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	Apr 1 2012 – Dec 1, 2012
Report submission date	Dec 31, 2012
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.

	2012	2012	Status
Task	2nd Q	3rd Q	
PLANNING AND PREPARATION			Ongoing
RETROSPECTIVE ANALYSIS			Ongoing
FIELD WORK			
UTL Survey			No broad-scale sampling activity was proposed for 2012, however LTL supported 2 months of field activities by UTL (and subsequent analysis)
Seward Line			Cruises successfully executed, analysis underway
DATA ANALYSIS			
Process Spring 2011 Cruise Data			Physical and chemical data streams processed, Chlorophyll and PP processed, Micro-zooplankton analysis in progress, Metazooplankton analysis completed for Seward Line, and Bongo nets WGOA
Process Summer/Fall 2011 Cruise Data			Physical and chemical data streams processed. Chlorophyll and PP processed. Micro-zooplankton analysis in progress, Metazooplankton analysis completed for Seward Line
Process Mooring Data			Completed

b. Describe report period progress.

Moorings & Drifters:

- No report

Physical Oceanography (Stabeno & Kachel):

- Processing of all 2011 cruises completed
- Processing of 2012 LTL cruises underway
- Considerable time has been spent securing ship time and resources for 2013 activities amid the constant changes ongoing at NOAA

Macro-nutrient data (Mordy):

- Nutrient data was processed for all 2011 cruises and from the ISUS nutrient mooring.
- Samples were collected from all hydrocasts during the 2012 field campaign. Sample analysis for 2012 will be prioritized from the accompanying chlorophyll data set.

Micro-nutrients (Aguilar-Islas):

- During this period the iron group focused on researching, obtaining, and preparing equipment to be used for water column sample collection during the 2013 field season, and on improving and optimizing analytical methods for the determination of low level iron in seawater to accommodate large sample throughput. In addition we collaborated with Dr. Kristen Buck (Bermuda Institute of Ocean Science) to determine the chemical speciation of dissolved iron in samples collected during the 2011 field season.
- In terms of equipment, the goal was to obtain state-of-the-art trace-metal sampling equipment in order to reduce the required wire time and increase the number of samples per cast for the 2013 field season. This is desirable as iron sampling requires additional wire time, and time is limited during LTL cruises. Trace-metal clean rosette systems have become available, and one such system was purchased with the PI's start-up funds during the summer of 2012, and was prepared for use during the 2013 season. This equipment was expected to be used onboard UNOLS or NOAA ships that could accommodate the additional winch required for its use.
- For the improvement of our analytical methodology, a UAF grad student was hired during the summer to develop, test, and implement an automated method with ICP-MS detection. The goal here was to prepare for the 2013 field season by building our capacity to process large amounts of samples in a more efficient way. In addition to determining low level dissolved iron in seawater, the new method is capable of determining a suite of trace metals which will help in the interpretation of the iron data.
- Marie Seguret was hired in November as a postdoctoral fellow. She has been working on the processing of particulate samples from the 2011 field season, and will start analysis in early 2013.

Phyto- and microzooplankton (Strom & Fredrickson):

- ***Chlorophyll analysis:*** Approximately 650 chlorophyll samples, collected by the UTL component during summer 2012 cruises, were analyzed at Shannon Point Marine Center during Nov. 2012. Data are entered into spreadsheets. Due to problems with sample collection and data recording on the first 2012 UTL cruise, the chlorophyll data will have to be reconciled with the in situ fluorescence data if they are to be interpretable. Due to problems interfacing the CTD deck unit with the GPS system on the Northwest Explorer, the 2012 CTD data are still in a raw state and lack position (station) information. As soon as we can get processed CTD data, we can reconcile the data and provide them to the program. All 2011 chlorophyll data from LTL, MTL, and UTL components are processed, integrated totals computed, and files with metadata have been uploaded to the project workspace. Maps have been created showing the areal distribution of total chlorophyll (spring, summer, fall) and the chlorophyll size distribution (spring only) for all study regions.

