EVOSTC ANNUAL PROJECT REPORT

Recipients of funds from the *Exxon Valdez* Oil Spill Trustee Council must submit an annual project report in the following format by **Sept. 1 of each fiscal year** for which project funding is received (with the exception of the final funding year in which a final report must be submitted). **Please help ensure that continued support for your project will not be delayed by submitting your report by Sept. 1. Timely receipt of your report allows more time for court notice and transfer, report review and timely release of the following year's funds.**

Satisfactory review of the annual report is necessary for continuation of multi-year projects. Failure to submit an annual report by **Sept. 1** of each year, or unsatisfactory review of an annual report, will result in withholding of additional project funds and may result in cancellation of the project or denial of funding for future projects. **PLEASE NOTE:** Significant changes in a project's objectives, methods, schedule, or budget require submittal of a new proposal that will be subject to the standard process of proposal submittal, technical review, and Trustee Council approval.

Project Number: 080811

Project Title: Prince William Sound Herring Forage Contingency

PI Name: Thomas Kline

Time period covered: FY08

Date of Report: August 28 2008

Report prepared by: Dr. Tom Kline

Project website (if applicable):

Work Performed: Summarize work performed during the reporting period, including any results available to date and their relationship to the original project objectives. Explain deviations from the original project objectives, procedural or statistical methods, study area or schedule. Also describe any known problems or unusual developments, and whether and how they have been or can be overcome. Include any other significant information pertinent to the project.

- **Funding of year 2 commenced in March, retroactive to include attendance at 2008 Alaska Marine Science Symposium.**
- **The P.I. and post-doc (Dr. Campbell) attended the 2008 Alaska Marine Science Symposium.**
- **The P.I. and post-doc participated in the herring workshops held in Cordova during March 2008, July 2008, and August 2008.**
- **Post-doc is on the herring plan writing committee.**
- **Four cruises were conducted, two to collect herring (November 2007 and March 2008) and two to collect zooplankton (Sept-Oct 2007 and May 2008). The scope of these cruises was described in the Interim Progress Report July 2007 and in the Powerpoint presentation shown during the October 2007 workshop. Preliminary results were shown in the latter. These previously shown results are not presented here so that new information can be instead.**
- **Further preliminary results are presented below (these are draft figures, some may be included in the presentation the P.I. will make at the Annual Herring Workshop, which is expected to take place in October 2008).**
- **Further lab processing of samples is in progress.**

Plankton Energetics

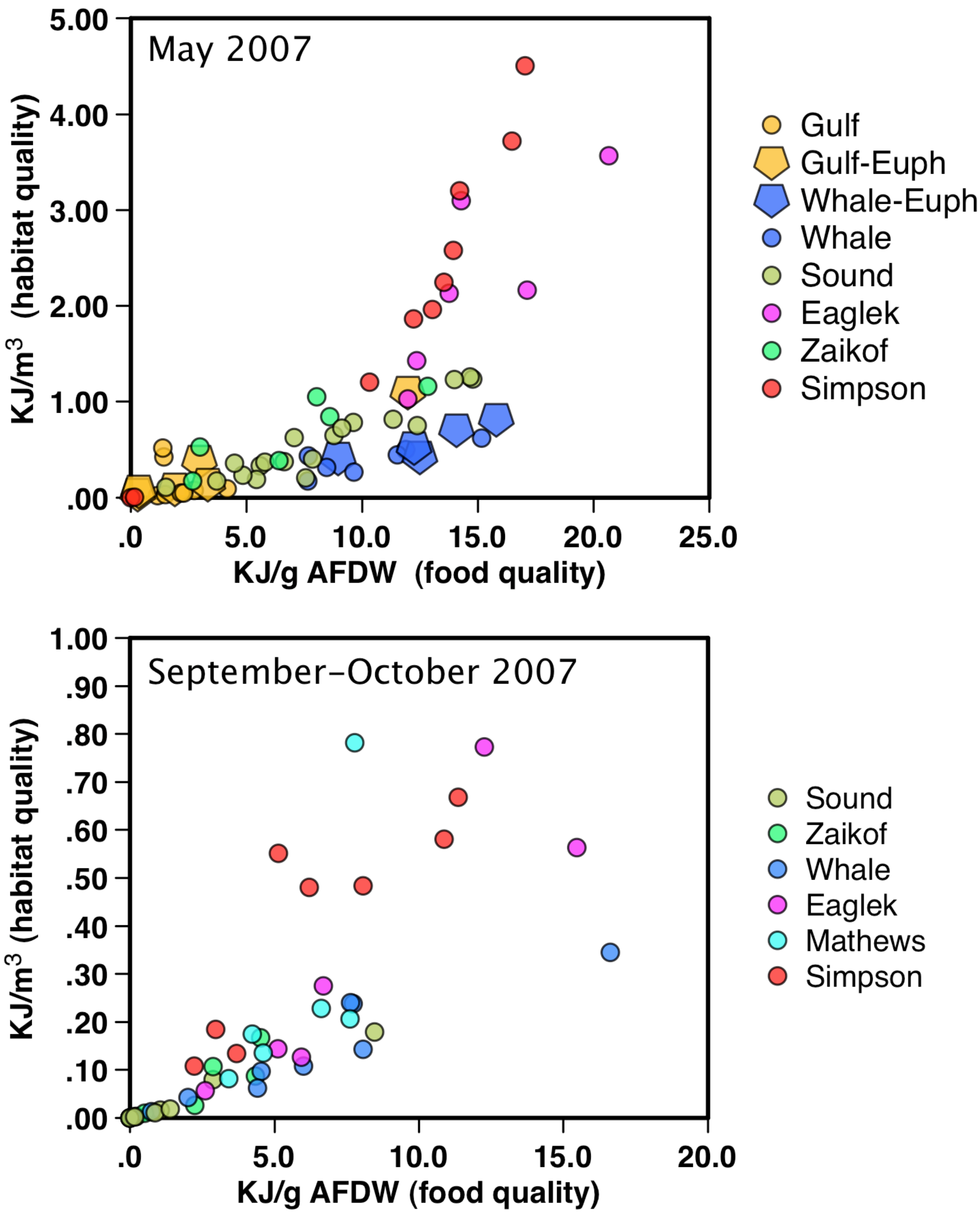

Figure 1. Plankton energy; May (top) and September-October (bottom) 2007.

Figure 1 summarizes zooplankton energy content data. Energy is expressed in terms of density with respect to water volume within listed habitats as a measure of habitat quality and in terms of energy density per unit mass (ash-free dry weight = AFDW) of zooplankton as a measure of food quality. The Prince William Sound (PWS) herring nursery bays (Whale, Eaglek, Zaikof, and Simpson) were each quite different with respect to both parameters. There was approximately one order of magnitude less energy available per unit volume of water in the fall compared to spring, however, food quality was generally comparable. Spring samples with a number of euphausiids are depicted as pentagons; this may have been important as winter forage for herring (as it has in Sitka Sound, J.J. Vollenweider, pers. comm.) and may be a source of good quality food where available such as in Whale Bay. Two of the bays had overall more energy per unit volume than the greater Sound or offshore in the Gulf. Each point in the figure above reflects one net sample from 50 to 100 m^3 of water (sample volume based on flow meter reading). These results confirm that plankton energy availability is highly variable in space and time and that not all herring nursery habitats are equal. This information will need to be considered for herring population supplementation projects, especially those involving juvenile life stages.

