1. PROJECT INFORMATION

GOA IERP Project Number:	G83 & G85
Title:	The role of cross-shelf and along-shelf transports as controlling mechanisms for nutrients, plankton and larval fish in the coastal Gulf of Alaska
Overall project duration	Oct 1, 2010-Jan 31, 2015
Overall project funding	$2,993,564 & $498,015,
Report period	Dec 1 2011 – April 1, 2012
Report submission date	May 1, 2011
Lead Author of Report*	Russ Hopcroft

Principal Investigator(s), Co-Principal Investigators and Recipient Organization(s):

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2. PROJECT OVERVIEW

a. Briefly describe the core purpose of your project, and the underlying need for this research.

The overall goal of this proposal is to determine how physical transport mechanisms influence lower trophic levels, and subsequently the survival and recruitment of five species of groundfish (*walleye pollock, Pacific cod, arrowtooth flounder, sablefish, Pacific ocean perch)* targeted by the GOA-IERP UTL program. We will examine primary production, the distribution of nutrients, zooplankton and larval fish, and the physical mechanisms that determine their spatial and temporal patterns in two distinct regions of coastal Alaska: eastern (EGOA) and western (WGOA). While many mechanisms controlling along-shelf and cross-shelf fluxes in the two regions are likely similar, we hypothesize that there are also distinct differences between the narrow shelf of EGOA and the broader downwelling dominated shelf of WGOA. Our three primary objectives for each region are to quantify, compare and contrast: (1) the timing and magnitude of the different cross-shelf exchange mechanisms, using an extensive suite of oceanographic (i.e., moorings, drifters, cruises) and atmospheric measurements, (2) how the distribution inorganic nutrients, including the different forms of iron, are affected by these oceanographic processes (3) how these physical mechanisms and nutrients influence the distribution, timing and magnitude of phytoplankton productivity, and (4) how both transport and primary productivity control the distribution, productivity, and fate of both zooplankton and ichthyoplankton. New observations will be supported by retrospective studies using previously collected data from these regions, in some cases extending our horizon back as much as 30 years. These products (and infra-structure) are identified as essential to the success of the other three modules of the GOA-IERP program.

b. State the specific GOAIERP hypothesis or hypotheses that your project is addressing.

- Quantify the importance, timing and magnitude of the climactic and oceanographic mechanisms that control ocean conditions in the EGOA and CGOA.
- Determine how physical, chemical and biological mechanisms influence the distribution, timing and magnitude of primary and secondary productivity in nearshore, inshore, and offshore areas of the EGAO and CGOA.
- Provide a synoptic view, from the shoreline out to beyond the shelf-break, of the distribution and abundance of forage fishes and the early life stages of five focal groundfish species.
- Use a comparative approach to assess spatial and temporal variability in the ecosystem, primarily between the EGOA and CGOA and among spring, summer, and fall.
- Use historical datasets to analyze temporal variability in potential climatic, oceanographic, or biological drivers influencing the early life survival of key groundfish species.

c. List the specific objective(s) of your research project.

- Compare and quantify the importance, timing and magnitude of the different cross-shelf and along-shelf transport mechanisms in the two regions.
- Determine the distribution of iron in the two regions, which processes best explain the observed distribution of iron size classes, and the iron nutritional status of ambient phytoplankton communities across and along the shelf.
- Compare and contrast how physical mechanisms influence the distribution, timing and magnitude of phytoplankton productivity in the two regions.
- Compare and contrast the mechanisms that control the distribution of the zooplankton prey for larval and juvenile fishes, and the structure of the food web between primary producers and these early life history stages of the target fish taxa in the two regions.

3. PROGRESS SUMMARY

a. Provide a table showing the timeline and milestones for the current reporting period only.

