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, 2012 to March 31, 2013
Report submission date	April 18, 2013
Lead Author of Report*	Jason Waite

Principal Investigator(s), Co-Principal Investigators and Recipient Organization(s):
Franz Mueter, fmueter@alaska.edu, PI of Retrospective Component
Miriam Doyle, Miriam.Doyle@noaa.gov. Co-PI representative from LTL
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Kalei Shotwell, Kalei.Shotwell@noaa.gov, Co-PI representative from UTL
Sarah Hinckley, Sarah.Hinckley@noaa.gov, Co-PI representative from Modeling

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*
1. Submit manuscript on Chl *a* variability to Deep Sea Research or Progress in Oceanography (1c,d)	**Jason Waite**	By July 31, 2012	
2. Complete early life history synthesis manuscript (Doyle, in prep) through internal review and submission to NOAA Professional papers, and respond to outside peer-reviews.	**Miriam Doyle**	October 1 2012 – April 30 2013.	
3. Present an over view of the retrospective synthesis of GOA historical ichthyoplankton data at the GOA IERP PI meeting in 2013.	**Miriam Doyle**	March 18-20 2013.	
4. Complete analysis of sablefish and POP recruitment trends, prepare manuscript	**Brendan Coffin / Franz Mueter**	November 1, 2012 – August 31, 2013	
5. Continue to compile seabird and marine mammal diet and abundance data from published and unpublished sources (1b).	**Jason Waite**	April 1, 2013 – December 31, 2013	
6. Analysis and characterization of spatial patterns (East-West comparison) across environmental variables and across all trophic levels.	**Franz Mueter, Jason Waite, Brendan Coffin, Kalei Shotwell**	February 1, 2013 – December 31, 2013	

b. Describe report period progress.

Objective 1a and 3)

Further collaboration with the Modelling group PIs has involved discussions regarding aspects of early life history patterns of the target species, sharing of additional newly synthesized larval lengths data, and provision of GIS shapefiles associated with the maps of egg and larval distributions that illustrate seasonal progression in production and drift of early ontogeny stages. The shapefiles have been exported to the AOOS GOA Project Workspace. Ongoing writing of the early life history review manuscript prompted some further exploration of historical ichthyoplankton data from EcoFOCI surveys. Some new synthesis was undertaken of seasonal patterns across species and habitats, and of larval length frequency distributions across the time-series for the key species. Results are described in section c. below. This extra work has delayed completion of the review manuscript but has led to some new insights into potential environmental forcing factors of importance to early ontogeny aspects of recruitment processes among GOA fish species.

Objective 1b)

Approximately 30 long-term, large-scale, annual and seasonal environmental indices, including the Pacific Decadal Oscillation (PDO), Aleutian Low, Southern Oscillation Index (SOI), North Pacific Index (NPI), and various regional sea surface temperature, upwelling, and discharge indices have been updated through 2012 (where possible). The file containing the updated data has been posted to the GOA-IERP Workspace.

There have been several delays in compiling the sea bird diet data. USFWS has provided updated summary tables for three monitoring sights with data through 2011 for some species. Multiple meetings and conference calls have been held between F. Mueter, J. Waite, and sea bird researchers from various other agencies to coordinate analyses in order to avoid overlap in effort. We have begun preliminary exploration of correlations between sea bird diet and other biological time series, such as recruitment indices and forage fish abundance surveys.

Objective 1c,d)

The manuscript examining chlorophyll-*a* variability in the GOA with respect to various environmental drivers has been submitted to Progress in Oceanography and is currently under review. We hope to have reviewer comments and a preliminary decision from the editor by May 2013.

Objective 1e)

We modeled sablefish and POP recruitment trends against environmental variables using structural equation modeling (SEM). We used this technique to investigate sequential causal hypotheses between climatic variables (NPGO, NOI, and PDO), regional variables (upwelling and freshwater discharge in the eastern and western GOA), and recruitment. We performed the analysis in two stages. The first stage tested a priori hypotheses about the seasonal lags during which each variable may show a significant relationship to recruitment of each species. The second stage was more exploratory and examined an expanded range of variable-lags throughout each species' early life-history.

A manuscript describing this analysis is currently being drafted as a Master's thesis by Brendan Coffin, a student at the University of Alaska Fairbanks. Once completed, it will be submitted and edited for publication in a journal to be determined.

Objective 1f)

A preliminary analysis of covariation in recruitment across the five species was conducted based on recruitment time series from published stock assessment reports.

Objective 2)

No activity to date.

c. Describe preliminary results.

