Are herring (*Clupea pallasi*) energetics in PWS a limiting factor in successful recruitment of juveniles and reproduction investment of adults?

Johanna Vollenweider and Ron Heintz

This proposal is for consideration for the Exxon Valdez Oil Spill Trustee Council FY2007 Invitation for Proposals.

Please find enclosed the following:

Thank you,

Johanna Vollenweider

Download the FY07 Invitation and Instructions at
http://www.evostc.state.ak.us/Proposals/forms.htm

I. FY07 Invitation: Narrative Forms for Proposals

PROPOSAL SIGNATURE FORM

THIS FORM MUST BE SIGNED BY THE PROPOSED PRINCIPAL INVESTIGATOR AND SUBMITTED ALONG WITH THE PROPOSAL. If the proposal has more than one investigator, this form must be signed by at least one of the investigators, and that investigator will ensure that Trustee Council requirements are followed. Proposals will not be reviewed until this signed form is received by the Trustee Council Office.

By submission of this proposal, I agree to abide by the Trustee Council's data policy (*Trustee Council Data Policy**, adopted July 9, 2002) and reporting requirements (*Procedures for the Preparation and Distribution of Reports***, adopted July 9, 2002).

PROJECT TITLE: Are herring (*Clupea pallasi*) energetics in PWS a limiting factor in successful recruitment of juveniles and reproduction investment of adults?

Printed Name of PI: Johanna Vollenweider

Signature of PI: ______________________________ Date __________

Printed Name of co-PI: Ron Heintz

Signature of co-PI: ______________________________ Date __________

Printed Name of co-PI: ______________________________

Signature of co-PI: ______________________________ Date __________

* www.evostc.state.ak.us/Policies/data.htm
** www.evostc.state.ak.us/Policies/Downloadables/reportguidelines.pdf

33 Trustee Council Use Only Project No. 070806 Date Received: ________

FY07 INVITATION
PROPOSAL SUMMARY PAGE

Project Title: Are herring (*Clupea pallasi*) energetics in PWS a limiting factor in successful recruitment of juveniles and reproduction investment of adults?

Project Period: November 2007 – September 2007

Proposer(s): Johanna Vollenweider* Co-PI: Ron Heintz*

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Study Location: Prince William Sound, Sitka Sound, Lynn Canal

Abstract: The causes underlying the depressed recruitment rates among Prince William Sound (PWS) herring are unknown, but are likely to include reduced survival of offspring to maturity. Potential agents for depressed recruitment include chronic exposure to pathogens and increased numbers of predators. While identification of the causative agents remains elusive, it is likely that their combined effects are reflected in herring energy dynamics. Previous work in PWS demonstrated the need for juvenile herring to acquire and store energy prior to winter to ensure survival when prey resources were scarce. Juveniles facing increased predation risk or immune response may have less surplus energy available to allocate to storage at the onset winter. In addition, continuing disease and predation stress may increase the rate at which individuals lose energy during winter. Thus decreased offspring survival may result from increased energetic demand over winter. Similarly, adults facing increased energy demand as a result of environmental stress are likely to have decreased energy available for reproduction with consequent effects on offspring survival rates. Therefore, we propose to examine the energy dynamics of herring in PWS and other locations to test the hypothesis that PWS herring stocks have higher energy consumption rates than healthier stocks in other parts of Alaska.

KeyWords: Pacific herring (*Clupea pallasi*), energy phenology, energetic stress, overwinter, size-selective mortality, reproductive investment, spatial variation, energy content, proximate composition

FUNDING INCLUDING 9% G&A:

EVOS Funding Requested for FY07 = $ 139.1K

Non-EVOS Funds to be used: FY07 $ 54.2K

(In the form of in-kind donation of personnel salaries from Auke Bay Lab)

An Estimate of $20.K was detailed for FY 08 but supporting details were not provided as required in the FY 07 Invitation.

GRAND TOTAL: $ 193.3K

Date: July 31, 2006 – (Revised 13 Aug 2006)

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PROJECT PLAN

I. PROJECT TITLE: Are herring (*Clupea pallasi*) energetics in PWS a limiting factor in successful recruitment of juveniles and reproduction investment of adults?

II. NEED FOR THE PROJECT

A. Abstract

The causes underlying the depressed recruitment rates among Prince William Sound (PWS) herring are unknown, but are likely to include reduced survival of offspring to maturity. Potential agents for depressed recruitment include chronic exposure to pathogens and increased numbers of predators. While identification of the causative agents remains elusive, it is likely that their combined effects are reflected in herring energy dynamics. Previous work in PWS demonstrated the need for juvenile herring to acquire and store energy prior to winter to ensure survival when prey resources were scarce (Paul and Paul 1998; Foy and Paul 1999; Norcross et al. 2001). Juveniles facing increased predation risk or immune response may have less surplus energy available to allocate to storage at the onset winter. In addition, continuing disease and predation stress may increase the rate at which individuals lose energy during winter. Thus decreased offspring survival may result from increased energetic demand over winter. Similarly, adults facing increased energy demand as a result of environmental stress are likely to have decreased energy available for reproduction with consequent effects on offspring survival rates. Therefore, we propose to examine the energy dynamics of herring in PWS and other locations to test the hypothesis that PWS herring stocks have higher energy consumption rates than healthier stocks in other parts of Alaska.

B. Statement of Problem

This study will assess energetic status of 2 critical life stage processes: size-selective mortality of juveniles, and reproduction investment by adults. Energetic status, assessed through measurement of caloric content and proximate composition (lipid and protein), varies by life stage and season (Paul et al. 1998; Foy and Paul 1999; Robards et al. 1999; Anthony et al. 2000; Vollenweider 2005). Juvenile herring must partition energy between growth to reduce predation risk (Sogard 1997; Pratt and Fox 2002; Garvey et al. 2004) and energy storage to prevent winter starvation (Paul et al. 1998; Foy and Paul 1999), particularly during periods of sustained fasting. Age-0 herring are particularly subject to starvation mortality (Foy and Norcross 1999). Similarly, mature fish must allocate energy between growth and storage. Larger herring are more fecund (Ware 1985), however, greater size does not necessarily translate to higher quality gametes (Paul et al. 1996; Paul and Paul 1999a). Spring-spawning adults must utilize energy stores accumulated over the previous summer and fall to provision gametes, fuel other reproductive costs and maintain body condition (Robards et al. 1999). We will measure the magnitude of pre-winter energy stores of juvenile and adult herring, as well as the remaining energy stores of survivors the following spring. In addition, we will measure the energetic status of mature fish before and after spawning.

Strategy: Past work has quantified juvenile energy stores prior to and following winter (Paul et al. 1998; Foy and Paul 1999; Norcross et al. 2001) and has characterized the energy content of female ova (Paul et al. 1996; Paul and Paul 1999a). This proposal will expand on previous studies, building on them in several ways. Foremost, we will make identical energetic measurements concurrently on herring in 2 other populations in southeastern Alaska (SEAK) (controls) to determine if herring in PWS incur elevated energy expenditures (Figure 1). We will assess the Sitka Sound stock, which is a robust stock that was paralleling the PWS stock in recruitment success prior to the spill. In addition, the Lynn Canal stock, which has been depressed for the past 24 years for unknown reason, will also be assessed. The costs of sampling the control stocks will be partnered with other studies, and the majority of effort and costs will be focused on PWS stocks. Comparisons of PWS to the other two stocks are critical to determine the uniqueness (or not) of the recruitment events for PWS; this information will influence recruitment modeling.

