Chapter 13

95320U Energetics of Pollock, Herring and Pink Salmon

Project Number and Title

SEA 95320U - Energetics of herring, pollock and pink salmon.

Principle Investigator

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Study History

SEA is a hypothesis driven ecosystem study designed to obtain an understanding of the mechanisms that influence levels of production for pink salmon and herring in Prince William Sound by investigating their early life stages. SEA research focuses on the flow of energy and material (carbon or nitrogen) 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 basic data base information on somatic energy content of key species so that interactions within and between species can be quantified. Energetic data flows to the SEA models which will be used to predict levels of fish production. This project was initiated in April 1995, thus this report constitutes the first year of activity. The first year was planned to be exploratory since none of the proposed measurements had ever been made before. Future directions of this component will be guided by the lessons learned in year one and by the SEA and EVOS planning process.

Abstract

The *Exxon Valdez* oil spill may have altered the trophic structure of the plankton feeding fish community by injuring intertidal spawning species. This project has started to describe the interannual over-winter somatic energy cycle of juvenile *Clupea harengus pallasi*. This information was not previously available and is needed to describe feeding success and to determine if the over-winter period is important in regulating recruitment of age 0 herring. Samples throughout Prince William Sound from two sites in the fall of 1994, seven sites in the spring of 1995 and ten sites in the fall of 1996 showed that there were large geographical differences in the nutritional status of recruiting herring. This is also true for fish within a school. The energy profile of over-wintering herring showed many of them were food limited.

Laboratory studies showed that juvenile herring use about 0.68 $KJ.g^{-1}$ wet wt per month when fasting and succumb to starvation when their somatic energy content is 3.5 to 3.0 $KJ.g^{-1}$ wet wt. These results suggest that fish with less than 5.5 $KJ.g^{-1}$ wet wt can not rely on stored energy reserves alone to survive the winter. Samples of juvenile herring that were collected from ten sites in the fall of 1995 showed that age 0 herring entering the winter of 1995-1996 generally had energy contents of less than 6 $KJ.g^{-1}$ wet wt. This initial survey suggests that many age 0 herring entered the over-wintering phase of 1995 in poor nutritional status and unless they could acquire significant energy through winter feeding, many of them would not survive. Analogous spring sampling will be done in 1996 to compare the energetics of fall fish and those that survived the winter. Similar sampling

is scheduled for two more years so that the interannual variation in somatic energy storage can be described.

This project has started to examine herring ovarian energy indices relative to weight and age to understand the populations' egg production potential which is the first step in the recruitment process. In 1995, sampling was done in three areas - the northeast, northwest and southwest portions of Prince William Sound. Ovaries will be sampled again in 1996 for comparative purposes as there is no previous information on the variability in the amount of energy allocated to egg production.

This project measures fall and spring somatic energy content of juvenile pollock (*Theragra chalcogramma*) to compare their nutritional status to that of competitors such as juvenile herring and pink salmon fry. This energetic profile will aid in the understanding of how pollock compete with these two injured fish species. Pollock are a major prey of many seabird species injured by the oil spill and our energetic measures will be useful in estimating bird energy intake. The first samples were collected from eleven sites in the fall of 1995 and are now being processed. Extensive sampling is scheduled again in the spring of 1996.

Measurements of the spring somatic energy content of pink salmon fry (*Oncorhynchys gorbuscha*) were made from four 1995 collections. We found that energy content of fry was related to their relative abundance, but not to body length. In 1996, energetic measurements of wild and hatchery pink salmon fry will be carried out so comparisons of their nutritional status versus geography and origin can be made. These measurements are part of the SEA effort to understand the role energy intake plays in the recruitment process of this injured species.

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.

Key Words: *Clupea harengus pallasi,* herring, energetics, ovary, *Oncorhynchys gorbuscha,* pink salmon fry, somatic energy, *Theragra chalcogramma,* pollock.

