1. PROJECT INFORMATION

GOA IERP Project Number:	Retrospective Components of all GOA IERP projects
Title:	Gulf of Alaska Retrospective Data Analysis
Overall project duration	October 1, 2010 to September 30, 2014
Overall project funding	(Included in UTL, MTL, LTL, and Modeling budget)
Report period	October 1, 2011 to March 31, 2012
Report submission date	April 24, 2012
Lead Author of Report*	Franz Mueter

Principal Investigator(s), Co-Principal Investigators and Recipient Organization(s):
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2. PROJECT OVERVIEW

a. Briefly (4-5 sentences) describe the core purpose of your project, and the underlying need for this research.

Retrospective analyses are an integral part of each of the major components of the GOAIERP. The overall goal of these analyses is to examine physical and biological characteristics across the Gulf of Alaska to (1) provide historical context for new observations and measurements, (2) quantify spatial and temporal variability in key physical and biological characteristics of the coastal GOA, (3) elucidate relationships between physical and biological drivers of recruitment and upper trophic level variability, (4) test *a priori* hypotheses about these relationships, and (5) develop new hypotheses for field biologists and modelers to test in the future.

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

The retrospective analyses cut across all project components and will address to various extents each of the three overarching project hypotheses:

*The gauntlet***:** The primary determinant of year-class strength for marine groundfishes in the GOA is early life survival. This is regulated in space and time by climate-driven variability in a biophysical gauntlet comprising offshore and nearshore habitat quality, larval and juvenile transport, and settlement into suitable demersal habitat.

Regional comparison: The physical and biological mechanisms that determine annual survival of juvenile groundfishes and forage fishes differ in the eastern and western GOA regions.

Interactions: Interactions among species (including predation and competition) are influenced by the abundance and distribution of individual species and by their habitat requirements, which vary with life stage and season.

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

The retrospective component will address at least two of the overall list of objectives that were developed to address the three overarching project hypotheses.

(4) Use a comparative approach to assess spatial and temporal variability in the ecosystem, primarily between the eastern and western Gulf of Alaska regions among spring, summer, and fall.

(8) Use historical datasets to analyze temporal variability in potential climatic, oceanographic, or biological drivers influencing the early life survival of key groundfish species.

Specific objectives are addressed within each of the different retrospective components and are listed separately by component:

1) *Upper Trophic Level (UTL) component:*
   a) Collate relevant life history information for the five focal species and other linked species such as time of spawning, development, growth, recruitment histories, and habitat preferences.
   b) Compile available datasets to characterize spatial and temporal variability in the physical and biological environment of the GOA shelf and slope regions, including adjacent offshore regions, and identify datasets that represent potential drivers of recruitment variability of the five focal species in the study region.
   c) Develop spatial maps of mean conditions for representative datasets by trophic category to identify long-term patterns and delineate a faunal or physical break between the eastern and central GOA.
   d) Quantify, by region, the temporal variability in potential climatic, oceanographic, or biological drivers influencing the early life survival of the five target groundfish species.
   e) Link variability in these drivers to observed recruitment variability using a generalized modeling approach informed by available information on potential mechanisms.
   f) Compare temporal trends in estimated recruitment trajectories between regions and across species to identify successful life history strategies under different climate regimes.

2) *Forage fish or Mid Trophic Level (MTL) component:*
   a) Collate historical information on forage community structure in the coastal GOA.
   b) Analyze how community structure has changed over time and relate observed changes to variability in the environment and to the abundance of upper level predators.
   c) Collect and analyze data on historical habitat associations and compare to environmental information to investigate how climate affects habitat.
   d) Compare current predator-prey relationships involving forage fish, as inferred from diet compositions, to historical food web information.

3) *Lower trophic Level (LTL) component:*
   a) Characterize scales of inter-annual and longer-term variability in phyto- and zooplankton.
   b) Examine egg and larval distributions and abundances of target species in relation to topographic features and local physical oceanography to infer ontogenetic drift patterns of target species.

c) Examine early life survival relative to forcing variables to illuminate potential mechanisms of environmental forcing of variability in larval abundances.
d) Elucidate the importance of wind forcing (gap & barrier winds) to shelf circulation