Objective 1a and 3)

Analysis of seasonal patterns in the ichthyoplankton for all species in the Gulf of Alaska has contributed to the development of a schematic representing timing of production and peak abundance of larvae in the GOA relative to zooplankton production cycles and associated availability of larval prey (Table 1). The GOAIERP focal species display a range of phenologies and early life history habitats that result in peak abundance of larvae spanning winter (arrowtooth flounder), spring (Pacific cod, walleye pollock, and sablefish), and late spring-summer (rockfish) months with likely significant variation in availability of different zooplankton prey. A manuscript is being developed (Doyle, Coyle and others) that will incorporate this seasonal schematic and investigate the early life history phenologies further with respect to detailed information on seasonality in the GOA zooplankton. One of the objectives will be to develop a hypothesis for a new research effort that will utilize gut content analysis of archived larval samples to investigate feeding patterns across species, seasons, habitats and larval sizes. Some extra time has also been taken to explore larval length data more thoroughly for each species, and especially over the late spring GOA ichthyoplankton time-series. This new synthesis indicates that for species that are in the plankton during winter and spring months, larvae tend to be larger during warm than cold years, and that this is attributable to growth responses rather than a shift in timing of spawning. For the spring cohort of rockfish larvae, lengths indicated very stable timing of release of larvae into the plankton over the time-series. These observations are relevant to the incorporation of larval growth parameters in IBMs.

Table 1. Seasonal succession in abundance of numerically dominant species of fish larvae in the Gulf of Alaska. GOAIERP focal species are in red font.

Species	**Common Name**	**Hab-itat**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
Hippoglossus stenolepis	Pacific halibut												
Atheresthes stomias	Arrowtooth flounder												
Leuroglossus schmidtii	Northern smoothtongue												
Hemilepidotus hemilepidotus	Red Irish lord #												
Hexagrammos decagrammus	Kelp greenling #												
Pleurogrammus monopterygius	Atka mackerel #												
*Ammodytes hexapterus**	Pacific sand lance												
Gadus macrocephalus	Pacific cod												
Theragra chalcogramma	Walleye pollock												
Lepidopsetta polyxystra	Northern rock sole												
Stenobrachius leucopsarus	Northern lampfish												
Pleuronectes quadrituberculatus	Alaska plaice												
Anoplopoma fimbria	Sablefish #												
Ophiodon elongatus	Lingcod #												
Clupea pallasi	Pacific herring												
Hippoglossoides elassodon	Flathead sole												
Platichthys stellatus	Starry flounder												
Glyptocephalus zachirus	Rex sole												
Microstomus pacificus	Dover sole												
Bathymaster spp.	Ronquils												
Lepidopsetta bilineata	Southern rock sole												
Isopsetta isolepis	Butter sole												
Sebastes spp.	Rockfish												
Mallotus villosus	Capelin												
Limanda aspera	Yellowfin sole												

*Now considered to be *A. personatus*

Larvae associated with the neuston

Level of abundance: Lowest Moderate Highest Absent

Primary larval habitat: Coastal Shelf Slope and Deeper

Objectives 1b, 1c, 1d)

We examined the 2011 chlorophyll-*a* anomaly with respect to the mean chl-*a* time series for 2002 – 2010 for the western and eastern Gulf of Alaska (divided at 145° W longitude). The two regions in 2011 displayed markedly different patterns. The pattern in the western GOA was similar to previous years, though the spring and fall blooms began and ended earlier than usual. The apparent early spring bloom is due primarily to unusually high chlorophyll concentrations on the off-shelf waters. Concentrations on the shelf were slightly lower than usual, compared to the 2002 – 2010 mean. Chlorophyll-*a* concentrations in the eastern GOA were low throughout the year; however, the biggest feature was what appears to be the lack of a spring bloom (Figure 1).