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Executive Summary

During its first year this project examined somatic energy content of pink salmon fry, age 0 and 1 herring (spring and late fall), age 0 pollock (spring and late fall), herring ovaries just prior to spawning, and adult herring bodies during fall. These parameters are key measures for SEA models which predict levels of fish production and species interactions. The key results for the species under study include the following.

Pink salmon fry: 1) There is considerable geographical variation in the energy content of pink salmon fry. 2) The relative abundance of the fry affects the energy content of the fry. 3) Fry allocate energy to increases in length preferentially. These energetic profiles will be used to understand transfer of energy from secondary producers, effects of intra-specific competition (including hatchery and wild fry), and consumption of fry by predators.

Age 0 and 1 herring: 1) There is considerable geographical variation in the fall energy content of different schools of herring recruits. 2) From the fall sampling it appears that recruits with insufficient energy reserves to survive a winter by fasting are common. 3) Herring recruits store energy for a winter fast and as their length increases, so does energy content at a much higher level than seen in pink salmon fry. 4) Based on our current, and incomplete, knowledge of the energy needs for age 0 herring during the over-winter period, it appears that many individuals are undernourished. These measures of energy storage and use will provide insight into the potential of individuals to survive winter. It will also help understand the effect of "river and lake" conditions, and be used to estimate consumption of herring by predators.

Age 0 pollock: Pollock exhibit the same growth mode as pink salmon fry, preferentially increasing in length. These samples are being processed now and no data is available for this report. The energetic profile for age 0 pollock will aid in the understanding of how pollock compete with the two injured species pink salmon fry and herring recruits.

Herring ovaries: The initial samples illustrate that ovary energy is strongly related to fish weight and there is not a strong geographical influence on this parameter. The amount of energy allocated

to ovaries will be correlated with egg production through EVOS models.

Adult herring whole bodies: SEA measures secondary production by a variety of methods. Adult herring are users of secondary production and their somatic energy content at the end of the feeding season reflects secondary productivity. The somatic energy values provide a separate measure by which the SEA secondary productivity estimates can be evaluated. The first samples were collected in the fall of 1995 and not enough data exists to comment on the outcome of this aspect of the study.

All energetic measures address SEA hypotheses and provide critical measurements for SEA models.

Introduction

During the first field season this project was a feasibility level study and it focused on somatic energy content of three species of pelagic fish in the EVOS region. These types of measurements have never been made before in Alaskan waters. We started to explore over-winter survival of juvenile herring and herring reproductive energetics. 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. Historically, 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, disease and spawning anomalies that may be related to pollution. This research effort will help identify the role of food in delimiting survival of recruiting herring. The study of herring energetics will be one input into the SEA secondary production model.

This project is also looking at the energetics of pink salmon fry, including both wild and hatchery fish. This aspect of the project will allow for a better understanding of the trophic interactions of small pollock, herring and pink salmon that co-occur in time and space. The salmon work will also improve our understanding of the trophic interactions between wild and hatchery salmon fry.

Typically high latitude fishes store energy during spring and summer feeding and throughout the winter reallocate energy to maintenance and reproduction (Smith *et al.*, 1990). Thus, seasonal tissue samples must be taken to account for the temporal variation in energy content. Age 0 and 1 year old 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.

Objectives

The objectives of this project for year one were:

1. Describe the interannual somatic energy content of ages 0 and 1 herring relative to geographical location.
2. Examine fall and spring energy stores of juvenile herring from several sites in Prince William Sound and model energy usage to describe the role nutritional status plays in over-winter

survival and feeding requirements.

3. Describe the spawning energetics of herring. Measure ovarian energy relative to weight, length, age and spawning site in female herring at three sites.
4. Measure fall energy content of adult herring from three sites.
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 and pink salmon fry.
6. Measure the spring somatic energy content of pink salmon fry to see if this methodology can be used to compare their nutritional status versus geography, secondary production, competitor abundance and origin.
7. 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-authored journal papers.

