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	May 1 2011 – Nov 30, 2011
Report submission date	Dec 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				Status
Task	1	2	3	4	
PLANNING AND PREPARATION					ongoing
RETROSPECTIVE ANALYSIS					ongoing
FIELD WORK					
Mooring Deployment & retrieval,					Delayed but successful
LTL Spring Cruises, EGOA (UNOLS), WGOA (Tiglax)					Executed and generally successful
Participate on UTL Fisheries Survey					Executed, and generally successful
LTL/Seward Line Fall Cruise (Tiglax)					Executed and generally successful
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					Many data streams processed but not QCed, zooplankton analysis only completed for Seward Line
Process Summer Cruise Data Sets					In progress, zooplankton samples not yet shipped out
Process Mooring Data					In progress

b. Describe report period progress.

Moorings & Drifters:

There were 8 moorings each deployed in the Kodiak region and in southeastern Alaska (Figure 1), each with an array of instruments (Table 1, 2). 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.

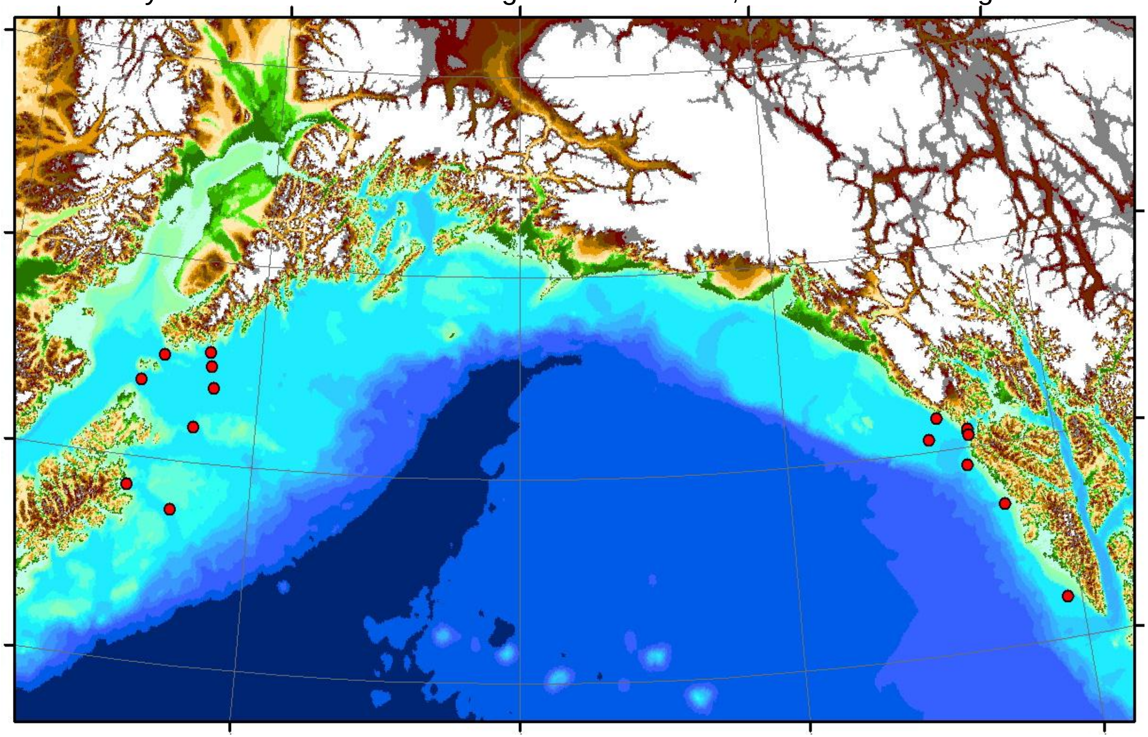

Figure 1: The locations of the 8 moorings, which were deployed in southeast Alaska. Measurements vary among mooring

Approx. Depth	Operation	Mooring	75 kHz ADCP	300 kHz ADCP	ISUS	Micro Cat	RCM 9	Sea Cat	Sound Rec AURAL	Temp. Sensors SBE-39	rel.
		Subsurface Moorings									
157 m	Deploy	11GPP-32A	1			1					1
144 m	Deploy	11GPP-34A	1			1					1
185 m	Deploy	11GPP-36A	1			1					1
191 m	Deploy	11KEP-41A	1			1					1
121 m	Deploy	11SVP-39A		1		1					1
120 m	Deploy	11PCP-1A		1		1	1				1
146 m	Deploy	11CBP-3A		1	0	2	1	1	1	8	1
		TOTAL	**4**	**3**	**0**	**9**	**3**	**1**	**1**	**8**	**8**

Table 1. ECO-FOCI moorings in the Kodiak I. area in 2011, and the equipment mounted on them. SeaCats and Micro-Cats record temperature and salinity, ADCPs record velocity throughout the water column, the Eco-Fluorometer measures fluorescence.

Approx. Depth	Operation	Mooring	75 kHz ADCP	300 kHz ADCP	Eco Fluor	ISUS	Micro Cat	Sea Cat	RCM 9	Sound Rec PAL	Temp. Sensors SBE-39	rel.
		Subsurface Moorings										
100 m	Deploy	11CSP-11A		1			1					1
125 m	Deploy	11CS-12A			1		2		3	1	8	1
126 m	Deploy	11CS-13A			1		2		3		8	1
146 m	Deploy	11IP-1A			1	1	1	1	3		6	1
132 m	Deploy	11IPP-2A	1				1					1
315 m	Deploy	11CSP-1A	1				1		1			1
100 m	Deploy	11CSP-2A		1			1					1
319 m	Deploy	11CSP-3A	1				1					1
		TOTAL	3	2	3	1	10	1	10	1	22	8

Figure 2. ECO-FOCI moorings in the Southeastern Alaska grid area in 2011, and the equipment mounted on them. SeaCats and Micro-Cats record temperature and salinity, ADCPs record velocity throughout the water column, the Eco-Fluorometer measures fluorescence., and the ISUS measures nitrate concentrations.