Euphausiids in Whale Bay, May 2007

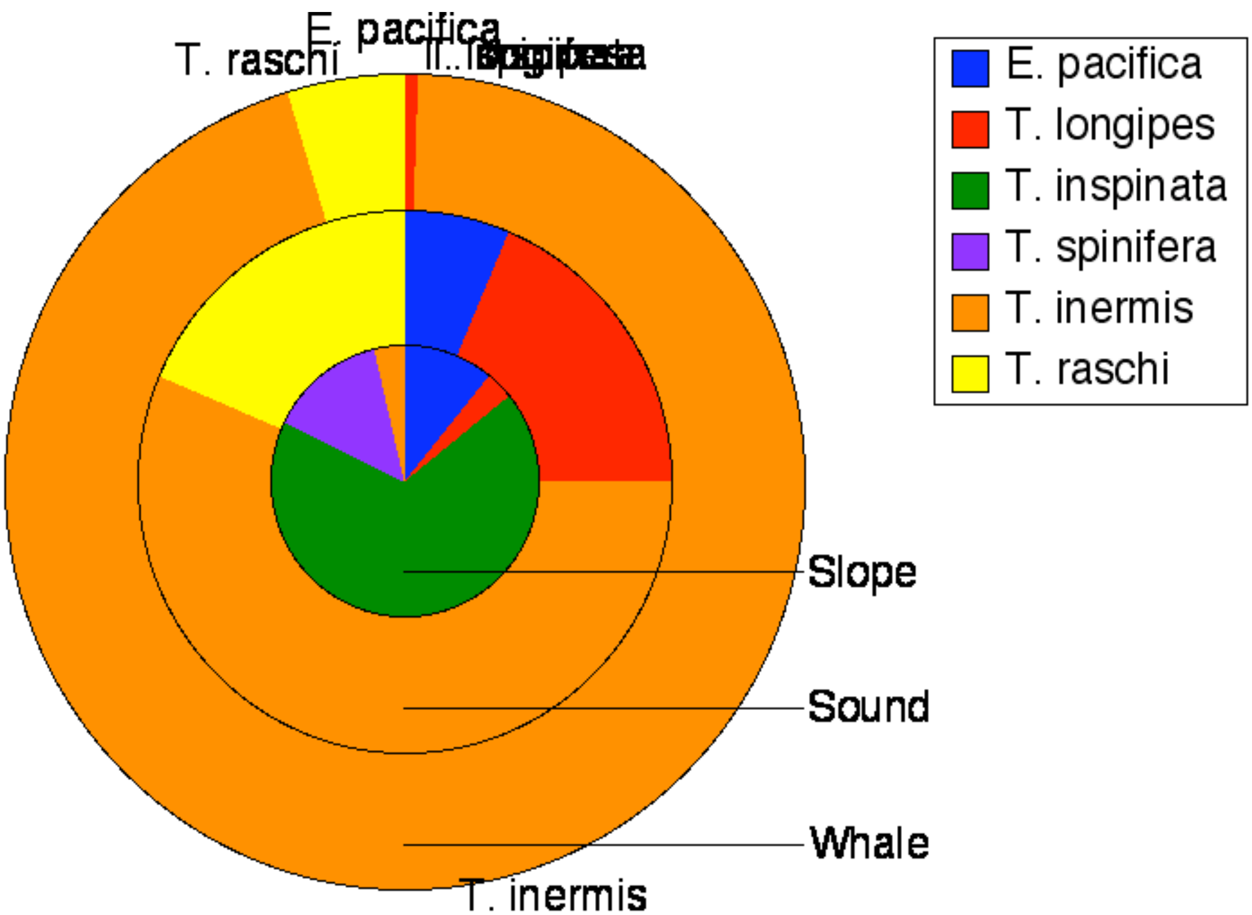

Figure 2. Species composition of Euphaussids, May 2007.

Whale Bay was the most euphuasiid rich area in May 2007. *Thysanoessa inermis* dominated the euphausiid species composition in Whale Bay (Fig. 2). They contributed a smaller fraction of those found elsewhere in the Sound and less still on the slope. They may have been a contributing factor to the higher energetic content of herring during the preceding winter (see below). Because *T. inermis* is a shelf species that is more abundant in colder years (Pinchuk et al. 2008), there is potential for inter-annual variation.

Herring as plankton

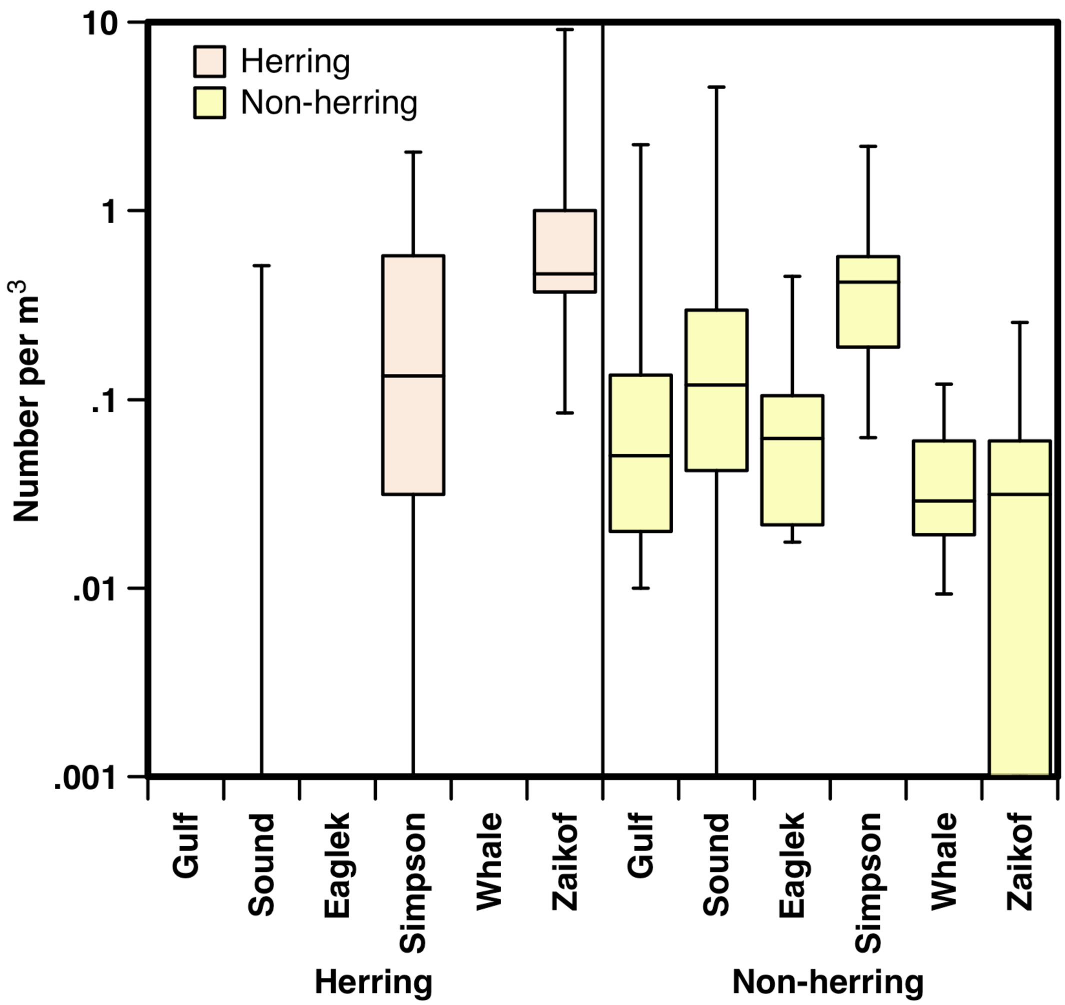

Figure 3. Herring larvae and other ichthyoplankton in PWS, May 2007.

Figure 3 summarizes the fish larval composition of zooplankton from the May 2007 plankton survey as box and whisker plots in terms of herring and non-herring (all other fish spp.). There was about one fish larva per 1 to 10 m^3 of water. Two to three week old (age consensus derived at October 2007 workshop) herring larvae contributed to significant portions of the ichthyoplankton composition in two of the nursery bays. Herring larvae were found in all tows made in Zaikof Bay and all but one tow made in Simpson Bay in May 2007. A similar pattern is expected for the 2008 survey based upon samples picked for SIA by the P.I. during the cruise. Herring larvae were found in just two of the tows made in the greater Sound in May 2007. Herring larvae were also observed in certain Sound tows made in May 2008. NOTE: Sampling herring larvae in our tows was not anticipated in the proposal (DPD); these serendipitous results, however, are critical to understanding the herring recruitment process and thus herring restoration in PWS. These results show the extreme spatial variability of herring recruitment processes that should be taken into account for intervention. Assessment of herring larval distribution like that shown here is a new tool that was not previously available to PWS herring restoration.

Plankton community structure (this section prepared by Dr. Rob Campbell)