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). All fish lengths in 320U were standard length (SL) measured to the nearest mm. All whole fish or ovary weights were taken to the nearest 0.1 g. All calorimetric samples were weighed to the 0.0001 g level.

Herring Ovarian Energetics

Adult herring were collected just prior to and after spawning by ADF&G, and frozen in seawater. During the spring of 1995, ovary energetic samples were collected from three sites (see collection log table at end of Methods, Table 1). In the laboratory, measurements taken on the females were standard length, wet weight, age (aging was done by E. Brown's component of SEA), and condition factor [CF = g wet wt x 100/(cm standard length)^3]. Sample sizes and locations are given in Table 1. Males in the sample were discarded without any measurement. Wet weight of the whole female fish and the ovary was measured to the nearest 0.1 g. Small subsamples of ovary were removed, weighed to the nearest 0.1 g, and dried for energy measurement. After freeze drying, test tissues were placed in a convection oven at 60°C until they reach a constant weight. Individual tissue wet and dry weight values were used to calculate the moisture content. Dried tissues were ground in a mill and measurements of caloric content made by bomb calorimetry. Ovarian energy measures were coordinated with fecundity estimates carried out using standard methods. Energetic estimates of ovaries after spawning were obtained from the post spawning collections.

Fall Whole Body Energy of Adult Herring

During the fall of 1995, collections of adult herring were made from three sites (Table 1). Fish were frozen in seawater aboard ship and kept frozen for processing. Fish of both sexes were analyzed for standard length, wet weight, age (aging was done by E. Brown's component of SEA), condition factor [CF = g wet wt x 100/(cm standard length)^3], and whole body energy content using the above methods. After taking weight, standard length, sex, and removing scales for aging, the still frozen bodies were ground. The tissue was then made into a paste in a mortar. A 30 g subsample was then freeze dried, oven dried and 0.5 g burned in the calorimeter.

Spring and Fall Age 0 and Age 1 Herring Body Energy

Juvenile herring samples were taken from several geographical areas in Prince William Sound (see Table 1 for sites and sample sizes). During 1994, two fall samples were collected and stored, frozen, in seawater until funding of this project (Table 1). During the spring of 1995 there were six collections of herring recruits for energetics and in the fall, ten more collections (Table 1). Fish were analyzed for standard length, wet weight, age (aging was done by E. Brown's component of SEA), condition factor [CF = g wet wt x 100/(cm standard length)^3], and whole body energy content using standard calorimetric methods. Carbon and nitrogen ratios of selected fish were measured by SEA 320-I.

Whole body energy profiles for starving age 0 herring were measured in the laboratory during the winter months of 1995 and 1996 (Harris *et al.*, 1986; Smith *et al.*, 1986). In the first experiment, age 0 herring were starved to death to get the energetic profile of fish that starve during the winter fast. In that experiment there were 33 fish, and the water temperature ranged from 6 to 4°C. In the next observation, fasting fish were collected in time series so crude estimates of daily energy use could be made. In that experiment there were 22 fish collected at time zero, 22 fish at day 27, and 22 fish at day 45, and the water temperature ranged from 7 to 5°C. Whole body energy content was measured for each individual using the standard methods. During the winter of 1996-1997, juvenile herring will be captured every two months from over-wintering areas somewhere near Cordova to supplement lab energy use estimates with real world measures. The somatic energy data set will be used by the SEA modeling component to create a model describing the over-winter energy needs of juvenile herring and the likelihood of individuals to survive the winter.

Somatic Energy of Pink Salmon Fry

Collections were made from four sites to see how useful somatic energetics would be to the SEA pink salmon fry studies. The relative abundance of fry was determined (Willette component of SEA), fish collected (see Table 1 for sample sizes, dates, locations) and frozen in seawater for analysis. Fish were analyzed for standard length, wet weight, condition factor [CF = g wet wt x 100/(cm standard length)^3], and whole body energy content using standard calorimetric methods.