	2011	2012	Status
Task	4	1	
PLANNING AND PREPARATION			ongoing
RETROSPECTIVE ANALYSIS			ongoing
FIELD WORK			
UTL Survey/LTL/Mooring Recovery, EGOA+WGOA (NOAA)			One moorings was damaged, one failed to respond. All the others were successfully recovered
DATA ANALYSIS			
Process Spring Cruise Data Sets			Most data streams processed, Micro-zooplankton analysis in progress, Metazooplankton analysis only completed for Seward Line
Process Summer/Fall Cruise Data Sets			Many datasets processed, Micro-zooplankton analysis in progress, Metazooplankton analysis only completed for Seward Line
Process Mooring Data			In progress

b. Describe report period progress.

Moorings & Drifters:

- Of the 8 moorings deployed in the Kodiak region and in southeastern Alaska, one of the moorings off Kodiak was damaged, and one in Southeast Alaska failed to respond for its pickup. All the others were successfully recovered: Kodiak moorings in late October, Southeast moorings in mid-November. Plans are being made to recover the SE Alaska mooring in July 2012 using an ROV.
- Except for the mooring in Chiniak Trough that was dragged, all mooring data have been processed and were presented on posters at the GOAIERP PI meeting. One ADCP (central mooring at Gore Point) failed and no data were collected. In addition one of the moorings in Cross Sound only worked for part of the period. The damage to the mooring in Chiniak Trough was extensive, and although some of the data were recoverable much of the data were not.
- Data from the moorings were presented on two posters (http://www.pmel.noaa.gov/foci/FOCI_workshops.html) and in a presentation at the GOAIERP PI meeting. The drifters that were deployed in spring of 2011, are presented in movie at http://www.ecofoci.noaa.gov/efoci_drifters.shtml under the heading GOAIERP.

Macro-nutrient data (Mordy):

- All of the nutrient samples have been analyzed, and final QC has been performed on the *Thompson*, *Tiglax* (Leg 1), and all of the MTL cruises. There is still some data QC being performed on nutrient data collected on Leg 2 of the spring *Tiglax* cruise, and all of the UTL cruises.
- During the Leg 2 of the spring *Tiglax* cruise, duplicate samples were collected for an inter-laboratory comparison between the PMEL and UAF nutrient labs. There was generally good agreement between the laboratories, although that analysis is not final.

Phyto- and microzooplankton (Strom & Fredrickson):

- Chlorophyll sample analysis was completed during December 2011. Approximately 1200 samples from 2011 UTL and MTL cruises were analyzed at Shannon Point Marine Center. Reconciliation with UTL and MTL field data sheets is complete, as is all data entry. Chlorophyll data from LTL cruises have been integrated with LTL nutrient and CTD data.
- Analysis of phyto- and microzooplankton communities from preserved samples. Approximately 30 samples were analyzed for microzooplankton (inverted microscopy) and 40 for pico- and nano-phytoplankton (epifluorescence microscopy) during the report period, all from the spring LTL (Thompson) cruise. Data are entered and preliminary community composition and biomass estimations have been made.
- Curve fitting and parameter estimation for all (27) photosynthesis-irradiance experiments (spring LTL cruise) was completed.

Metazooplankton (Hopcroft)

- Much of this reporting period has been spent in co-ordination activities.
- Sample processing has been primarily restricted to traditional analysis of Seward Line samples.
- The Zooscan system required for image analysis of most samples was found to be non-operational, but has since been repaired with training activities now underway.

c. Describe preliminary results.

Physical Oceanography (Stabeno & Kachel):

Analysis of the status of the GOA in spring 2011 were completed (Table 1) and while many of the parameters differed from “average”, at first glance, it is not clear why the spring bloom was delayed in SE Alaska.

Status of the Gulf of Alaska Spring 2011

ENSO: La Nina with a negative PDO.
SST: Temperatures were slightly (-0.5 to -1°C) below normal in March/April. off both Kodiak and Sitka. Seward Line temperature in May were ~ -0.5°C lower than normal.

Mean Cloud Cover: March and April had above average (~10-15%).
Net Short Wave Radiation: average.

