Utilization of Near-Shore Habitat by Juvenile Pacific Salmon on British Columbia's Central and North Coast

Final Report

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RAINCOAST CONSERVATION FOUNDATION

Introduction

A paucity of information exists about the pathways taken by juvenile salmon during their outward migration from natal streams to the open ocean. Yet, this important habitat is being compromised through industrial development. Salmon farming, logging, and mining, are all impacting near-shore habitat. Continued coast-wide declines in salmon returns, and the concerns of coastal First Nation communities, have prompted Raincoast to investigate the near-shore habitat utilized by juvenile salmon.

The many inlets, islands, and passages, provide a diverse and complex selection of potential habitats for juvenile salmon on the central coast of British Columbia (BC). Upon leaving their natal streams, the near-shore migration of juvenile salmon is a critical time for feeding and rapid growth before they move toward the open ocean. However, it is also a very vulnerable time, when mortality rates are known to exceed 65%[1]. The purpose of this study was to collect primary information about this very important life history stage of salmon. The questions we sought to answer were:

- When are peak abundances for juvenile salmon in near-shore habitats on the central coast? Does this vary among species?
- Are there differences in abundance and species composition between bays and channels?
- What factors, if any, can be used to predict juvenile salmon movements?
- How long do juvenile salmon spend in these near-shore habitats?
- What are the ambient lice levels on juvenile salmon in this area? Does this differ between areas exposed to and peripheral from open net-cage salmon farms?

In this report, we have included a brief description of our answers to these questions. As in most investigations, we are left with more questions than answers. Raincoast will extend this research into the northern reaches of BC's central coast in spring 2008, where active salmon farms have been placed along primary migration routes of vulnerable salmon runs. We will combine this work with sea lice sampling, and anticipate a peer-reviewed publication on our non-invasive methods within the year.

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[1] Parker, R.R. 1965. Estimation of sea mortality rates for the 1961 brood-year pink salmon of the Bella Coola area, British Columbia. J. Fish. Res. Board Can. 22: 1523-1554.

Study Area

This research took place on the central coast of BC, among the waters of Heiltsuk traditional territory. Streams and rivers draining into the ocean in this area support pink, chum, coho, and sockeye salmon, as well as Dolly Varden and steelhead/rainbow trout[2]. The coastline is characterized by numerous inlets and islands composed of protected bays and deep channels, representing a diversity of habitats from eelgrass and mud flats, to steep rock drop-offs and deep water. We visited 56 sites over a period of 8 weeks from mid-April to mid-June 2006. Transect locations were selected for their variability in habitat type, and were thought to represent predicted migration pathways for juvenile salmon in the area (Figure 1).

Experimental Design

Sample locations were haphazardly chosen in every inlet and passage in the study area. For each location, transects were set-up on either side of the channel. Each transect paralleled the shoreline and was 1000 m long with the width being from the beach to approximately 10 meters from shore. Efforts were made to locate the site in an area that encompassed the three primary habitat types (bay, point, channel).

Each transect was sampled approximately once per week. The survey was completed using a motorized boat with two observers (equipped with polarized sunglasses), and one driver. The driver would idle slowly along the shoreline while the observers scanned the water ahead, and on either side, of the vessel. When a school of fish was observed, the distance along transect, distance from shore, school size (square metres), and habitat type were recorded. This procedure was performed for each school of fish observed along a transect. Then, using a 50 x 1.5 metre (5 mm mesh size) beach seine, one school of fish was selected and captured. To deploy the seine net, an assistant on shore held one end of the net, while the assistant on the boat held the other end. The boat slowly created an arch away from the shore, and then returned to shore approximately 30 metres away. The two ends of the net were pulled together, and 50 fish were randomly selected using a small dip-net. School abundance, and species composition of remaining fish were estimated, and released. All fishes collected were euthanised, transferred individually to sample bags, placed immediately on ice, and frozen within hours. All samples were sent to the Raincoast lab for further analysis of length, weight, external parasite levels (sea lice), and host species identification.

Measured Variables

In an effort to correlate habitat type with fish abundance, biotic and abiotic variables were measured for every school observed along a transect. Variables included: dissolved oxygen, salinity, temperature (all measured using a YSI meter, 1.0 metre below the ocean

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[2] Jacobs, M. 2001. The Heiltsuk Stream Inventory 2000 Summary Report. Prepared for the Heiltsuk Tribal Council.

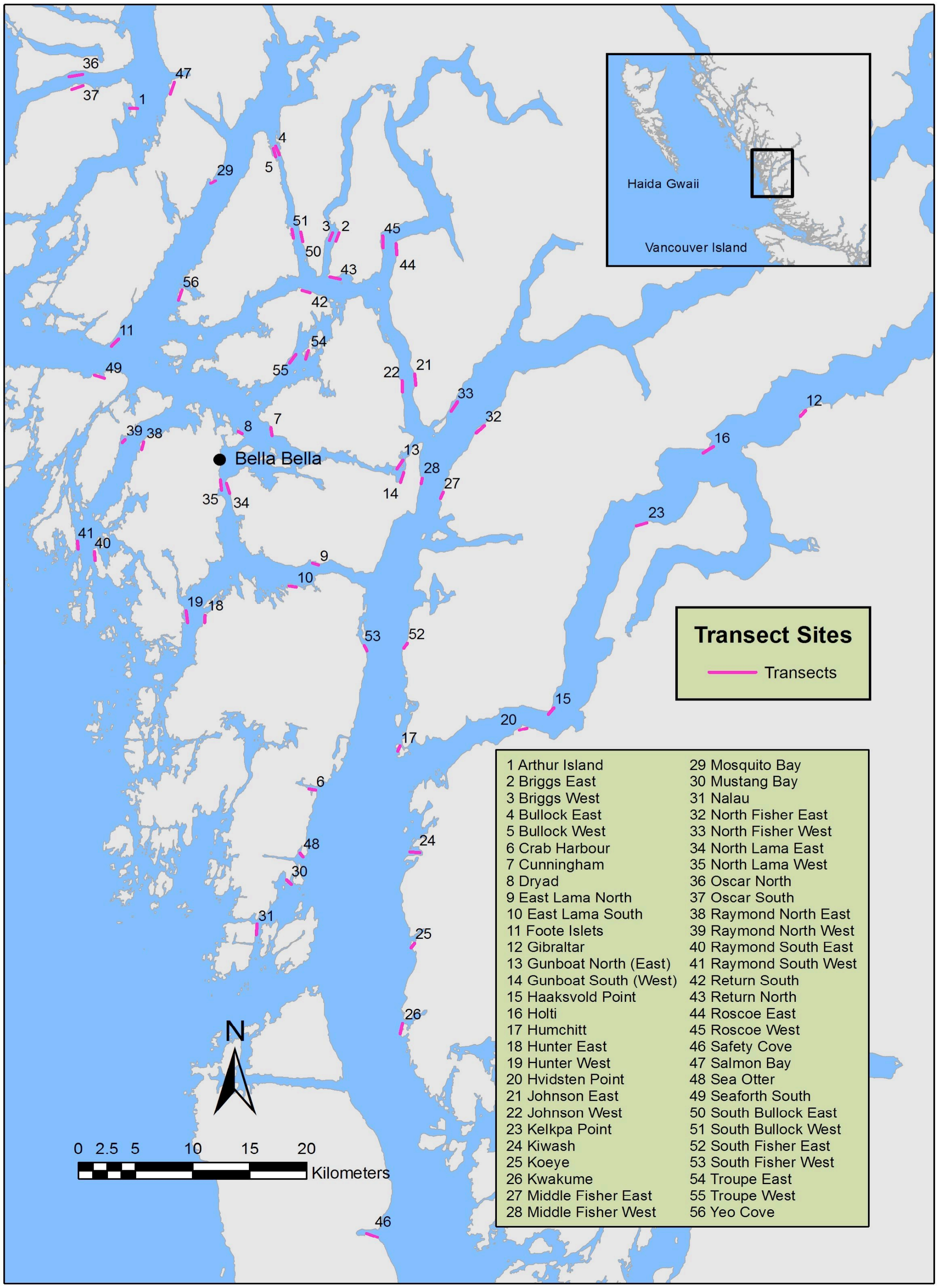


Figure 1. Transect sites selected for near-shore habitat utilization of juvenile salmon study on the central coast of BC during April to June 2006.