Somatic Energy of Age 0 Pollock

Pollock under 100 mm SL were collected at seven sites (see Table 1 for sample sizes, dates, locations) and frozen in seawater for analysis. Fish were analyzed for standard length, wet weight, condition factor [CF = g wet wt x 100/(cm standard length)^3], and whole body energy content using standard calorimetric methods.

Table 1. Collections of specimens for energetic measurements for SEA 320U during year one. (Key: HO = Herring ovary; AHWB = Adult herring whole body; JHWB = Juvenile herring whole body; PSFWB = Pinks salmon fry whole body; A0PWB= Age 0 pollock whole body.)

Tissue Type	Date (month/day/year)	Location in PWS	Number of Fish
HO	4/4/95	Ester Island	35
HO	4/14/95	Port Fidalgo	29
HO	4/17/95	Montague Island	46
AHWB	10/25/95	Green Island	100
AHWB	11/1/95	Knowles Head	100
AHWB	11/3/95	Jack Bay	100
JHWB	10/26/94	Orca Inlet	92
JHWB	10/29/94	Port Gravina	100
JHWB	5/17/95	Ester Island	36
JHWB	5/5/95	Parry Island	108
JHWB	5/2/95	Montague Island	57
JHWB	5/27/95	Port Gravina	101
JHWB	5/7/95	Hogg Bay	63
JHWB	4/30/95	Orca Inlet	101
JHWP	5/14/95	Eaglek Bay	100
JHWB	11/5/95	Eaglek Bay	100
JHWB	11/3/95	Jack Bay	100
JHWB	10/20/95	Zaikof Bay	59
JHWB	11/7/95	Sawmill Bay	100
JHWB	10/25/95	Green Island	100
JHWB	10/19/95	Whale Bay	97
JHWB	11/1/95	Knowles Head	98
JHWB	10/16/95	Simpson Bay	100
JHWB	11/3/95	Snug Cornor Cove	100
JHWB	11/8/95	Hogg Bay	42
PSFWB	5/4/95	Ester Island	92

Tissue Type	Date (month/day/year)	Location in PWS	Number of Fish
PSFWB	5/31/95	Ester Island	62
PSFWB	5/27/95	Port Gravina	42
PSFWB	6/2/95	Perry Island	42
A0PWB	10/16/95	Simpson Bay	100
A0PWB	10/20/95	Zaikof Bay	100
A0PWB	10/18/95	Whale Bay	100
A0PWB	11/1/95	Knowles Head	100
A0PWB	11/5/95	Eaglek Bay	100
A0PWB	11/7/95	Sawmill Bay	100
A0PWB	11/7/95	Hogg Bay	100

Results

Herring Ovarian Energetics

Ovary energy was measured from herring collected at three sites. Figure 1 shows the mean (and sd) for the values. The allocation of energy to ovaries is related to feeding conditions (Hay *et al.*, 1988). There was a strong correlation between fish weight and energy content of the ovary (Fig. 1, lower panel). However, there was no marked differences in weight specific energy content with geographical location of the collection (Fig. 1, middle panel) once fish weight was factored into the analysis (Fig. 1, upper panel versus middle panel). Post spawning samples demonstrated that almost all the energy stored in the ovary prior to spawning is released with spawning. Collections will be made for the last time in the spring of 1996 to obtain insight into the interannual variation in energy allocated to ovaries.

Fall Whole Body Energy of Adult Herring

The data for the first year's sampling of this parameter is not yet processed.

