MODELING BIOENERGETICS OF JUVENILE PINK SALMON IN PRINCE WILLIAM SOUND AND THE COASTAL GULF OF ALASKA

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INTRODUCTION

We currently lack a mechanistic understanding of the carrying capacity for juvenile salmon in the Gulf of Alaska (GOA). Pink salmon are the most abundant Pacific salmon species, and the GOA supports the largest pink salmon population in North America (Heard 1998). Significant hatchery input to Prince William Sound (PWS) supplements natural production, with a release of 621 million fry in 2001 (Moffitt 2001).

Pink salmon fry migrate to PWS within a month after emerging in the spring and inhabit the waters of the GOA for the next 14-16 mo of their 2-yr life cycle. During their first months in marine waters, juveniles are highly vulnerable to predation, and rapid growth is their best form of protection against predators. Throughout the summer and fall of their first year they reside over the continental shelf and grow from roughly 7 g in July to nearly 100 g in October. The amount of prey necessary to achieve this amount of growth is unknown.

J. Boldt

We continue to release millions of pink salmon fry each year without knowing the amount of prey available for consumption in the ocean and whether we are approaching carrying capacity. Poor ocean survival has substantially contributed to salmon declines in recent years (Bradford 1995), and juvenile salmon growth rates may interrelate with overall survival (Mortensen et al. 2000). Competition for food may affect growth rates, and, thus, juvenile pink salmon survival (Brodeur et al. 2000).

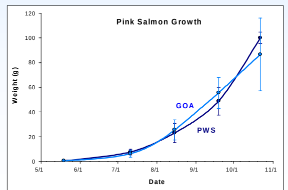
The primary objective of this Global Ocean Ecosystem Dynamics (GLOBEC) study was to use bioenergetics model simulations to compare spatial and temporal patterns of juvenile pink salmon growth and consumption over their first five months in PWS and the coastal GOA.

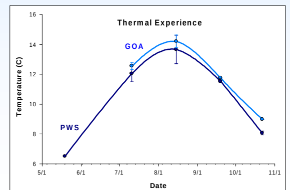
BIOENERGETICS

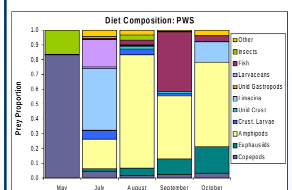
The bioenergetics approach describes how energy flows through a consumer and is partitioned into consumption, growth, metabolism and waste over time based on consumer weight change, diet, and thermal experience, and the energy density of both consumer and prey (Kitchell et al. 1977). Bioenergetics models calculate daily weight at a specific growth potential using the energy-balance equation:

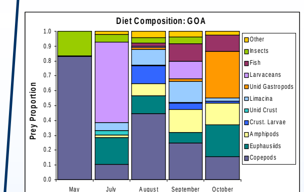
$$C = G + M + W,$$

where C is total energy consumption, G is growth, M is metabolic costs, such as respiration, and W is waste, which includes egestion and excretion. Each term of this equation contains several formulae that alter energy fluctuation over specified time intervals (as fishes rarely grow at a constant rate) according to such factors as body size and ocean temperature. We used the Wisconsin Bioenergetics Model (Hanson et al. 1997), which has performed well for salmonids (Beauchamp et al. 1989, Ruggerone and Rogers 1992, Brodeur et al. 1992), to determine consumption patterns of two juvenile pink salmon cohorts: one remaining in PWS for the 157-day period from May through October, and one migrating to the GOA by July.









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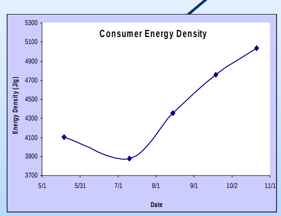
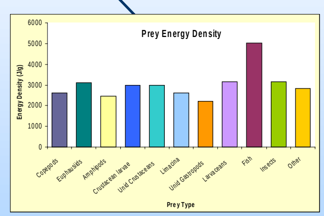




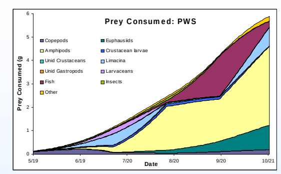
The primary sources of data for this project were the Alaska Department of Fish and Game (ADF&G) PWS hatcheries and the Global Ocean Ecosystem Dynamics (GLOBEC) juvenile salmon process cruises in PWS and the GOA from July through October 2001 (see poster by Moss et al.). This allowed reasonable spatial and temporal data resolution during the first summer and fall that juvenile pink salmon spend in the marine environment, and encompassed the PWS to coastal GOA migration period.

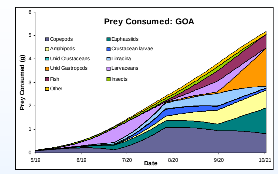
RESULTS

In both simulations, juvenile pink salmon ate a large amount of prey, both in grams and as a proportion of their maximum consumption (P-value). However, the large P-values, though likely indicative of high consumption rates, also reflected relatively low prey quality. Prey energy densities of approximately 3000 J/g prompted the pink salmon to ingest larger quantities of prey to obtain the energy needed to satisfy the observed growth rate.

No large differences in growth or consumption were seen between regions. Juveniles that stayed in PWS ate slightly more prey (to reach a slightly larger final weight) and ingested a higher proportion of their maximum consumption (P-value=0.87). Growth was slightly more efficient in PWS (26.4%) compared to the GOA (24.6%). It should be noted that the average final weight of the PWS cohort was calculated from a sample size of two; therefore these results may deviate from reality.

Area	P-value	Total Prey Consumed (g)	Growth Efficiency
PWS only	0.8708	377.08	26.4%
to GOA	0.8252	349.19	24.6%





The next logical step will be to expand individual consumption rates to localized population-level consumption rates (e.g. grams of prey consumed per km^2), based on pink salmon catch and distribution data during this simulation period (see poster by Haldorson and Boldt). Also, growth rate depends on both the inherent growth potential of a fish and the effects of environmental limitations on growth rate imposed by habitat (Brandt et al. 1992), which are not accounted for by the model. Linking a visual foraging model with the bioenergetics model will improve our understanding of the growth and consumption of juvenile pink salmon during their first five months at sea, and provide more insight on whether the available zooplankton biomass could be limiting as prey.

CONCLUSIONS

- Juvenile pink salmon eat a large proportion of their maximum consumption.
- No large differences in rates or patterns of growth and consumption were found between PWS and the coastal GOA.
- Further insight on carrying capacity will be gained by comparing consumption estimates to the exploitable zooplankton biomass in each region and by linking the bioenergetics model to a visual foraging model

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