- ***Microzooplankton analysis:*** An additional ~45 samples for microzooplankton abundance, community composition and biomass were analyzed during the report period. Based on the 14 vertical profiles currently analyzed, we can see that the composition and biomass at 10 m are reasonable predictors of water column composition and biomass. Therefore we have begun to move forward with analysis of only samples from 10 m, to achieve better coverage over the 2011 sampling regions and seasons. This should allow us to address project questions of seasonal and regional contrasts for microzooplankton composition and biomass.
- Analysis of optical properties (from transmissometry, in situ fluorescence, incident and in-water PAR data, and extracted chlorophyll data) of the spring 2011 water column is underway, to determine whether observed phytoplankton characteristics (low biomass, adaptation to low light levels) could be attributable to attenuation of incident light by non-phytoplankton materials in the water column.
- Cruise planning for 2013 has begun. We are working on obtaining various permissions, permits and facilities for radio-isotope work on the F.V. Dyson and possibly other platforms. We are also in discussion with other project members on cruise sampling protocols, station grids, logistics, gear, and personnel.
- Strom is also participating in the data management working group, trying to help wrestle the project workspace into a format that is more accessible.

Metazooplankton (Hopcroft)

- Much of this reporting period has been spent in co-ordination activities by Hopcroft. Hopcroft participated in the first portion of the UTL cruise to ensure equipment was working and that the oceanography students understood sampling methodologies.
- A master's student, Sterling Ulrich, was started on the project to participate in field activities and take the lead on scanning/analysis of broad-scale zooplankton samples. The student began during summer, conducted open-water training, and then participated on the 2 3-weeks UTL summer cruises as well as the September Seward Line cruise. The fall has been spent on learned to ID zooplankton and developing familiarity with ZooScan system.
- Samples were processed manually for the Spring 2012 Seward Line, and for 505µm Bongos from much of the eastern grid for Spring 2011.

Ichthyoplankton Component (Napp, Matarese & Doyle)

- Collections from the 505µm Bongo net during 2012 have been sent to Poland for analysis of ichthyoplankton

c. Describe preliminary results.

Physical Oceanography (Stabeno & Kachel):

Nothing to report for this period

Macro-nutrient data (Mordy):

Using repeat hydrographic data from the spring 2011 EGOA cruise on the R/V Thompson, we estimated rates of Net Community Production (net drawdown of dissolved inorganic nitrogen) of ~0.4-1.0 g C m^{-1} d^{-1} (Fig 1). The silicate – nitrate plot indicates residual silica concentrations of ~5-15 µM upon nitrate depletion (y-axis intercept in Fig. 2). This level of residual silicate was reminiscent of the middle and inner shelf concentrations over the WGOA during the summer GLOBEC cruise in 2001 (Strom et al., 2006). Residual silicate is indicative of indicative of diatom limitation, and in this case was ultimately attributed to iron limitation. In spring 2011, there was plenty of iron to support diatom production (see iron component, A. Aguilar-Islas), so some other factor was limiting diatom growth. The dominance of small cells suggests light limitation, although grazing of large cells cannot be entirely discounted (see phytoplankton component, S. Strom).