Winds: Mean seasonal upwelling winds at Sitka during the winter were stronger than in any year since 1967.
Downwelling winds, were ~ average from fall 2010 through summer 2011.
Wind Mixing: Fall through spring ~ average, but summer was above average.
Mixed Layer Depth: mixing ~ normal (from ARGO drifters by F&O Canada).

Subarctic Gyre: The position of the dividing streamline of the West Wind Drift at 145°W in April and May was farther south than average. Since 2000, only 2005 was it farther south in spring.
The fraction of flow going to the GOA was below average.

Table 1. Characteristics of Gulf of Alaska in spring 2011.

Summer production occurs in several places in the GOA as a result of a variety of mechanisms (Figure 2). The narrow shelf of SE Alaska functions in a different way the central gulf, with well-mixed nutrient rich being introduced to shelf from both Cross sound and Chatham Strait. On the central shelf local mixing occurs at several sites, vertically mixing nutrients into the euphotic zone.

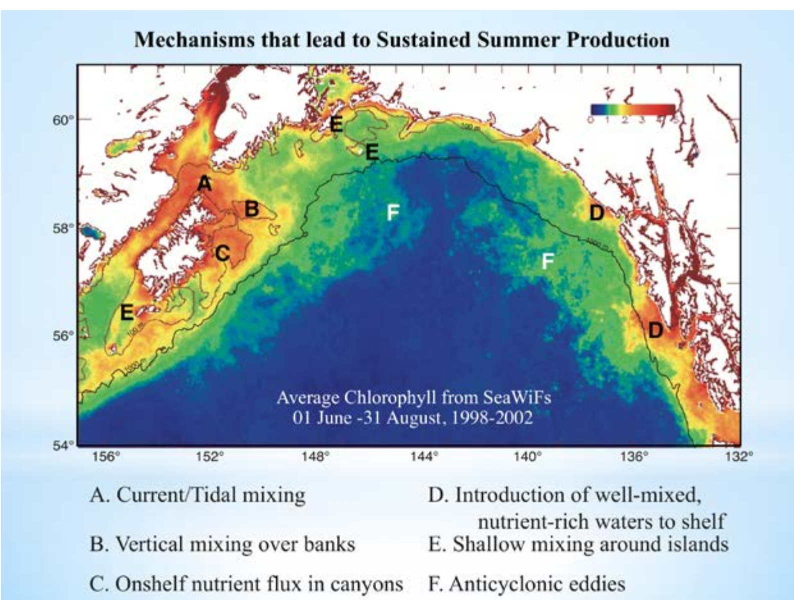
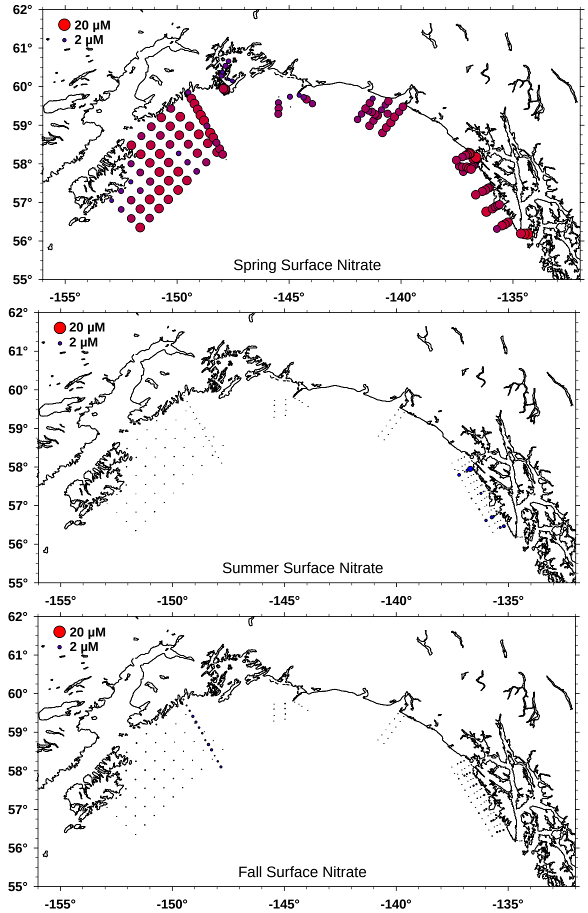


Figure 1. Map indicating different mechanisms that introduce nutrients into the euphotic zone during summer. Data from moorings, drifters, and ship measurements all contributed to composite.