3. PROGRESS SUMMARY

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

What	*Who*	*Start and end dates*	*Other key dates*
Task 1: Continue compilation and analysis of upper trophic level data (fish, seabirds, mammals) (1b)	**Jason Waite**	Oct 1, 2011 – Mar 31, 2012	AMSS, Jan 16-20, 2012
2. Characterize interannual variability in upwelling and wind mixing in eastern and western GOA.	**Jason Waite, Brendan Coffin**	Nov. 1, 2011 – Dec 31, 2012	
3. Validation of Chl a from SeaWiFS/MODIS with available in-situ measurements (1c)	**Jason Waite**	Nov. 1, 2011 – Dec 31, 2012	
3. Draft manuscript on Chl *a* variability (1c,d)	**Jason Waite, Franz Mueter**	Jan 31, 2012	
4. Compile and summarize discharge data, characterize interannual variability	**Brendan Coffin**	Oct 1, 2011 – Mar 31, 2012	
5. Update analysis of groundfish survey data through 2011 to characterize trends and variability in the GOA groundfish community 1990-2011, summarize results and post to SharePoint, outline potential manuscript	**Jason Waite, Franz Mueter**	Feb 1, 2012 – Mar 31, 2012	GOA IERP PI meeting, week of March 5
6. Post summary of results with key maps and indicator time series on SharePoint site as they become available (1c,d)	**Jason Waite**	Oct 1, 2011 – Mar 31, 2012	
7. Continue compilation, analysis and synthesis of historical ichthyoplankton data and contribute summary information to SharePoint site.	**Miriam Doyle**	Oct 1, 2011 – Mar 31, 2012	
8. As requested, continue to provide parameter information to Modelers for development of IBMs	**Miriam Doyle**	Oct 1, 2011 – Mar 31, 2012	
9. Continue to develop a manuscript that will provide a comprehensive review of the early life history patterns of the 5	**Miriam Doyle**	Oct 1, 2011 – Mar 31, 2012	

key species in the context of the GOA-IERP program (1a)			

b. Describe report period progress.

Objective 1a)
Synthesis of the historical ichthyoplankton data from primarily the western Gulf of Alaska (GOA) continues with the development of a manuscript (see Objective 3 results below) describing detailed early life history pelagic exposure patterns for the focal species. Temporal and spatial patterns of spawning, larval abundance and size, and larval drift patterns are discerned from the available data and links between early life history patterns and the environment are evaluated with respect to early ontogeny aspects of the recruitment process. A limited amount of historical data from the eastern GOA allows a regional comparison of early life history patterns between the eastern and western GOA.

Objective 1b)
Compilation of upper trophic level data (fish, seabirds, mammals) is ongoing (Task 1). Seabird data from the North Pacific Seabird Database has been obtained and analysis has begun. Marine mammal diet data from unpublished and published sources has been compiled, and data from the 2011 bottom trawl survey has been added to the existing fish data. Sea surface height (SSH) data was recompiled for 1998-2011 at 1/4° resolution based on a newly available Aviso data product. Chl-a, SST, and PAR data was subsequently resampled from the original 4 or 9 km resolution to 1/4°, replacing the 1/3° product used for earlier analyses. All compiled gridded data is being converted to netCDF format and will be made available on the newly-developed GOA IERP data portal.

Objective 1c,d)
A first draft of a manuscript has been prepared (Task 3) that includes results of spatial and temporal analysis of chlorophyll-a variability from 1998-2011 using a combined SeaWiFS and MODIS-Aqua dataset. Cluster analysis was performed to delineate regions of similarity and generalized additive models were used to explore relationships between regional variability in chlorophyll anomalies with respect to sea surface temperature, photosynthetically-available radiation, sea surface height anomalies (eddy activity), upwelling, and freshwater discharge. Seasonal variability in discharge has been summarized and summary figures will be uploaded to ocean workspace. Validation of remotely-sensed data with *in situ* data is ongoing (Task 3) and will be updated/completed as more *in situ* chlorophyll data becomes available. Groundfish analysis is being updated to include 2011 survey data (Task 5). Updated summary figures for chlorophyll, SST, SSH, and PAR time series, EOF results, and climatologies have been posted to the SharePoint site (Task 6). These figures will be posted to the new GOA-IERP data portal in the upcoming weeks.

Objective 1e
Monthly discharge data have been acquired for years 1931 – 2008 from the University of Alaska Fairbanks Institute of Marine Science (IMS). Interannual and seasonal trends have been investigated using generalized additive models (GAMs) and linear models. Log-transformed sablefish recruitment was regressed against monthly mean gulfwide freshwater discharge and monthly mean gulfwide upwelling indices. Discharge and Upwelling were examined at multiple monthly lags. GAMs were used to explore for potential non-linear relationships between recruitment and explanatory variables, and linear models were used to determine significant variables and lags that may help explain variability in recruitment of sablefish.