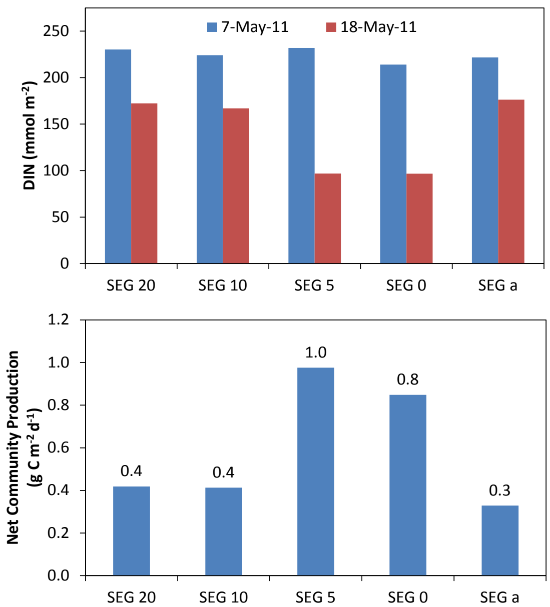

Fig. 1. Concentrations of dissolved inorganic nitrogen (top) from two occupations of the SEG hydrographic line, and rates of net community production (bottom).

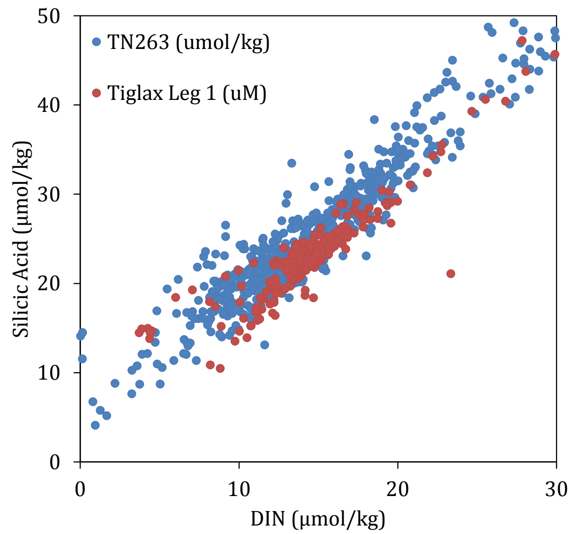

Fig. 2. Relationship between silicic acid and dissolved inorganic nitrogen in spring 2011

Iron (Aguilar-Islas, Rember & Stockwell)

The chemical speciation analysis has yielded some interesting results. Dissolved iron is >99% chelated by organic ligands in the marine environment, due to its low inorganic solubility in seawater. Analytical techniques distinguish two Fe-binding ligand classes. The L1 ligand class has a high affinity for Fe, while the L2 ligand class binds Fe less strongly. During spring and fall 2011 the concentration of L1 ligands was always in excess of the Fe concentration (Fig. 3a), and the percentage of excess ligand increased with decreasing Fe concentration in a power law relationship (Fig. 3b). Conditional stability constants (K) measure the Fe binding strength of each ligand class. For this data set K_1 and K_2 values were high, meaning that dissolved iron was strongly bound by the natural organic ligand pool. This could be a factor in explaining the lack of diatom growth during the spring of 2011, as strongly bound Fe could have been unavailable to cells. Comparing these values with the limited organic speciation data available for Pacific waters, it is interesting to note that the high values in the Gulf of Alaska are more similar to those found in waters influenced by the Columbia River Plume, than to K values found in waters over the Bering Sea shelf.