During the Spring LTL cruise of the Thompson (TN263) off southeastern Alaska six ARGOS-tracked drifters, drogued at a depth of 40m, were deployed. Of these, one deployed just north of Sitka, AK failed within 2 days. Both drifters deployed in Chatham Strait exited the strait before traveling generally northward along the coast. The one deployed on the west side of Chatham went directly south; while the one deployed on the east side started north, before turning south and rounding the tip of Baranof I. Two drifters deployed at the mouth of Cross Sound exhibited strikingly different behavior. The one deployed on an ebb tide traveled northward, eventually entering the CGOA via Amatouli Trough, then proceeding down Sheilikof Strait. The other one stayed within the Cross Sound Estuary area for two months before ceasing operation. While several drifters exhibited on and off-shelf transport, the one deployed at the shelf edge near Yakutat joined one eddy, then another, where it is still circling in late November. Movies of the drifter tracks are updated daily on the weblinks:

2011 buoy track annimation - Cross Sound Area
2011 buoy track annimation - Yakutat Area
2011 buoy track annimation - Shelikof Strait

Field Work:
Two LTL cruises were executed simultaneously during April/May. The *M/V Tiglax* deployed Mooring and conducted sampling from April 26 - May 8 in the Western Gulf, while the *R/V Thompson* sampled from April 30 - May 21 in the Eastern and Northern Gulf. LTL supplied core oceanographic sampling equipment along with a chemical/biological oceanographer for all UTL cruise which ran almost continuously from June 30th to October 8th, as well as a CTD technician to setup for the first UTL cruise and between Cruises 3 & 4 to troubleshoot equipment. LTL also provided some equipment, and most oceanographic supplies for MTL sampling over the field season.

The status of various data and sample sets appear in an attached excel table. Progress has been greatest on spring LTL cruises (Fig. 2, 3), and often limited for the UTL and MTL cruises, hence this report concentrates primarily on the spring cruises. More details on the cruise tracks for UTL appears in their report.

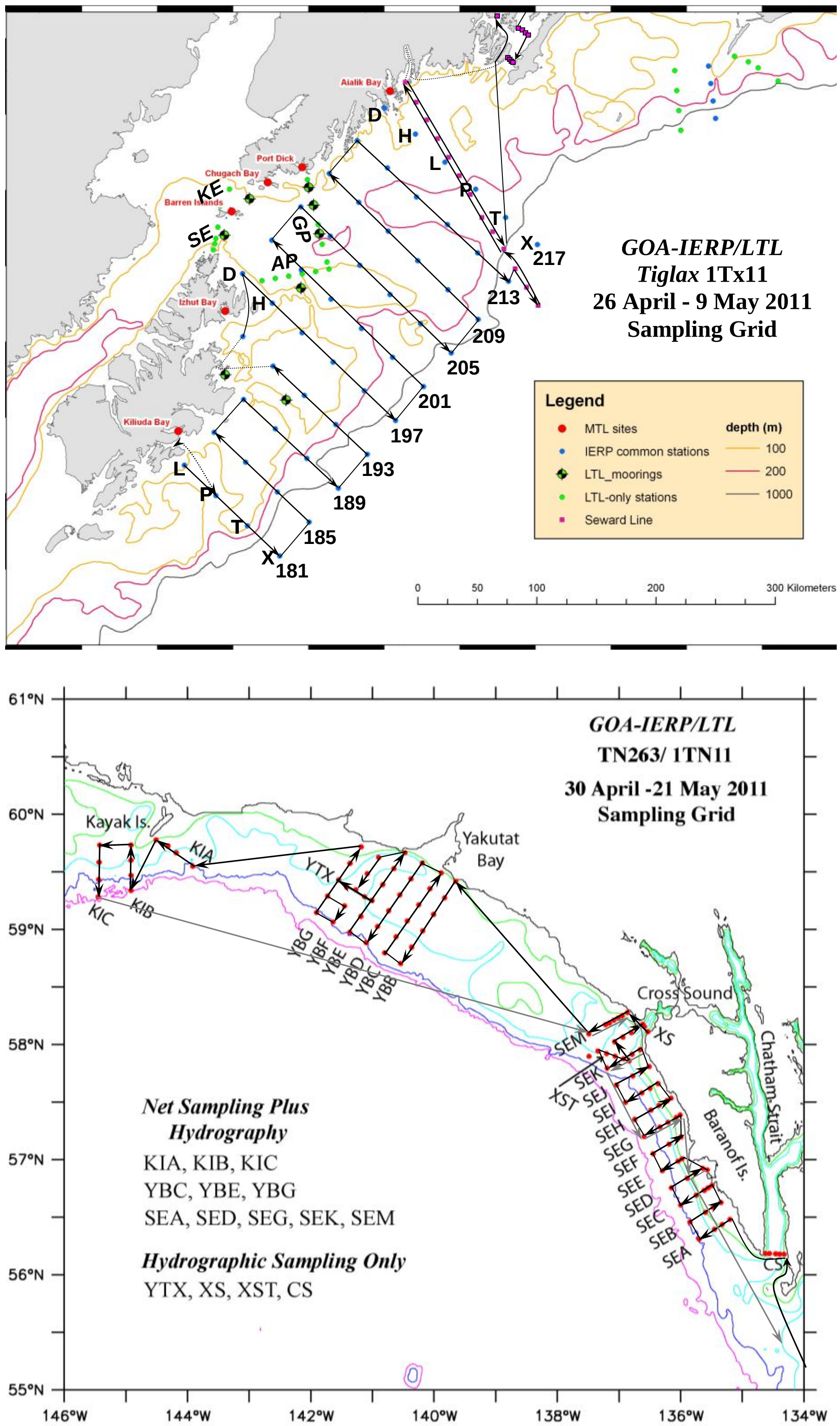

Figure 2. Sampling stations and cruise tracks from Spring 2011 LTL cruises.

c. Describe preliminary results.