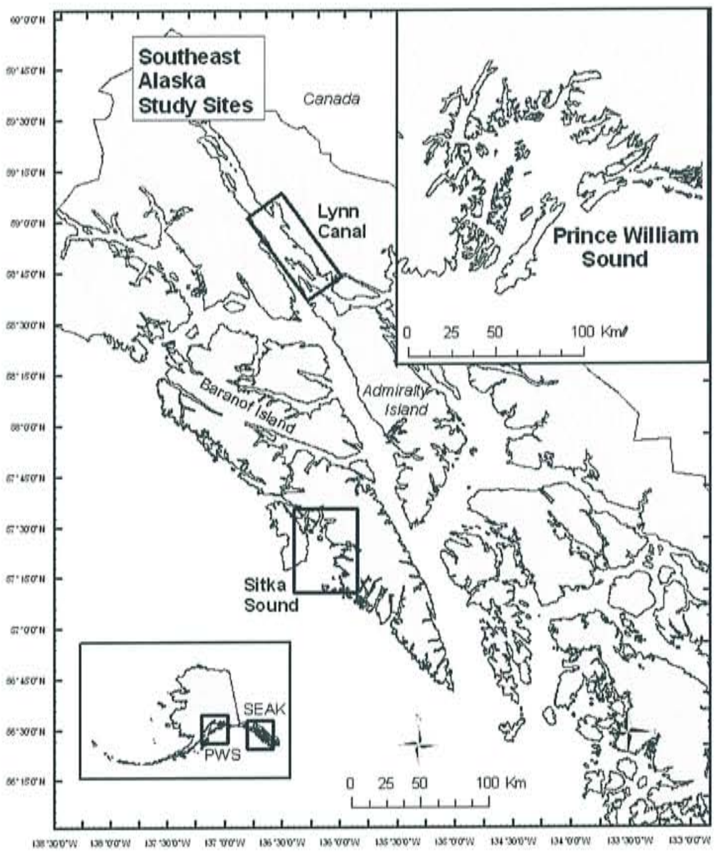

Figure 1. Map of 3 stocks of herring to be analyzed for energetic status, including Prince William Sound, Lynn Canal and Sitka Sound.

We will assess measurements of proximate composition (lipid, protein, moisture, ash) of fish and gonads in order to determine the proportion of available energy used and the sources of energy. Total energy content is useful to calculate changes in energy, however, it is a coarse measure that is not necessarily reflective of energy availability. Nor is total energy content a measurement sensitive to trade-offs amongst lipid and protein stores (Hudson et al. In prep), which are the main sources of energy during starvation (Takeuchi et al. 1987; Machado et al. 1988; Mommsen 1998). Though lipid catabolism is often the preferred source of energy to safeguard important protein sources (Black and Skinner 1986), some life stages have pressure to conserve lipid stores (Ogata et al. 2002). Additionally, some fish have developed adaptations to utilize energy beyond what is available in lipid stores, such as sockeye salmon which may conduct more than 75% of their migrations after lipid stores have been depleted (Mommsen 1998). Thus, we will examine the proximate composition of herring carcasses and gonads in order to compare the magnitude and source of energy utilization of herring in the 3 stocks under study. Differences in the amount of energy required by fish to survive winter as well as the sources from which energy is mobilized will be illustrative to determine if PWS are energetically stressed beyond levels observed in other locations.

Our current understanding of the seasonal and annual energy phenology of herring in Lynn Canal spanning 5 years (2001-2005) will provide valuable insight into results from this proposed study. Pre- and post- winter energetic measurements made in Lynn Canal from this proposal will be placed in context of the seasonal energy cycle we have previously observed (Figure 2) (Vollenweider et al. *In prep*). Despite our prior knowledge of Lynn Canal energy dynamics, inclusion of a 2006/2007 measurement of the Lynn Canal stock concurrent with PWS and Sitka sound is imperative due to interannual variability in fish condition and ocean conditions (Paul and Paul 1999b; Stokesbury et al. 1999; Vollenweider 2005; Vollenweider et al. *In prep*).

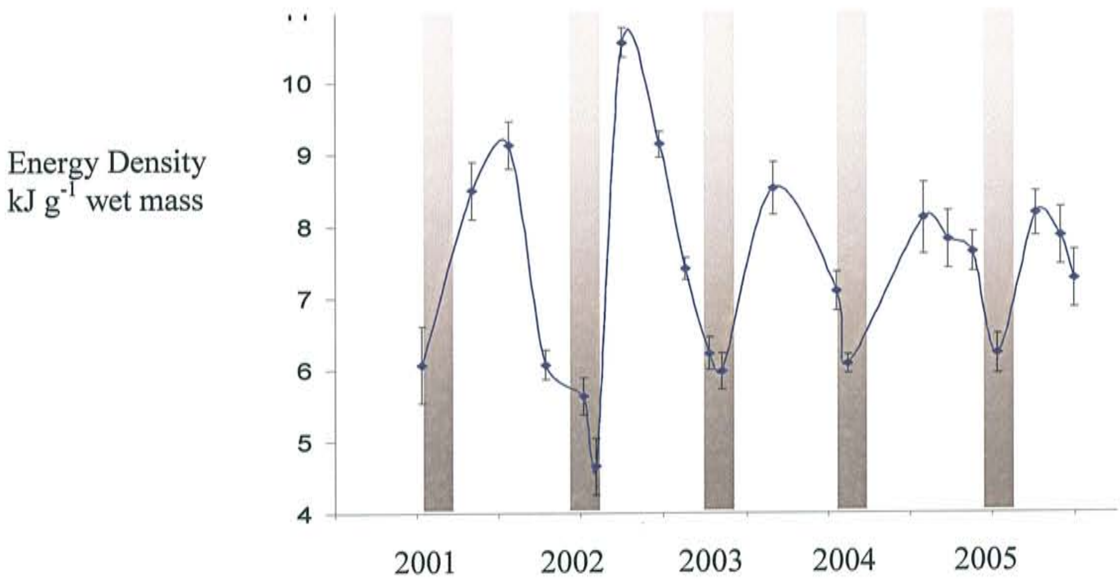

Figure 2. Energy phenology of herring in Lynn Canal, where gray bars represent spawning periods.

Another element of this study which will elaborate on previous work includes the measure of total reproductive energy expenditure of adult herring, rather than solely the energy provisioning ova (Paul et al. 1996; Paul and Paul 1999a). With the inclusion of our measures of adult energy stores prior to winter, we will examine how pre-winter energy stores relate to ova provisioning, as well as quantify additional energy expenditures for processes such as spawning behavior and maintenance metabolism. It is important to account for this additional energy expense because the bulk of reproductive energy is not transferred directly to ova (Smith et al. 1988). For example, of the total energy walleye pollock expend during spawning, only 13% and 40% of the total energy loss is attributed to reduction in gonad energy in males and females, respectively (Smith et al. 1988).