Spring and Fall Age 0 and Age 1 Herring Body Energy

Two samples of herring recruits were available in the SEA archives from the fall of 1994. One from Port Gravina had an average energy content of 7.0 $KJ.g^{-1}$ wet wt; while a concurrent sample from Orca Inlet had an average of 4.6 $KJ.g^{-1}$ wet wt (Fig. 2, upper panel). These samples demonstrated that there is a strong geographical difference in the energy content of recruiting herring. In spring 1995, the age 0 and 1 herring that survived the winter had average energy contents generally between 4 and 6.5 $KJ.g^{-1}$ wet wt (Fig. 2, middle panel). Those fish entering the winter of 1995-1996 typically had a similar energetic content as the fish surviving the previous winter, 4.0-6.5 $KJ.g^{-1}$ wet wt (Fig. 2, lower panel) suggesting that many of them may not survive. Spring sampling in 1996 will identify the energy content of survivors.

In the laboratory, experiments with 0 age herring have demonstrated that fish starved to death have somatic energy contents of 3 to 3.5 $KJ.g^{-1}$ wet wt. Fasting fish use about 0.66 $KJ.g^{-1}$ wet wt a month at 6.6°C. Under those conditions, a recruit facing a 90 day fast would need to have an energy content >5.5 $KJ.g^{-1}$ wet wt to survive. Many of the fish in the fall of 1995 sampling had lesser amounts of energy suggesting that growth and energy storage in many age 0 herring is limited by food availability. Future thermal refinements to the laboratory energy use model, and winter time sequence sampling of fish from the field, are planned to improve the bioenergetic energy use model. The bioenergetic model will assess the potential of individuals to survive the winter.

Somatic Energy of Pink Salmon Fry

In 1995, the work with somatic energy content of fry was experimental to see if it would be a useful tool to quantify feeding success of fish relative to their abundance, location and origin. Collections were made from three sites. At the Ester Island site there was a high abundance of hatchery fry, at Perry Island fry occurred in more moderate abundance and in Port Gravina there were far fewer wild fry (abundance data from Willette component of SEA). At the site where high numbers of fry competed for prey, the average energy content was 3.2 $KJ.g^{-1}$ wet wt versus 3.6 and 4.4 $KJ.g^{-1}$ wet wt for the areas with decreasing intraspecific competition (Fig. 3). These differences are statistically significant. Concurrent data sets of temperature and prey abundance are being analyzed to enhance the interpretation of these results, but the feasibility study does show that measuring energy content helps identify the effects of feeding success.

Somatic Energy of Age 0 Pollock

Samples from seven sites in the SEA study area were collected in the fall of 1995. All the samples have been processed, however, the data will not be analyzed in time for this report. The data will provide insight into how recruiting herring and age 0 pollock compete for food resources and their relative success.

Discussion

The energetics portion of SEA was initiated in mid-April 1995 so it is just completing its first year of operation. The first year was a feasibility effort since none of the parameters measured had been measured before. 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 will be quantified. The somatic energy measures should identify individuals that have not stored enough energy to survive the winter period. The SEA herring recruit bioenergetic model, combined with wide scale geographical sampling of age 0 herring, will help predict post-larval year class recruitment potential during the first year of life.

The energy analysis of adult herring ovaries in the spring will be correlated with EVOS herring egg deposition models (**Haldorson *et al.*, 19xx**) and SEA primary-secondary production models. These energy measures will possibly turn out to be inexpensive proxies for hind-casting annual secondary productivity.

Conclusions

Somatic energy measurements are a valuable tool for identifying the transfer of energy through the food web to SEA target species, pink salmon fry and herring. They measure subtle differences that are unobservable from length wet weight measures and quantify gross differences. Quantifying energy transfers is critical to building SEA models and the energetics component of SEA provides these input values. Energetics measures are being used to simulate and test SEA hypothesis lake-river and over-wintering, and the production and competition models. Additionally, the energetic data set allows for trophic comparisons of pelagic analogs like pollock and herring, and transfer of energy to other animals such as APEX birds.