A. Current/Tidal mixing
B. Vertical mixing over banks
C. Onshelf nutrient flux in canyons
D. Introduction of well-mixed, nutrient-rich waters to shelf
E. Shallow mixing around islands
F. Anticyclonic eddies

Macro-nutrient data (Mordy):



On the spring cruises, nitrate concentrations were high, suggesting sampling occurred prior to the spring bloom.

Nitrate was depleted from surface waters during later cruises, most notably during the summer cruises. This indicates traditional draw-down of surface nutrients by phytoplankton typical of summers.

Nutrients remained low in surface waters during the fall, with some limited sign of nutrient resupply (by vertical mixing). We continue to work on integrating data from the various program components

Figure 2. Concentration of nitrate in surface waters (upper 10m) from combined cruises within each sampling season

Iron (Aguilar-Islas, Rember & Stockwell)

May 2011 South East GoA findings. As stated in the previous report, surface seawater samples were collected in a trace metal clean manner from seven transects along the cruise track. These samples showed surface dissolved iron (DFe) concentrations ranged from 0.28 nM offshore to 4.50 nM inshore near Kayak Island (Figure 3a), with an average surface DFe value of 1.52 nM. We have now put these values in context with macronutrient data to address Objective 2. The nitrate plus nitrite (N+N) concentration in the same surface samples ranged from 0.18 uM to 12.27 uM (Figure Xb) with an average concentration of 6.82 uM. Comparing DFe to N+N in surface waters suggests DFe concentrations were not responsible for the low biomass and absence of diatoms observed during the cruise, as DFe was either in excess or sufficient relative to N+N when assuming Redfield ratios for carbon and nitrogen, and a cellular Fe:C ratio of ~20 - 100 umol mol^{-1} (diatoms cellular Fe:C ratios can vary widely depending on iron availability). The Fe:C ratio derived from DFe and N+N during May in surface waters had a geometric mean of 40 umol mol^{-1}. If the observed DFe were available to the phytoplankton community on time scales of days, then sufficient Fe was available to accompany the uptake of the available N+N. Because DFe is > 99% bound to organic ligands, it is of interest to know the characteristics of the ligands binding DFe at any given time. The ambient iron-binding ligand pool is being characterized in collaboration with Dr. Kristen Buck (Bermuda Institute of Ocean Science), and results will be available by mid-May, 2012. The chemical lability of suspended particular iron is also of interest, as particulate labile Fe has the potential to become bioavailable. Processing and analysis of the suspended particulate Fe pool (surface samples and depth profiles) to assess its lability will take place this summer. A master student (Alice Mehalek) will be assisting with these samples.