C. Relevance to Restoration Goals and Priorities

This project addresses "Injured Resources and Services: Evaluation and Restoration". In particular, we will examine Pacific herring, an injured resource which has been classified as "not recovered". One indication of recovery has been identified as highly successful recruitment of a year class. We will directly test hypotheses for recruitment failures. Identification of processes contributing to recruitment failures (or conversely, ruling out of these processes) will provide valuable information to managers for remediation.

III. PROJECT DESIGN

A. Objectives

We will compare 2 mechanisms that may be inhibiting herring recruitment in Prince William Sound, including (1) over-winter mortality of juveniles, and (2) low reproductive energy investment by adults. These processes will be compared to herring stocks in 2 other areas, including (i) Sitka Sound, a region in which a thriving herring stock is commercially fished, and (ii) Lynn Canal, a region in which depressed herring stocks are not currently commercially fished. Comparison of PWS to the 2 SEAK locations will provide insight into where PWS herring recruitment processes lie on a continuum and implications for management. Specifically, we will:

1. Measure caloric content and proximate composition in YOY and age-1 herring in the fall and the subsequent spring.
2. Measure caloric content and proximate composition in adult herring in the fall and in the subsequent spring, before and after the spawning event. Gonads will be separated and measured separate from the rest of the carcass.
3. Compare the measurements from 3 regions and interpret the regional differences and similarities with implications for management.

B. Procedural Methods and Scientific Design

Winter Energy Expenditure of Juveniles

We will compare over winter whole-body energy expenditure of juvenile herring (YOY and age-1) in PWS to Sitka Sound and Lynn Canal. At each of the 3 study sites, we will measure the maximum energy depots juvenile herring acquire from summer feeding. Multiple cruises will be conducted during the late fall in order to capture the peak energy content. Timing of the peak energy content varies between years, hence the need for collections in multiple months (Vollenweider 2005; Vollenweider et al. *In prep*). On 2 cruises in the following spring, we will measure remaining energy depots and calculate the quantity of energy used over winter.

Adult Reproductive Investment

We will determine if adult herring in PWS are investing the same amount of energy in reproduction as fish in Sitka Sound and Lynn Canal. From each location, we will collect mature fish spanning the size range of herring present. Reproductive investments on a size-adjusted basis will be examined as the proportion of energy invested in the gonads and the proportion expended for additional costs such as reproductive behavior and maintenance. Reproductive energy investments will be calculated similarly to methods employed with the juveniles, subtracting spring energy content from peak energy contents in the fall. Sampling collections will mirror juvenile collections with the addition of a 2nd spring sampling cruise following spawning. For each observation, we will measure carcass energy content and gonad energy content.

Body Composition Analysis

During all cruises, we will use bioelectrical impedance analysis (BIA) to quantify the energetic status of a large number of individuals in the field (several hundred individuals for each observation; this will capture all age classes present). BIA is a non-lethal, inexpensive and rapid method available in a small, portable unit that uses impedance differences between fat and fat-free tissues to assess energy content and proximate composition in organisms. BIA provides accurate and reliable estimations of fish body composition, with a high linear correlation ($R^2 >$ 0.96 for brook trout, *Salvelinus fontinalis*) for all proximate components, including water, protein, fat, fat-free and dry weights (Cox and Hartman 2005). BIA is most accurate with species-specific validation, which we have completed for juvenile Pacific cod (*Gadus macrocephalus*) (Figure 3). In 2006 we will complete the models for Pacific herring, crescent gunnels (*Pholis laeta*), Pacific sanddabs (*Citharichthys sordidus*), Saffron cod (*Eleginus gracilis*), and Pacific sand lance (*Ammodytes hexapterus*). Voucher specimens of different age classes will be brought back to the lab for verification using proximate analysis (lipid, protein, moisture and ash content) (n=100). Additionally, energy content will be measured using bomb calorimetry (n=100).

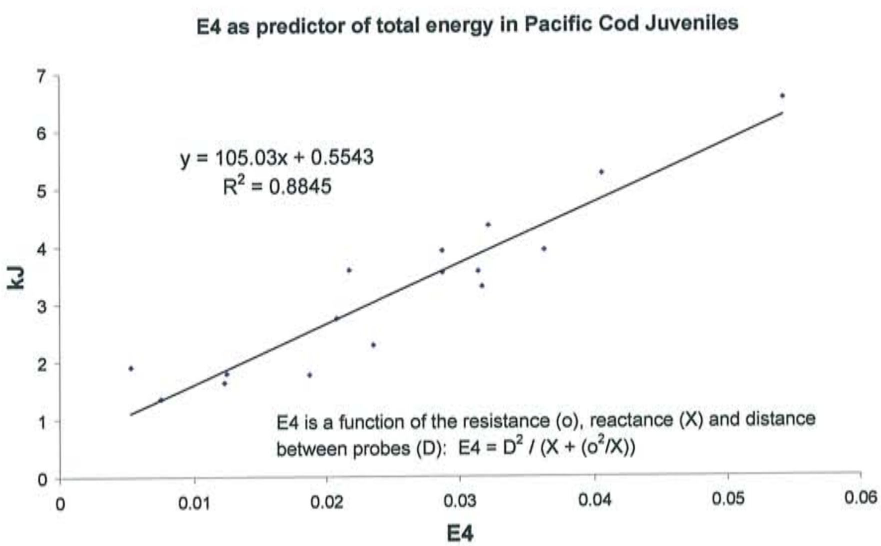

Figure 3. Bioelectrical impedance analysis correlations with total energy content (kJ) of juvenile Pacific cod.

Temperature profiles will be measured during all sampling trips at each location from which herring are sampled.

C. Analysis and Statistical Methods

We will compare the overwinter energetic status of herring from the 3 study sites using scaling relationships between body length and body composition (Hurst and Conover 2003). Isometric scaling between fish length and energy stores would indicate individuals from different locations are storing and using energy similarly. In contrast, allometric relationships would

indicate that alternate strategies are employed by fish of variable size. These comparisons will allow us to infer seasonal patterns of energy allocation within and amongst stocks, and will provide insight regarding energy stress of herring in PWS. In addition, these analyses will account for differences in fish size between stocks, allowing us to directly compare similarly-sized fish between stocks rather than other measures such as population means.
Size-selective mortality may be a confounding factor in our measurements. Smaller individuals are most at risk of starvation over winter, incurring greater weight specific basal metabolism with no corresponding increase in energy storage capacity (Shuter and Post 1990). This would have the effect that we would be measuring different populations in the fall and spring, leading to conservative estimates of winter energy use. To assess this, we will examine differences in size distributions of fish collected pre- and post- winter (Sogard 1997). Fall and spring abundance estimates from the Alaska Department of Fish and Game, Cordova, will also be compared to assess mortality. In addition, indication of allometric energy allocation would further provide support for size-selective mortality. We have used these 3 factors previously to document size-selective mortality of walleye pollock (Heintz and Vollenweider *In review*) and juvenile eulachon and capelin (Hudson et al. *In prep*).

We will use published estimates for herring metabolic rate (Rudstam 1989) to calculate the proportion of overwinter energetic demand contributed by energy stores (lipid) or structural energy (protein). These analyses will be illustrative of the ability of fish to meet metabolic demand either from energy stores alone or supplemented by feeding. For example, we found that pollock in Lynn Canal can not meet energetic demand using on-board energy stores alone until they reach approximately 300mm in length (Heintz and Vollenweider *In review*) (Figure 4). Until they reach this threshold size, they must utilize structural energy sources (protein) to meet energy requirements.