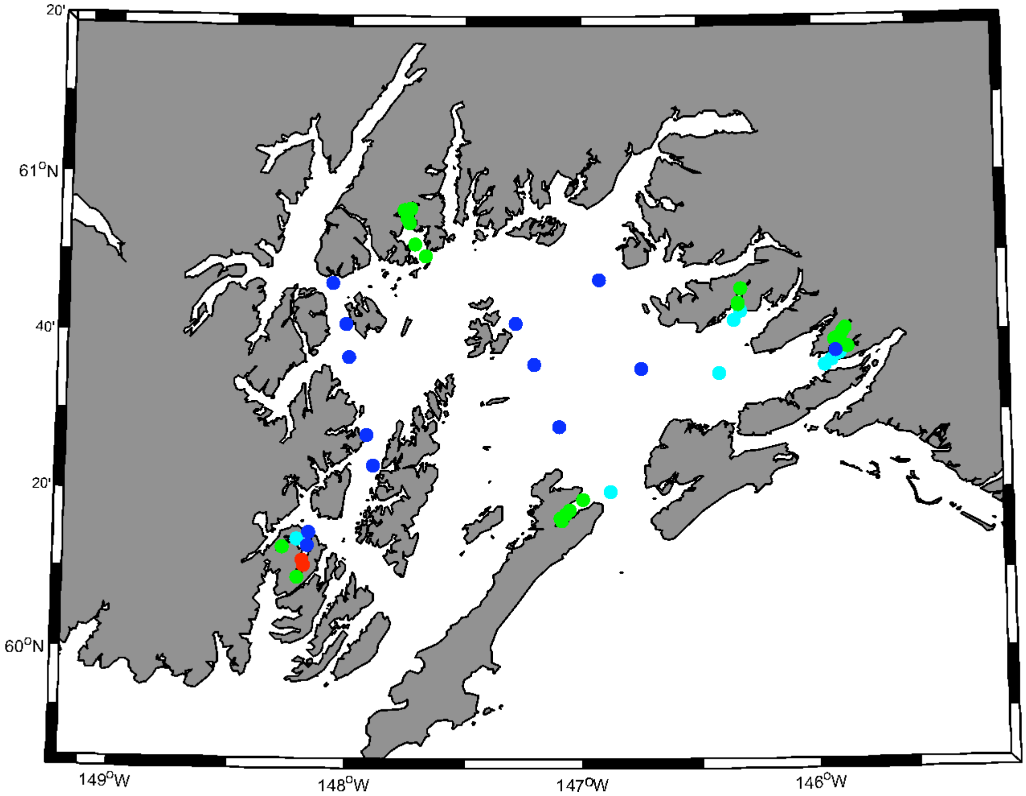

Figure 4. Hierarchical clustering analysis of plankton taxa in PWS September-October 2007. Map of the stations indicating the cluster identity of each station. Colors correspond to the identified clusters (Fig. 5; Green = Bay cluster; Light blue = Eastern PWS cluster; Dark blue: Central PWS cluster; Red = Whale Bay cluster).

Patterns in the structure of the plankton community were analyzed by hierarchical clustering and indicator species analysis (ISA; Figs. 4 and 5). Rare species (occurring in <10 % of stations) were not included in the analysis, and data was log10(n+1) transformed prior to analysis. Clustering was done on the Euclidean distance matrix from the species × station matrix, using Ward's linkage method. The resulting clusters broke down fairly well into geographic areas (Fig. 4), with well-defined clusters for three of the bays (Simpson, Eaglek and Zaikof), and an open water cluster that could be further subdivided into central and eastern PWS clusters. Stations in Whale Bay fell into all of the clusters, as well as two stations that fell into a cluster unique to Whale Bay (Fig. 5).

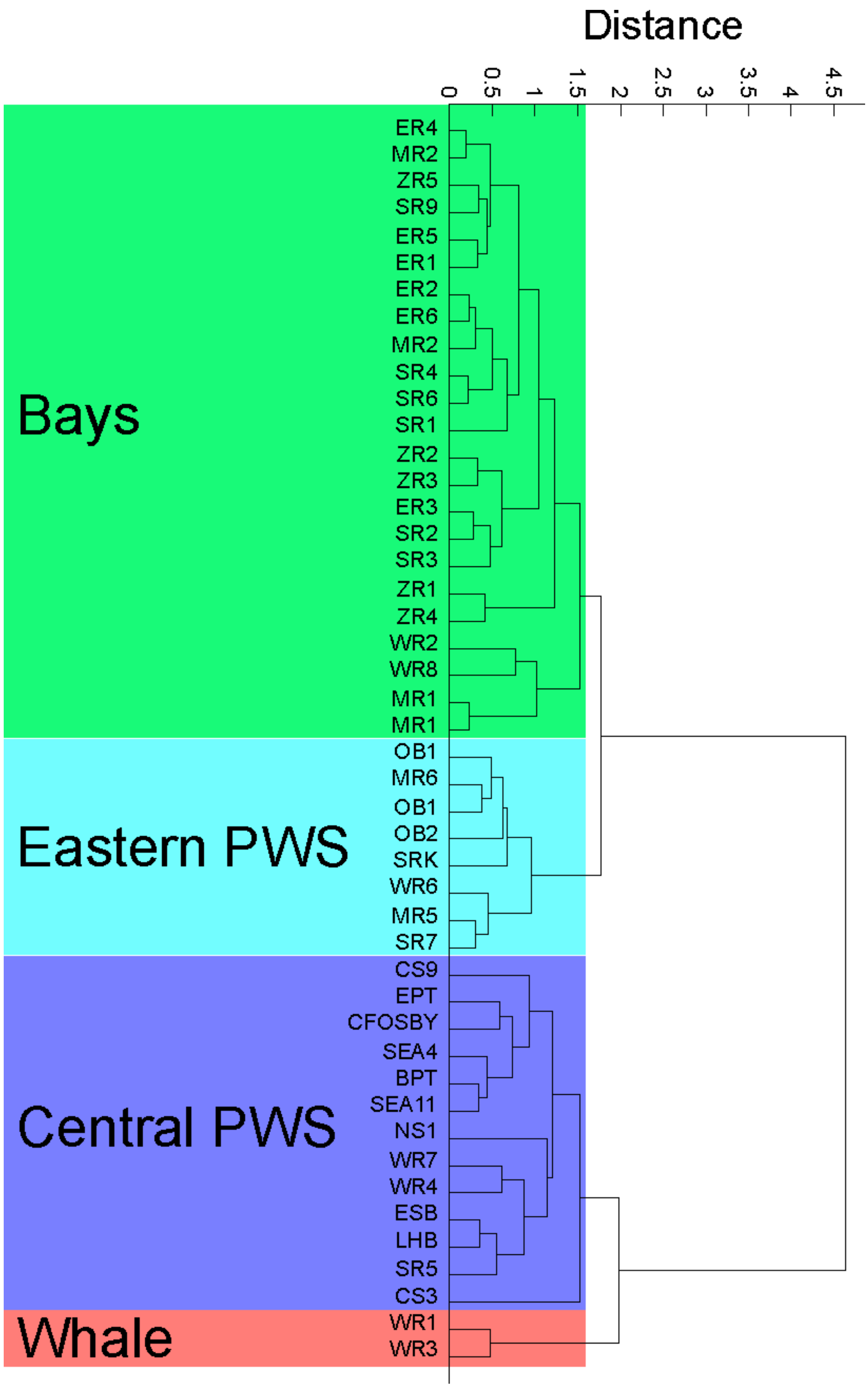

Figure 5. Hierarchical clustering analysis of plankton taxa in PWS, September-October 2007. Dendrogram showing the resulting station groupings.

Indicator species analysis (Dufrene and Legendre, 1997) was used to identify the important plankton taxa in the station groups identified by the cluster analysis. The ISA statistic for each group is the product of the relative abundance of the taxa in the group (scaled to all groups) and the frequency of occurrence of species in the group. An associated probability was calculated for each ISA statistic by Monte Carlo simulation (10000 iterations), and a critical value of 0.05 used to diagnose significant groups. The results of the ISA were sorted within each group to produce a list of taxa ranked by their relative importance in each cluster (Table 1). There were several taxa common to the different clusters, particularly large copepods (<2 mm), small pteropods (>0.5 mm), and cnidarian medusae. The differences between the clusters were thus primarily caused by differences in the abundances of the different taxa. Abundances of the common taxa identified by ISA (Fig. 6) varied considerably between areas, with larger numbers of small copepods occurring in the bay stations, and larger copepods and pteropods (which are more oceanic species) occurring in the open water stations. Euphausiid calyptopis (immature life stage) were also common at the bay stations.

Table 1. Indicator species analysis (ISA) for the station groups identified by hierarchical cluster analysis. The taxa are vertically sorted by relative importance within each cluster, with more important taxa above less important taxa.