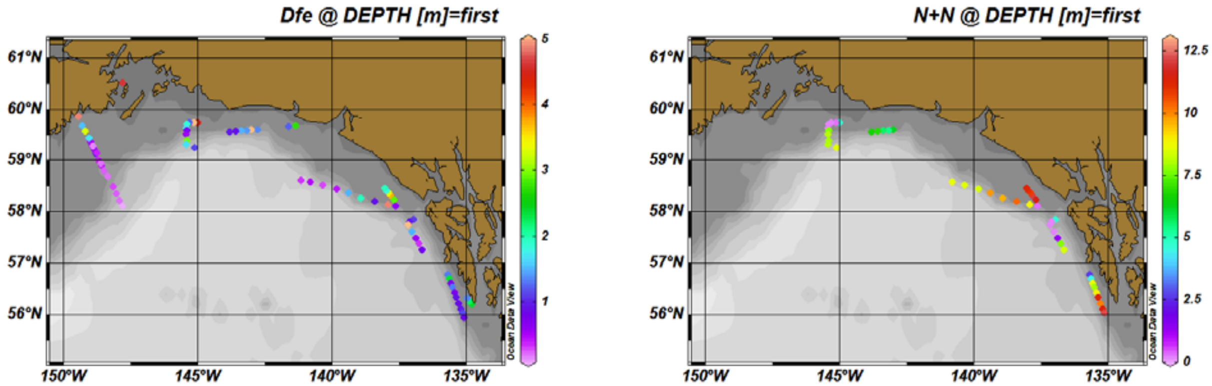
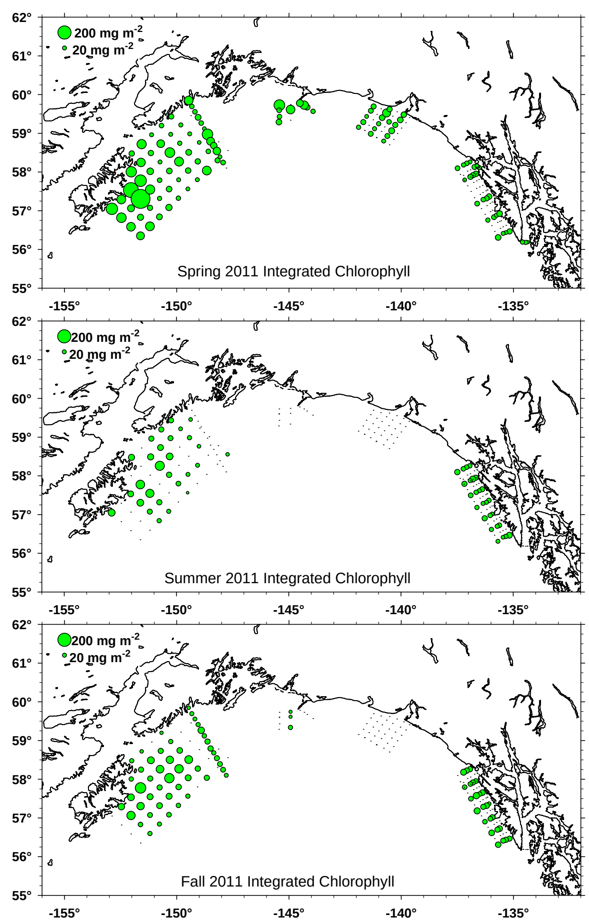


Figure 3. A) Concentrations of surface dissolved iron (DFe) along 7 transects during the May 2011 cruise and along the GAK line during September 2011. B) Surface nitrate plus nitrite (N+N) along 7 transects during the May 2011 cruise.

September 2011 Western GoA findings. As previously reported, surface DFe concentrations along the GAK line ranged from 0.052 nM at GAK 13 to 4.87 nM at GAK 1 (Figure 3b). The dynamic nature of these waters was highlighted by DFe concentration differences in time. The photochemical efficiency (Fv/Fm) of the ambient phytoplankton community was also determined during this cruise. Maximum photochemical efficiency in surface waters tended to decrease from nearshore to offshore. Lowest value was found at GAK 13 where chlorophyll was low (~ 0.5 µg Chl L^{-1}), DIN measured about 10 µM, and DFe was likely at limiting concentrations (0.052 nM). Within the euphotic zone, maximum photochemical efficiency (Fv/Fm) tended to increase with depth. There was a good correlation (R^2 = 0.78) between chlorophyll concentrations and fluorescence maximum values (Fm) for the cruise, considering techniques were still being fine-tuned. Macronutrient analysis is being done by Dr. Mordy's group at PMEL, and will be available this summer. Organic ligand analysis will also be available in mid-May 2012. Particulate suspended samples will be processed and analyze this summer along with May cruise samples.