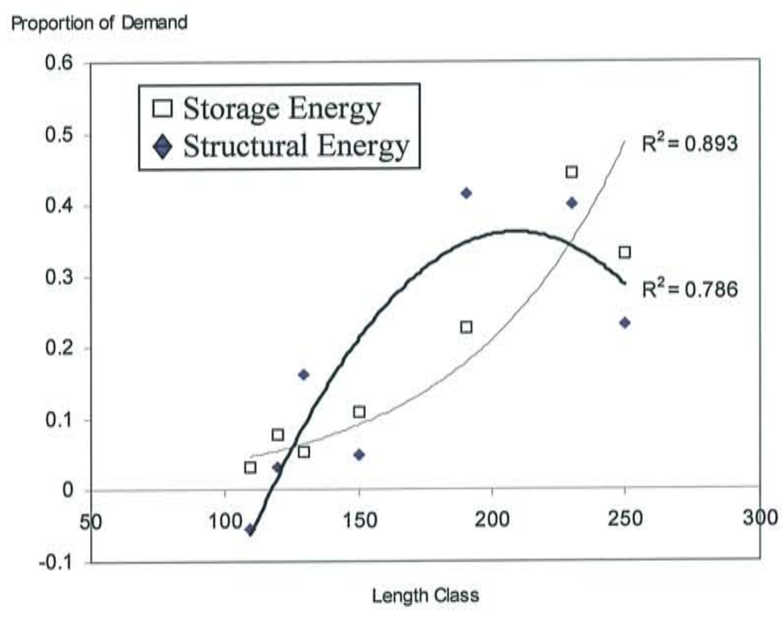

Figure 4. Proportion of metabolic demand met by storage energy (storage lipids) and structural energy (protein and membrane lipids) for juvenile pollock in Lynn Canal.

The age of a subsample of herring will be validated through scale analysis (Chilton and Stocker 1987), and ages of remaining specimens will be inferred from constructed length-age regressions.

D. Study Area

The study will be conducted in three locations in order to place PWS energetic processes in context of other herring stocks (Figure 2). Comparison to other stocks is critical, to provide contrast to stocks in variable condition.

1. Prince William Sound

Following EVOS, biomass estimates of the Prince William Sound herring stock fell to 18,000-38,000 tons from previous estimates ranging between 60,000-140,000. Commercial harvests have occurred from as many as 5 fisheries (sac roe-2 seasons, spawn on kelp-2 seasons, and food/bait) when a minimum spawning biomass threshold of 22,000 tons is reached (25% of the unfished stock). Commercial takes have fluctuated significantly over the years, peaking at 28,000 tons in management year 1991/1992. Since the 1999/2000 season, however, no fishery has occurred due to the failure of the stock to rebound after EVOS (Ashe et al. 2005).

Herring spawning and nursery areas have been well documented in PWS, as has the timing of these events (Lasker 1985; Brown and Carls 1998; Willette et al. 1998; Stokesbury et al. 2000; Norcross et al. 2001; Brown et al. 2002). Each data point we collect will consist of fish sampled from multiple areas because habitat diversity within the Sound appears to be influential on fish condition (Foy and Norcross 1999; Paul and Paul 1999b; Stokesbury et al. 1999; Norcross et al. 2001).

2. Sitka Sound

Herring stocks in Sitka Sound provide contrast to PWS stocks as it maintains a large spawning biomass that has sustained a high commercial exploitation rate. Spawning biomass has undergone significant fluctuations, increasing from 8,000 metric tons in 1970 to approximately 60,000 metric tons in the late 1980's. Spawning biomass likely reached similar high abundances in the late 1950's (Collie 1990). Consistent commercial harvests for the sac roe fishery have occurred since 1978, guideline harvest levels ranging from 2,000 to 11,831 tons. The 2006 guideline harvest rate was set at 10,412 tons (Davidson et al. 2006).

Due to the commercial importance of herring in Sitka Sound, the distribution of adults is well known (Alaska Department of Fish and Game), though juvenile distribution is less documented (Haldorson and Collie 1990).

3. Lynn Canal

Lynn Canal provides a "compromised" system for comparison to PWS. In recent years the spawning biomass has been too small in recent years to support a commercial exploitation. The sac roe fishery has not been open since 1982. Currently, the mature spawning biomass is 668 tons, well below the minimum spawning threshold value of 5,000 tons (Davidson et al. 2006).

We have investigated the seasonal distribution and abundance of herring in Lynn Canal since 2001 and have considerable knowledge regarding nursery areas of juveniles and overwintering areas for adults (Vollenweider 2005; Sigler and Csepp *in press;* Heintz and Vollenweider *In review;* Vollenweider et al. Submitted).

IV. COORDINATION AND COLLABORATION WITH OTHER EFFORTS

Sampling PWS will rely heavily on collaboration with other studies in an effort to reduce costs and effort (Table 1). The greatest costs incurred by this study are derived from chartering vessels in PWS. We plan to offset these costs by going out on cruises of with groups already sampling herring, including Some of the detailed collaboration in PWS is dependent upon funding of the partner studies. Field work in Sitka Sound will incur relatively little cost as Dr. Cox's laboratory resides there. All work in Lynn Canal will be carried out by Auke Bay Lab (ABL) aboard the NOAA R/V Quest, incurring no charter costs.

Dr. Keith Cox, a major collaborator and co-author, has a background of creating habitat bio-assessment models for specific geographic areas as well as developing new technologies to measure fish energy content. Cox has expertise in fish bioenergetics and how environmental and human actions affect fish scaling from individuals to populations. In this, he has developed, innovated and published the only work using bioelectrical impedance analysis (BIA) with fish that is capable of measuring energy content, compartmental growth, proximate composition and health. This work has involved pilot studies on tuna, chinook salmon, brook trout and rainbow trout with scientific publications for each species in progress.

Collaboration with whale predation studies: Whale predation studies on herring are being proposed/implemented in Lynn Canal (SEAK) and Sawmill Bay (PWS). In both areas, whale predation has been hypothesized as leading contributing factor to the poor recruitment of these struggling stocks. While platforms for collections/observations are likely not to be the same, it is significant that these two study themes are linked in personnel, collaborators, and study sites. Data from this study (biomass estimates; energy content) will be part of the modeling data used in the whale predation study.

V. SCHEDULE

A. Project Milestones

Objective 1. Measure caloric content and proximate composition in YOY and age-1 herring in the fall and the subsequent spring.
Field measurements to be met by May 2007; Chemical analysis to be met by July 2007.

Objective 2. Measure caloric content and proximate composition in adult herring in the fall and in the subsequent spring, before and after the spawning event. Gonads will be separated and measured separate from the rest of the carcass.
Field measurements to be met by May 2007; Chemical analysis to be met by July 2007.

Objective 3. Compare the measurements from 3 regions and interpret the regional differences and similarities with implications for management.
Statistical analysis and interpretation to be met by September 2007.