Bays	Eastern PWS	Central PWS	Whale Bay
Copepods <2 mm	Pteropods <0.5 mm	Copepods <2 mm	Pteropods <0.5 mm
Pteropods <0.5 mm	Medusae	Medusae	Copepods <2 mm
Medusae	Ctenophora	Pteropods <0.5 mm	Pteropods >0.5 mm
Larvacea	Copepods <2 mm	Cladocera	Euphausiid calyptopis
Euphausiid calyptopis	Larvacea	Larvacea	Medusae

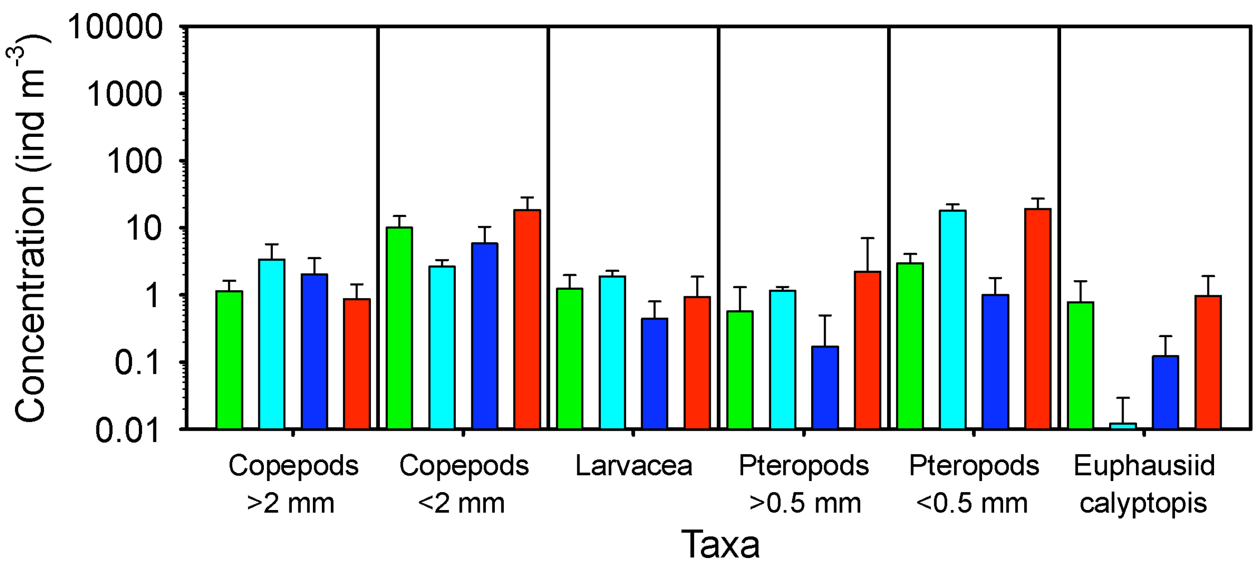

Figure 6. Abundance (mean ± standard deviation) of the more common plankton taxa identified by ISA, arranged by the station groups identified by hierarchical cluster analysis. Color indicates the cluster group, and corresponds to the colors used in fig. X (Green = Bay cluster; Light blue = Eastern PWS cluster; Dark blue: Central PWS cluster; Red = Whale Bay cluster).

Characterization of herring food sources using stable isotope analysis (SIA)

Validation of stable isotope analysis diagostics

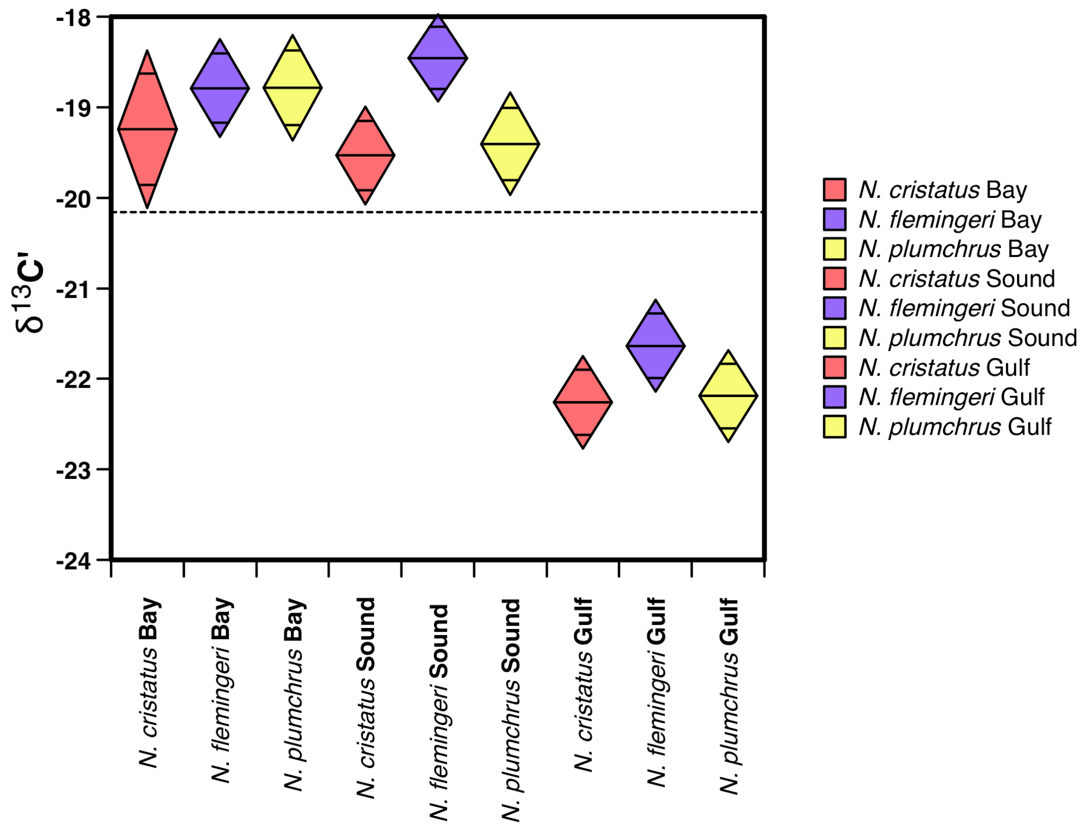

Figure 7. Stable isotope diagnostics.

Figure 7 summarizes the May 2007 $\delta^{13}C$' data of the three *Neocalanus* spp. by habitat type (herring nursery bays = Bay, other parts of PWS = Sound, offshore in the Gulf of Alaska = Gulf) as 'diamond mean comparison plots' to validate SIA as a tracer of Gulf of Alaska (GOA) carbon in PWS by confirming previous observations (e.g., Kline et al. 2008). The dashed line is the grand mean of all sample groups. The diamonds show group means by their widest line and 95% confidence intervals at the vertices. The short horizontal lines within the diamonds indicate where groups are significantly different from each other by non-overlap. Rationale for the SIA single species approach was given in Kline (1999) and Kline (2009). PWS carbon, including that from within herring nursery bay habitats, continues to be observed within a narrow $\delta^{13}C$' range of -20 to -18 whereas that of the GOA is < -21. These data are critical for interpreting the isotope shifts measured in herring, below. Planktivorous fish such as herring consuming carbon exclusively of PWS origin are expected to have $\delta^{13}C$' values of -19 to -17 based on these observations and trophic fractionation effects (e.g., Kline et al. 2008). Values more negative than ~ -20 range can thus be inferred to reflect incorporation of GOA or oceanic carbon.

Neocalanus is an oceanic copepod taxon requiring water deeper than 300m for part of its life history. The mere occurrence of *Neocalanus* in the relatively shallow PWS herring nursery bays (Fig. 7) quite distant from this deep water speaks volumes for the connectivity of these habitats with the greater oceanic system.

Herring food sources and whole-body energy composition (WBEC) during 2006-7

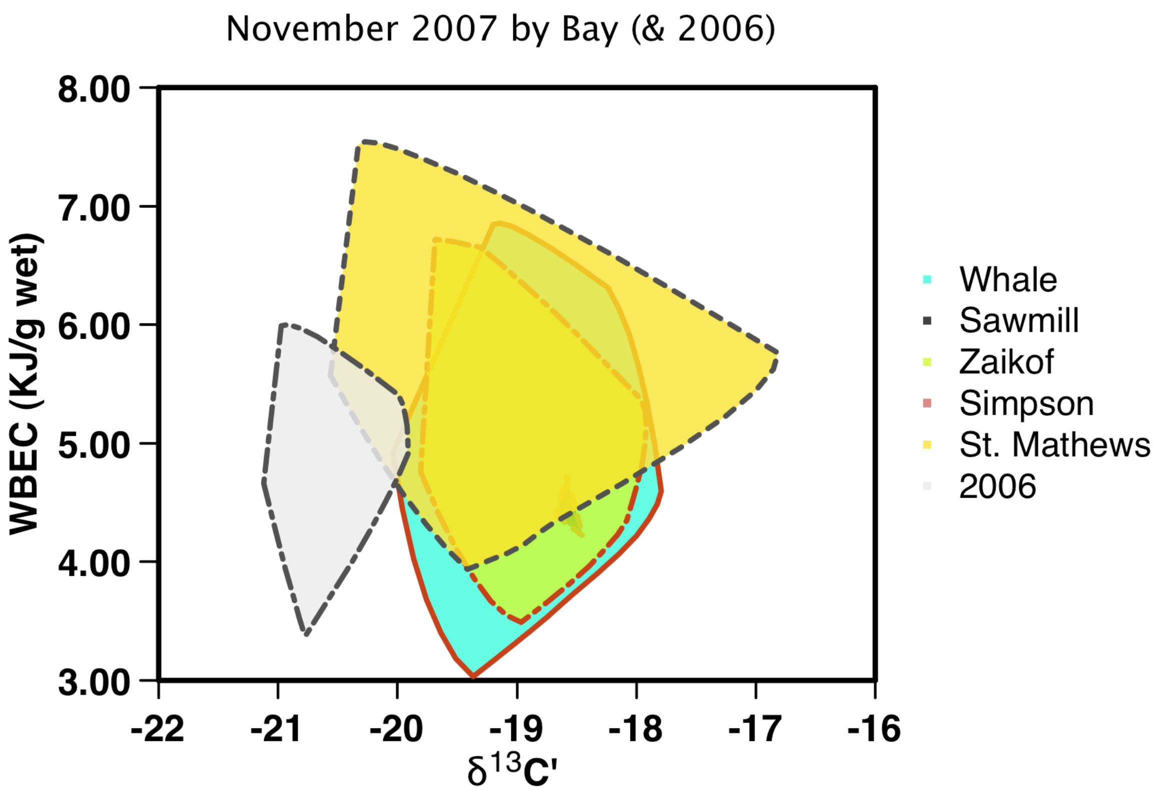

Figure 8. Fall 2006 and 2007 herring energy in relation to SIA.