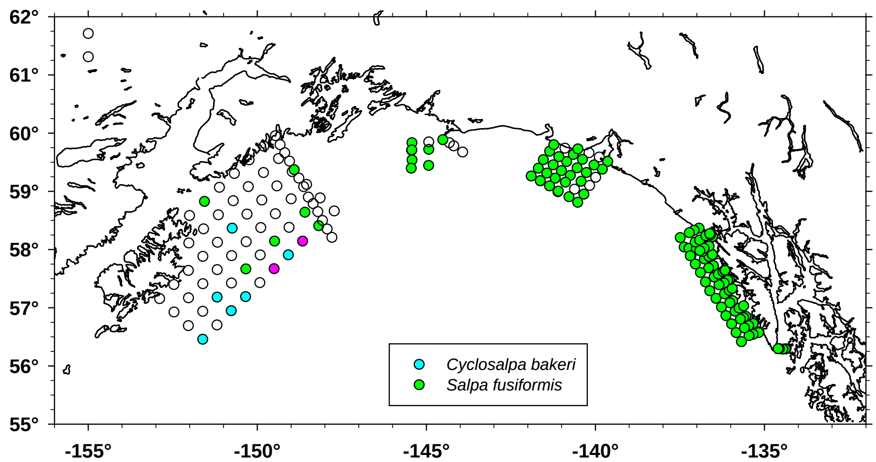


Phyto- and microzooplankton (Strom & Fredrickson):

Spring chlorophyll levels were anomalously low relative to long-term average values in both the eastern and western study regions. Summer and fall data are still being interpreted, but there is little evidence for any major blooms during those seasons. Spring phytoplankton communities were dominated by very small cells in most areas, with the most abundant groups being *Synechococcus* and pico-eukaryotes. Much of the spring 'microzooplankton' biomass was in the heterotrophic nanoflagellate category. Ciliates were the dominant larger microzooplankton type, but their biomass was quite low and most ciliates in the community were very small (<40 µm). Spring phytoplankton appeared low light-adapted throughout the May cruise period. Evidence for this is seen in the high photosynthetic efficiencies and the high incidence of photoinhibition.

Figure 4. Integrated Chlorophyll over the upper 50m.

Metazooplankton (Hopcroft)



The biggest surprise of the 2011 sampling season remains the widespread distribution of at least 2 salp species over the entire field season. Quantitative counts of salp abundances are anticipated to be available late summer of 2012. We are pooling observations with those of other programs in the Northeastern Pacific region to determine the extent of this bloom phenomena.

Ichthyoplankton Component (Napp, Matarese & Doyle)

Fish eggs and larvae collected on the two pilot cruises in 2010 (spring and summer, 1NW10 and 2NW10) have been sorted, verified and added to our database, while samples from the spring 2011 R/V *Thompson* (1TT11), *Tiglax* (1TX11) and *Dyson* (2DY11) cruises and the 2011 summer (1NW11 and 2NW11) have been sorted, but not verified. The 2011 spring cruise (1TT11) sampled a much wider area north and south than either of the 2010 pilot cruises. On both spring cruises (1NW10 and 1TT11), eggs of walleye pollock were collected, often in deep water on the shelf. No eggs were collected from the remaining four target species on any of the cruises. Larvae of all five target species were collected on the spring 2010 cruise, and four of the five (all except Pacific cod) were collected on the spring 2011 cruise. Rockfish and sablefish larvae were the most commonly collected larvae for both cruises. A neuston net was used in 2011 in addition to the 60-cm bongo and it proved to be more effective than the 60-cm bongo at collecting sablefish larvae. The neuston net captured sablefish larvae over a greater number of stations than the bongo, with the greatest number of sablefish larvae generally captured at the shelf break. Larvae of arrowtooth flounder were generally collected over deep water and at the shelf break on both spring cruises (2010 and 2011). However, between the two cruises, larvae were smaller in 2010 (6.0–12.0 mm) than in 2011 (9.5–22.0 mm), most likely due to the difference in timing between the two cruises. In 2010 the spring cruise occurred in mid-April, while in 2011 the spring cruise occurred in early May. Larvae of Pacific cod were collected on the spring 2010 cruise on the shelf, but were rare. In summer of 2010, the only target species collected was rockfish larvae. These larvae, on average, were not significantly larger than the larvae collected in spring of 2010 (4.79±2.86 mm in summer vs. 4.93±0.96 in spring), but the distribution of the larvae collected in the summer was further north and west of Cross Sound than those collected in the spring. A poster was presented at the PI meeting (March 6-8) with our results to date.