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HERRING SPAWNING 1995

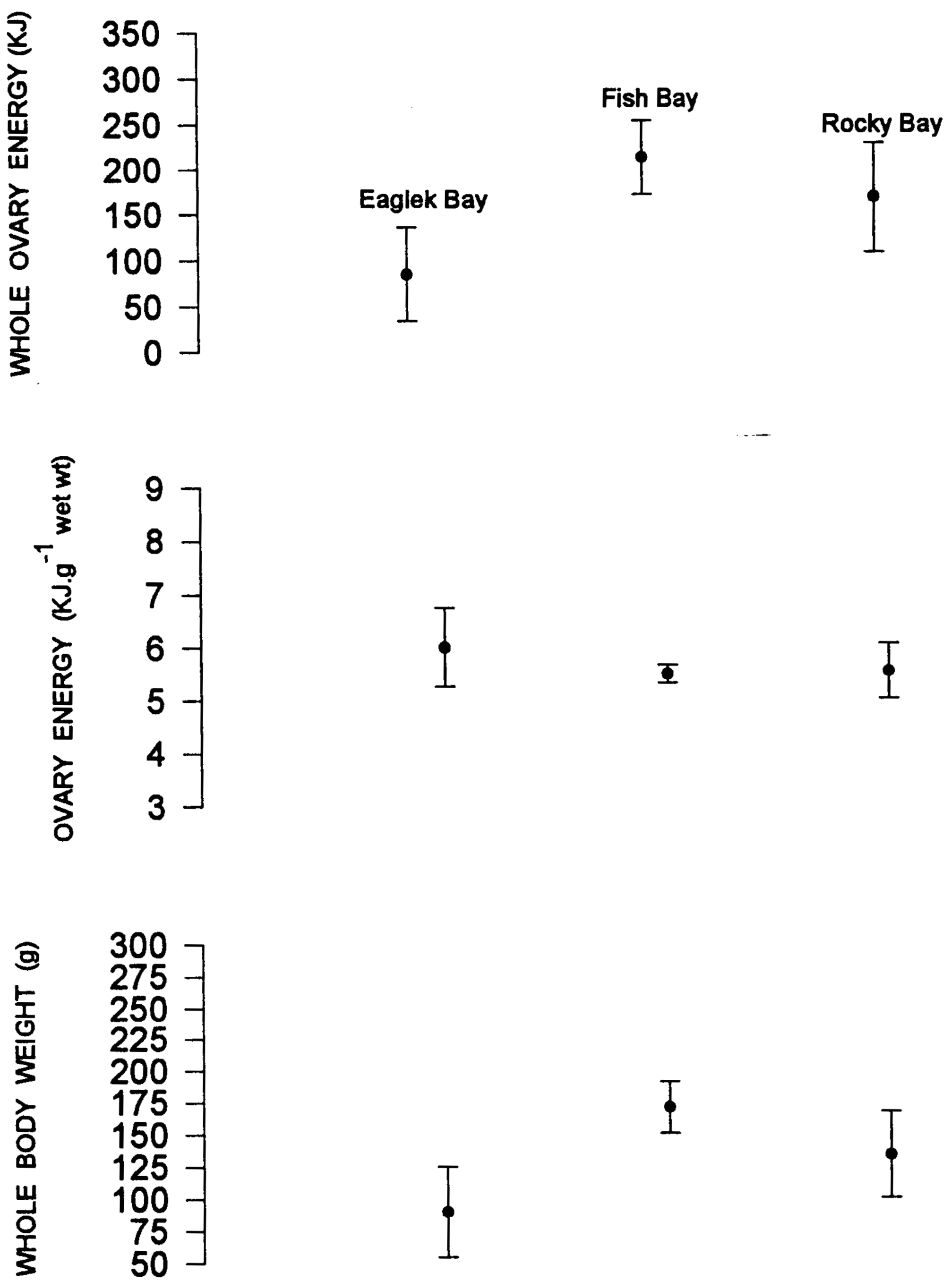

Figure 1. Herring ovary energetics in the spring of 1995. Data = mean, sd.