Physical Oceanography (Stabeno & Kachel):

Surface temperatures at the start of the spring cruise in Southeastern Alaska were ~6.5°C, and increased slowly over the cruise warming past 8°C during activities around Yakutak (Fig 3a), during the return leg three weeks later surface temperatures in SE has warmed as much as 2°C in some areas (Fig, 3b). Surface salinities were low in some nearshore waters in SE, and particularly in nearshore water around Yakutak, and near the tip of Kayak Island. Temperatures in the Western Gulf were slightly cooler typically between 5-6°C, with slight cooler temperatures over the banks south of Kodiak Island where sampling began. Temperature profiles in the Western Gulf show the beginning of stratification with a notably cool subsurface layer. Climatology along the Seward Line shows spring 2011 to be slightly cooler than the average observed over the past 14 years (Fig 5).

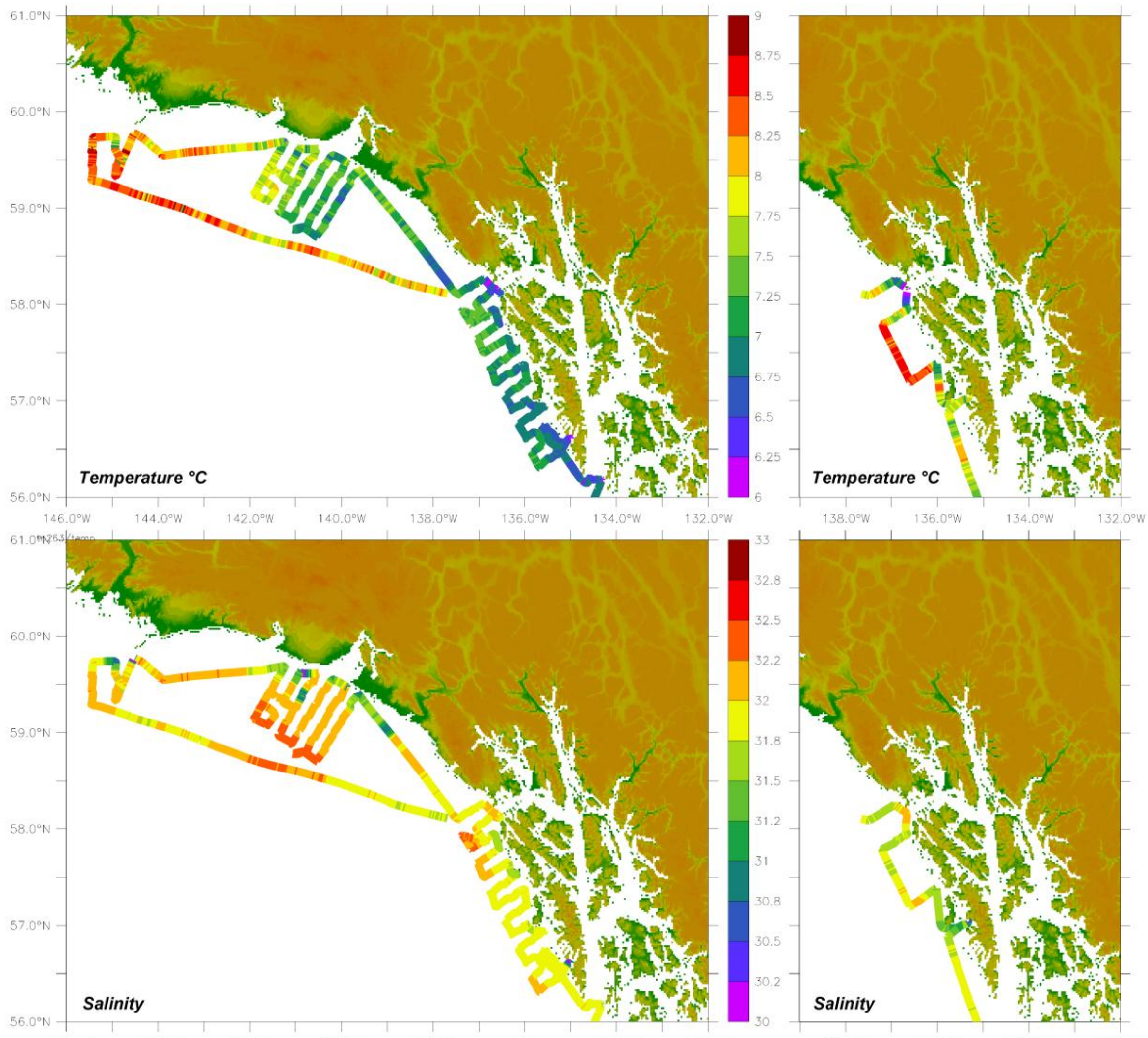

Figure 3. Sea surface temperature and salinity as measured by the underway system during the 2011 Thompson cruise. Panels on left are temporal continuance of cruise tracks.