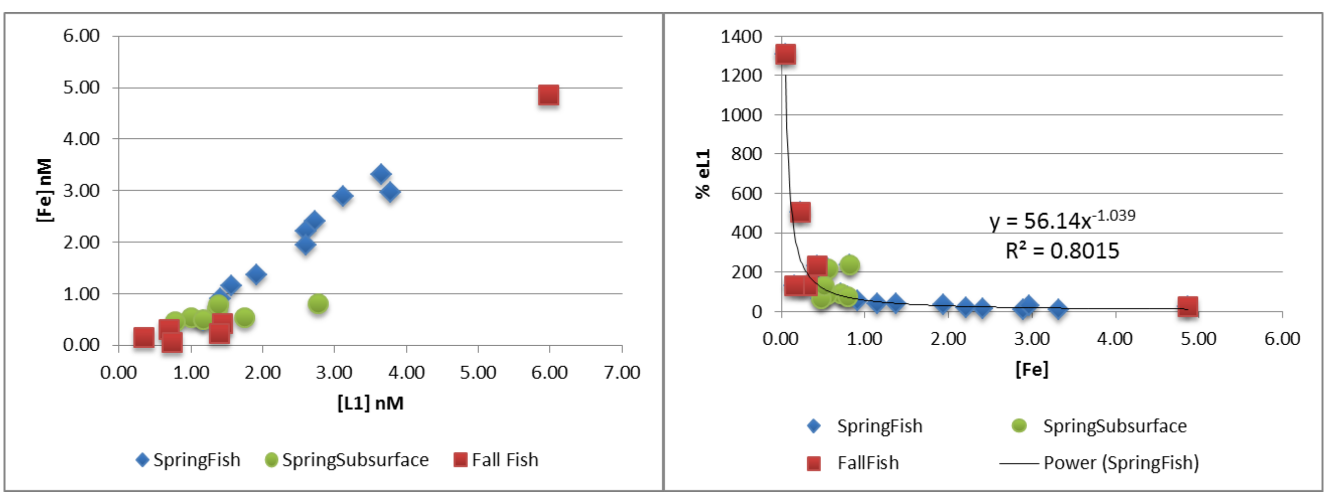

Fig. 3. A) The concentration of iron ([Fe]) relative to the concentration of the strong iron binding ligand class ([L_1]) shows L_1 was always in excess.
B) The percentage of excess strong binding ligand concentration (% eL_1) relative to the concentration of dissolved iron ([Fe])

Phyto- and microzooplankton (Strom & Fredrickson):

Last report, we noted that Spring chlorophyll levels were anomalously low relative to long-term average values in both the eastern and western study regions. Further sample analysis shows that 2011 coastal waters in both east and west had low levels of both chlorophyll and microzooplankton biomass throughout all sampled seasons (spring, summer, fall). Indeed we are seeing some of the lowest microzooplankton biomass levels that I have ever measured in Alaska waters, including iron-limited open Gulf waters. The only consistent exception, where levels are creeping up toward 'moderate', are stations in the western portion of the western grid. Dinoflagellates, normally an important component of the summer community and episodically abundant during spring diatom blooms on this shelf, were notably scarce during 2011.

There is some evidence that the low light environment apparently experienced by the phytoplankton (as indicated by their spring photophysiology) was due to absorption of light by non-phytoplankton materials in the spring water column. We are continuing to investigate this possibility, which may have important implications for the timing and amount of spring runoff in coastal waters relative to primary production.