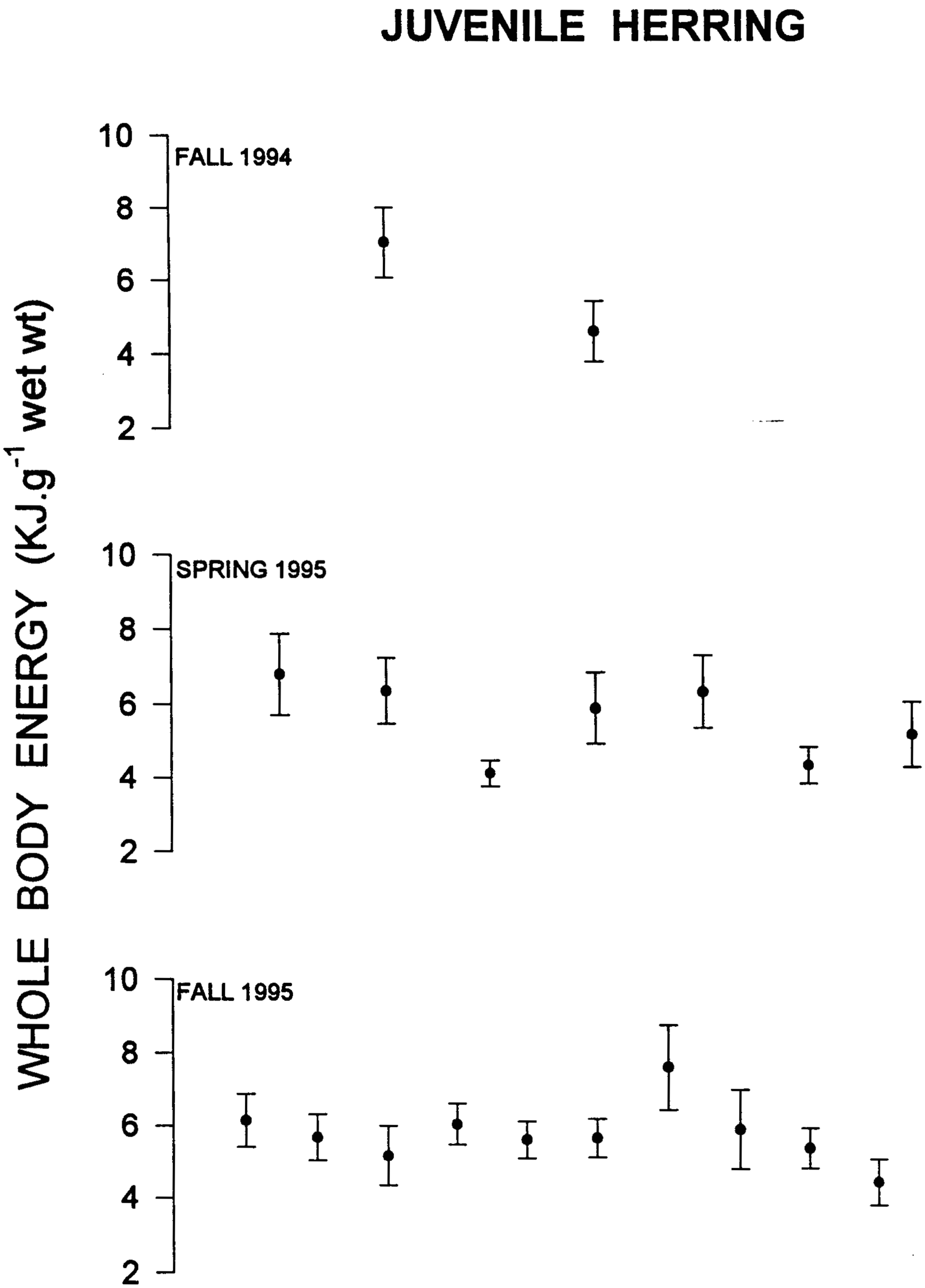

Figure 2. Somatic energy content (mean and sd) of juvenile herring. Each data set represents fish from a different geographical area.