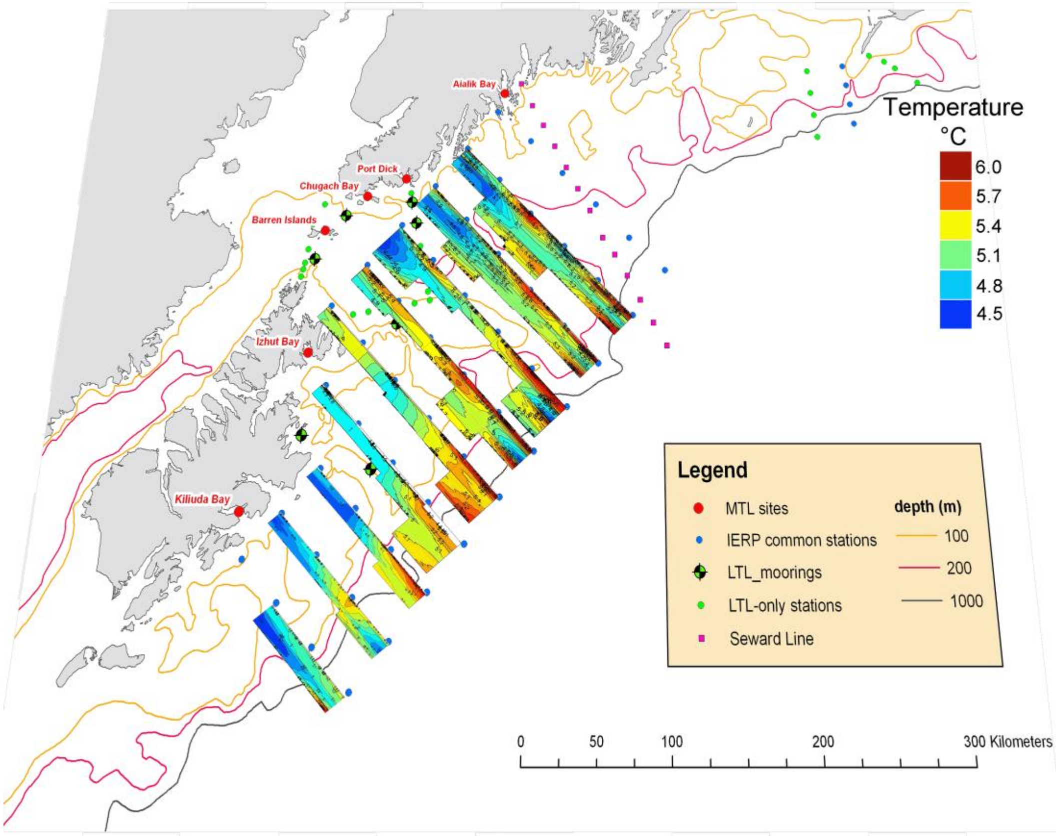

Figure 4. Temperature sections along the UTL survey grid in the Westerns Gulf during late April through early May. Note cooler waters over the shoals south of Kodiak Island as well as in the northwestern part of the grid.

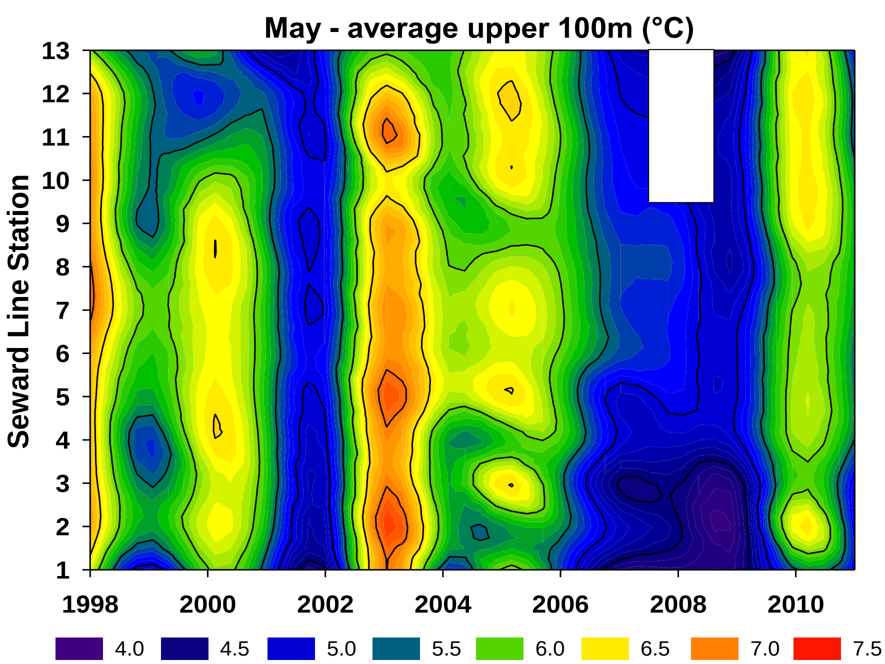

Figure 5. Average temperature in the upper 100m of water along the Seward Line. The 2011 temperatures are ~0.5 °C colder than the mean.

Macro-nutrient data (Mordy):

At present, nutrient data is only complete for the *Thompson* cruise. Nitrate concentrations in surface water at the start of the cruise in SE were generally above 10 µM (Fig. 6a), they declined somewhat in the Yakutak transects and were slowest in the nearshore waters around Kayak Island. During the return leg nitrate concentrations had been dawn down completely in nearshore water along repeated transects and in situ fluorescence suggested correspondingly high concentrations of chlorophyll (Fig. 6b).