Objective 2)
No activity to date.

Objective 3)
Spatial, seasonal, and interannual patterns of variation in abundance of the early ontogenetic stages of the focal species have been integrated into the development of individual pelagic exposure profiles for these species. Seasonal patterns in abundance, distribution and larval length frequencies are described as well as interannual variation in larval abundance from the late spring western GOA time-series, 1981-2009. Vertical distribution patterns of the larvae during progressive sub-intervals of development are synthesized from MOCNESS samples collected intermittently primarily during spring (1986-2003) and some summer months (2002-2004). Limited historical ichthyoplankton data (published and unpublished) from the eastern GOA are reviewed and utilized in a comparison of pelagic exposure patterns between the western and eastern GOA. Observed similarities and synchronies with other species (as presented in Doyle and Mier, submitted), as well as evaluation of links between larval abundance patterns and the physical environment are also included in the exposure profiles. Relevant summary tables and figures from this synthesis will be posted to the new GOA-IERP data portal in the coming months.

c. Describe preliminary results.

Objectives 1b, 1c, 1d)
We have divided the study region into 4 regions of similarity (Figure 1) with regards to chlorophyll variability: 1) Eastern Shelf Region; 2) Eastern Off-shelf Region; 3) Western Shelf Region; and 4) Western Offshelf Region. Chlorophyll variability in the Eastern Onshelf Region (waters landward of the 1000 m isobath and east of Cook Inlet) is driven primarily by coastal upwelling, freshwater discharge, SST, and PAR anomalies (Waite & Mueter, in prep). SST anomalies were positively correlated with chl-a anomalies in the spring, but negatively correlated in the fall. Upwelling, discharge, and PAR anomalies were all positively correlated with chl-a anomalies. Chlorophyll variability in the Eastern Offshelf Region (waters seaward of the 1000m isobath and east of the Kenai Peninsula) appears to be driven primarily by SSH and upwelling anomalies. Chl-a anomalies are positively correlated with eddy activity (SSH) in the early spring, but negatively correlated in the summer and fall. PAR and freshwater discharge anomalies are significantly correlated with chlorophyll anomalies in the Western Shelf Region (Figure 1), and SST, SSH, and discharge anomalies are significantly correlated with chl-a anomalies in the Western Offshelf region.

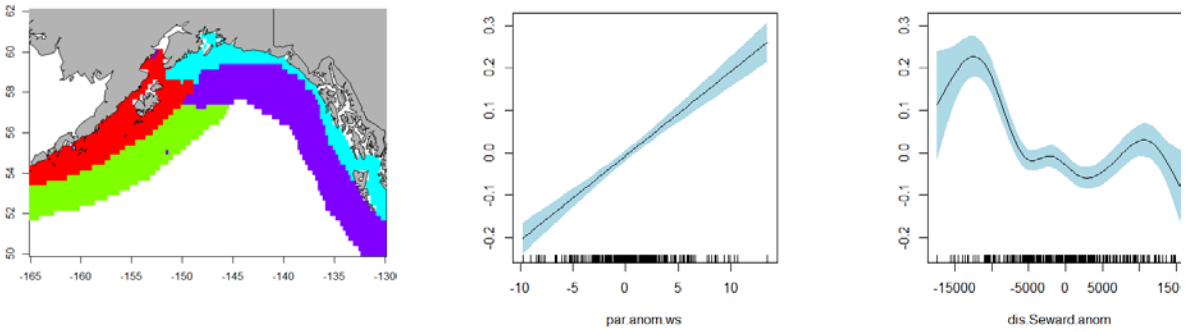

Figure 1*. Regions of chlorophyll variability (left) and relationship between chl-a anomalies in the Western Shelf Region with PAR and freshwater discharge anomalies.*

EOF analysis has also been completed on PAR data from a combined SeaWiFS and MODIS-Aqua dataset for 1998-2011. The second EOF (Figure 2) mode shows a spatial break between 147–150°W, which is similar to the spatial break demonstrated by the second SST EOF mode. This break also closely aligns with delineation between the eastern and western chlorophyll regions (Figure 1).

