.

Monthly beach seining in 2005-2006 in a combination of sheltered bays and high-energy exposed beaches of WRIA2 (Barsh and Wyllie-Echeverria 2006) brought several hundred juvenile salmon (Chinook, chum, pink and coho) and thousands of "forage fish" (smelt, herring, sand lance) to hand. Juvenile salmon were most abundant on relatively coarse high-energy beaches. (Compare the negative relationship of salmon fry with fine sediments in fresh water habitats described by Suttle et al. 2004). Sites with the highest juvenile salmon abundance were not vegetated, although sub-tidal eelgrass beds were generally present offshore, and salmon may have sought refuge or prey in those meadows between episodes of feeding closer to shore. Juvenile Chinook, the most piscivorous Pacific salmon, were most abundant from May to August, overlapping the seasonal peak abundance of juvenile smelt and other "forage fish".

These results are significant because they diverge from observations elsewhere that associate juvenile salmon with eelgrass communities (*e.g.* Simenstad 1994) and "pocket estuaries" (Beamer et al 2003). We may be seeing juvenile salmon from natal areas that do not afford them the protected delta-pocket estuary environments studied by Beamer in Skagit, Island and Snohomish Counties. Or, we may be seeing salmon at a different life-history phase with different habitat preferences. We generally see chum and pink smolts arriving in February at a small size (<50 mm Fork Length), which suggests that they have not spent much time elsewhere, while Chinook in our samples have generally been 80 to 120 mm Fork Length.

There is much more to learn about the kinds of prey and other conditions that attract juvenile Chinook and other Pacific salmon to *particular* high-energy beaches in WRIA2; the extent to which the abundance of particular prey determines juvenile salmon habitat choices (as opposed, *e.g.*, to oceanographic conditions); the extent to which the prey base varies from year to year; and the extent to which prey availability is affected by land-use practices. Answers to these questions will help refine county efforts to identify the most important habitat conditions for Chinook, and to protect and enhance Chinook habitat in ways most likely to increase juvenile Chinook growth and survival during their seasonal residence in WRIA2.

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Appendix

INVENTORY OF JUVENILE CHINOOK DNA SPECIMENS
Fork lengths in mm

Provenience	Date	Gear	Fork Length	Tube
Cowlitz Bay, Waldron	2005 May 15	Beach seine	73	Kw12
			142	Kw13
			117	Kw72
	2005 June 12	Beach seine	69	Kw6
			100	Kw10
			87	Kw15
	2006 July 16	Beach seine	76	Kw2
	2006 Aug 22	Tow net	78	Kw17
			113	Kw18
			95	Kw19
			115	Kw20
			115	Kw21
			107	Kw22
			139	Kw23
			137	Kw24
			123	Kw25
			119	Kw26b
			96	Kw30
			110	Kw31
			95	Kw32
			197	Kw34
			109	Kw39
			110	Kw40
			101	Kw41
			162	Kw42
			100	Kw45
			125	Kw73
			90	Kw54
			113	Kw62
			135	Kw74
			115	Kw55
			125	Kw56
			136	Kw57
			107	Kw58
			117	Kw59
			108	Kw60
			118	Kw61
			96	Kw28

			82	Kw69
			85	Kw64
Cowlitz Bay, Waldron	2007 May 26	Tow net	85	Kw65
			76	Kw66
			95	Kw67
	2007 June 18	Tow net	96	Kw68
Griffin Bay, San Juan	2006 June 18	Beach seine	218	Kw3
			165	Kw5
	2005 July 29	Beach seine	103	Kw16
			83	Kw33
			120	Kw35
			103	Kw36
			105	Kw37
			108	Kw38
			92	Kw43
			100	Kw44
Hughes Bay, Lopez	2006 Aug 24	Tow net	138	Kw46
			65	Kw47
			102	Kw48
			132	Kw49
			111	Kw50
			104	Kw51
			88	Kw52
			110	Kw53
Jones Island	2005 July 27	Beach seine	210	Kw7
			118	Kw14b
Severson's Bay, Waldron	2005 June 12	Beach seine	79	Kw1
Shoal Bay, Lopez	2007 May 24	Tow net	76	Kw63
Spirit Cove, San Juan	2006 June 18	Beach seine	86	Kw4
Watmough Bight, Lopez	2005 July 29	Beach seine	114	Kw9
Zora's Cove, Shaw	2005 July 28	Beach seine	95	Kw8
			118	Kw11