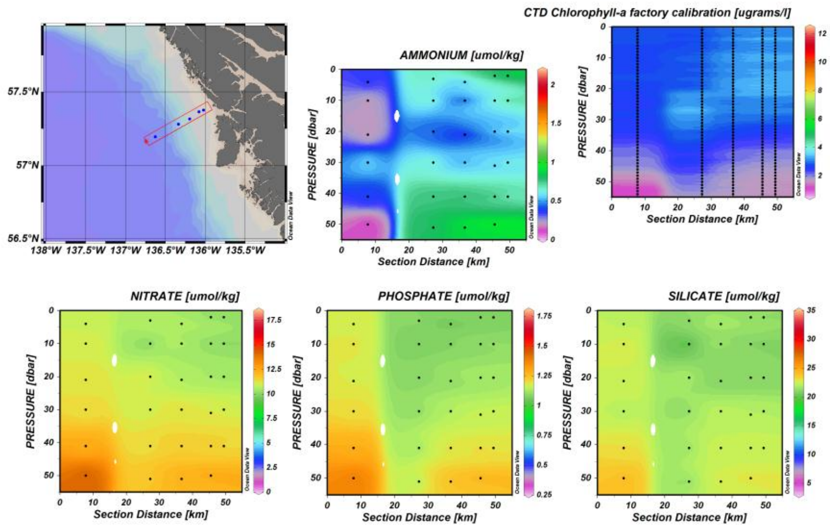

Figure 6a. Concentrations macro-nutrients and in situ chlorophyll fluorescence along the SEG line in early May 2011.

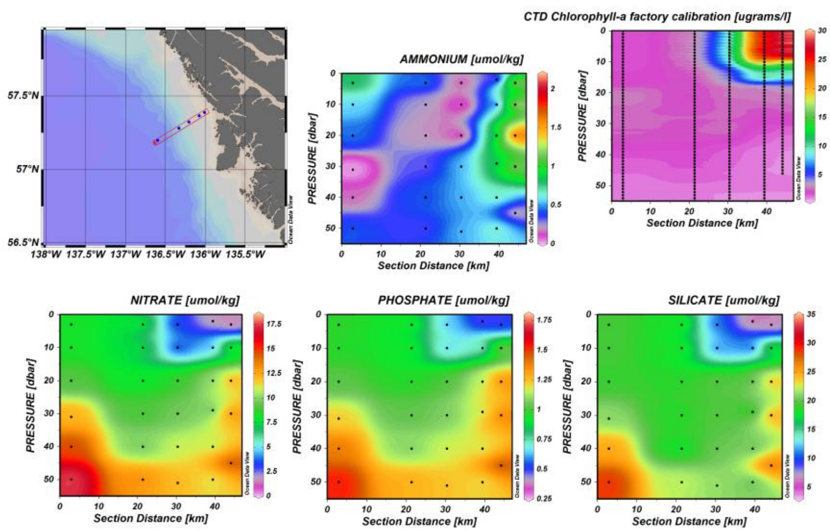

Figure 6b. Concentrations macro-nutrients and in situ chlorophyll fluorescence along the SEG line in late May 2011. Note the inverse relationship between chlorophyll and nitrate.

Iron (Aguilar-Islas, Rember & Stockwell)

During the Thompson cruise, a total of 115 surface samples were collected along 7 transects: 52 for each of total dissolvable iron and dissolved iron; 5 samples for soluble iron; and 6 samples for organic iron speciation. Seawater and suspended particles were also collected at 9 stations from various depths (20 - 1000 m) for a total of 161 samples: 38 for each of suspended particles, total dissolvable iron; dissolved iron and soluble iron, plus 9 samples for organic iron speciation. During the Fall *Tiglax* cruise a total of 47 surface samples were collected; 22 for total dissolvable iron; 22 for dissolved iron; 3 samples for organic iron speciation.

Analysis of samples collected during the 2011 cruises is in progress. To date we have determined the concentration of dissolved iron for surface transects and vertical profiles. During April/May 2011 we observed surface dissolved iron concentrations ranging from 0.28 nM (offshore along transect 5) to 4.50 nM inshore near Kayak Island. The vertical distribution of dissolved iron at the stations sampled during April/May 2011 showed typical distributions with concentration increasing with depth. It is worth noting we proposed to collect samples from 6 stations in the eastern GOA, but were able to collect from 9 stations, and obtained surface samples from a wide region (Fig. 2). During September 2011the western GOA had in general lower surface dissolved iron concentrations ranging from 0.052 nM at GAK 13 to 4.87 nM at GAK 1 (Figure 7). Concentrations dropped quickly from inshore to offshore and subnanomolar concentrations of dissolved iron were observed from GAK4 to GAK 13. The dynamic nature of these waters can be seen in concentration differences in time. One sample taken from a station in Prince William Sound had a dissolved iron concentration (4.6nM) in the same range as the innermost GAK station (4.87 nM DFe at GAK1).

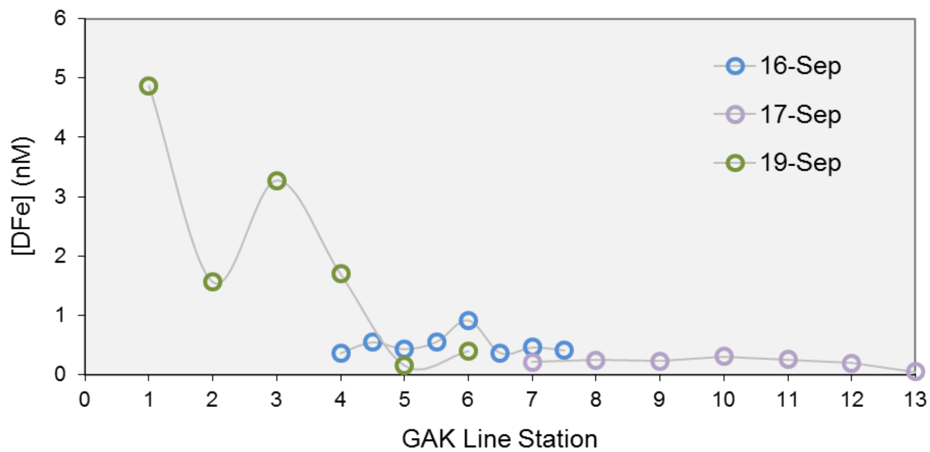

Figure 7: *Surface dissolved iron (DFe) concentrations along the GAK line during September 2011. Data was collected over three days.*