surface), turbidity (with the use of a Secchi disk as a measure of plankton abundance), slope (flat 0-5%, sloping 5-20%, or steep >20%), substrate (sand, mud, or hard), exposure (low, medium, or high), stratification (mixed, weekly mixed, or stratified), and habitat type (bay, point, or channel).

Results

When are peak abundances for juvenile salmon in near-shore habitats on the central coast? Does this vary among species?

Based on the mean school size observed across all transects, the peak migration for all species through this area of the central coast happened the week of May 15th to 21st, 2006 (Figure 2).

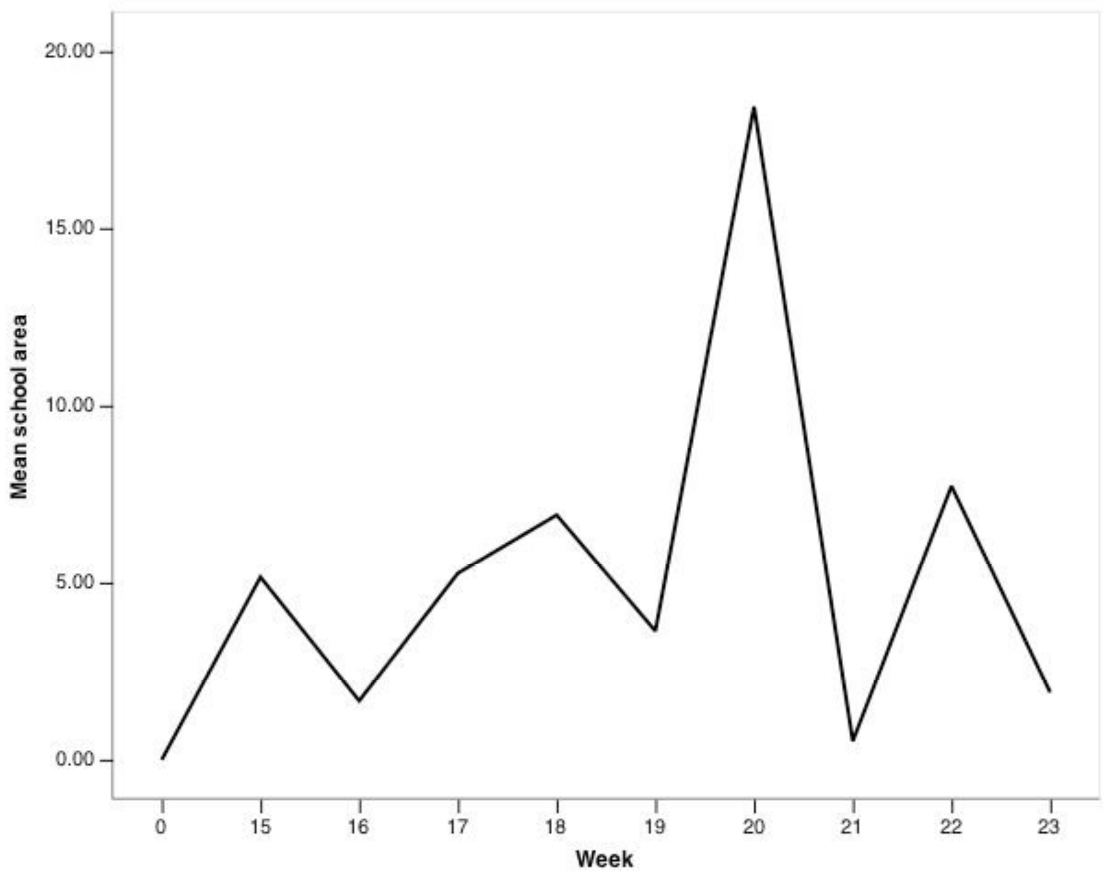


Figure 2. Mean school size (area) of juvenile salmon observed across all transects during the sampling period from April 10th, 2006 (Week 15) to June 11th, 2006 (Week 23).

Juveniles retained from the beach seines were identified to species. This information has been used to look at the relative abundance of each species throughout the sampling period, however, we are aware that sampling protocols have influenced these data. For example, weather on a particular day may have prevented crews from conducting the beach seine and therefore numbers of individuals for that particular week might be lower than were actually present. However, with this in mind, we find that relative abundances correspond closely with those in Figure 3.

Pink salmon were the most abundant species captured in the seine nets, with the highest abundance observed the week of May 15th to the 21st (Figure 3). Chum were the next most abundant species with the majority out-migrating over a longer period, between May 1st and May 21st. Although several other species were found in the seine surveys, including juvenile coho and sockeye salmon, too few were present to accurately assess migration timing.