Figure 8 relates the whole body energy content (WBEC) of age-0 herring (Y-axis) to their $\delta^{13}C$' values (x-axis) observed during November 2006 (limited samples) and November 2007 as a reflection of pre-winter condition. Data are presented as 'convex hulls' that show the range for each parameter by data group. Herring in 2007 were relatively less dependent on GOA then 2006. A number herring from St. Mathews had relatively greater GOA carbon (values more negative than -19) and these tended towards higher WBEC. The relatively high overlap in $\delta^{13}C$' values among bays within a given sampling period is similar to that reported by Kline (1999). These results confirm that herring energy sources are variable in time on inter-annual time scales (2006 and 2007 was quite different compared to differences among bays at a given time; parallels previous observations e.g., Kline 2007). This inter-annual variability was hypothesized to reflect variability in ocean climate processes driving exchange between PWS and GOA (Kline 1999) and is a consideration for intervention projects on juvenile life stages.

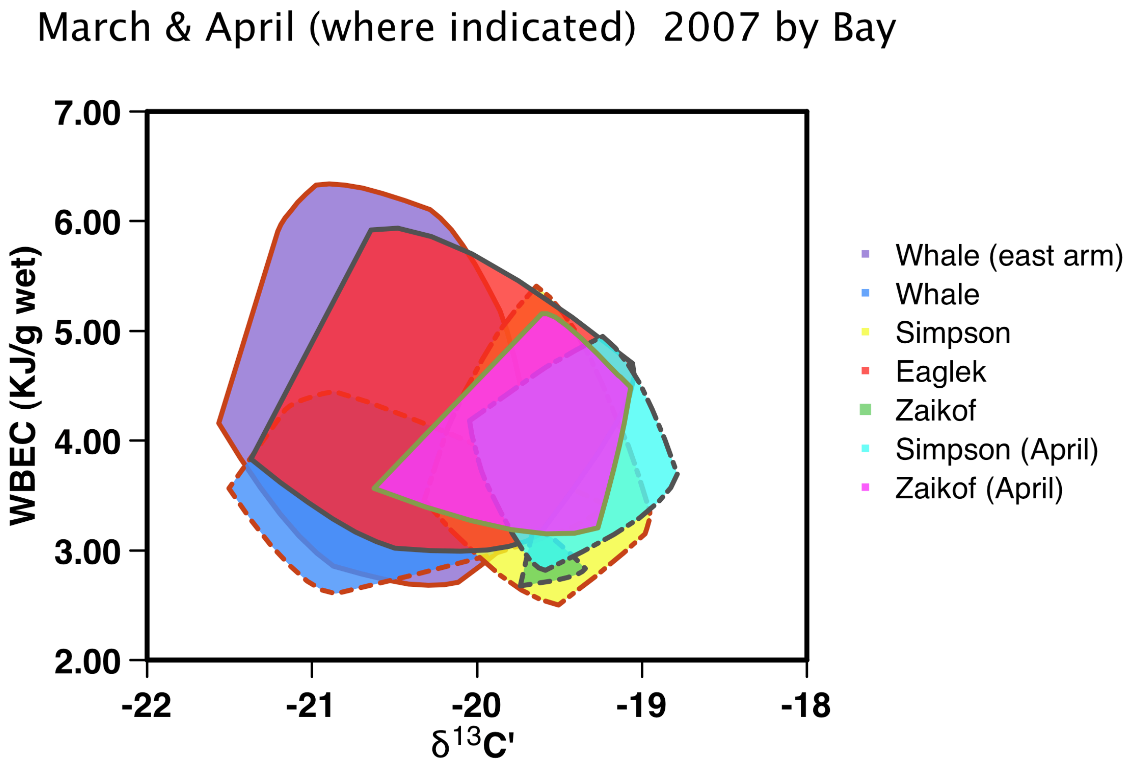

Figure 9. Spring 2007 herring energy in relation to SIA.

Figure 9 relates the whole body energy content (WBEC) of age-0 herring in relation to $\delta^{13}C'$ values observed during March to April 2007 among PWS herring nursery bays as a reflection of post-winter condition. A fortuitous second set of samples from April provided by Steve Moffitt (ADFG) lacked the lowest WBEC values observed in March. The $\delta^{13}C'$ values overlap in part with those observed in the fall of 2006 so are more negative than those observed later in 2007 (Fig. 8). The East and main arm of Whale Bay tended to have herring with higher energy content as well as lower $\delta^{13}C'$ values that may have resulted from feeding on euphausiids there (see Fig 2).

Interaction with other fishes

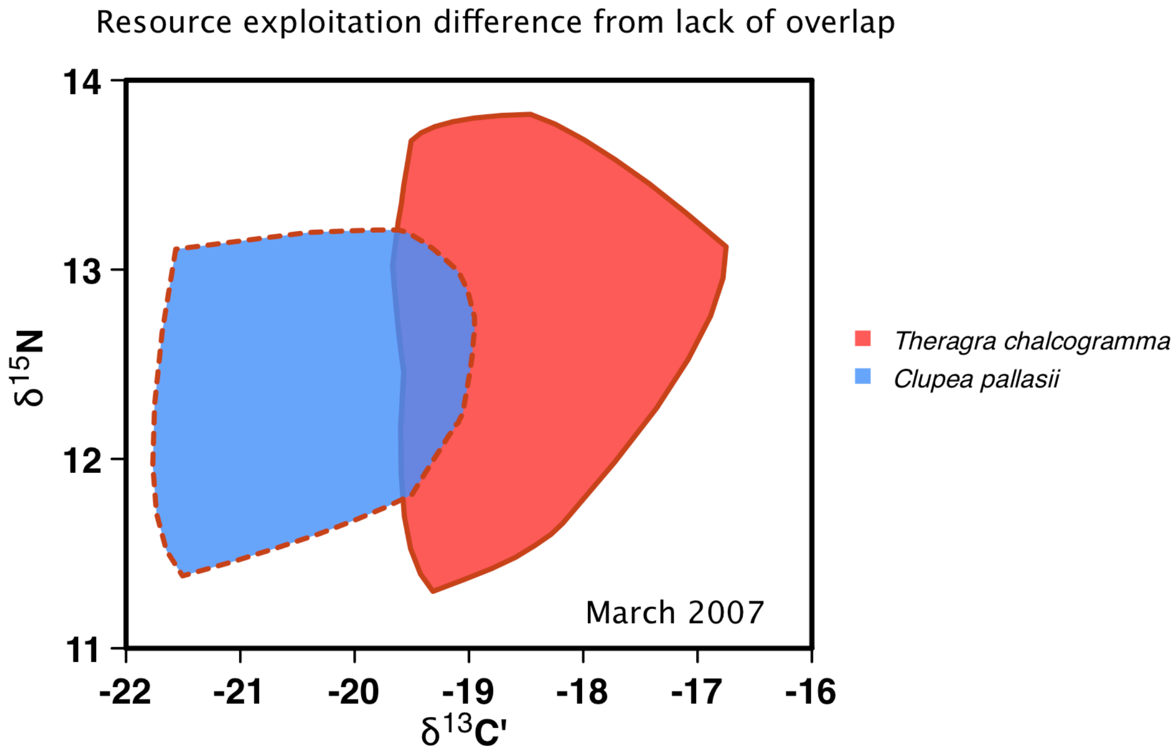

Figure 10. Overwintering dietary (carbon source) difference between herring and pollock.

Stable isotope analysis of age 0 and 1 walleye pollock (*Theragra chalcogramma*) sampled incidentally with herring in March 2007 plotted in Figure 10 provides a measure of over-winter dietary overlap. Data are not inconsistent with predation on herring by a few of the pollock (these have higher δ^{15}N values). Lower δ^{13}C' values of herring are similar to the values observed in November 2006 (Fig. 8), which is consistent with little feeding during winter, the intervening period. The much higher δ^{13}C' values in pollock suggest feeding on PWS carbon during winter as inferred by Kline (2008). Pollock are thus able to maintain or increase energy content during the winter while herring cannot (Kline 2008). The upshot of this is that some food resources that are available to pollock in winter are apparently not available herring. There is far less overlap between herring and pollock in March compared to November (Fig. 11).

