***Exxon Valdez* Oil Spill**
Restoration Project Annual Report

SEA Fish Energetics

Restoration Project SEA 320U
Annual Report

This annual report has been prepared for peer review as part of the Exxon Valdez Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have not been addressed in this annual report.

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Study History: SEA is a hypothesis driven ecosystem study designed to identify the mechanisms that influence herring production in Prince William Sound by investigating their early life stages. SEA research focuses on the timing and magnitude of energy flowing through the food web. Tracking this flow provides insight into links between primary and secondary production and species interactions. Food and predation are key forces that operate within the context of environmental parameters like temperature and transport. This component of SEA provides information on whole body energy content of key fish species so that interactions within and between species can be quantified, and insight into the feeding conditions on geographical and temporal scales described. The data from 320U supports inquiries into the River-Lake hypothesis, the Over-Winter hypothesis, and the key question "is it food impeding recovery of herring". This project was initiated in April of 1995, thus this report constitutes the third year of a three year field sampling program. During year four 320U findings will be provided to the SEA synthesis project.

Abstract: The Exxon Valdez oil spill may have altered the trophic structure of the plankton feeding fish community by injuring intertidal spawning herring. This project describes the interannual variations in the somatic energy cycle of juvenile *Clupea pallasi*. Collections were (or will be) made in the spring and fall of 1995-98, and summer and fall of 1996 and 1997, and winter 1996-97. This bioenergetic information is needed to determine if food resources are limiting growth of recruits and if the over-winter period is important in regulating recruitment of age 0 herring. The analysis of somatic energy content (SEC) showed that there was large geographical differences in the nutritional status of recruiting herring. This is also true for fish at individual capture sites. Other SEA components are examining the physical oceanographic and prey distribution patterns related to these differences. The energy profile of over-wintering herring showed that the typical recruit was food limited and exhibited nutritional stress during the winters of 1995-96. Few 1996 recruits were captured in the spring of 1997 and at many sites they were in a near death condition. In the fall of 1997 recruits from one bay had high SEC values but at the other two sites they were in poor condition and few of them survived the winter. Acquiring enough energy during the summer and fall feeding season appears to be an important factor in determining survival through their first winter for juvenile herring.

This project measures fall and spring somatic energy content of juvenile pollock (*Theragra chalcogramma*) to compare their nutritional status to that of juvenile herring. Somatic energy content of age 0 walleye pollock was examined in the fall and spring during two years. In the fall

of 34 mm and a mean SEC of 2.7 kJ/g. By 3 August the mean SL increased to 69 mm and SEC averaged 3.4 kJ/g. On 10 October age 0 pollock had an average SL of 81 mm and SEC of 3.6 kJ/g. Based on these mean values growth rates for age 0 pollock in 1996 were 0.4 mm/d. This type of information on seasonal and size specific variations in SEC is critical to understanding the role of pollock in the food web both as predators and prey.

The information gathered by this energetics project is being related to SEA zooplankton surveys, prey selection studies and trophic isotopic studies through the SEA modeling effort. The data also supports the APEX predator-feeding analysis.

Key Words: *Clupea pallasi,* herring, energetics, ovary, somatic energy, *Theragra chalcogramma,* pollock.

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Project Data:

The last sampling period for this project will be March of 1998. Samples are frozen fishes that are dried and combusted. The process destroys the sample. Small amounts of tissue from selected fishes are passed on to SEA project 320I (Kline). The data collected is energy content of whole body tissues. Energetic data is stored as SIGMAPLOT, EXCEL, and ASCII files. The data becomes available as the material is published in journals. The custodian is Dr. A. J. Paul, University of Alaska, Seward Marine Center, POB 730, Seward, AK 99664 (Phone 907 224-5261; Fax 224-3392; email ffajp@aurora.uaf.edu).

Executive Summary:

During its third year this project examined somatic energy content of age 0 and 1 herring (spring and late fall) and age 0 pollock (spring and late fall). These parameters are key measures for SEA and other EVOS models which predict levels of fish production and species interactions. The key results for the species under study include:

Herring somatic energy: 1) There is considerable geographical variation in the fall energy content of recruits captured in different areas. 2) From the spring sampling it appears that recruits from the 1994 year class were well nourished and passed the over-winter period in good condition allowing for hope that a reasonable survival of individuals will follow. 3) Most of the 1995 and 1996 year classes were undernourished when entering the winter and survivors were in poor condition the following spring. 4) Few 1996 recruits were captured in the spring of 1997. 5). YOY herring metamorphose in July and so they start this phase of development long after the spring bloom is ended. They then have just a few months to prepare for the poor feeding conditions of winter. Because of this YOY herring are susceptible to being under-nourished for over-wintering.

Age 0 pollock: 1). Pollock metamorphose about a month before the herring and are longer than herring of the same age. 2). Pollock recruits appear to increase in length during the winter at some sites and maintain their nutritional status or improve it unlike herring who lose somatic energy during the winter. The energetic profile for age 0 pollock will aid in the understanding of how they compete with herring recruits.