Phyto- and microzooplankton (Strom & Fredrickson):
Chlorophyll levels in spring on the shelf were lower than expected and few stations showed signs of high chlorophyll levels dominated by large cells (i.e. a spring bloom). Rather, chlorophyll concentrations at most stations were <3 µg/liter, and nearly all chlorophyll was in cells <20 µm in size. An exception was the area offshore of Kayak Island. The indication from chlorophyll measurements that most spring phytoplankton biomass was in small cells was borne out by the analysis of pico- and nanoplankton community composition by epifluorescence microscopy. We observed an unexpectedly high abundance of the very smallest phytoplankton cells, including the cyanobacteria *Synechococcus* spp. and an unidentified tiny (<2 µm) photosynthetic flagellate. The former reached abundances of $1.1x10^5$ *Synechococcus*/ml at YBE2.5 (off Yakutat Island). Preliminary observations indicate that diatoms, whether large or small, were scarce at most spring stations. Carbon biomass estimates for this community are in progress.

In total 27 experiments to assess the phytoplankton photosynthesis-irradiance relationship and estimate primary production were conducted on May RV Thompson cruise to SE Alaska. Preliminary analyses indicate that the phytoplankton community was adapted to relatively low light levels at most stations. Photosynthetic responses differed between the small (picoplankton) and large (diatom) size fractions, with the former contributing most of the production on a volumetric basis, but the latter often exhibiting higher photosynthetic rates per unit chlorophyll. Photoinhibition at near-surface light levels was commonly observed in both size fractions.

Microzooplankton samples collected from selected grid stations on LTL and UTL cruises are in the early stages of analysis.

Metazooplankton (Hopcroft)
Metazoan zooplankton was collected successfully on all cruises, with the exception of stations not occupied during UTL cruises in 2011. Taxonomic processing of zooplankton was only proposed to be conducted along the Seward Line due to budget constraints. Although failure of the hydrographic winch prevented stratified night-time zooplankton collection using the Multinet on the Seward Line, the dominant copepod species that net targets in the spring can be assessed with somewhat broader confidence intervals using the daytime Calvet collections.

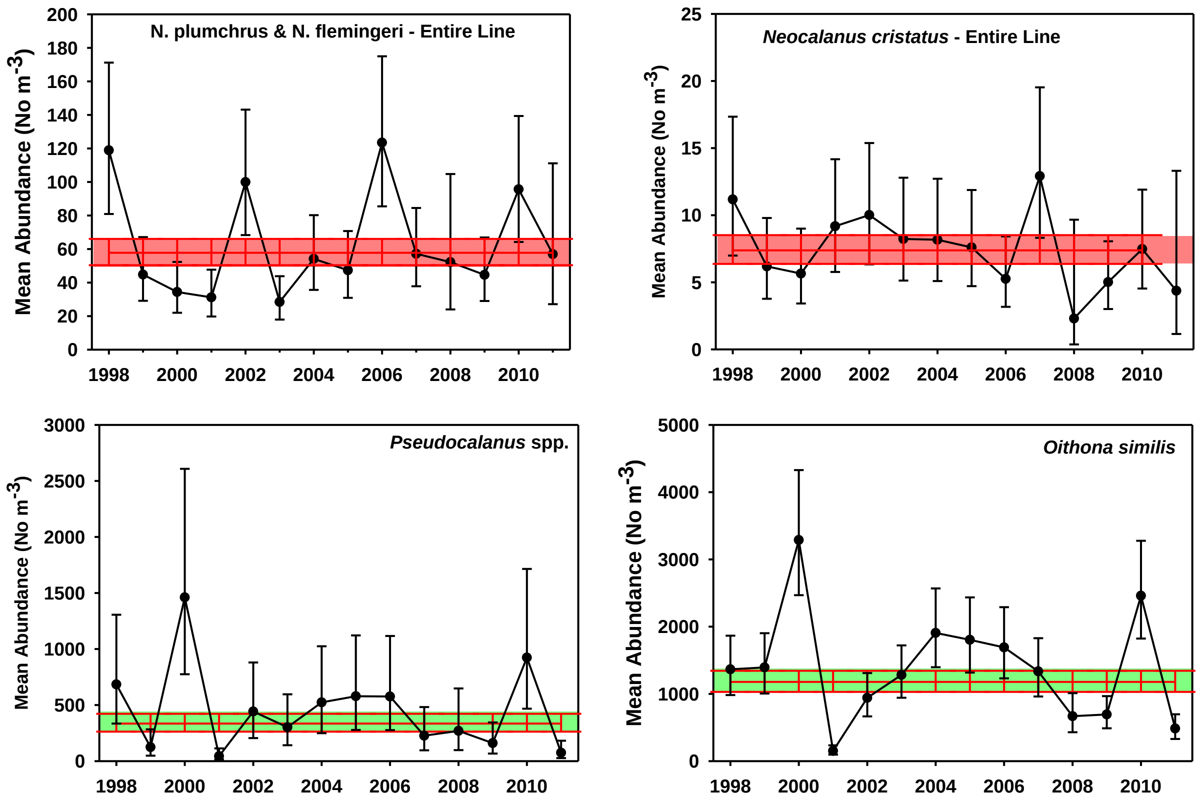

Figure 8. The dominant spring-time zooplankton species of the Coastal Gulf of Alaska as observed along the Seward Line. For these 4 copepod species, Neocalanus spp. abundances are typically based on Multinet samples, while Pseudocalanus spp. and Oithona similis are based on Calvet collections.