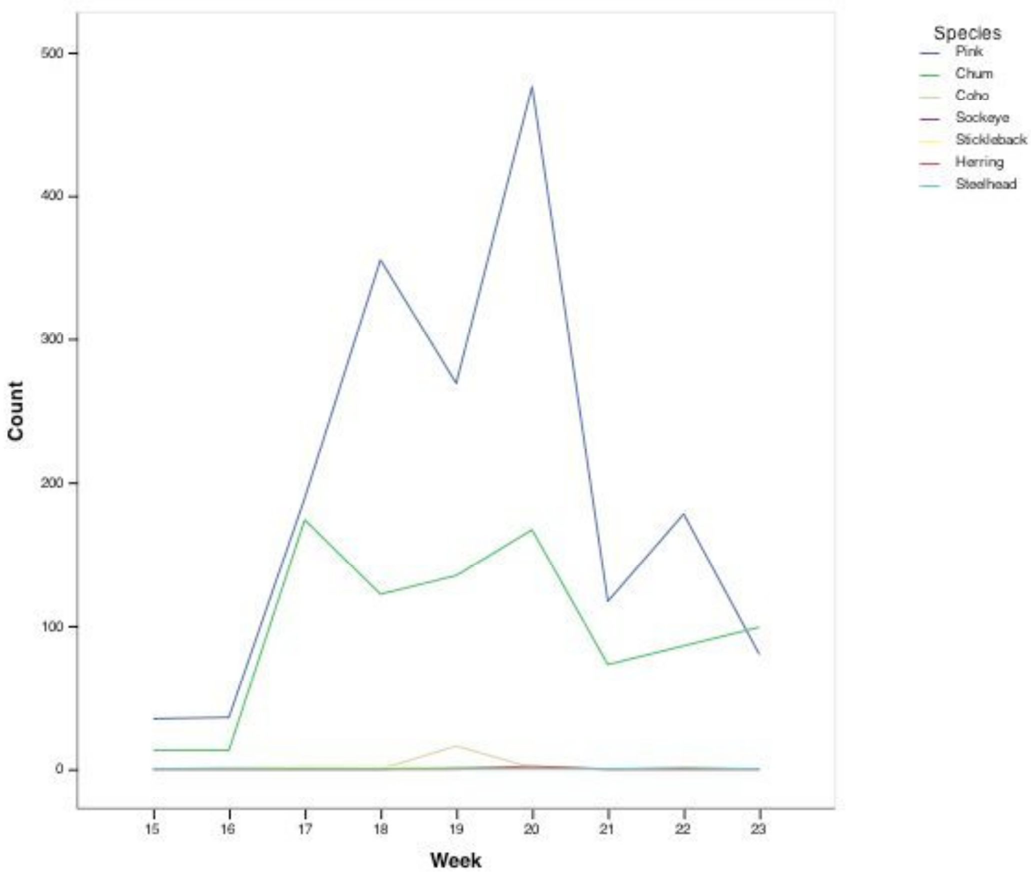


Figure 3. Number of juvenile salmon and other fishes collected during beach seine surveys throughout the 2006 sampling period, for all transects combined.

Are there differences in abundance between bays, points, and channels?

There are differences in juvenile salmon abundance between bay, point, and channel habitats (Figure 4). The largest schools are most often found among channels ($\bar{x}$=12.5m^2), followed by bays ($\bar{x}$=5.5m^2), then points ($\bar{x}$=4.5m^2). Although this evidence suggests a preference by juvenile pink and chum salmon for channel habitats during their outward migration, these differences are not statistically significant due to large deviations from the mean.

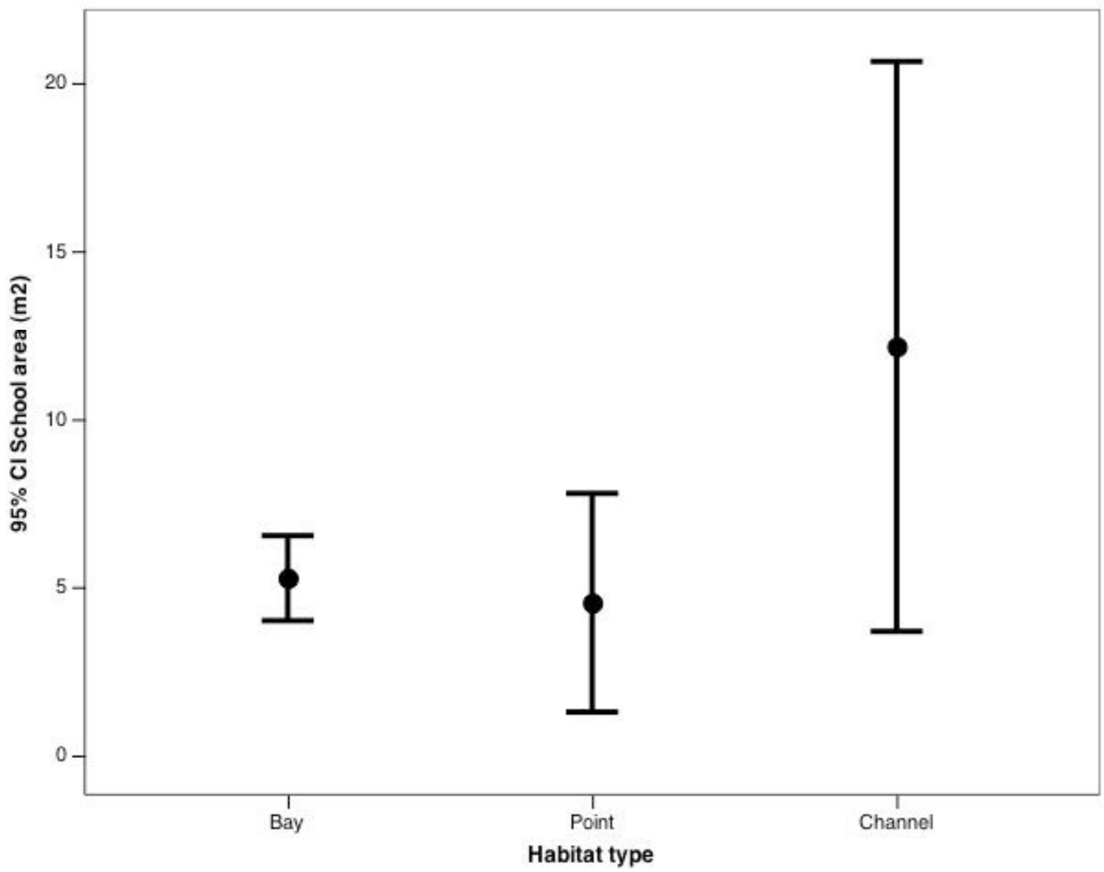


Figure 4. Observed differences in the abundance of juvenile salmon across habitat types (bay, point, channel), using 95% Confidence Intervals [CI], during the 2006 study period.

What factors, if any, can be used to predict juvenile salmon movements?

Of the nine variables measured during weekly surveys to predict juvenile salmon abundance (movements), six show promising results. Of these, five indicate an association with the presence and abundance of juveniles: temperature, stratification, turbidity, substrate, and exposure. However, temperature is the only variable to show a statistically significant association, and a predictive model using the combined variables has not [as yet] been performed.

There appears to be a strong association between juvenile salmon abundance and temperature, with most juveniles found in ocean waters below 9°C (Figure 5). Juveniles may follow this temperature regime as they leave natal rivers, and migrate towards the open ocean, choosing to travel amongst cooler currents. However, it is necessary to note that of the 794 temperature readings, only 27 were classified as Warm. This uneven distribution potentially biases our results.