Introduction:

This project explores the role nutritional status plays in over-winter survival of juvenile herring. In recent history, herring and pollock have been among the most abundant pelagic forage fishes in south central Alaska. After the Exxon Valdez oil spill the herring population of Prince William Sound has been exhibiting reduced abundance and increased prevalence of disease. Age 0 herring store energy during the summer feeding season and either fast or feed at low rates during the winter. If they have insufficient energy stores to maintain normal schooling activities until the spring zooplankton bloom, then high mortalities might occur. Low energy storage might be due to low zooplankton standing stocks or to competition for food resources.

A portion of the effort examined somatic energy in age 0 pollock during the fall and spring, which are trophic analogs with herring, so the nutritional status of these forage species can be compared.

Objectives: This projects objectives follow:

1. Describe the interannual somatic energy content of herring especially age 0 relative to geographical location. This work is in progress.
2. Examine fall and spring energy stores of juvenile herring from several sites in Prince William Sound and describe the role nutritional status plays in over-winter survival. This work is in progress.
3. Describe the spawning energetics of herring. Measure ovarian energy relative to weight, age and spawning site in female herring. This work is completed.
4. Measure fall and spring energy content of adult herring. This work is completed.
5. Measure fall and spring somatic energy content of juvenile pollock and make comparisons of their nutritional status to geographical location and that of juvenile herring. This work is in progress.
6. Relate the analysis of all the above objectives to SEA zooplankton surveys, prey selection studies and trophic isotopic studies through the SEA modeling effort and multi-author journal SEA synthesis papers. This work is in progress.

Methods:

The methods applied to the energy cycles were similar to those used by the investigator in previous bioenergetic studies (Harris *et al.*, 1986; Paul *et al.*, 1993, Smith *et al.*, 1988; Smith *et al.*, 1990; Paul and Willette, 1997). All fish lengths in 320 U were standard length (SL) measured to the nearest mm. All whole fish weights were taken to the nearest 0.1 g. All calorimetric samples were weighed to the 0.0001 g level.

Herring Ovarian Energetics

All this work was completed in 1996 and available in Paul, A. J., J. M. Paul and E. Brown. 1996. Ovarian energy content of Pacific herring from Prince William Sound, Alaska. Alaska Fishery Research Bulletin. 3:103-111.

Somatic Energy of Herring

Juvenile herring were captured with 50m diameter x 4m deep purse seines with 3 mm stretch mesh. At each collection site at least three sets were made to capture specimens. Adult herring were collected with commercial herring purse seines (182m diameter, 22m deep, 3cm mesh). After capture all fish were immediately frozen in seawater aboard ship and kept frozen until processing. Recruiting herring were collect during the fall of 1994 (2 sites), spring of 1995 (6 sites), fall of 1995 (9 sites), spring of 1996 (8 sites), fall of 1996 (4 sites), spring of 1997 (1 of 4 sites surveyed), fall of 1997 (4 sites) and spring of 1998 (4 sites).

In the laboratory the fish were partially thawed, just enough to handle, but not enough so fluids were lost. Scales were removed from selected fish just above or below the lateral line, 3 rows behind the operculum for aging. All fish were measured for standard length (SL) to the nearest mm, then weighed to the nearest 0.1 g. The SEC of the whole individual was determined in terms of kJ/g wet weight. Herring under 150 mm SL were freeze dried whole. Larger fish while still partially frozen were ground, then the ground body made into a paste in a mortar. A 30 g subsample was then freeze dried. After freeze drying, test tissues were placed in a convection oven at 60°C until they reached a constant weight. Individual tissue wet and dry weight values were used to calculate the moisture content of every fish. Dried tissues were ground in a mill and measurements of caloric content made by bomb calorimetry. All calorimetric samples were weighed to the 0.0001 g level with a single sample burned per fish.

Somatic Energy of Age 0 Pollock

Pollock under 115 mm SL were collected at several sites in 1996 and 1997 and frozen in seawater for analysis. Fish were analyzed for standard length, wet weight, and whole body energy content using standard calorimetric methods noted above.

Results:

Somatic Energy of Herring

In herring SEC increases with age, the most profound differences being between the YOY and age 1 fish, and the other age groups. The average fall SEC values for YOY fish and age 1 herring were 5.7 (± 0.6) and 8.0 (±1.2) kJ/g wet wt respectively. The age 2 and older fish had similar SEC values with mean values ranging from 9.4 to 10.2 kJ/g wet wt. There was considerable range in SEC values between individuals indicating many of them did not eat enough to maximize their energy reserves. In the spring all size classes of herring had markedly less stored energy than those captured in the fall. Like the fall samples, there was also lots of variability in individual SEC values in the spring specimens relative to measures of fish size. The average spring SEC values for all YOY and age 1 fish in their respective age classes were nearly identical at 4.4 (± 0.6) and 4.4 (±0.6) kJ/g wet wt respectively. The age 2 and older fish had SEC with mean values ranging from 5.2 to 6.3 kJ/g wet wt with lots of variability.