Related paper in preparation
Jason N. Waite and Franz J. Mueter (In prep). Spatial and temporal variability of chlorophyll-*a* concentrations in the coastal Gulf of Alaska, 1998-2011, using cloud-free reconstructions of SeaWiFS and MODIS data.

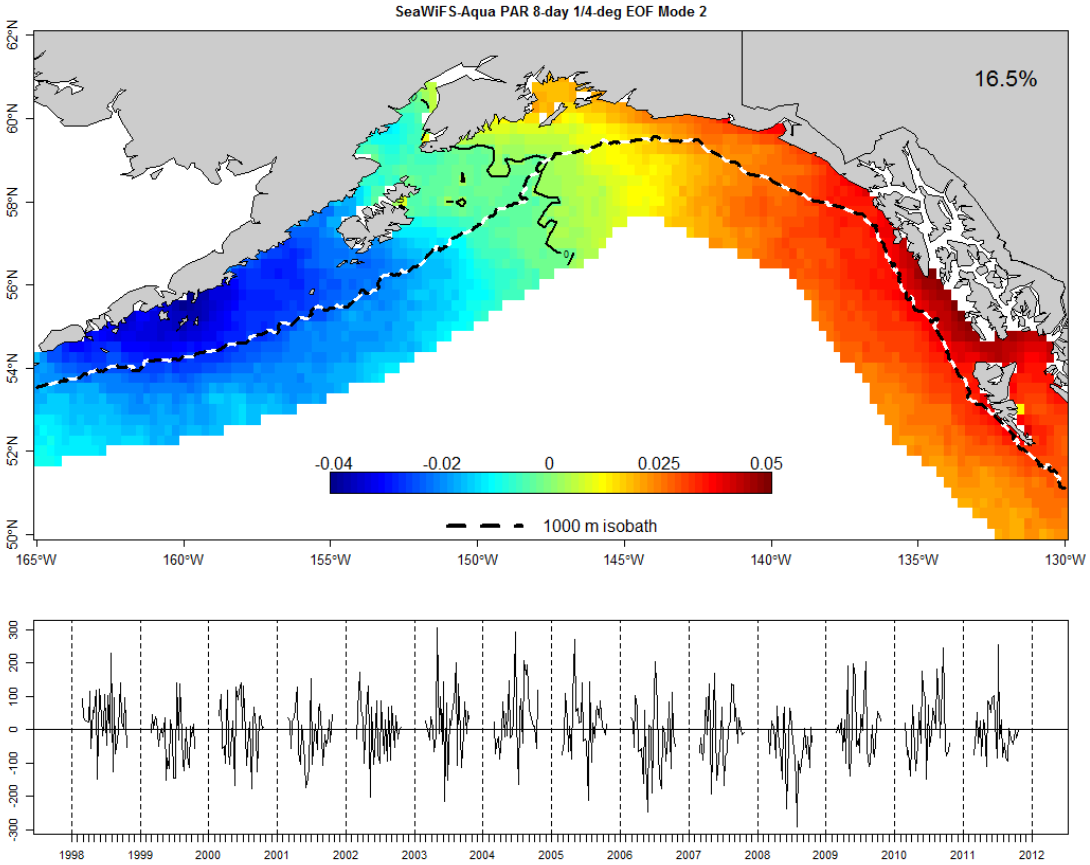

Figure 2. *EOF mode 2 spatial loadings (upper panel) and time series (lower panel) for combined SeaWiFS and MODIS-Aqua 1/4° 8-day PAR data for 1998-2011.*

Objective 1e)
Sablefish recruitment shows a significant negative relationship with February discharge ($\beta = -0.48$; $t = -2.13$; $p = 0.04$) and a significant positive relationship with March discharge ($\beta = 0.53$; $t = -2.40$; $p = 0.02$). No significant relationship between upwelling and recruitment was found at any lag.