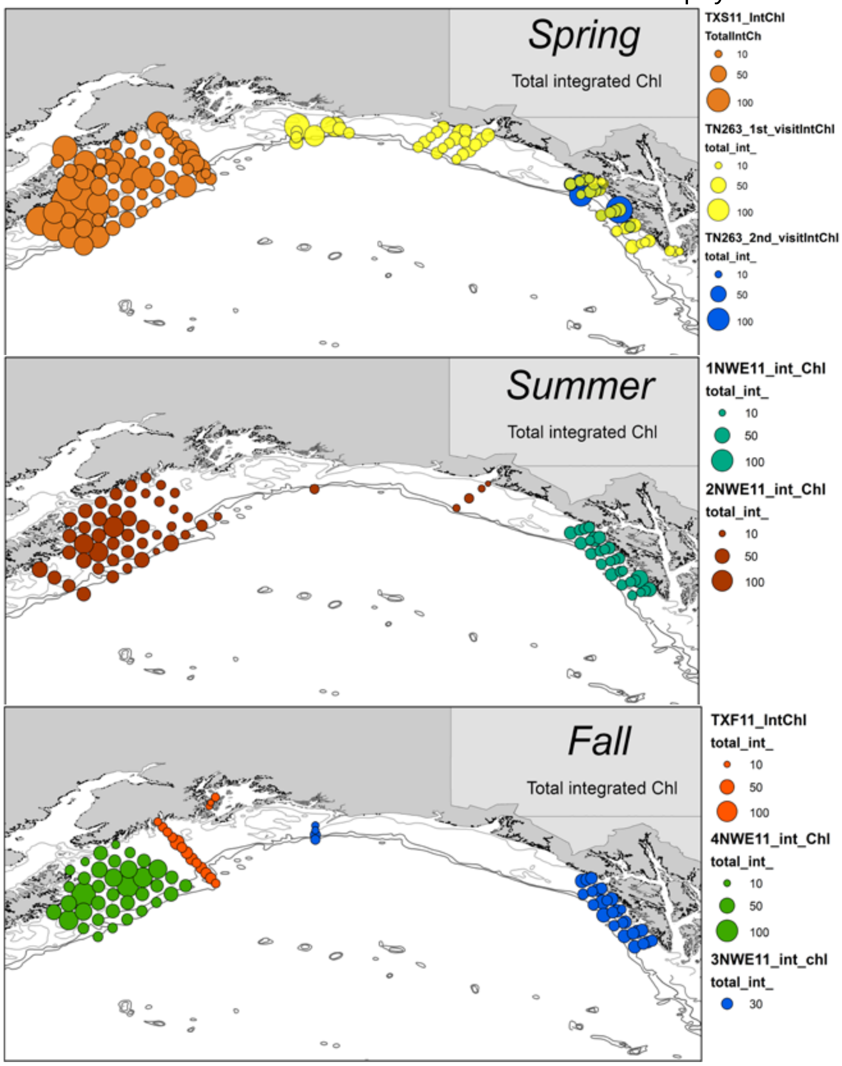

Fig. 4. Integrated chlorophyll during the 2011 surveys

Metazooplankton (Hopcroft)

The biggest surprise of the 2011 sampling season remains the widespread distribution of 3 salp species over the entire field season, particularly in the eastern Gulf. Quantitative salp abundances are to be represented at AMSS. Observations are being pooled with those of other programs in the Northeastern Pacific region.

Ichthyoplankton Component (Napp, Matarese & Doyle)

During the 2011 GOA_IERP field season, five cruises collected ichthyoplankton using bongo and neuston gear. Two cruises were conducted in spring (1TT11, 1TX11; 26 April–21 May), one was in late spring (2DY11; 2–9 June), and two were in the summer months (1–2NW11; 3 July–21 August). The only eggs identified from cruises were those of walleye pollock (*Theragra chalcogramma*). Larvae of all five target species were collected in 2011 and highest abundances occurred during spring. Sablefish (*Anoplopoma fimbria*) were collected on four of the five cruises, but none were collected during summer in the west.

Both neuston and bongo gear were necessary to fully describe sablefish distribution in the GOA. The bongo net was more effective at sampling the smaller larvae (6.5–16.5 mm SL) that reside at depth, while the neuston net collected larger larvae and early juveniles (7.2–19.8 mm SL) that occur at the surface. Arrowtooth flounder larvae and walleye pollock eggs and larvae were collected on all three spring cruises, with higher abundances in the west. Pacific cod larvae were only collected on two western cruises (1TX11 and 2DY11). Rockfish (*Sebastes* spp.) were the most abundant overall of the five target species and were collected on every cruise. In the summer, only rockfish, with a few sablefish, were caught. Most rockfish collected in summer were <4.0 mm SL; larvae >4 mm SL comprised only 16% of those measured. On average, rockfish larvae collected in summer were smaller than those collected during the spring cruises (3.75 mm SL vs. 5.78 mm SL). This implies either the larvae collected in summer are of a different cohort than those collected in spring or they are different species.

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. An LTL group meeting in Seattle during the report period, as well as numerous conference calls, assisted with integration within the group.

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, and several PIs are behind our proposed schedule for analyses.