Figure 1

Origins of juvenile Chinook in San Juan County:
Sampling stations (2005-2007)
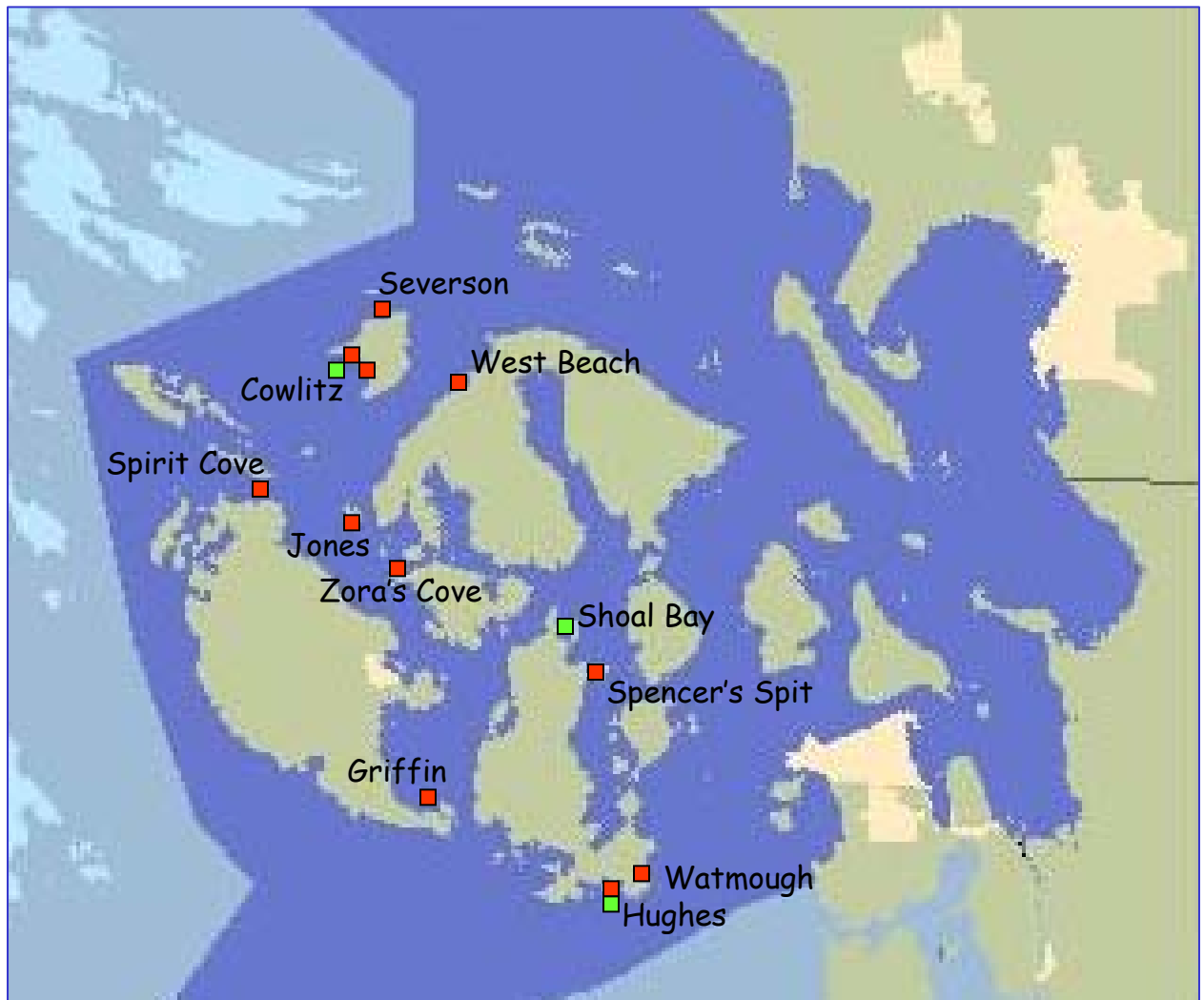
Beach seine (2005-2006)
Tow net (2006-2007)

Figure 2

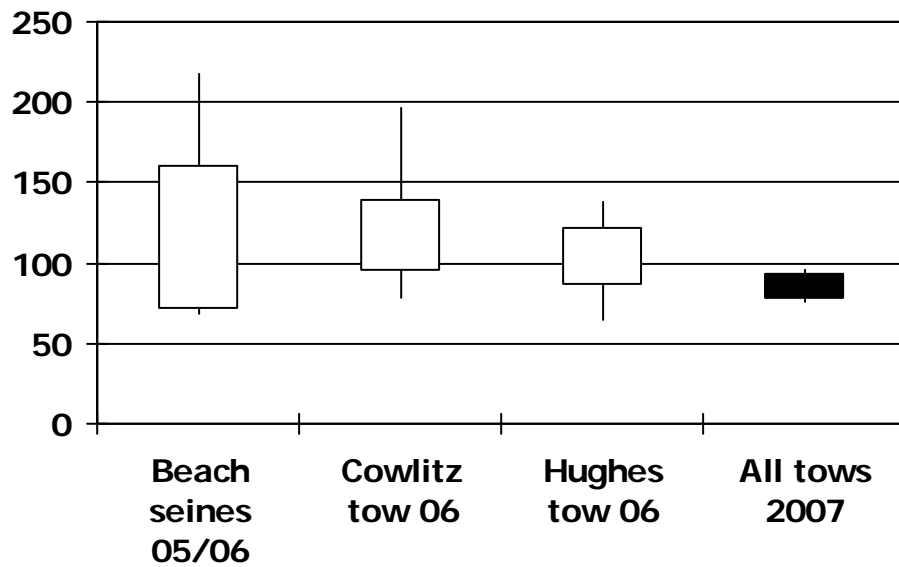# Fork Lengths of juvenile Chinook in mm by area and gears (2005-2007)

Figure 3

Origins of juvenile Chinook
found in WRIA2 waters (2005-2007)