Resource competition suggested by dietary overlap

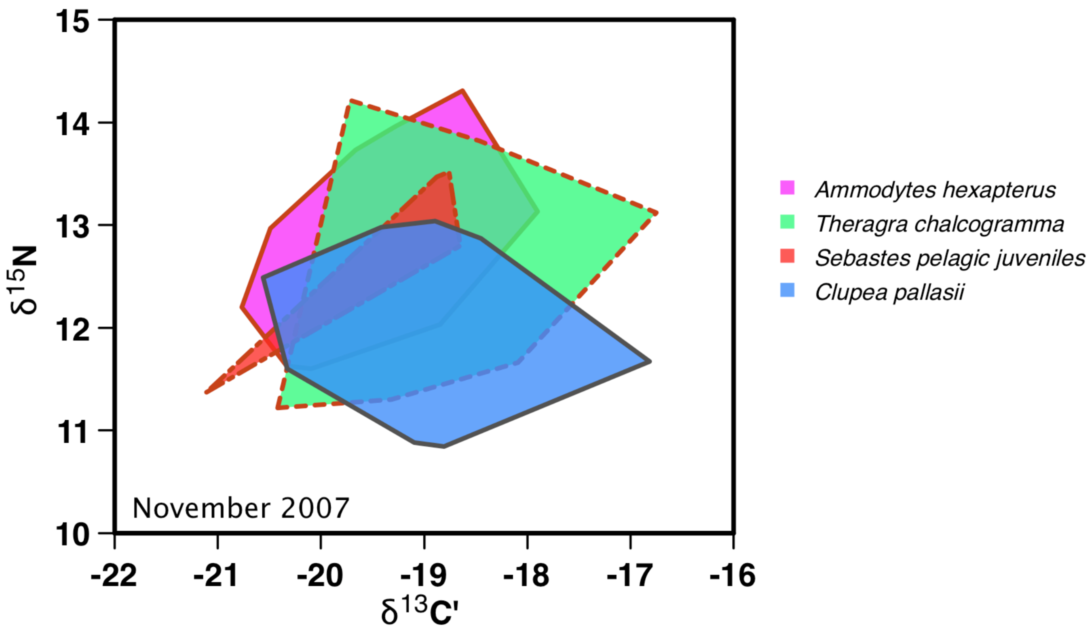

Figure11. Dietary overlap between herring and other species, November 2007 based on SIA.

Center of the $\delta^{13}C'$ value distribution near -19 suggests that mostly PWS carbon was important for fall 2007 herring food webs, which contrasts with 2006 observations and some of those from the 1990's (Fig. 11; Kline 1999, 2007). There is relatively high concordance in both stable isotope values among fish taxa. Nevertheless herring $\delta^{15}N$ values were slightly lower suggesting that not all resources available to competitors were also available to herring. This could be explained by herring not able to consume higher trophic plankters, which can have higher $\delta^{15}N$ values such as amphipods, decapods or carnivorous coepods (Kline 1999).

Preliminary results from the May 2008 plankton survey

Massive phytoplankton bloom observed in Zaikof Bay

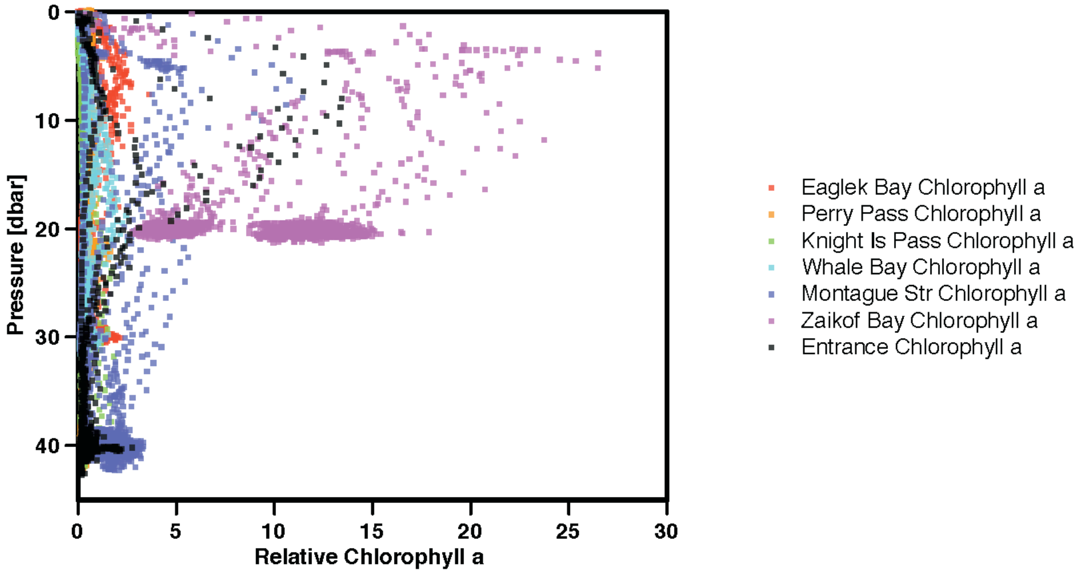

Figure 12. Distribution of chlorophyll with depth (1 dbar = 1 m) in PWS in late May 2008 indicating very high concentrations down to 20m depth in Zaikof Bay. Data from the fluorometer that is integrated into the Multinet zooplankton sampling device.

There was a very noticeable bloom of diatoms in Zaikof Bay based on surface water color and microscopic observations made during the May 2008 plankton survey. This bloom extended in depth to at least 20m (Fig. 12). The Hinchinbrook Entrance transect from Porpoise Rocks to Naked Island had the second highest concentrations of chlorophyll which was followed by Montague Strait transect from Northwest Passage to Montague Point.

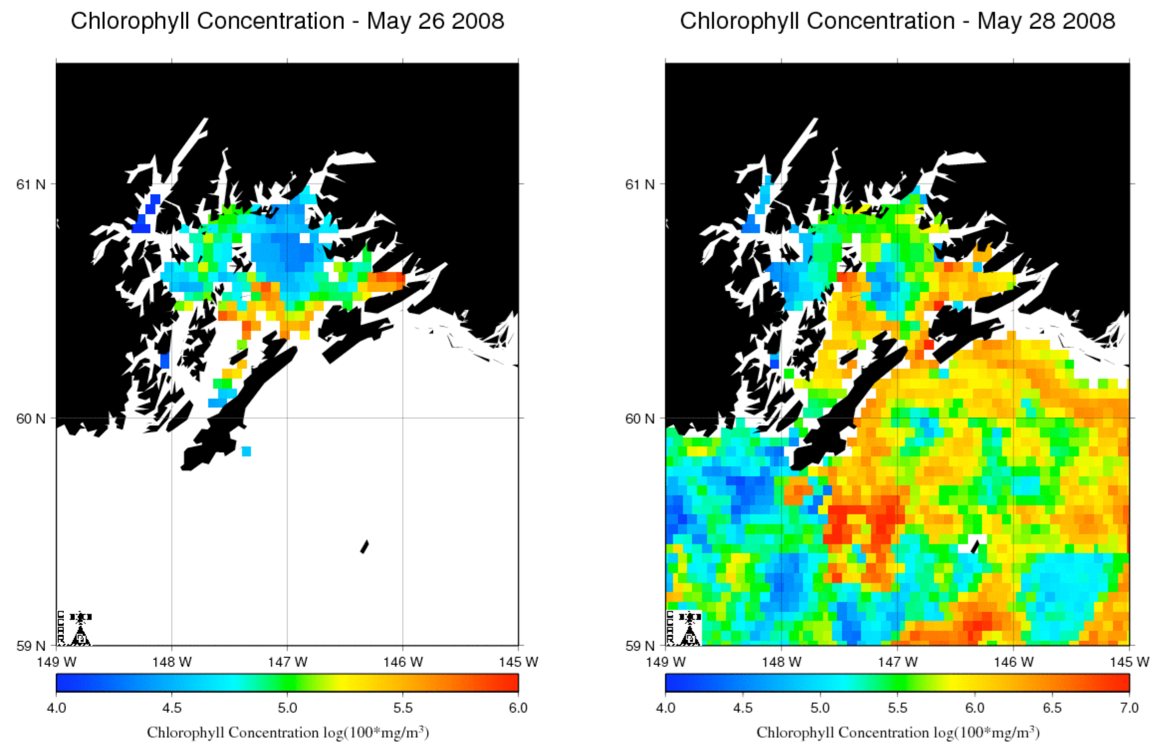

Figure 13. Surface chlorophyll distribution at end of May 2008 cruise and two days later. Data obtained from Colorado Center for Atmospheric Research website: http://argo.colorado.edu/~realtime/welcome/. Note how there is almost no coverage within actual herring nursery bays (only Gravina).