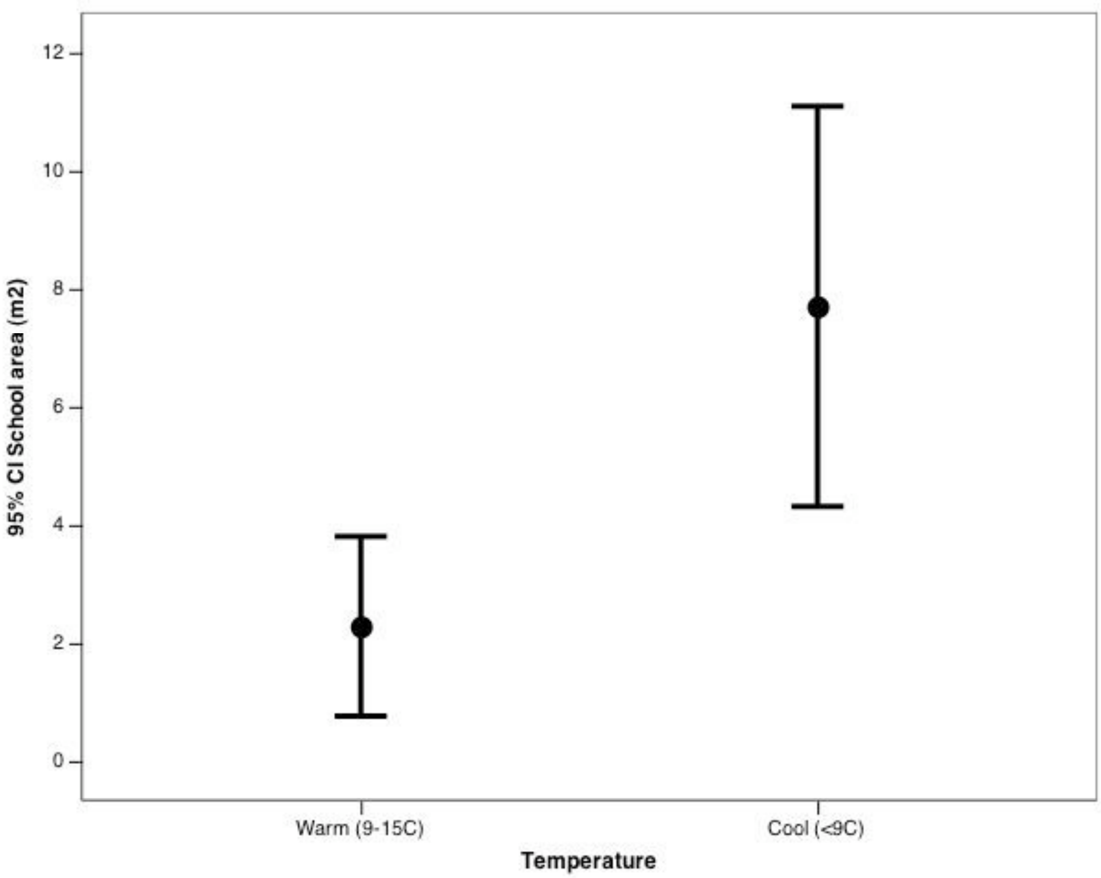


Figure 5. Abundance of migrating juvenile salmon in Warm (9°-15°C), versus Cool (<9°C), ocean water, using 95% Confidence Intervals [CI], during spring sampling, 2006.

There appears to be a strong relationship between the presence and abundance of migrating juvenile salmon, and sea-water stratification (Figure 6). Specifically, school size of juveniles increases as sea-water conditions shift from a mixed environment - to weekly mixed - to stratified. Although we have yet to test whether an association exists between temperature and stratification, it is likely that sea-water experiences a shift from mixed, to stratified, as ocean temperatures decline. Given this, it is difficult to assess whether migrating juveniles are more heavily influenced by ocean stratification, or ocean temperature, without further analysis. Regardless of uncertainty, we repeatedly observe larger schools of juveniles where temperatures are low, and sea-water is stratified.

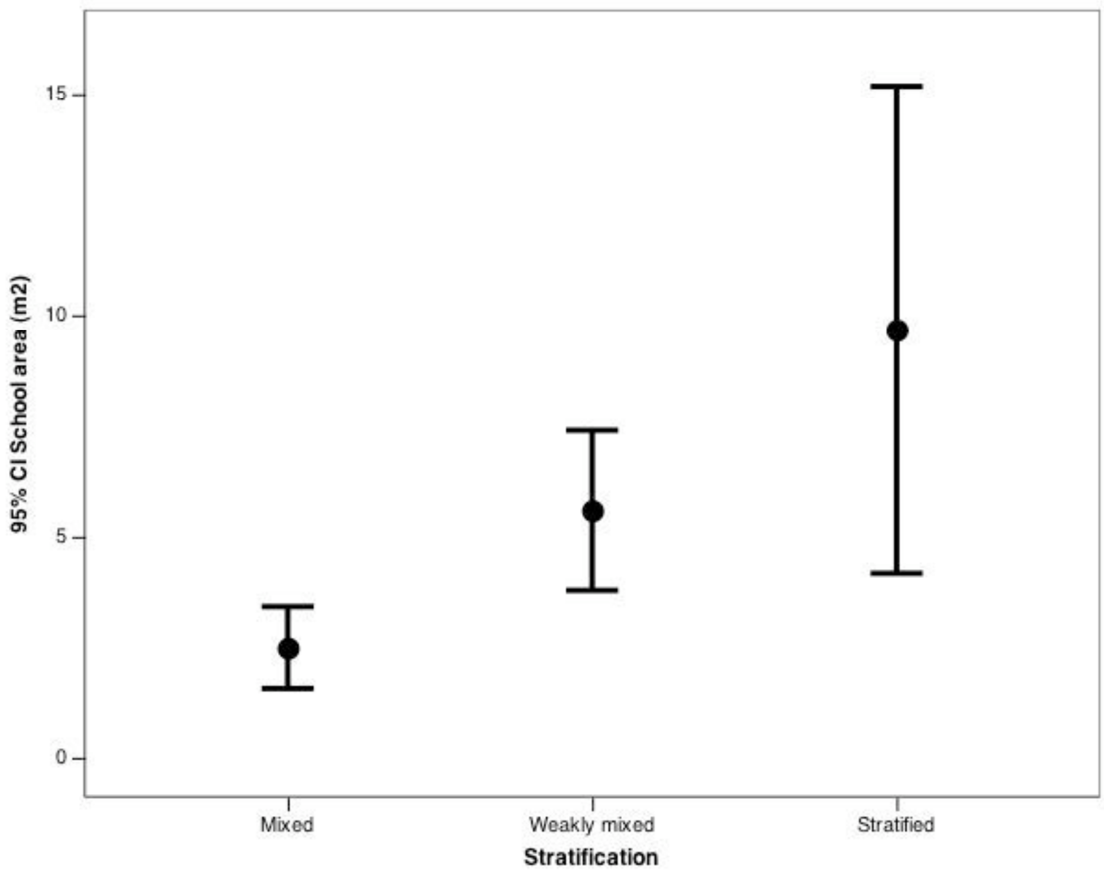


Figure 6. Abundance and association of migrating juvenile salmon with sea-water Stratification (mixed, weakly mixed, and stratified), using 95% Confidence Intervals [CI], during spring sampling, 2006.

Ocean turbidity also appeared to be a novel predictor of juvenile salmon abundance (Figure 7). Results show an interesting association between turbidity levels, and size of juvenile salmon schools. Schools of juveniles are largest when turbidity levels reach depths of 4 to 8 feet, and decrease in size above and below these depths. Based on the premise that ocean turbidity is related to plankton density, we suggest that juveniles are more likely to occupy waters where plankton densities occur at these depths. We would like to perform plankton tows during spring, 2007, to assess more accurate association of plankton densities, turbidity, and juvenile salmon abundance.