Table 1. Cruise logistics and collaborators for sample collection, including time period, # of cruise days, cost of identified cruise days, and method of capture.

	PWS		**Sitka Sound**		**Lynn Canal**	
Period	Juveniles Collaborator days/cost/method	Adults Collaborator days/cost/method	Juveniles Collaborator days/cost/method	Adults Collaborator days/cost/method	Juveniles Collaborator days/cost/method	Adults Collaborator days/cost/method
October	No collections	CBEP 3d/$2K/jig	SJ 3d/$0.9/sm trawl	SJ 3d/$0.9/jig	ABL 3d/$0/sm trawl	ABL 2d/$0/jig
November	PWSSC 4d/$0/seine	ADF&G-Moffitt 4d/$0/seine	SJ 3d/$0.9/sm trawl	SJ 3d/$0.9/jig	ABL 3d/$0/sm trawl	ABL 2d/$0/jig
December	Charter 5d/$12.5K/seine	CBEP 3d/$2K/jig	SJ 3d/$0.9/sm trawl	SJ 3d/$0.9/jig	ABL 3d/$0/sm trawl	ABL 2d/$0/jig
March	Charter (PWSSC?) 5d/$12.5K/seine	PWSSC/ ADF&G-Moffitt 5d/$0/seine	SJ 3d/$0.9/sm trawl	SJ 3d/$0.9/jig	ABL 3d/$0/sm trawl	ABL 2d/$0/jig
April	Charter 5d/$12.5K/seine	CBEP (ADF&G-Moffitt?) 3d/$2K/jib	SJ 3d/$0.9/sm trawl	SJ/ ADF&G-Hebert 2d/$0/trawl	ABL 3d/$0/sm trawl	ABL 2d/$0/jig
Total d/$	**19d/$37.5K**	**18d/$6K**	**15d/$4.5K**	**14d/$3.6K**	**15d/$0**	**10d/$0**

- ADF&G – Alaska Department of Fish and Game, S. Moffitt (Cordova), K. Hebert (Sitka)
- PWSSC – Prince William Sound Science Center, Dick Thorne
- CBEP – Chenega Bay Environmental Program, Kate McLaughlin
- SJ – Sheldon Jackson College, Keith Cox
- ABL – Auke Bay Lab

B. Measurable Project Tasks

The timing of this Request For Proposals is late in the year relative to our planned collections in the fall and winter. However, our first sample collections incur low costs, allowing us to make these collections prior to the announcement of the EVOS proposals, at the expense of ABL if the project is not funded (see Tables 1-2).

FY 07, 1st quarter (October 1, 2006-December 31, 2006)

October:	Sample collection in Lynn Canal and Sitka Sound, all age classes Sample collection of adult herring in PWS via contract with Chenega Bay Environmental Program
November:	
Early Nov:	EVOS proposal approval
Mid Nov:	Sample collection at all 3 study sites, all age classes
Late Nov:	EVOS funds allocated
December:	Sample collection at all 3 study sites, all age classes

FY 07, 2nd quarter (January 1, 2007-March 31, 2007)

March:	Sample collection at all 3 study sites, all age classes

FY 07, 3rd quarter (April 1, 2007-June 30, 2007)

April:	Sample collection at all 3 study sites, adult herring only

FY 07, 4th quarter (July 1, 2007-September 30, 2007)

May-June:	Proximate analysis and bomb calorimetry of voucher specimens
July-August:	Statistical analysis, summary, report writing
September 1:	Submit Annual Report

FY 08, 1st quarter (October 1, 2007-December 31, 2007)

October-December:	Draft peer-reviewed manuscript

FY 08, 2nd quarter (January 1, 2007-March 31, 2007)

January	Annual Marine Science Symposium

Table 2. Proposed sampling locations, season, number of collections, and data acquired. Collection # indicates the sequence of sample collections within each region. Note that juvenile energy content will not be measured in PWS on the first sampling trip in the fall (October/Collection #1) due to limitations incurred by our winter field work schedule and the timing of the allocation of EVOS funds. Other sampling collections in October can proceed with little monetary requirement, at the expense of Auke Bay Lab if the project is not funded.

Region	**Season**	**Collection #**	**Data Acquired**
PWS	Fall	2-3	Juvenile (YOY & age-1) whole-body energy
		1-3	Adult carcass energy
		1-3	Adult gonad energy
	Spring	4	Juvenile (YOY & age-1) whole-body energy
		4	Adult carcass energy (pre-spawn)
		4	Adult gonad energy (pre-spawn)
		5	Adult carcass energy (post-spawn)
Sitka Sound	Fall	1-3	Juvenile (YOY & age-1) whole-body energy
		1-3	Adult carcass energy
		1-3	Adult gonad energy
	Spring	4	Juvenile (YOY & age-1) whole-body energy
		4	Adult carcass energy (pre-spawn)
		4	Adult gonad energy (pre-spawn)
		5	Adult carcass energy (post-spawn)
Lynn Canal	Fall	1-3	Juvenile (YOY & age-1) whole-body energy
		1-3	Adult carcass energy
		1-3	Adult gonad energy
	Spring	4	Juvenile (YOY & age-1) whole-body energy
		4	Adult carcass energy (pre-spawn)
		4	Adult gonad energy (pre-spawn)
		5	Adult carcass energy (post-spawn)
Total # Collections		**15**	

VI. RESPONSIVENESS TO KEY TRUSTEE STRATEGIES

A. Community Involvement and Traditional Knowledge (TEK)

The principal collaborator and co-author of reports and presentations stemming from this study is Dr. Keith Cox, a professor at Sheldon Jackson College (SJC). SJC is a small private four year undergraduate Alaska Native Minority Serving Institution located on Baranof Island in Sitka Sound, Alaska. The coastal location, small class sizes and strong Fisheries Program make SJC an ideal institution to carry out this type of project. This project would also 1) provide additional undergraduate research and educational opportunities for students at SJC that would allow a hands on approach leading to the understanding of trophic level interactions at individual through ecosystem levels, 2) allow SJC to further develop research partnerships with the National Oceanic and Atmospheric Administration (NOAA) Alaska Fisheries Auke Bay Laboratory, and 3) support the NOAA Future Fishery Management Leadership Project that provides financial support to a deserving junior and senior level student at SJC.

NOAA Future Fishery Management Leadership Scholarship

Objective: To recruit an academically well qualified student with sophomore status who will then obtain financial support from NOAA Fisheries during their junior year and then foster an interest by the student in a career in the Marine or Fisheries Science program at Sheldon Jackson College. The student may then be eligible for further support at the graduate level graduate school in Marine or Fisheries Sciences and upon graduation, be competitive for jobs within NOAA Fisheries. This student will be involved in the majority of the Sitka Sound field work, and will present a summary of their involvement at Auke Bay Lab.

B. Resource Management Applications

Recruitment failures are preventing recovery of PWS herring stocks. The information learned from this proposal will have two ramifications. First, we will place the energetic status of PWS herring in context with other herring stocks, and determine if recruitment processes in PWS are unique or more limited in comparison to other regions. This will influence the thinking and planning of potential herring enhancement projects. Second, data from this study would augment models of herring recruitment and reproduction. Furthermore, results may provide a basis for structuring a monitoring program where lipid and energy phenology could possibly be used to index recruitment. Other assessments, such as disease and predation may be limiting the population, but energetic limitations, whatever their source, would provide a basis for population stress. It is important to determination which factors are the major contributors to recruitment limitations, and which are secondary. Restoring a population without understanding the limiting factors is risky.