Changes in SEC of captive age 0 Pacific herring forced to fast during winter was measured and compared to cohorts collected in the field. Somatic energy content of fasting captives declined at a rate of 23 J/g wet wt.d^{-1} at a mean temperature of 6.6°C. Fish that died during fasts had SEC values ranging from 2.8 to 3.6 kJ/g wet wt. During March 1996 the SEC of field collected age 0 herring averaged 3.8 kJ/g, with ≈40% having SEC ≤ 3.6 kJ/g wet wt. Thus, by March the average recruit had used most of its stored energy. These observations confirmed that in the northern Gulf of Alaska region age 0 herring rely heavily on stored energy to survive their first winter.

The results mentioned in this section were prepared for publication with the following 2 papers accepted:

1). Paul, A. J., J. M. Paul and E. Brown. 1997. Fall and spring somatic energy content for Alaskan Pacific herring (*Clupea pallasi* Valenciennes 1847) relative to age, size and sex. J. Exp. Mar. Biol. Ecol. In press.

2). Paul, A. J. and J. M. Paul. 1997. Comparisons of whole body energy content of fasting age zero Alaskan Pacific herring (*Clupea pallasi*) and cohorts over-wintering in nature. J. Exp. Mar. Biol. Ecol. In press.

Papers in progress deal with changes in SEC during the summer growth period and over the winter of 1996-1997. The final papers will review geographical and interannual variations in SEC of herring recruits for the period of 1994 to 1998.

Somatic Energy of Age 0 Pollock

Pollock samples collected in 1996 and 1997 have been processed. The data provides insight into how recruiting herring and age 0 pollock compete for food resources and their relative success and link to APEX studies of pollock-bird interactions, APEX and SEA fish stomach analysis-isotope studies, and assessments of secondary productivity. A journal paper on seasonal changes in whole body energy content of age 0 walleye pollock and estimated consumption rates is in preparation.

Discussion:

The examination of somatic energy content of age 0 herring, and their competitors age 1 herring and age 0 pollock shows promise for understanding the level of competition between these pelagic analogs. Coupled with SEA models and APEX and SEA stomach analysis these prey competition interactions could be quantified in EVOS synthesis models. The somatic energy measures should identify age 0 herring that have not stored enough energy to survive the winter. The bioenergetic herring over-winter model (Patrick) will help identify poor year classes 3 years in advance of their entry into the fishery. The SEC signatures also are a reflection of zooplankton standing stock.

CONCLUSIONS

Somatic energy measurements are a valuable tool for identifying the transfer of energy through the food web to pelagic fish. They measure subtle differences in individuals that are not observable from length-wet weight measures. Quantifying energy transfers is critical to building

SEA and other EVOS models. Additionally the energetic data set allows for trophic comparisons of pelagic analogs like pollock and herring, and transfer of energy to other animals like APEX birds. Satisfactory progress is being made towards achieving all objectives. No methods problems have occurred. The project should be successfully competed on time.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Harris, R., T. Nishiyama, anr A. J. Paul. 1986. Carbon, nitrogen and caloric content of eggs, larvae, and juveniles of the walleye pollock, *Theragra chalcogramma*. J. Fish. Biol. 29: 87-89.

Paul, A. J., J. M. Paul, and R. L. Smith. 1993. Ths seasonal chang s in somatic energy contentçof Gulf of Alaska yellowfin sola *Pleuronectes asper* Pallas 1814. J. Fish Biol. 43: 131-138.

Paul, A. J., J. M. Paul and E. Brown. 1996. Ovarian energy content of Pacific herring from Prince William Sound, Alaska. Alaska Fishery Research Bulletin. 3:103-111.

Paul, A. J., J. M. Paul and E. Brown. 1997. Fall and spring somatic energy content for Alaskan Pacific herring (Clupea pallasi Valenciennes 1847) relative to age, size and sex. J. Exp. Mar. Biol. Ecol. In press.

Paul, A. J. and J. M. Paul. Comparisons of whole body energy content of fasting age zero Alaskan Pacific herring (Clupea pallasi) and cohorts over-wintering in nature. J. Exp. Mar. Biol. Ecol. In press.

Paul, A. J. and Mark Willette 1997. Geographical variation in somatic energy content of migrating pink salmon fry from Prince William Sound: a tool to measure nutritional status. In: International symposium on the role of forage fishes in marine ecosystems. Alaska Sea Grant Rpt. 97-01 pp. 707-720.

Smith, R. L., A. J. Paul, and J. M. Paul. 1988. Aspects of energetics of adult walleye pollock, *Theragra chalcogramma* (Pallas), from Alaska. J. Fish. Biol. 33: 445-454.

Smith, R. L., J. M. Paul, and A. J. Paul. 1990. Seasonal changes in energy and the energy cost of spawning in Gulf of Alaska Pacific cod. J. Fish. Biol. 36: 307-316.

Chapter 12

Synthesis and Integration