

## SUMMARY AND CONCLUSIONS

### SUMMARY

#### CATCH TIMING

- Water was consistently warmer and less saline at NPS sites than at SPS sites. Delta sites had lower salinities and more variable water temperatures than nearshore and neritic sites.
- The timing of peak catches was similar at delta and nearshore sites within sampling regions but differed between NPS and SPS sites.
- During April-September sampling seasons in 2001 and 2002, the majority of juvenile salmon were caught between April and June (pink and chum salmon generally peaking earlier than chinook and coho salmon), with most peak catches in May. A second peak for chinook salmon occurred during July in NPS.
- Peak catches of all juvenile salmon species in neritic waters occurred in June at SPS sites.
- Peak catches for chum and chinook salmon were greater at SPS than NPS sites in both years, whereas coho and pink salmon catches were greater at NPS sites.  
With the exception of NPS chum salmon, total and peak catches of each species were greater in 2002 than 2001.
- The proportions of hatchery coho and chinook salmon to unmarked conspecifics were much greater in SPS than NPS in both years.

#### SIZE

- Mean sizes of juvenile salmon were slightly but consistently smaller at NPS than at SPS sites and at delta versus nearshore and neritic sites.
- Overall, chinook and chum salmon were larger in 2001 than 2002, although there was no consistent difference in sizes between 2001 and 2002 for all species and between regions.

- Overall, hatchery coho and chinook salmon were larger than their unmarked counterparts.

## DIET

- Prey composition differed markedly between NPS (predominately insects) and SPS (predominately planktonic crustaceans) sites, likely a result of substantially higher freshwater inputs to NPS.
- Diel feeding chronologies indicated that juvenile salmon fed most actively during daylight, but diet composition changed between light and dark periods.
- In general, juvenile salmon shifted from predominantly epibenthic feeding in April-May and at delta sites to more planktonic and neustonic feeding during June-July and at nearshore marine and neritic sites.
- Epibenthic and planktonic copepods and larvaceans were the primary prey for pink and chum salmon. Chum and pink salmon ate predominantly planktonic prey during daylight, but shifted to epibenthic prey during and after dusk.
- Epibenthic and planktonic crustaceans, including gammarid amphipods, crab larvae, euphausiids, and shrimp (primarily hippolyttid and pandalid), were the major prey for coho salmon, whereas insects and fish prey were episodically important.
- Chinook salmon fed mainly on insects in NPS, and on crab larvae, euphausiids and hyperiid amphipods in SPS.
- Fish constituted only 5-10% of the diet for chinook and coho salmon <200mm FL, but piscivory increased with size. Larger chinook and coho salmon became more piscivorous at crepuscular and post-dusk hours, feeding mainly on sand lance and juvenile salmon (pink and chum) in April-June.
- For chinook and coho salmon, diet composition was similar between hatchery and unmarked fish.

## CONSUMPTION DEMAND

- Weekly consumption demand for each salmon species was higher at SPS than at NPS sites.

- There was a higher consumption demand for insects and fish at NPS sites than at SPS sites.
- Hatchery chinook salmon at NPS sites consumed more prey (by weight in grams) per week than unmarked chinook salmon.
- In a preliminary examination of intrageneric predation by coho and chinook salmon on pink/chum salmon (33-43mm FL), I estimated that an individual juvenile coho salmon (100-130mm FL) consumed 1-2 pink/chum salmon per day, while a chinook salmon (80-90mm FL) consumed one pink/chum salmon every 2.5-5 days.

#### GROWTH PERFORMANCE

- Overall, growth performance for peak juvenile salmon cohorts was lower but more constant in SPS than in NPS, and higher in 2002 versus 2001, driven primarily by the higher proportions of energy rich adult insects consumed in NPS and in SPS in 2002.
- In NPS, pink and chum salmon experienced the highest growth efficiencies in April, whereas coho salmon had the highest growth efficiencies in mid to late May.
- Modeled chinook salmon cohorts experienced variable feeding conditions with peaks in growth efficiencies both in May and July. Simulated growth efficiencies for chinook salmon were, however, lower than for other salmon, particularly in May when relative abundances of the other salmon species were highest.
- While there were no differences between growth performance of unmarked and hatchery chinook salmon in SPS, unmarked chinook salmon in NPS experienced higher growth rates and efficiency than hatchery counterparts.
- Diet quality for chinook and pink salmon may be more favorable in neritic environments as nearshore foraging conditions decline.
- Increasing spring water temperatures, which approached the upper limits of thermal tolerances for salmon in NPS, may have caused decreased growth efficiencies for salmon nearshore, particularly at peak temperatures in July.

## CONCLUSIONS

- Juvenile salmon occupy nearshore Puget Sound waters between at least April-September. Extended species residence times (their seasonal duration in the catches) suggest that nearshore environments may be particularly important to chinook salmon in NPS, and to chum salmon in SPS.
- Juvenile salmon at SPS sites were larger than those at NPS sites, partly due to differences in the magnitude of hatchery inputs.
- The potential for dietary overlap was greatest between juvenile pink and chum salmon, between chinook and coho salmon of a similar size, and between hatchery and unmarked chinook salmon.
- Juvenile and subadult chinook and coho salmon have the potential to be significant predators on smaller juvenile salmon (pink and chum salmon mainly, but also chinook salmon) during peak outmigration pulses.
- Foraging conditions for juvenile salmon were dynamic, varying spatially, annually, and seasonally.
- Insects provide a high quality prey resource at sites in NPS, but fluctuations in diets and water temperatures produced variable growth conditions for juvenile salmon at those sites.
- The greater consistency of foraging conditions and water temperatures at sites in SPS led to more consistent growth conditions at those sites.
- Due to spatial and temporal differences in the forage base and environmental conditions, the timing and location for juvenile salmon entering Puget Sound may influence their early marine growth (e.g. high but variable, or moderate but constant) and ultimately survival.

## FUTURE WORK

This study was intended as an initial examination of juvenile salmon trophic dynamics in Puget Sound. Future studies will be needed to target key uncertainties, and increase the understanding of juvenile salmon ecology in Puget Sound. These include:

- 1) Measuring individual and average residence times and actual growth of juvenile salmon in Puget Sound to obtain more realistic consumption estimates for growing salmon.
- 2) Increased spatial coverage including offshore sampling will be needed to determine where salmon habitats salmon occupy, in particular elucidating the nearshore-offshore usage patterns. Coordination with similar ongoing projects in Puget Sound will be a very important way to broaden spatial and topical coverage. Diet comparisons are available between historic, literature values, and concurrently from other regions including: nearshore marine areas in central PS (King County), offshore areas in central Puget Sound (DFO, Canada), nearshore and offshore Skagit Bay (NMFS Mukilteo), Shilshole Bay (Army Corps), and Sinclair Inlet (WDFW).
- 3) Measurements of food supply and availability will be needed to consider questions of food limitation and carrying capacity.
- 4) Determining abundances of predator populations and conducting a more intensive predation study will help attain a better estimate of potential predation pressure.
- 5) Expand to the broader food web: Declines have also been observed in at least seven other marine fish in Puget Sound (Pacific herring – *Clupea harengus pallasii*, Pacific cod – *Gadus macrocephalus*, Pacific hake – *Merluccius productus*, walleye pollock – *Theragra chalcogramma*, brown rockfish – *Sebastes auriculatus*, copper rockfish – *S. caurinus*, and quillback rockfish) which include potential competitors, prey, and predators of larval and juvenile salmon.