VII. PUBLICATIONS AND REPORTS

Vollenweider JJ, Heintz RA, Cox K (2007) Are herring (*Clupea pallasi*) energetics in PWS a limiting factor in successful recruitment of juveniles and reproduction investment of adults?

Final Report to EVOS	2007
Peer Reviewed Journal	2008

Vollenweider JJ, Heintz RA, Cox K (2008) Spatial variation in energy allocation strategies of Pacific herring (*Clupea pallasi*). Peer Reviewed Journal.

Moran J, Vollenweider JJ, Heintz RA (2008) Seasonal predation rates by humpback whales (*Megaptera novaeangliae*) on Pacific herring (*Clupea pallasi*) in Prince William Sound and southern Lynn Canal. Peer Reviewed Journal. (drafted with collaboration humpback whale study, pending concurrent funding of proposals – J. Moran)

Vollenweider JJ, ADF&G (2008) Pacific herring (*Clupea pallasi*) derived energy available to marine predators in Prince William Sound. Peer Reviewed Journal. (Combination of ADF&G's biomass estimates & energy data acquired in this study)

VIII. PROFESSIONAL CONFERENCES

- Alaska Marine Science Symposium
- Alaska Chapter of American Fisheries Society

Literature Cited

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Heintz RA, Vollenweider JJ (*In review*) Seasonal and ontogenetic changes in the energy allocation strategies of walleye pollock. Canadian Journal of Fisheries and Aquatic Sciences

Hudson J, Heintz RA, Vollenweider JJ (*In prep*) Overwinter changes in energy content and proximate composition of juvenile capelin and eulachon in southeastern Alaska. Fishery Bulletin

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Sigler MF, Csepp DJ (*In press*) Seasonal abundance of two important forage species, Pacific herring and walleye pollock, in Lynn Canal, southeast Alaska. Fisheries Research

Smith RL, Paul AJ, Paul JM (1988) Aspects of energetics of adult walleye pollock, *Theragra chalcogramma* (Pallas), from Alaska. Journal of Fish Biology 33: 445-454

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Vollenweider JJ (2005) Variability in Steller sea lion (*Eumetopias jubatus*) prey quality in southeastern Alaska. Juneau Center, School of Fisheries and Ocean Sciences, Fairbanks

Vollenweider JJ, Heintz RA, Hudson J (*In prep*) Seasonal and annual energy phenology of Pacific herring (*Clupea pallasi*) in Lynn Canal, southeastern Alaska

Vollenweider JJ, Heintz RA, Kelly BP (*Submitted*) Seasonal variation in whole-body proximate composition and energy content of forage fish in southeastern Alaska. Marine Ecology Progress Series

Ware DM (1985) Life history characteristics, reproductive value, and resilience of Pacific herring (*Clupea harengus pallasi*). Canadian Journal of Fisheries and Aquatic Sciences 42: 127-137

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Budget Justification
Total FY 07 Budget Request: $139.1K
(FY 08 Estimate $20.K was noted but not detailed as required within the FY 07 Invitation)

***Personnel:* $11.4 K**
2 months salary for Vollenweider ($11.4 K) are requested for data analysis and report/manuscript writing.

In-kind contribution for personnel salaries include ($54.2 K):

In-kind contribution for PI Vollenweider (4 months/$22.8 K) will be provided by NOAA Fisheries, Auke Bay Lab for project organization, sample collections and data summarization.

In-kind contribution for PI Heintz (2 months/$19.0 K) to assist in report/manuscript writing/editing will also be provided by NOAA Fisheries, Auke Bay Lab.

In-kind contribution for major collaborator Cox (3 months/$12.4 K) will be provided by Sheldon Jackson College for sample collection and report/manuscript editing.

***Travel*: $12.2 K**

Vollenweider will present results at the annual Marine Science Symposium in Anchorage, Alaska in 2008 (Alaska location unknown) ($1.3 K).

Travel for field work:
PWS ($9.9 K): Vollenweider and 1 contracted field technician will travel from Juneau to Prince William Sound to conduct field work (contractor will share lodging with Vollenweider, contractor is not eligible for per diem) (2 people * 5 sampling cruises * 34 total field days per person)
Sitka ($1.0 K): 1 person will travel from Juneau to Sitka 2 times to coordinate field sampling methods with Sitka personnel
Lynn Canal: No travel required

***Contractual:* $90.1 K**
Vessel contracts ($45.6 K)
The bulk of the vessel contract funds are required for sampling in PWS (see Table 1). Reliance upon collaboration with other studies (some of which is pending their funding) will be used to reduce costs. Charter costs in Sitka Sound are particularly low and are provided somewhat in-kind as we will be chartering a vessel from a major collaborator, Keith Cox, at Sheldon Jackson College. Lynn Canal cruises incur no charter costs and will be provided in-kind as all trips will be carried out by Auke Bay Lab (ABL) aboard the NOAA R/V Quest.

Contract cost for sample collection by Chenega Bay Environmental Program ($7 K) (see Table 1).
Contract costs for the chemical analysis (proximate composition and bomb calorimetry) of voucher specimens to verify BIA models ($15 K).

Contract costs for a field laborer in addition to a PI for sample collection:

- PWS ($9.5 K)
- Lynn Canal ($6.5 K)
- Sitka Sound ($6.5 K)

***Commodities*: $8.6 K**

Fuel for Lynn Canal vessel: NOAA R/V Quest ($2 K)

Fuel for Sitka Sound vessel: Sheldon Jackson College R/V Mel ($2 K)

Shipment of supplies/samples to and from field sites ($1.4 K)

Expendable supplies for the chemical analysis of voucher specimens (proximate composition and bomb calorimetry (e.g., gases, solvents, reagents) ($2 K)

Expendable supplies for sample preservation (e.g. zip-lock bags, boxes, other containers & packaging) ($1.2 K)

***Equipment:* $5.3 K**

A 3rd bioimpedance analyzer (BIA) is required for concurrent sampling in the 3 study sites ($3.5 K)

2 small trawls for sample acquisition via the SEAK sampling vessels (NOAA R/V Quest, Sheldon Jackson R/V Mel) are required ($1.8 K)

***Trustee Council Agency 9% G&A:* $11.5K**

Existing Equipment Usage:

Accelerated Solvent Extractor
Leco Protein Analyzer
Thermogravimetric Analyzer
Parr Semi-micro Bomb Calorimeter
Bioimpedance Analyzers (2)
NOAA R/V Quest

DATA MANAGEMENT STATEMENT

This project involves collecting biological specimens, taking measurements, performing chemical analyses, and analyzing and interpreting results. Data management and quality control will be the responsibility of J. Vollenweider and R. Heintz of the Auke Bay Lab, using established scientific protocols. If this proposal is funded, then we will work with EVOSTC to set up a data management plan, so that energetic data on herring will be archived in a publicly available ACCESS database.