Results from the retrospective analyses are reported separately.

d. Describe integration activity.

Planning and co-ordination meeting have occurred throughout the period between the LTL, UTL, MTL and Modeling.

Integration of chlorophyll, nutrient and CTD data from the LTL cruises has largely been accomplished. Discussions with the retrospective group have helped with development of hypotheses regarding anomalous spring conditions. Other zooplankton researchers on the U.S. and Canadian west coast have been contacted concerning anomalous spring 2011 zooplankton community composition.

e. Describe any concerns you may have about your project's progress.
Concerns remain similar to last report. Cost overruns and consequent delayed data/sample processing remain a high concern with PIs.

Due to the large number of samples and amount of data from UTL and MTL cruises, we are behind our proposed schedule for analysis of microzooplankton samples. Key project technician K. Fredrickson will be on maternity leave beginning June 2012 for a minimum of 3 months. Training of new personnel is underway but sample processing efficiency is not going to be as high during June-December 2012.

Similarly, resources expended on equipment, supplies, and personnel to staff 2011 field activities have consumed funds budgeted to image analysis of samples – the new student coming into the project will not begin works on these samples until fall as they are now committed to new UTL cruises in July and August.

f. Poster and oral presentations at scientific conferences or seminars

Russ Hopcroft, Miriam Doyle, Ann Matarese, Calvin Mordy, Jeff Napp, Phyllis Stabeno, Suzanne Strom. A Broad-Scale Look At Physics Through Plankton In The Coastal Gulf of Alaska. Alaska Marine Science Symposium, Anchorage AK, January 17, 2012

Jamal Moss, Sarah Hinckley, Russell Hopcroft, Olav Ormseth. The Gulf of Alaska Project: an Integrated Ecosystem Research Program. Alaska Marine Science Symposium, Anchorage AK, January 17, 2012

Nancy Kachel, Ana Aguillar-Islas, Calvin Mordy, Sigrid Salo, Phyllis Stabeno, Suzanne Strom, Alongshelf Differences in Hydrography and Currents in the Gulf of Alaska, poster, Alaska Marine Science Symposium, Anchorage AK, January 17, 2012 ***&*** GOAIERP PI meeting, Juneau AK, March 6-8, 2012.

Phyllis Sabeno, Nancy Kachel, Calvin Mordy, Sigrid Salo, Preliminary Results from the southeast Alaska Moorings: 2011, poster, GOAIERP PI meeting, Juneau AK, March 6-8, 2012.

Nancy Kachel, Ana Aguillar-Islas, Calvin Mordy, Sigrid Salo, Phyllis Stabeno, Suzanne Strom, Alongshelf Differences in Hydrography and Currents in the Gulf of Alaska, poster, GOAIERP PI meeting, Juneau AK, March 6-8, 2012.

g. Education and outreach

Aguilar-Islas participates in a new program called "Mentoring Students in Science" in which an 8th grade student in an honors science class partners with a scientist to learn about careers in science. The GOAIERP is used as an example during communication with the student partner. This partnership is ongoing.

Kachel, N. Science Day Presentations at Jane Adams K-8 School, Seattle, WA. November 19, 2012.