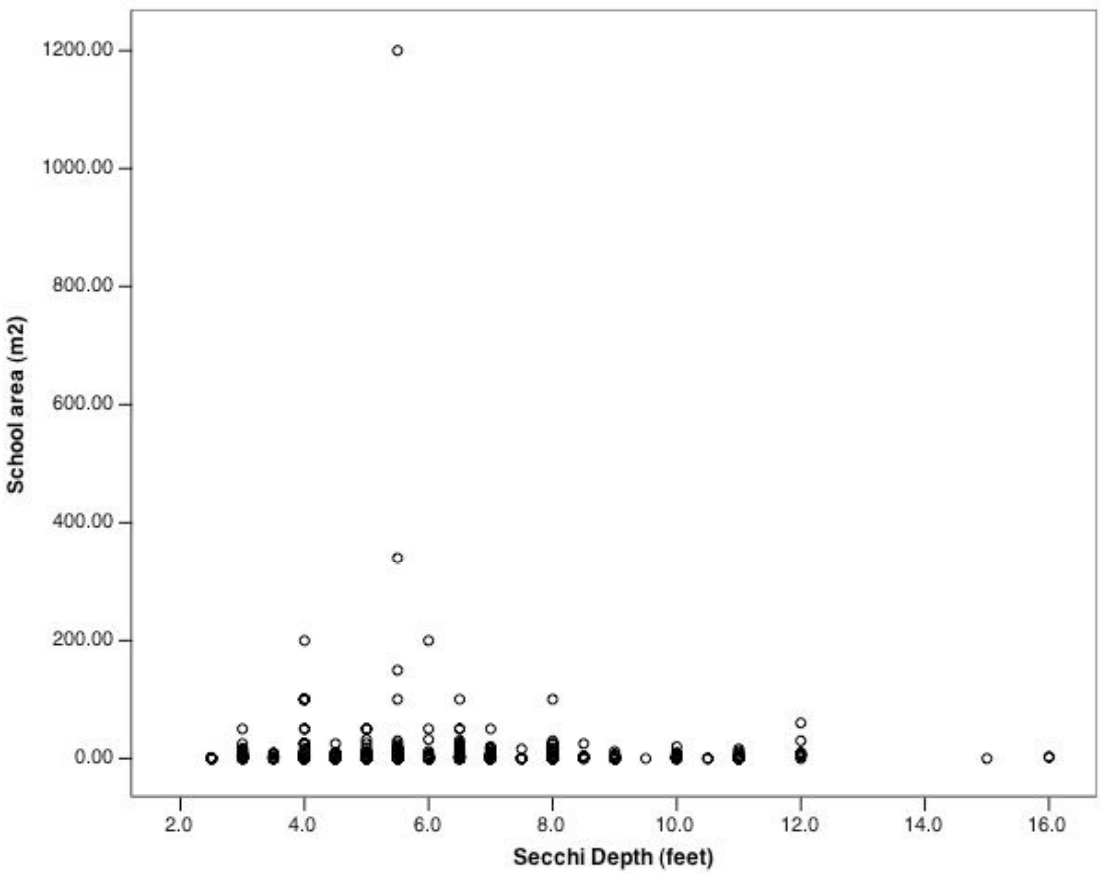


Figure 7. Abundance and association of migrating juvenile salmon, with Secchi depth (a proxy for plankton abundance), using 95% Confidence Intervals [CI], during spring sampling, 2006.

The school size of migrating juvenile salmon appears to correlate with the accompanying substrate below which they occupied (Figure 8). Schools of juveniles were largest in areas situated above mud substrate ($\bar{x}$=11.5m^2), compared with rock ($\bar{x}$=6m^2), and sand ($\bar{x}$=4.5m^2). Of all the substrates, mud is most often associated with Eelgrass, other aquatic vegetation, and marine organisms; known nursery grounds for juvenile salmon. Although mud substrate is not a clear predictor of juvenile salmon abundance (measured in school size), it likely is if measured in number of schools rather than abundance (further analysis necessary).

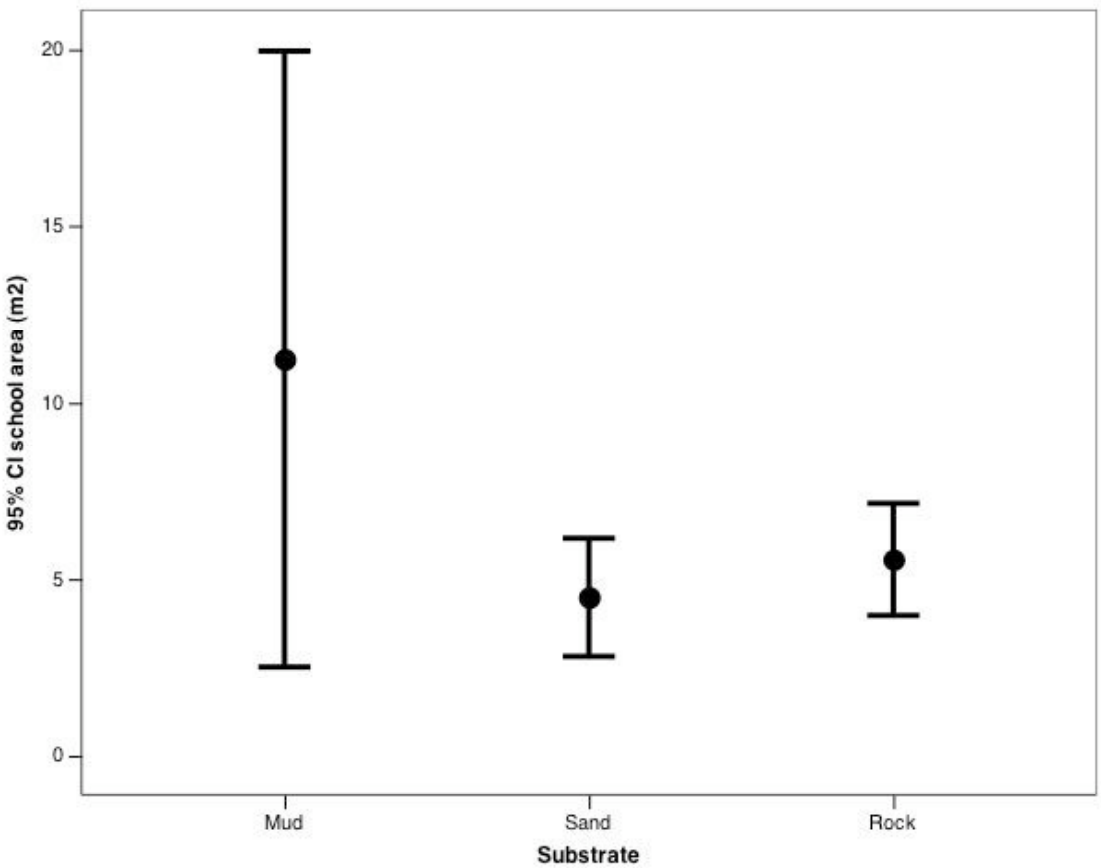


Figure 8. Abundance and association of migrating juvenile salmon, with Substrate (mud, sand, and rock), using 95% Confidence Intervals [CI], during spring sampling, 2006.

The school size of migrating juvenile salmon also correlated with the accompanying exposure to predation, which they occupied (Figure 9). Schools of juveniles were largest in areas of lowest exposure ($\bar{x}$=8.25m^2), compared with highest ($\bar{x}$=6.25m^2), and moderate ($\bar{x}$=2.5m^2). One might expect to find juveniles more often in areas of lowest exposure to predation, but perhaps not anticipate their abundance in areas also of highest exposure. However, survival for juvenile salmon is a constant trade-off for the need to avoid predators, and the need to find food. Thus, it is sensible to suggest that juveniles likely move into areas of high exposure where food is abundant, and otherwise seek areas of low exposure.