Objective 2)
No results to date

Objective 3)
The comprehensive early life history reviews of the five key species are being developed into a single large manuscript for submission to the NOAA professional paper NMFS series (Doyle, in prep). Some key findings from this synthesis include: Seasonal variation in the occurrence and distribution of "hot-spots" in larval abundance unique to each species, reflecting their prevailing spawning and larval habitats; the identification of cross-shelf larval transport pathways for the deep water spawners (arrowtooth flounder, sablefish, and rockfish i.e. *Sebastes* spp.) that are associated with troughs and gulleys along the continental slope, particularly Amatuli trough to the northeast of Kodiak Island and outer Shelikof sea valley to the southwest; the occurrence of separate spring and summer cohorts of *Sebastes* spp. larvae that

indicate two distinct rockfish species groups and spawning events; the detection of differences in spawning activity and larval abundance between the eastern and western GOA with Pacific cod and walleye pollock prominent in the west and sablefish and rockfish species in the east. Interannual variation in abundance of larvae of the target species during late spring from 1981through 2009 are presented in Figure 3. Preliminary results have been presented at the 2012 Alaska Marine Sciences meeting, and at the GOAIERP March 2012 Principal Investigator's meeting. Related early life history synthesis research incorporating the GOAIERP species was presented at the 2012 Western Groundfish Conference in Seattle in February, and is included in a manuscript submitted to Canadian Journal of Aquatic Sciences (Doyle and Mier, submitted), April 13th 2012.

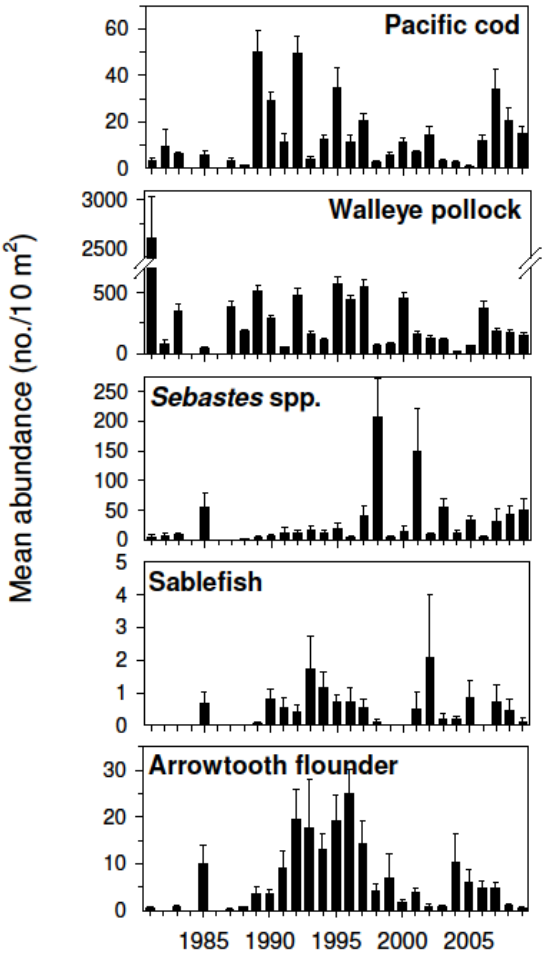

***Figure 3**: Interannual variation in abundance of four of the focal species and rockfish (Sebastes spp.) larvae from the late spring western GOA time-series, 1981-2009.*

Related papers submitted or in preparation

Doyle, M.J. and Mier, K.L. (submitted). A new conceptual framework for evaluating early life history aspects of recruitment dynamics among marine fish species. Canadian Journal of Fisheries and Aquatic Sciences.

Doyle, M.J. (in prep). Pelagic early life history exposure patterns of selected commercially important fish species in the Gulf of Alaska. For submission to NOAA Professional Papers NMFS series.

d. Describe integration activity.

Most PIs and Jason Waite have participated in monthly conference calls. Information on retrospective datasets and preliminary results from analyses has been shared via the SharePoint website. Juneau PIs (Shotwell, Mueter) met on several occasions with Jason Waite and Brendan Coffin (M.S. student) to discuss and coordinate analyses being done at UAF and at the Auke Bay Lab and to outline potential manuscripts. Doyle and Hinckley have met several times to discuss information useful to the modeling work. All PIs, Jason Waite, and Brendan Coffin participated in the PI meeting in Juneau in March 2012.