1. Study design (p.8), study sites (p.10) and statistical analyses (p.9) are given elsewhere in this proposal.
2. Standard scientific protocols will be used for field studies and hypothesis testing. Chemistry QA/QC measures are standardized for our lab and are published in Vollenweider 2005, Vollenweider et al. *Submitted*, Heintz and Vollenweider *Submitted*, and Hilgruber et al. 2006 (see literature cited).
3. Data characteristics:
    a. If funded, we will use MetaLite, freeware created by USGS for collecting and validating Federal Geographic Data Committee (FGDC)-compliant metadata, as requested.
    b. Quantitative datasets obtained in this proposal include:
        1. Species-specific measurements: seasonal body composition of herring (energy, lipid and protein content) in 3 locations: Prince William Sound, Sitka Sound, and Lynn Canal; age of herring from the 3 locations
        2. Physical measurements: water temperature in the 3 study locations
4. Conversion of Bio-electrical Impedance Analysis (BIA) measurements to body composition estimates (energy, lipid, protein content) will be based on regressions we are in the process of determining for herring (p.8, Body Composition Analysis) (methods outlined in Cox and Hartman 2005).
5. Handling and custody of samples will follow standard ABL and protocols, which follows a dataflow from sample custody sheets, through chemical analysis to final archival in a standard database. Samples for chemical analysis will maintained in a frozen state to prevent degradation prior to chemical analyses.
6. Calibration and evaluation of analytical instruments are routinely performed at ABL and the University of Alaska. These evaluations include analysis of standard QA/QC samples of known composition (Vollenweider 2005, Vollenweider et al. *Submitted*, and Hilgruber et al. 2006).
7. Data will be reported as described earlier in this proposal (p.15, Publications and Reports, Professional Conferences). In addition, raw data & accompanying metadata will be published on the internet in a publicly-available form once peer-reviewed manuscripts have been published. This is standard protocol for the Nutritional Ecology Lab. Standard software will be used (Microsoft Office). Minitab will be used to perform statistical analyses.

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EMAIL: Johanna.Vollenweider@noaa.gov

EDUCATION:

B.S. Marine Biology, Chemistry Minor, December 1998, University of North Carolina, Wilmington
M.S. Fisheries Biology, May 2005, University of Alaska, Fairbanks Alaska
Advisor: Brendan P. Kelly, Ph.D.

SELECTED BIOENERGETIC/LIPID BIOCHEMISTRY PUBLICATIONS:

Vollenweider J, Heintz R, Kelly BP (*Submitted*) Seasonal variation in whole-body proximate composition and energy content of forage fish in southeastern Alaska. Marine Ecology Progress Series

Hudson J, Heintz R, **Vollenweider J** (*Submitted*) Overwinter changes in energy content and proximate composition of juvenile capelin and eulachon in southeastern Alaska. Fishery Bulletin

Heintz R, **Vollenweider J**, Sigler M (*Submitted*) Seasonal and ontogenetic changes in the energy allocation strategies of walleye pollock. Canadian Journal of Fisheries and Aquatic Science

Vollenweider J, Womble J, Heintz R (2006) Estimation of seasonal energy content of Steller sea lion (*Eumetopias jubatus*) diet. In: Sea Lions of the World. AW Trites, SK Atkinson, DP DeMaster, LW Fritz, TS Gelatt, LD Rea, and KM Wynne (Eds). Alaska Sea Grant College Program, University of Alaska Fairbanks. p 117-130.

Vollenweider JJ (2005) Variability in Steller sea lion (*Eumetopias jubatus*) prey quality in southeastern Alaska. Juneau Center, School of Fisheries and Ocean Sciences, Fairbanks

Vollenweider JJ, Heintz RA, Hudson J (*In prep*) Seasonal and annual energy phenology of Pacific herring (*Clupea pallasi*) in Lynn Canal, southeastern Alaska

Schaufler L, Logerwell E, **Vollenweider J** (2006) Geographical variation in Steller sea lion prey quality in Alaska. In: Sea Lions of the World. AW Trites, SK Atkinson, DP DeMaster, LW Fritz, TS Gelatt, LD Rea, and KM Wynne (Eds). Alaska Sea Grant College Program, University of Alaska Fairbanks. p 117-130.

Hillgruber N, **Vollenweider JJ** (*In prep*) Distribution, composition and energy density of zooplankton in the southeastern Bering Sea. For submission to Marine Biology or Fisheries Oceanography. Currently published as a final report to NPRB (2006)

Vollenweider JJ, Csepp D. Steller sea lion (*Eumetopias jubatus)* response to pre-spawning eulachon (*Thaleichthys pacificus)* in northern southeastern Alaska. ASFC Quarterly Research Report. July-Sept 2005.

RECENT COLLABORATIONS INVOLVING BIOENERGETICS

Csepp, D. NOAA Fisheries, Auke Bay Lab, Groundfish Assessment Program, Juneau, AK
Heintz, R.A. NOAA Fisheries, Auke Bay Lab, Nutritional Ecology Lab, Juneau, AK
Hillgruber, N. University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau, AK
Hudson, J. NOAA Fisheries, Auke Bay Lab, Nutritional Ecology Lab, Juneau, AK
Kelly, B.P. University of Alaska Southeast, Juneau, AK
Logerwell, E. NOAA Fisheries, AK Fishery Science Center, Seattle, WA
Mathews, E. University of Alaska Southeast, Juneau, AK
Schaufler, L. NOAA Fisheries, Auke Bay Lab, Nutritional Ecology Lab, Juneau, AK
Sigler, M. NOAA Fisheries, Auke Bay Lab, Groundfish Assessment Program, Juneau, AK
Tollit, D. N Pacific Universities Marine Mammal Research Consortium, B.C., Canada
Womble, J.N. NOAA Fisheries, Auke Bay Lab, Groundfish Assessment Program, Juneau, AK

Ron A. Heintz
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Auke Bay Laboratory
11305 Glacier Hwy.
Juneau, AK 99801 USA

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EMAIL: Ron.Heintz@NOAA.GOV

EDUCATION:

B.S. Ecology Ethology and Evolution, June 1979, University of Illinois, Urbana Illinois
M.S. Fisheries Biology, May 1987, University of Alaska, Juneau Alaska
PhD Candidate: University of Alaska, Fairbanks Alaska

PROFESSIONAL MEMBERSHIPS:

American Fisheries Society
American Institute of Biological Scientists
American Chemical Society

EMPLOYMENT AND STUDY FOCUS:

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Auke Bay Laboratory since 1985.

Prior to 2000

Examined the effects of crude oil exposure during embryogenesis on the life history of fish.

Since 2000

Leads AFSC Nutritional Ecology Laboratory program investigating the nutritional status and trophic relationships of marine forage species.

SELECTED BIOENERGETIC/LIPID BIOCHEMISTRY PUBLICATIONS:

Vollenweider, Johanna J. **R. Heintz** and B. Kelly. In Review. Seasonal variation in the proximate composition and whole-body energy content of forage fish. Marine Ecology Progress Series.

Heintz R. and J Volllenweider. In Review. Seasonal and ontogenetic changes in the energy allocation strategies of walleye pollock. Can. J. Fish. Aquat. Sci.

Hudson, JP, **R. Heintz,** J Vollenweider. Overwinter energy dynamics of capelin and eulachon in southeastern Alaska. Fishery Bulletin.