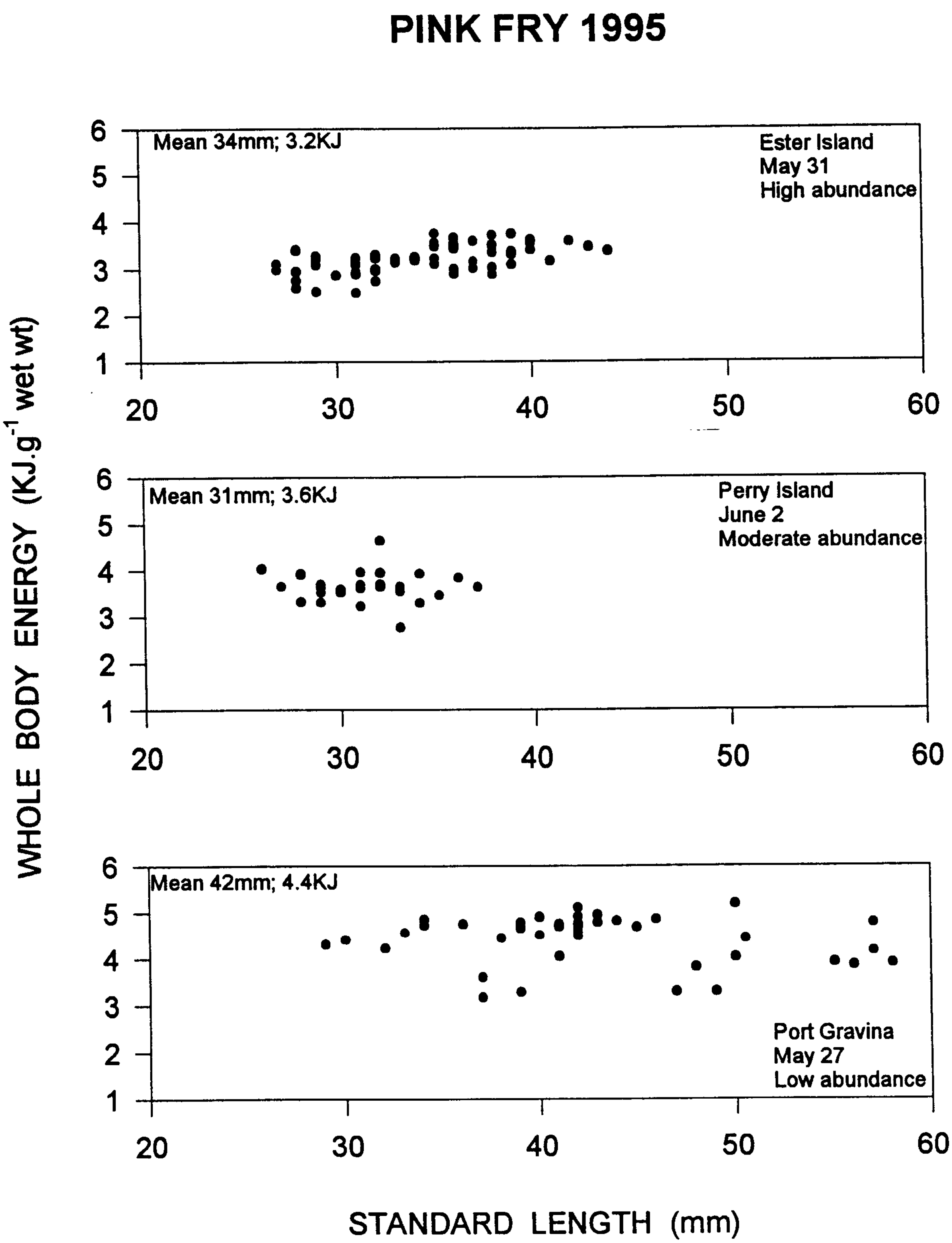

Figure 3. Whole body energy of pink salmon fry in three areas of Prince William Sound.