Phytoplankton can be detected from space because they contain photosynthetic chlorophyll pigments that naturally fluoresce. However, this fluorescence can only be seen from a satellite orbiting in space when skies are clear. The cloudiness that prevails in our area often precludes remote sensing from space. This happened during the May 2008 plankton survey; the first day with clear skies was the last day of the cruise, 26 May. Figure 13 (left) is a satellite-derived image showing surface chlorophyll in PWS on the last day of the cruise. This was just the beginning of a clearing trend so that two days later there was even better coverage, which is shown in Figure 13 (right). Figure 13, left and right collectively, shows that (1), chlorophyll was most concentrated in parts of PWS bordering the Gulf, (2) that the bloom was even stronger out in the Gulf and (3), that the bloom can shift in distribution in matter of a few days. A limitation of satellite-derived images is that only the surface of the ocean is looked at and that smaller spatial scales features such as the chlorophyll in herring nursery bays (Fig. 12) within PWS are not seen. Chlorophyll standing stock as a reflection of primary productivity is an important consideration since Perry and Schweigert (2008) showed that northeast Pacific herring carrying capacity is correlated to primary productivity.

Evidence for late bloom from copepod development

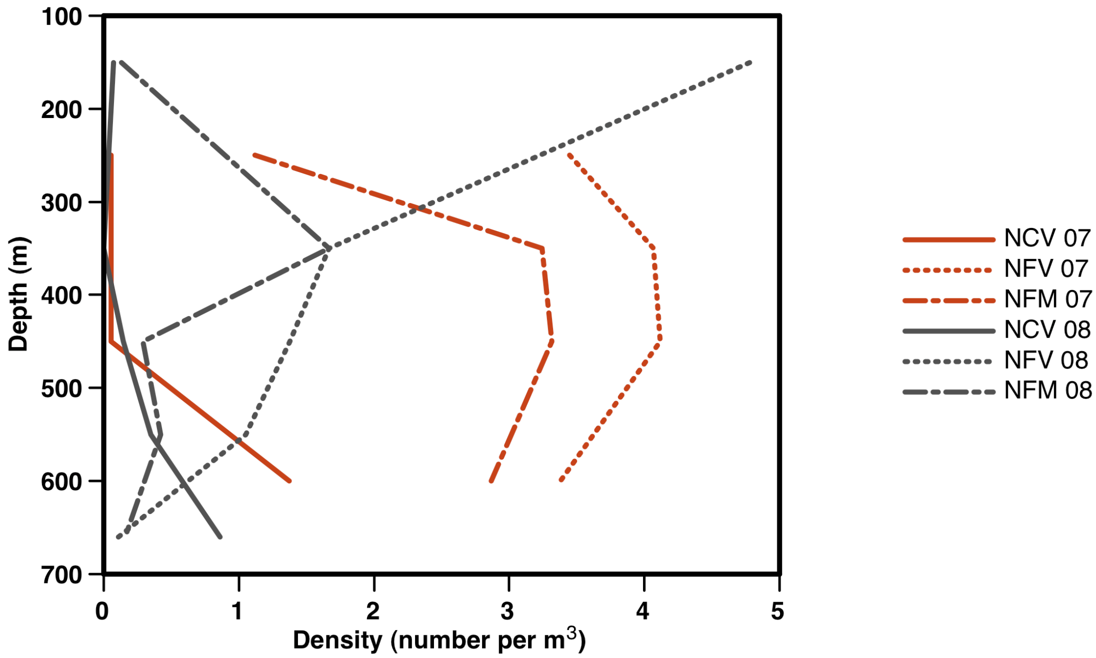

Figure 14. Comparison of vertical distributions of late developmental stages of key copepod species from the deep part of PWS in May 2008 with that of May 2007. There were less stage copepodite-V *N. cristatus* in late May 2008 compared to late May 2007 (NCV in Fig. 14). We observed far fewer male *N. flemingeri* in 2008 compared to 2007 (NFM in Fig. 14). Females were all but absent. There were more copepodite-V stage *N. flemingeri* in shallow water but less in deep water 2008 than 2007 (NFV in Fig. 14). My interpretation is that neither species had yet progressed as far in its maturation and migration pattern in 2008 compared to 2007. Hence the bloom in 2008 was relatively late. The sampling and data analysis shown in this figure is due to synergistic funding provided by the Oil Spill Recovery Institute and the Murdock Charitable Trusts.

Recent Pacific Decadal Oscillation Index (PDOI) trends: 2008 has been a cold year

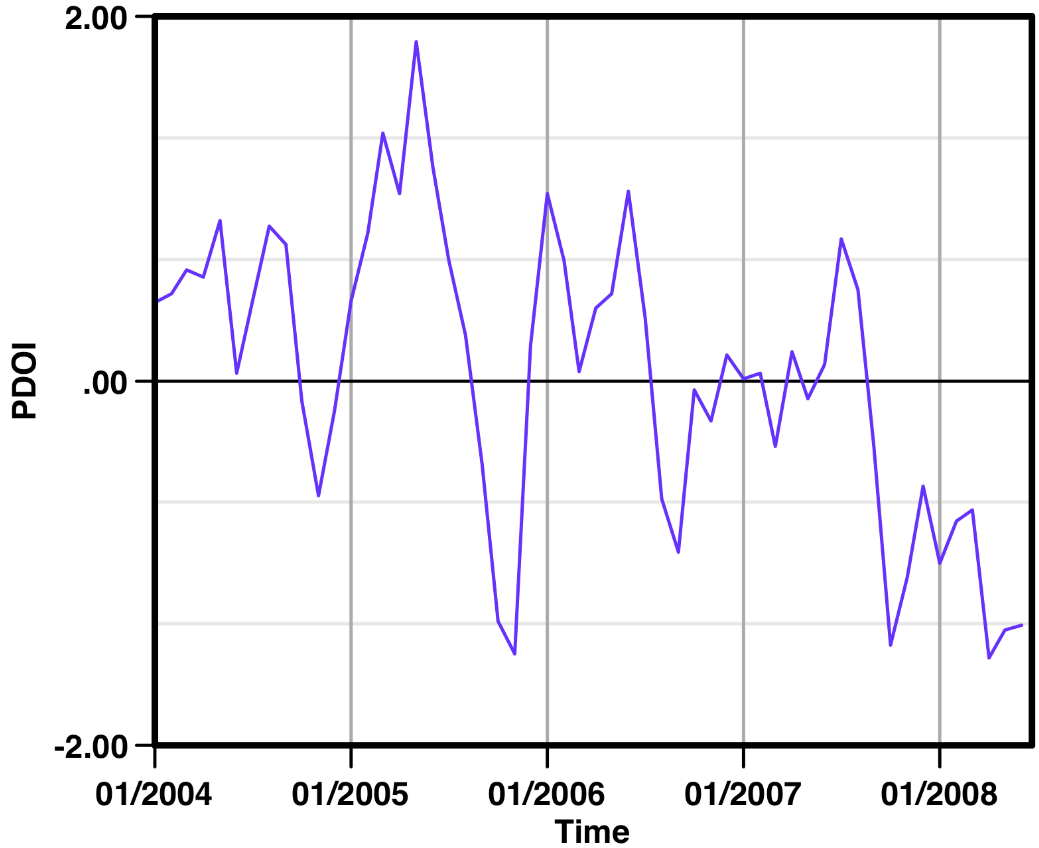

Figure 15. PDOI trend of the last 4.5 years showing continuous negative anomaly during the first half of 2008. Data from PDOI webpage: http://jisao.washington.edu/pdo/.

The PDOI, a measure of the north Pacific sea temperatures, slipped into a negative or cool phase in late 2007 that has persisted through 2008 until the present (Fig. 15). Cooler temperatures may to slow development rates (Q10 law), which may provide an explanation for the apparent late bloom. Herring recruited well in the 1980's when the PDOI was positive; thus quite different from present ocean conditions.