Vollenweider, Johanna J., Jamie Womble, **Ron Heintz**. Forage fish species contribution to total energy content of Steller sea lion diet in southeastern Alaska. Proc. 22nd Wakefield Fisheries Symposium: Sea Lions of the World

Otis, T., **R.A. Heintz** and K.P. Severin. In Review. Discriminating among Alaska's herring stocks using heart fatty acid profiles and otolith microchemistry. Oil Spill Restoration Project Final Report (Restoration Project 02538), Alaska Department of Fish and Game, Homer, Alaska.

Heintz, R.A., B.D. Nelson, J. Hudson, M. Larsen, and L. Holland. 2004. Marine subsidies in freshwater: Effects of salmon carcasses on lipid class and fatty acid composition of juvenile coho salmon. Trans. Am. Fish. Soc. 133:559-567.

Gende, S.M., T.P. Quinn, M.F. Willson, **R. Heintz**, T. M. Scott. 2004. Magnitude and fate of salmon-derived nutrients and energy in a coastal stream ecosystem. J. Fresh. Ecol. 19:149-160.

RECENT COLLABORATIONS INVOLVING BIOENERGETICS

ADFG: Ted Otis, Lori Rea, Shawna Kaparovich, Lee Hulbert, Carrie Beck
UAF: Nicola Hillgruber, Mark Wipfli, Sherry Tamone, Mike Stekoll
UAA: John Kennish, Dan Rinella
DOI/NPS: Jamie Womble
DOI/USGS: Chris Zimmerman
NOAA AFSC: Thomas Hurst, Jeff Napp, Elizabeth Logerwell, Mike Sigler, Dean Courtney
AIA: Bruce Wright

2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

Budget Category:	Authorized FY 2006	Proposed FY 2007						
Personnel		$11.4						
Travel		$12.2						
Contractual		$90.1						
Commodities		$8.6						
Equipment		$5.3	LONG RANGE FUNDING REQUIREMENTS					
Subtotal	$0.0	$127.6	Estimated FY 2008					
General Administration		$11.5						
Project Total	$0.0	$139.1	$20.0					
Full-time Equivalents (FTE)		0.2						
			Dollar amounts are shown in thousands of dollars.					
Other Resources		$54.2						

Comments:

The following personnel costs will be provided <u>in-kind</u>:

Vollenweider, Johanna	Fisheries Research Biologist	ZPII-1	4 months	$5,710/month	$22,840
Heintz, Ron	Director Nutritional Ecology Lab	ZPIII-3	2 months	$9,499/month	$18,998
Cox, Keith	Faculty		3 months	$4,130/month	$12,390
					$54,228

This proposal is being accepted as a 1-Yr request; FY 08 budget was not detailed within the budget spreadsheet or the budget justification as required in the FY 07 Invitation. The financial information is only considered complete for the FY 07 funding request. G&A formula was corrected to 9% - 8/13/06

Travel to the American Fisheries meeting n the amount of $1,300 was removed during the proposal review processes. This resulted in a decrease of agency G&A in the amount of $100.

FY07

Prepared: July 31, 2006
Revised 13 Aug 06

Project Number: 070806
Project Title: Are herring energetics in PWS as a limiting factor in successful recruitment of juveniles and reproduction investment of adults?
Agency: NOAA Fisheries/Auke Bay Lab

FORM 3A
TRUSTEE
AGENCY
SUMMARY

2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2006 - September 30, 2007

Personnel Costs:		GS/Range/	Months	Monthly		Proposed
Name	Position Description	Step	Budgeted	Costs	Overtime	FY 2007
Vollenweider, Johanna	Fisheries Research Biologist	ZPII-1	2.0	5,710.0		11.4
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		2.0	5710.0		$11.4
					Personnel Total	$11.4

Travel Costs:	Ticket	Round	Total	Daily	Proposed
Description	Price	Trips	Days	Per Diem	FY 2007
Vollenweider attendance @ Alaska Marine Science Symposium	660.0	1	3	200.0	1.3
Travel for field work:					
*Prince William Sound (2 people * 5 trips/person * 34days/person)	750.0	10	34	71.8	9.9
**Sitka Sound (1 person * 2 trips)	250.0	2	6	85.0	1.0
Lynn Canal (no travel required)	0.0	0	0	0.0	0.0
					0.0
*PWS per diem accounts for vessel & town-days (calculated per diem includes lodging only for contracted field technician)					0.0
**Sitka Sound per diem excludes lodging, which will be provided In-Kind by Sheldon Jackson College					0.0
					0.0
					0.0
				Travel Total	$12.2

FY07

Prepared: July 31, 2006
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FORM 3B
Personnel
& Travel
DETAIL

2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

Contractual Costs:	Proposed
Description	FY 2007
Vessel charter	
Prince William Sound	
Charter	37.5
Contract with Chenega Bay Environmental Program	7.0
*Sitka Sound	8.1
**Lynn Canal	0.0
*Sitka Sound vessel contract is provided at a reduced rate due to collaboration with faculty	
**The NOAA vessel R/V Quest will be used in Lynn Canal and thus charter costs are In-Kind	
Chemical analysis of voucher specimens (100 samples * $150/sample)	15.0
Contract field technician	
Prince William Sound	9.5
Lynn Canal	6.5
Sitka Sound	6.5
When a non-trustee organization is used, the form 4A is required. **Contractual Total**	$90.1

Commodities Costs:	Proposed
Description	FY 2007
Fuel for vessel in Lynn Canal (NOAA R/V Quest)	2.0
Fuel for vessel in Sitka (Sheldon Jackson R/V Mel)	2.0
Shipment of supplies/samples to and from field sites	1.4
Supplies for chemical analysis (solvents, compressed gas, misc consumables) (100 samples * $20/sample)	2.0
Supplies for specimen preservation	1.2
Commodities Total	$8.6

FY07

Prepared: July 31, 2006
Revised 13 Aug 06

Project Number: 070806
Project Title: Are herring energetics in PWS as a limiting factor in successful recruitment of juveniles and reproduction investment of adults?
Agency: NOAA Fisheries/Auke Bay Lab

FORM 3B
Contractual &
Commodities
DETAIL

2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

New Equipment Purchases: Description	Number of Units	Unit Price	Proposed FY 2007
Bio-Impedance Analyzer & probes (for determination of energy content and proximate composition)	1	3500.0	3.5
Trawl net for juvenile capture from NOAA Quest, SJ Mel	2	900.0	1.8
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$5.3

Existing Equipment Usage: Description	Number of Units	Inventory Agency
Leco Protein Analyzer	1	NOAA/ABL
Accelerated Solvent Extractor	1	NOAA/ABL
Leco Thermogravimetric Analyzer	1	NOAA/ABL
Parr Semi-micro Bomb Calorimeter	1	NOAA/ABL
Existing Bio-Impedance Analyzers	2	NOAA/ABL
NOAA R/V Quest	1	NOAA/ABL

FY07

Prepared: July 31, 2006
Revised 13 Aug 06

Project Number: 070806
Project Title: Are herring energetics in PWS as a limiting factor in successful recruitment of juveniles and reproduction investment of adults?
Agency: NOAA Fisheries/Auke Bay Lab

FORM 3B
Equipment
DETAIL