Phyto- and microzooplankton (Strom & Fredrickson):

We are spending considerable time on reconciling data. Sample and data collection, including CTD data, on many of the 2011 cruises was not carefully documented or was missing key components. This was due to a combination of lack of prior planning and use of inexperienced personnel on cruises. Unfortunately, the time and money saved on planning and cruise personnel has been more than spent on post-cruise data wrangling and outright loss of data. I am concerned that we are going into the 2013 field year with some of the same handicaps. In a nutshell, the time required to deal with poorly collected data has slowed our progress on real science questions.

Iron:

We still have concerns relating to the spatial and temporal distribution of our sampling. The trace metal rosette we obtained this summer was meant to increase our sampling capability during spring and fall 2013 cruises onboard UNOLS/NOAA vessels. Unfortunately, we now know that the *R/V Thompson* will not be available for the LTL spring cruise, and after visiting the *Dyson* we discovered that its layout and equipment will not be able to accommodate sampling with the trace-metal rosette. We now have to fall back to our vane samplers which during a given Fe cast period provide fewer samples than a rosette system. Thus, if we want a better coverage of the water column at a given station, we will need to compromise on the number of stations we will be able to sample.

For cruises onboard the *Tiglax*, our concern, in addition to sample coverage, has to do with the lack of ship space to set up a trace-metal clean station for sample processing. This means that obtaining vertical water column samples from the vanes won't be possible, as there is no place to process them cleanly onboard. The inclusion of a van would eliminate this limitation.

Zooplankton:

Heavy use of the project's student for unplanned/unbudgeted field activities in 2012 has resulted in limited progress on sample analysis. Needs for oceanographic equipment (CTDs, winches, rosettes) and infrastructure (i.e. van rental, van purchase) have effectively left Hopcroft with little salary compensation available for this time spent on this project.

f. Poster and oral presentations at scientific conferences or seminars
None during the reporting period – several talks and posters are accepted for the AMSS and ALSO meeting.

g. Education and outreach
None during the reporting period.

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*
Plan and execute 2013 field	**ALL**	Winter 2012/13 – Fall 2013	
Analyze chl, microzoo, phyto samples - Begin data analysis	**Fredrickson, Strom**	ongoing	See detail A
Processing of metazooplankton	**Hopcroft**	ongoing	
Interpret 2011 Ichthyoplankton Data	**Napp, Matarese**	ongoing	
Process 2012 & 2013 macro-nutrient samples	**Mordy, Hopcroft**	ongoing	
Process 2012/13 CTD datasets	**Stabeno, Mordy, Danielson**	ongoing	
Analysis of various Fe forms	**Aguilar-Islas/ Buck**	ongoing	

A. Over the next 6 months we plan to:
1) Plan and execute the spring LTL cruises on Dyson and Tiglax; participate in planning for sample collection on 2013 MTL (?) and UTL cruises.
2) Use optical data, phytoplankton growth rate estimates from C:chl ratios plus microscopy-derived biomass estimates, along with micro- and mesozooplankton grazing rate estimates, to examine factors that might have prevented a spring bloom in 2011.
3) Estimate daily primary production rates (spring LTL cruise) from photosynthesis parameters and environmental data.
4) Analyze an additional 30-50 samples for microzooplankton composition and biomass, and use PCA to examine patterns with season and location. Compare these data with phytoplankton and mesozooplankton data to get insights into differences in trophic structure among seasons and regions.
5) Evaluate chlorophyll data from all 2012 cruises and integrate with nutrient and other data types.
6) Work with scientists in GOA-IERP and beyond to develop our understanding of the cause(s) of the anomalous spring 2011 conditions.

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
Macro-nutrient data all 2011 cruises	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 – all 2011 cruises	Draft Available	Suzanne.Strom@wwu.edu
Metazooplankton – Seward Line 2011	Draft Available	rrhopcroft@alaska.edu
2010 Ichthyoplankton	Available	Kimberly.Bahl@NOAA.gov
2011 Ichthyoplankton	Available	Ann.Matarese@NOAA.gov