Lisa Guy, Calvin Mordy and Scott McKeever. Satellite-Tracked Drifters, Polar Science Weekend at the Pacific Science Center, March 1-2, 2012. Seattle, WA.

Scott McKeever. Volunteered as a judge at the Orca Bowl, School of Oceanography, University of Washington, March, 2012.

4. PROGRESS STATUS

Planned field activities for 2011 were mostly completed. Repair has been completed of mooring equipment damaged in 2011. Plans are underway to recover the mooring that failed to release in 2011. options are being considered to conduct more extensive measurement of iron and primary production in 2013.

5. FUTURE WORKPLAN and DATA DELIVERY

Workplan

What	*Who*	*Start and end dates*	*Other key dates*
Analyze chl, microzoo, phyto samples - Begin data analysis	**Fredrickson, Strom**	Fall2011/Winter2012	See detail A
Processing of metazooplankton	**Hopcroft**	Fall2011 – Fall/Winter 2012	
Interpret 2011 Ichthyoplankton Data	**Napp**	Fall2011/Winter2012	See detail B
Process maco-nutrient samples	**Mordy, Hopcroft**	Fall2011/Winter2012	
Process mooring and CTD datasets	**Stabeno, Mordy, Danielson**	Fall2011/Winter2012	
Fe-binding organic ligand analysis	**Aguilar-Islas/ Buck**	Finish May 2012	
Particulate Fe sample processing	**Graduate Student**	Starting May 2012	

A. Over the next 6 months we plan to:

1) Continue analysis of microzooplankton samples and data, including a subset of those collected during summer and fall UTL cruises.
2) Examine samples collected for large phytoplankton biomass and composition; use compiled data from those samples, epifluorescence samples (small phytoplankton biomass and composition) and size-fractionated chlorophyll to estimate phytoplankton carbon:chlorophyll ratios.
3) Estimate daily primary production rates (spring LTL cruise) from photosynthesis parameters and environmental data.
5) Evaluate chlorophyll data from all 2011 cruises and integrate with nutrient and other data types. Potentially analyze chlorophyll samples and evaluate data from 2012 cruises to the study region.
6) Plan for 2013 field work.
7) Work with scientists in GOA-IERP and beyond to develop our understanding of the cause(s) of the anomalous spring 2011 conditions.

B. During the next 6 months our focus will be to finish the verification of samples from the spring 2011 western GOA (1TX11), the late spring Shelikof Strait (2DY11) and the summer eastern and western GOA cruises (1NW11 and 2NW11, respectively).

Data delivery.

GOAIERP Data Delivery Table		
Data type for delivery	Delivery Month & Year	Person sending data, with email address
LTL Cruise reports with stations completed	Available	hopcroft@ims.uaf.edu
Satellite-tracked drifter data - location	Real-time data on website.	Dave.Kachel@NOAA.gov
Surface dissolved Fe from LTL April/May and September 2011 cruises; Vertical profiles of dissolved Fe from LTL April/May 2011 cruise.	Available	amaguilarislas@alaska.edu
Surface and vertical profile total dissolvable Fe data from the LTL April/May 2011 and September 2011 cruises	Available	amaguilarislas@alaska.edu
Maco-nutrient data spring/summer/fall 2011	Draft Available	Calvin.W.Mordy@noaa.gov
Spring hydrogaphic data (T, S, PAR, fluorescence, oxygen, nutrients)	Available	Dave.Kachel@NOAA.gov Peggy.sullivan@noaa.gov
Photosynthesis data – spring 2011 Thompson cruise	Available	Suzanne.Strom@wwu.edu
Chlorophyll data – spring 2011 Thompson and Tiglax cruises	Available	Suzanne.Strom@wwu.edu
Chlorophyll data – summer/fall 2011	Draft Available	Suzanne.Strom@wwu.edu
Metazooplankton – Seward Line 2011	Draft Available	rrhopcroft@alaska.edu
2010 Ichthyoplankton	Available	Kimberly.Bahl@NOAA.gov