Abundance of all *Neocalanus* species was at or below the long-term mean, with the larger numbers of earlier life-stages present suggesting somewhat delayed rates of growth (Fig. 8). Even abundance of small copepods such as *Pseudocalanus* and *Oithona* targeted by the Calvet was well below the long-term mean. Overall this suggests not only a delayed timing of spring productivity, but one of lower magnitude, with likely consequences for higher trophic levels dependent directly or indirectly on zooplankton production.

Work continues on training the computer to classify zooplankton at standard LTL grid stations from scanned images. The processing capacity freed up by not having Multinet collections along the Seward Line in spring 2011 will be diverted to processing the majority of 505 µm collections by traditional techniques in addition to scanning. This approach will both validate the method, and provide a better dataset for comparison to the model predictions.

Ichthyoplankton Component (Napp, Matarese & Doyle)

Efforts were split between two different activities during the reporting period: analyzing samples and data from the 2010 pilot cruises (spring and summer), and planning and staging the 2011 cruises. Bongo samples were collected in 2010 on the two UTL pilot cruises for the southeast coast of Alaska (Fig. 9). The samples were processed at the Polish Plankton Sorting and dentification Center and verified in our Seattle laboratory. They show that in the spring, larvae from each of the five key I species were present with the majority of the larvae from the target species being collected seaward of the shelf break in water depths greater than 2,000 m.

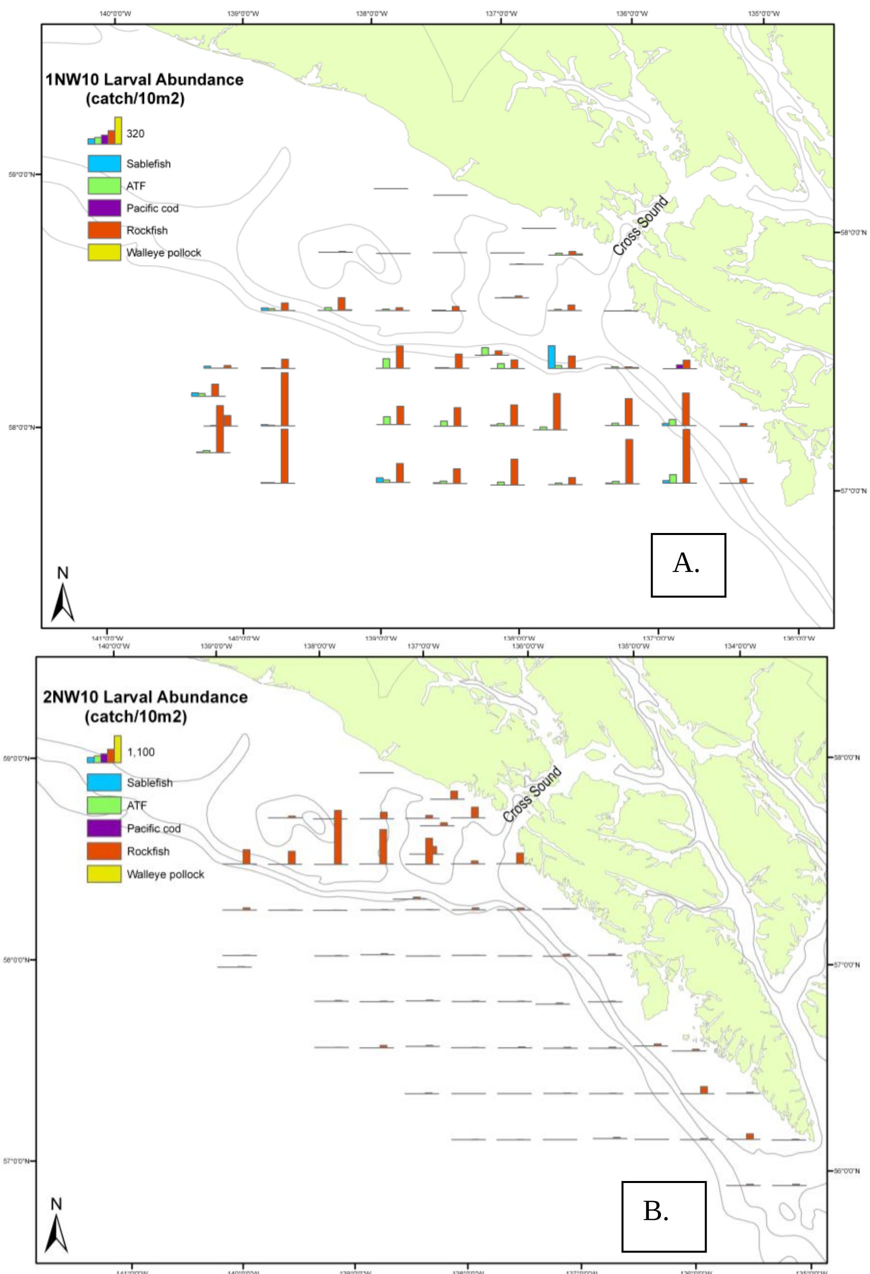

Figure 9. Larval abundance (No. larvae per 10 m^2) for the GoA IERP target taxa collected during the 2010 pilot study. Note the difference in scale height in the two figures. A) Spring, B) Summer.