Settled volume analysis

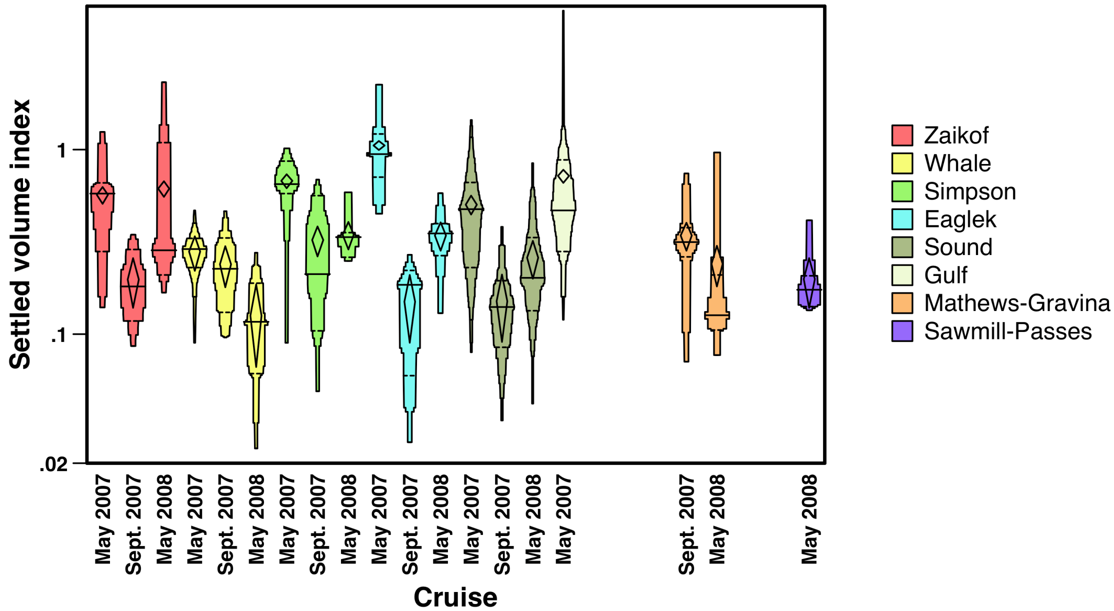

Figure 16. Spatial and temporal variability of net plankton volume per unit volume water sampled shown as distributional box and whisker plots.

Relative settled volume (Fig. 16) provides a synoptic comparison of the plankton populations from the three completed plankton surveys. The four key herring nursery bays are shown on the left. Sawmill Bay and nearby passes and St. Mathew Bay and adjacent Port Gravina were also sampled when time allowed. These supplemental sites were also sampled for juvenile herring (Fig. 8). May 2008 included extreme high and low plankton densities. The high values from Zaikof in May 2008 were probably influenced by phytoplankton contributing to the sample.

Literature cited

Dufrene, M. and P. Legendre 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecol. Monogr. 67:345-366

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Pinchuk, A.I., K.O. Coyle, and R.R. Hopcroft. 2008. Climate-related variability in abundance and reproduction of euphausiids in the northern Gulf of Alaska 1998-2003. Progr. Oceanogr. 77:203-216.

Completed and Future Measurable Project Tasks

FY08 1st Quarter (October 1, 07 to December 31, 07)
November Complete juvenile herring survey #2, November 2007: COMPLETED
December Complete analysis of juvenile herring survey #1, March 2007: COMPLETED
December Complete analysis of zooplankton survey #1, May 2007: COMPLETED
December Complete analysis of zooplankton survey #2, September 2007: COMPLETED

FY08 2nd Quarter (January 1, 08 to March 31, 08)
January Annual Marine Science Symposium: COMPLETED
March Complete juvenile herring survey #3, March 2008: COMPLETED

FY08 3rd Quarter (April 1, 08 to June 30, 08)
May Complete zooplankton survey #3, May 2008: COMPLETED
June Complete analysis of juvenile herring survey #2, November 2007: COMPLETED

FY08 4th Quarter (July 1, 08 to September 30, 08)
September Complete zooplankton survey #4, September 2008 (TO BE DONE)
August Submit Annual Report (THIS REPORT)

FY09 1st Quarter (October 1, 08 to December 31, 08)
November Complete juvenile herring survey #4, November 2008

FY09 2nd Quarter (January 1, 09 to March 31, 09)
January Annual Marine Science Symposium
March Complete juvenile herring survey #5, March 2009

FY09 3rd Quarter (April 1, 09 to June 30, 09)
June Complete analysis of zooplankton survey #3, May 2008
June Complete analysis of juvenile herring survey #3, March 2008

FY09 4th Quarter (July 1, 09 to September 30, 09
September* Complete analysis of zooplankton survey #4, September 2008
September* Complete analysis of juvenile herring surveys #4, November 2008 and #5, March 2009
April, 2010 Submit Final Report, to the Trustee Council Office

* the NOAA contract is expected to extend beyond the end of FY09; accordingly the work will be completed one year after the anticipated start of the FY09 contract (March 2009) and not the calendar date given here.

Future Work: Summarize work to be performed during the upcoming year, if different from the original proposal. Describe any proposed changes in objectives, procedural or statistical methods, study area or schedule. ***NOTE****: Significant changes in a project's objectives, methods, schedule or budget* *require submittal of a new proposal subject to the standard process of proposal submittal, technical review and Trustee Council approval.*

No changes other than addition of herring larval analysis see. Fig. 3.

Coordination/Collaboration: Describe efforts undertaken during the reporting period to achieve the coordination and collaboration provisions of the proposal, if applicable.

• Field work sampling for herring involved collaboration with the project being led by Dr. Thorne
• Collected live materials for Dr. Hershberger's project
• Herring length frequency data requested by Dr. Bishop transmitted to Herring P.I.'s via email
• These data were provided to Dr. Bishop also as XL spreadsheets
• Preliminary graphs transmitted to Herring P.I.'s via email
• Samples were provide to this project by other projects; from Steve Moffitt (ADFG) and J.J. Vollenweider (NOAA)

Community Involvement/TEK & Resource Management Applications: Describe efforts undertaken during the reporting period to achieve the community involvement/TEK and resource management application provisions of the proposal, if applicable.

• Contributed to community herring planning effort
• Conducted special plankton outreach laboratory sesssions for Cordova High School students
• Gave lectures on plankton to the community
• Preliminary results sent to collaborators for use in resource management

Information Transfer: List (a) publications produced during the reporting period, (b) conference and workshop presentations and attendance during the reporting period, and (c) data and/or information products developed during the reporting period. ***NOTE****: Lack of compliance with the Trustee Council's data policy and/or the project's data management plan will result in withholding of additional project funds, cancellation of the project, or denial of funding for future projects.*

a)
Kline, T.C. Jr. 2007. Rockfish trophic relationships in Prince William Sound, Alaska based on natural abundance of stable isotopes. *In*: J. Heifetz, J. Dicosimo, A.J. Gharrett, M.S. Love, V.M. O'Connell, and R.D. Stanley (eds), Biology, Assessment, and Management of North Pacific Rockfishes, Alaska Sea Grant College Program, AK-SG-07-01.

Includes herring data.

Kline, T.C. Jr. 2008. Ontogenetic, temporal, and spatial variation of feeding niche in an unexploited population of walley Pollock (*Theragra chalcogramma*). *In*: G.H. Kruse, K. Drinkwater, J.N Ianelli, J.S. Link, D.L Stram, V. Wespestad, and D. Woodby (eds), Resiliency of gadid stocks to fishing and climate change, AK-SG-08-01.

Compares pollock with herring; analyses competition and over-wintering energy interactions.

Kline, T.C. Jr., J.L. Boldt, E.V. Farley, Jr., L.J. Haldorson, and J.H. Helle. 2008. Pink salmon (*Oncorhynchus gorbuscha*) marine survival rates reflect early marine carbon source dependency. Progr. Oceanogr. 77:194-202.

Provided evidence that oceanic subsides affects PWS food webs sufficient to drive 50% of pink salmon marine survival. Summarizes carbon source diagnostics presently being used.

Prepared draft article for the PWSSC Breakwater newsletter.

b)
Poster presentation at the 2008 Alaska Marine Science Symposium

Poster presentation at 2008 Ocean Sciences meeting

c)
Herring length frequency data requested by Dr. Bishop transmitted to Herring P.I.'s via email. These data were provided to Dr. Bishop also as XL spreadsheet.

Preliminary graphs transmitted to Herring P.I.'s via email.

Incorporated results of Sitka herring project (using results presented by Jeep Rice in April and from email exchange with J.J. Vollenweider) herewith.

Interacted with an external (to the herring program) researcher Dr. Barb Block on the present climatic state of the Sound vis a vis the PDOI.

Synergistic funding aided in explaining the delayed nature of the 2008 bloom.

Budget: Explain any differences and/or problems between actual and budgeted expenditures, including any substantial changes in the allocation of funds among line items on the budget form. Also provide any new information regarding matching funds or funds from non-EVOS sources for the project. ***NOTE:*** *Any request for an increased or supplemental budget must be submitted as a new proposal that will be subject to the standard process of proposal submittal, technical review, and Trustee Council approval.*

none

We can accept your annual report as a digital file (Microsoft Word or WordPerfect), with all figures and tables embedded. Acrobat Portable Document Format (PDF) files (version 4.x or later) are also acceptable; please do not lock PDF files or include digital signatures.

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We appreciate your prompt submission of your annual report and thank you for your participation.