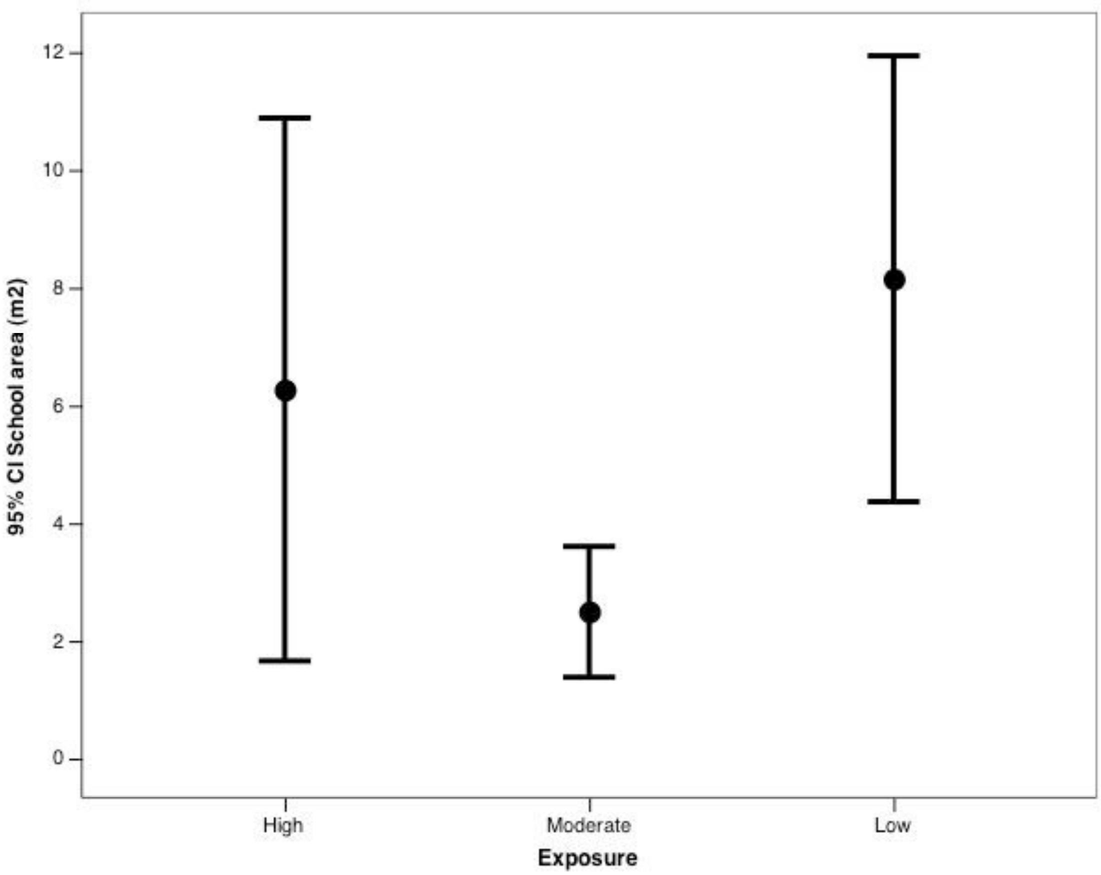


Figure 9. Abundance and association of migrating juvenile salmon, with Exposure (high, moderate, and low), using 95% Confidence Intervals [CI], during spring sampling, 2006.

How long do juvenile salmon spend in these near-shore habitats?

The average fork length (Figure 10), and mass, of juveniles increased over the study's duration. This suggests that juveniles collected later in the study period had spent time foraging among near-shore oceanic habitat, compared with juveniles collected in the early weeks of the study (having only recently left natal streams). Based on size and known rates of growth and migration speed, we hope to calculate the approximate origin of juveniles sampled at each transect location.

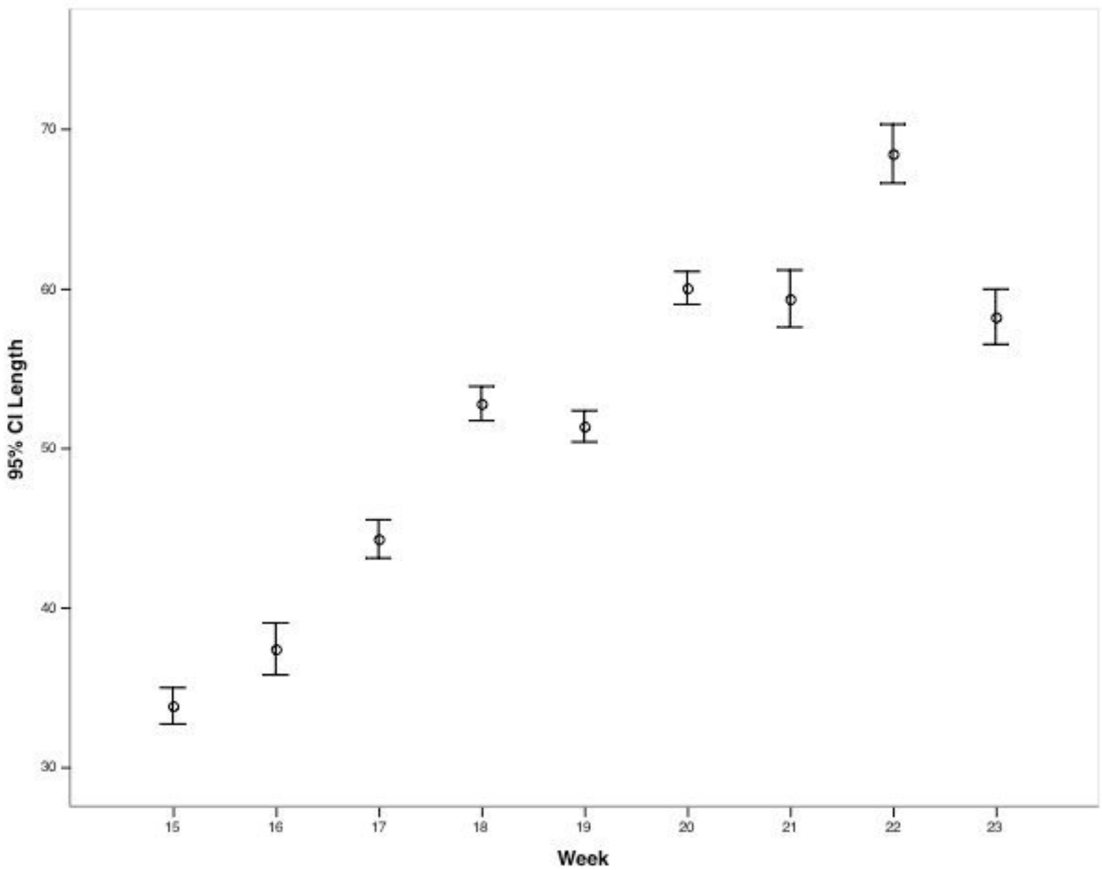


Figure 10. Mean length of juvenile salmon collected during associated weeks of the study period, using 95% Confidence Intervals [CI].