During the 2010 spring cruise the vast majority of larvae were rockfish. The walleye pollock collected were still in the egg stage, and were located north of Cross Sound in water depths of less than 500 m. In the summer, only one of the five key species were collected – rockfish. The majority of rockfish larvae were in the vicinity of Cross Sound and on the shelf in water depths of 1,000 m or less. The average length of rockfish larvae collected in the summer was very similar to the average length in the spring (approximately 4.8 mm) suggesting that the summer larvae were recently extruded, i.e. a second cohort in summer that was different from the spring spawning fish (either different species or a different stock).

The group was also very active in the planning of the 2012 field season and participated in the spring cruise aboard the R/V *Thomas G. Thompson* sampling from Chatham Strait to Kayak Island (see attached TN263 Cruise Report). We also obtained samples for larval fish from the spring R/V *Tiglax* cruise (western GoA) and the first two summer F/V *Northwest Explorer* cruises (southeastern and western GoA). All samples have been sent to Poland for sorting, identification, enumeration, and measurement. Data from the spring samples will likely arrive in January and the data from the summer cruises in May. During the Thompson cruise, we obtained 116 neuston, 114 bongo, and 29 MOCNESS samples for preservation and analyses. While at sea on the R/V *Thompson*, we did a quick examination of the contents of the other bongo net sample that was preserved for zooplankton. Our general impressions were as follows: very few pollock or cod larvae were in the surface waters of the southeastern Alaska during the R/V *Thompson* cruise; rockfish larvae (*Sebastes* spp.) were commonly found near and beyond the shelf edge, when present; sablefish larvae (*Anoplopoma fimbria*) were often in the neuston net on the outer shelf and their abundances seemed to be higher at night, than during the day. Arrowtooth flounder (*Atheresthes stomias*) larvae were not observed in these quick examinations.

Sample collection on the R/V *Tiglax* and F/V *Northwest Explorer* were equally successful. The spring R/V *Tiglax* cruise collected 47 neuston and 46 bongo samples on the shelf and at the shelf break in the western GoA. The F/V *Northwest Explorer* collected 52 neuston and 50 bongo in the southeast and 53 bongo and neuston samples in the western GoA.

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. Greatest effort was involve in activities related to UTL cruises.

e. Describe any concerns you may have about your project's progress.

Changes in ship schedules prevented measurement of iron or primary production in WGOA during spring. Fall iron sampling was limited to surface waters during fall along the Seward Line due to limitations in lab and deck space, plus a tight sampling schedule imposed by bad weather and equipment failures. It is doubtful that iron profiles can be conducted from the *Tiglax* unless suitable space for storage of samplers and a trace metal clean processing station can be created. Similarly, give the difficulties of using radioisotopes on the Thompson, it is unlikely that radioisotopes can be use on the *Tiglax* to construct P-I curves without a suitable lab-space for their use, although it may be possible to measure bulk primary production with stable isotopes. This limited sampling is not adequate to address regional differences between the eastern and western GOA for these parameters. During the 2013 field season we anticipate that the NOAA and the UNOLS vessels would be adequate for radioisotope use and iron sampling/processing.

However, time, space, and equipment limitations on the *M/V Tiglax* need to be resolved for work to be executed from that platform.

Underway sampling of hydrographic data expected on the *M/V Tiglax* was not possible due to possible due to equipment failures, and the chief scientist was not made aware of this prior to either cruise. This region is dynamic, and an operational underway sensor package is needed on the *Tiglax* during the 2013 cruise(s) to match to underway measurements of iron.

Three major hurdles experienced during the extended field season were: record keeping/cruise data dissemination, staffing, and equipment. The first issue resulted because the LTL component involved many different cruises, often with sample collection being accomplished by one Project for another. We learned from this experience and will do a better job in 2013 to ensure efficient and complete data recording and effective data custody procedures are in place. Staffing and equipment issues were discussed at the recent GABI meeting and will also be worked on during the intervening year.

A major concern remains Ballooning responsibility for additional project components and cost overruns on ship-time, equipment/supplies, travel and personnel costs. While the PIs remain committed to doing what it takes to create a successful program, these added demands will limit future flexibility.

f. Poster and oral presentations at scientific conferences or seminars

None presented – several abstracts are submitted to the 2012 AMSS.

g. Education and outreach

Hopcroft participated in the Gulf of Alaska teacher's workshop head in Anchorage late July.

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.

4. PROGRESS STATUS

Most planned activities were completed over the field season. Despite sampling difficulties, iron measurement appears to have been successful during both spring and fall cruises. Analysis has fallen behind due to diversion of personnel onto cruises and delays in receiving samples.

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	
Processing of metazooplankton	**Hopcroft**	Fall2011/Winter2012/Spring 2012	
Interpret 2010 Ichthyoplankton Data	**Napp**	Fall2011/Winter2012	
Process maco-nutrient samples	**Mordy, Hopcroft**	Fall2011/Winter2012	
Process mooring and CTD datasets	**Stabeno, Mordy**	Fall2011/Winter2012	
Total dissolvable Fe analysis	**Aguilar-Islas, Rember**	January/February 2012	
Particulate Fe sample processing	**Graduate Student**	Starting May 2012	

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.	January 2012	amaguilarislas@alaska.edu
Surface and vertical profile total dissolvable Fe data from the LTL April/May 2011 cruise	March/April 2012	amaguilarislas@alaska.edu
Spring hydrogaphic data (T, S, PAR, fluorescence, oxygen, nutrients)	Drafts available for Thompson – awaiting post-season calibration	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
2010 Ichthyoplankton	September 2011	Kimberly.Bahl@NOAA.gov