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

No major concerns at this point. Some of the datasets that were identified in initial scoping, for example seabird trends and diets, have been difficult to acquire or are not available in a format that can readily be prepared for analysis. Datasets for analysis will be prioritized as not all of the initially identified datasets can be fully analyzed within the scope of the retrospective component.

f. Poster and oral presentations at scientific conferences or seminars

- Jason Waite gave an oral presentation at the Alaska Marine Science Symposium in Anchorage, AK, in January 2012, on the results of the chlorophyll-a retrospective analysis (Jason N. Waite and Franz J. Mueter. "Spatio-temporal analysis of chlorophyll-a concentrations in the coastal Gulf of Alaska, 1998-2010"
- Franz J. Mueter, Miriam J. Doyle, Jason N. Waite, S. Kalei Shotwell, Kimberly M. Rand, and Sarah Hinckley. "Gulf of Alaska Retrospective Data Project". Alaska Marine Science Symposium, Anchorage, Alaska, January 2012.
- Brendan Coffin and Franz Mueter. Poster presentation on "Environmental Covariates of Recruitment of Two Demersal Fish Species, Sablefish (*Anoplopoma fimbria*) and Pacific Ocean Perch (*Sebastes alutus*), in the Gulf of Alaska". Western Groundfish Conference. Seattle, WA, February 2012.
- Jason N. Waite and Franz J. Mueter. Poster presentation on "Spatio-temporal variability of chlorophyll-a concentrations in the Gulf of Alaska, 2000-2011".
  - Ocean Science Meeting, Salt Lake City, Utah, February 2012.
  - GOA-IERP PI Meeting (March 7) in Juneau
- Miriam Doyle and Kathy Mier. "A new conceptual framework for evaluating early life history aspects of recruitment dynamics among marine fish species." Oral presentation at the Western Groundfish Conference, Seattle, February 6-10, 2012.
- Miriam Doyle. Poster presentation on "Building early ontogeny pelagic exposure response profiles for GOAIERP species based on historical ichthyoplankton data: Pacific cod"
  - GOA-IERP PI Meeting (March 7) in Juneau.
  - EcoFOCI seminar (March 21) at NOAA PMEL, Seattle.

g. Education and outreach

None to date

4. PROGRESS STATUS

We have made satisfactory progress and completed the tasks scheduled for the current reporting period. Data compilation is ongoing and analyses to date have focused on lower trophic level dynamics, including an analysis of historical ichthyoplankton data and an analysis of satellite-based Chlorophyll estimates.

This has resulted in one draft manuscript to date. These analyses will provide important baseline information for the modeling efforts, as well as time series indices of physical and lower-trophic level variability to be used in analyses of recruitment trends of our focal species.

5. FUTURE WORKPLAN and DATA DELIVERY

Workplan

What	*Who*	*Start and end dates*	*Other key dates*
1. Characterize spatial, seasonal and interannual variability in upwelling in eastern and western GOA (Obj. 1b, d)	**Brendan Coffin, Franz Mueter**	Nov. 1, 2011 – Dec 31, 2012	
2. Characterize seasonal and interannual variability in discharge in eastern and western GOA (1b, d)	**Brendan Coffin**		
3. Continue validation of Chl a from SeaWiFS/MODIS with available in-situ measurements (1c)	**Jason Waite**	Nov. 1, 2011 – Dec 31, 2012	
4. Submit manuscript on Chl *a* variability to Deep Sea Research or Progress in Oceanography (1c,d)	**Jason Waite**	By July 31, 2012	
5. Post data and results from analysis of environmental variability and Chl. a to GOA IERP Ocean Workspace (1b,c,d)	**Jason Waite**	Apr 20 - May 31, 2012	
6. Continue and complete analysis of groundfish survey data (1b)	**Jason Waite / Franz Mueter**	August 1, 2012 – December 31, 2012	
7. Continue to compile seabird and marine mammal diet and abundance data from published and unpublished sources.	**Jason Waite**	April 1, 2012 – December 31, 2012	
8. Complete analysis of available seabird diet data, and begin analysis of seabird abundance data and marine mammal diet data.			
9. Post summary data and results from synthesis of historical GOA ichthyoplankton data for target species to GOA IERP Ocean Workspace (1a, 3).	**Miriam Doyle**	April 30 – September 30 2012	
10. Continue to collaborate with Modeling group by providing early ontogeny information for target species relevant to the development of the IBMs.	**Miriam Doyle**	April 30 – September 30 2012	
11. Complete a draft of the manuscript describing the early life history exposure profiles of the target species and submit for internal review at AFSC, Seattle. Follow up with preparation for submission to NOAA NMFS professional papers.	**Miriam Doyle**	April 30 – September 2012	

Data delivery.

GOAIERP Data Delivery Table		
Data type for delivery	Delivery Month & Year	Person sending data, with email address
Updated8-day, ¼ x ¼ degree spatially averaged and gap-filled SST, PAR, chlorophyll *a* data for coastal Gulf of Alaska	June 30, 2012	Jason Waite jwaite3@alaska.edu