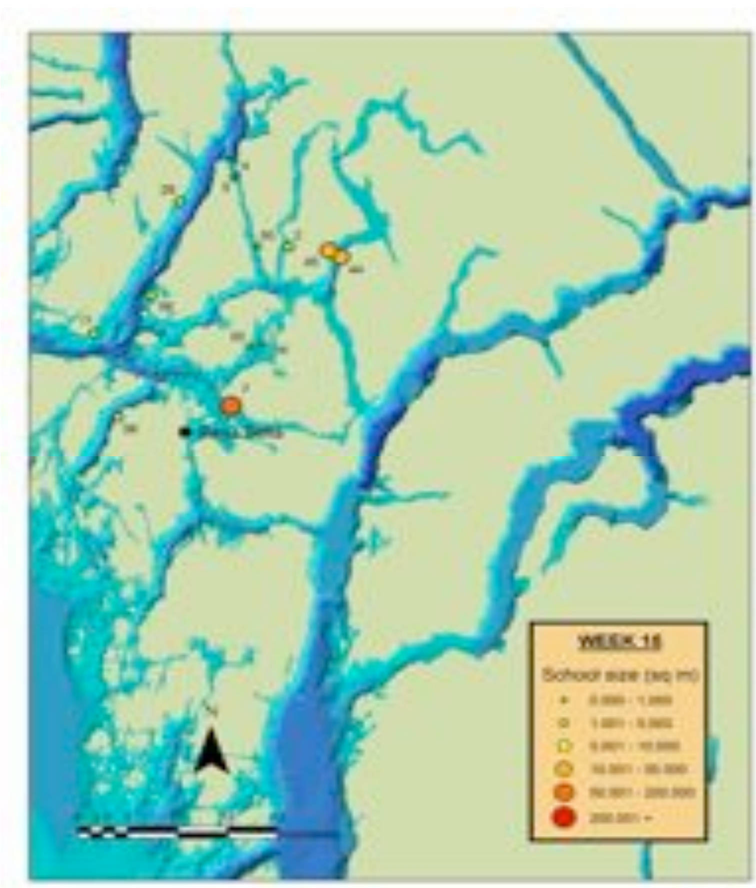
What are the ambient sea lice levels on juvenile salmon in this area? Does this differ between areas far from and near to open net-cage salmon farms?

Of the 2650 fish sampled, 95.2% were louse free; resulting in ambient sea lice levels in the Bella Bella region of 4.8%. For comparison, a high-density salmon farming region (such as the Broughton Archipelago) repeatedly shows lice levels as high as 80%.

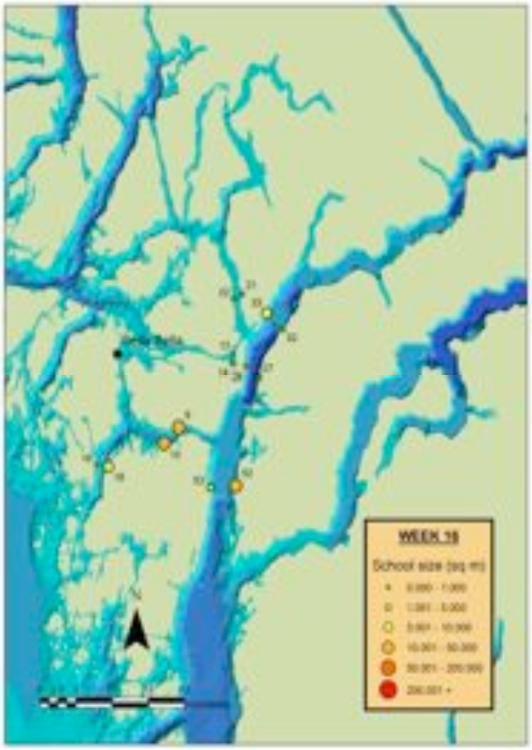
Although lice levels were higher near the two Klemtu salmon farms, there was no significant difference in the mean number of lice found on juveniles collected near and away from the farms ($P=0.3$, $df=2648$, $t=1.15$). A more detailed investigation of sea lice levels near and away from salmon farms on the central coast will be initiated spring 2008.

Migration Pathways

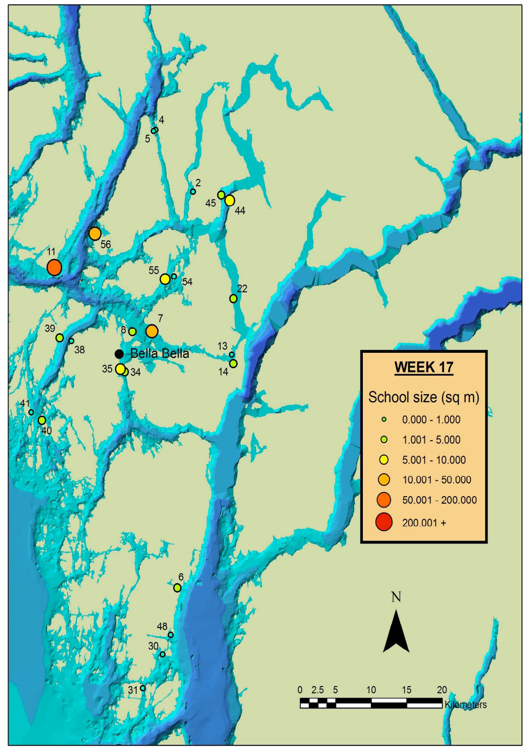
Regardless of the lack of predictive evidence for specific habitat utilization of juvenile salmon in the study area, general migration patterns exist (Figures 11a-i). In early April, small schools begin to emerge in the region north of the village of Bella Bella, near natal streams, and along in-shore inlets (Figure 11a). Over subsequent weeks, schools increase in size as they travel south. Schools begin to appear south of Bella Bella, with the largest



11a.



11b.



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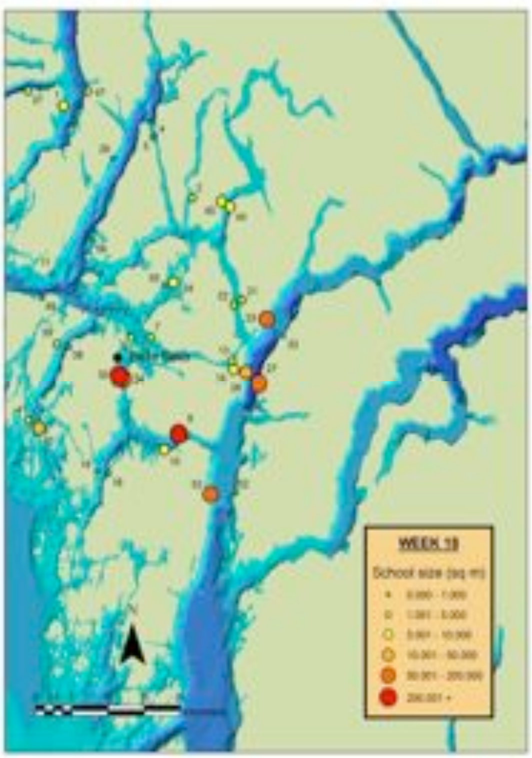

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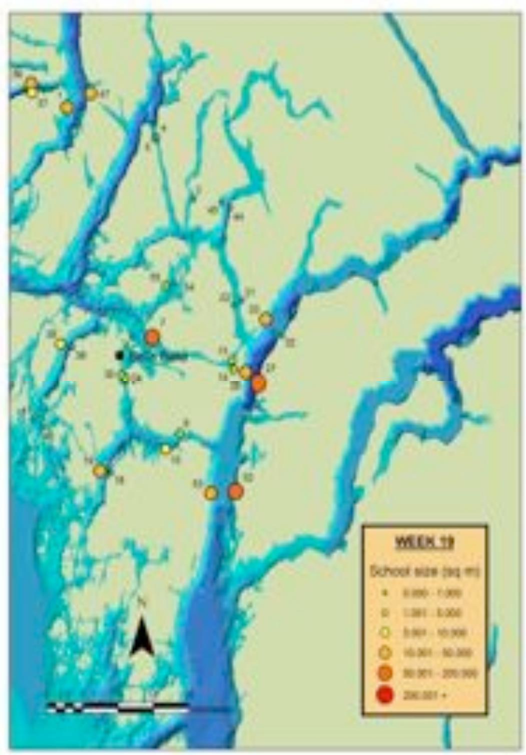

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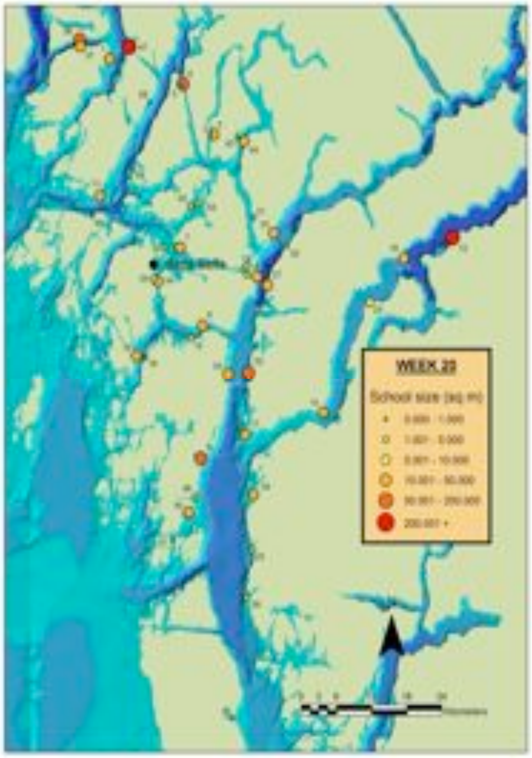

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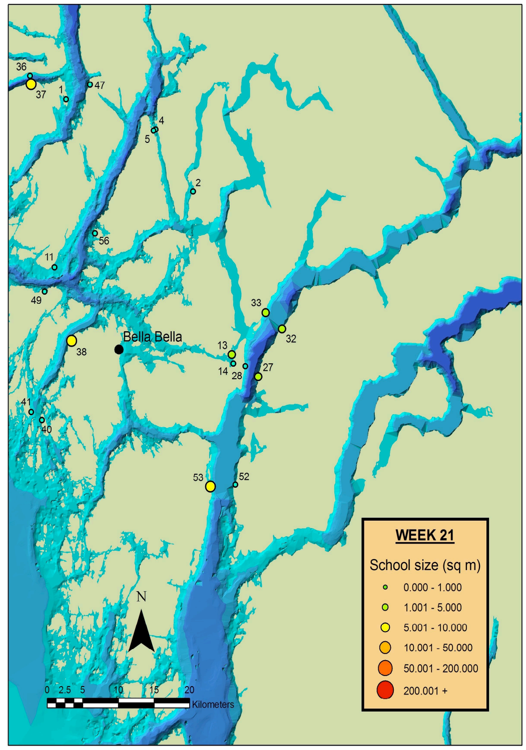

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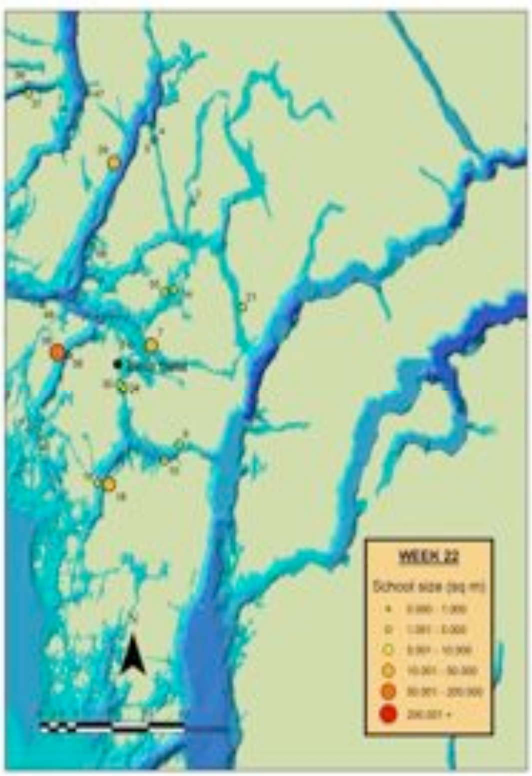

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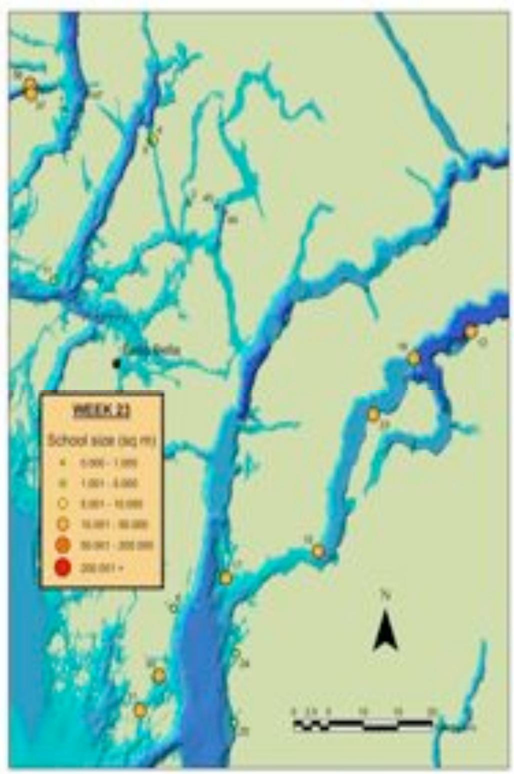

11i.

concentrations along near-shore habitats of Lama Passage, Dean Channel, and Fisher Channel. Although Seaforth Channel, located immediately north of Bella Bella, is the first major westerly route accessible for juveniles migrating to the open ocean, most schools appear to continue southward. Schools travelling down Lama Passage tend to migrate towards Fisher Channel, (avoiding the narrower Hunter Channel), before joining larger schools travelling down Dean Channel. By week-20 (May 15th to 21st), juveniles from the Bella Coola region begin to appear along Burke Channel, travelling towards Fisher Channel. Schools elsewhere begin to decrease in size by week-21 (May 22nd to 28th), and are only observed along Burke Channel at the end of the migration period (June 5th to 11th).

Next steps

Although this is a final report, Raincoast is currently planning a spring-2008 migration mapping field season. A single year of data has not been enough to accurately assess, and predict, juvenile salmon habitat utilization patterns on the central coast. This data is, however, enabling us to tighten our experimental design. We are currently collaborating with Dr. John Reynolds' lab from Simon Fraser University (SFU), as to the improvement of experimental design, in hopes that 2008 will be the final data collection period needed to build our migration-mapping model for the central coast.

Raincoast is also currently planning year-one of a two-year project for the area north of Bella Bella (Mussel Inlet and Sheep Passage), where four salmon farms are currently operating. We plan to assess sea lice levels of juveniles near and away from farms, and map the migration pathways that begin at Mussel River (a sanctuary for wildlife), past the farms to the open ocean.

We are further collaborating with SFU with respect to the preparation of a peer-reviewed manuscript, detailing the non-lethal methods used in this project to map migration routes for juveniles.

Acknowledgements

We gratefully thank the Heiltsuk Nation for grating us permission to study in their traditional territory; Chris Williamson for launching this project in 2005 as a pilot study; field assistants Jordon Wilson, Mitch Cliffton, Randy Carpenter, Jeff McConnechy, Craig White, and others (T.J., Harvey, Lindsey, Chelse, Johan, Carla) for their efforts; and the Gordon and Betty Moore Foundation, and Vancouver Foundation, for funding.