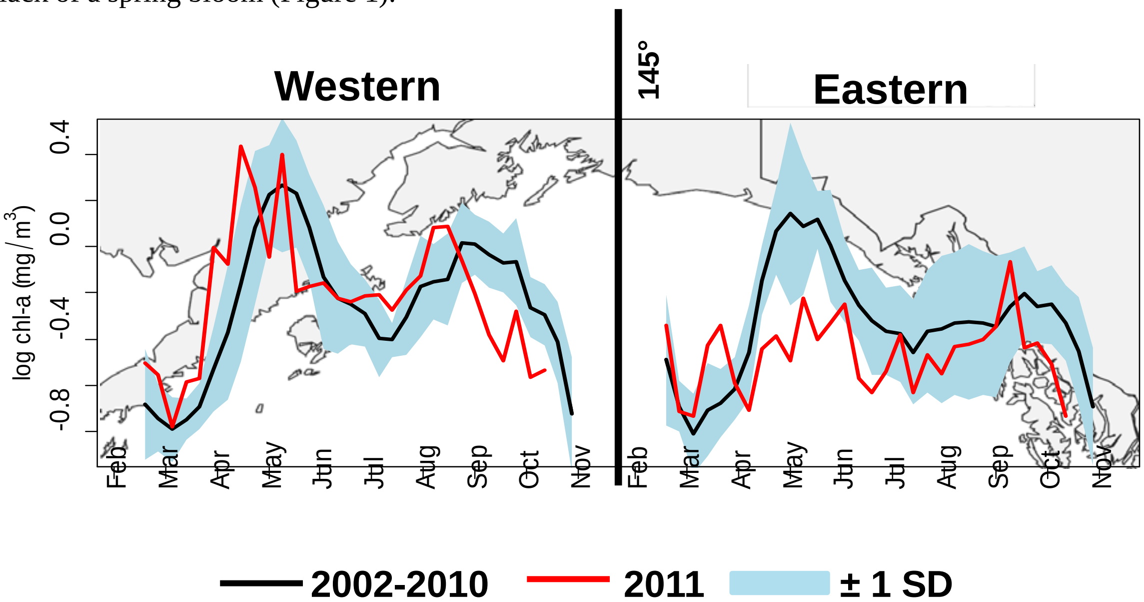

Figure 1. Chlorophyll-*a* time series for the western and eastern Gulf of Alaska, comparing 2011 with the 2002-2010 mean.

Principle component analyses (PCA) are being used to examine key chl-*a* indices with respect to various short-term, gulf-wide and regional environmental indices. In all analyses, 2011 appeared as an obvious outlier, both in terms of environmental factors and chlorophyll patterns. In particular, 2011 was characterized by a high SOI, low PDO, high winter freshwater discharge, low spring freshwater discharge, and low upwelling (Figure 2, left), as well as higher than normal spring-time chl-*a* concentrations in the western offshelf region, and lower than normal concentrations in the eastern and western shelf regions (Figure 2, right).

Preliminary canonical correspondence analyses (CCA) between the environmental and chlorophyll variables indicate the strongest relationship between the negative chlorophyll anomaly in 2011 (and 2009) was with the relatively high winter discharge (and low spring discharge). The winter and spring conditions in these two years appear to have affected the timing of the spring bloom (later), though the difference in the magnitude of the spring blooms is not explained.

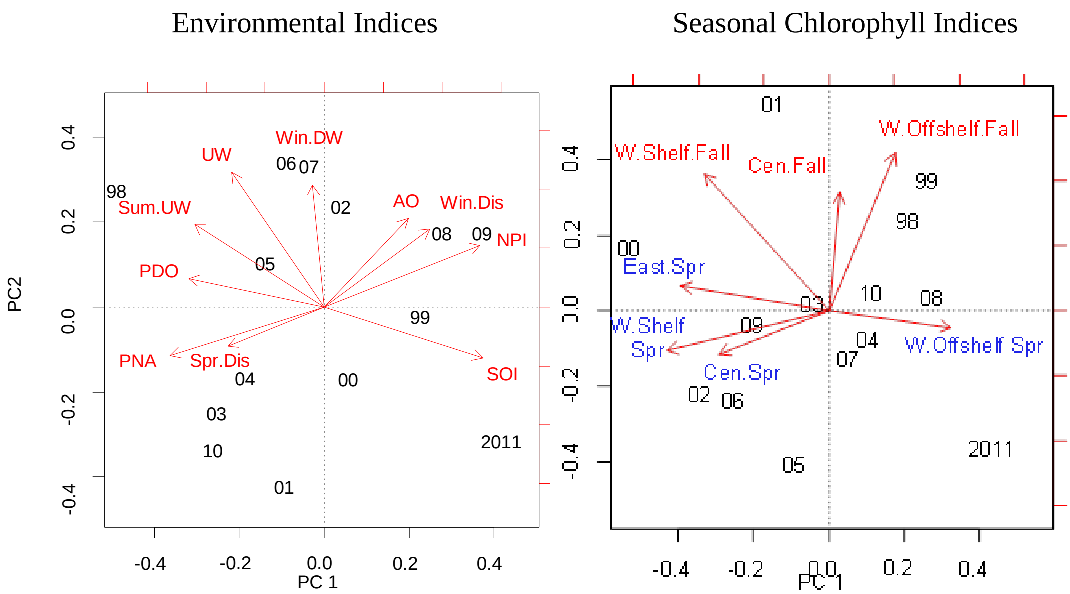

Figure 2. PCA plots of short-term (1998-2011) environmental (left panel) and chlorophyll indices (right panel).

Objective 1e)

PCA, CCA, and generalized modeling analyses are being used to examined relationships between recruitment, ichthyoplankton, and forage fish time series with respect to various long-, medium-, and short-term environmental indices. Preliminary results suggest that recruitment of sablefish is strongly related to chlorophyll anomalies in the western GOA. A weaker relationship was also found between Pacific ocean perch recruitment and chlorophyll anomalies in the same region (Figure 3). Relationships between recruitment indices and ichthyoplankton time series were also examined. No obvious relationships were found, with the exception of a moderate correlation between the Pacific cod recruitment index and the larval time series ($r = 0.44$, $p = 0.034$).

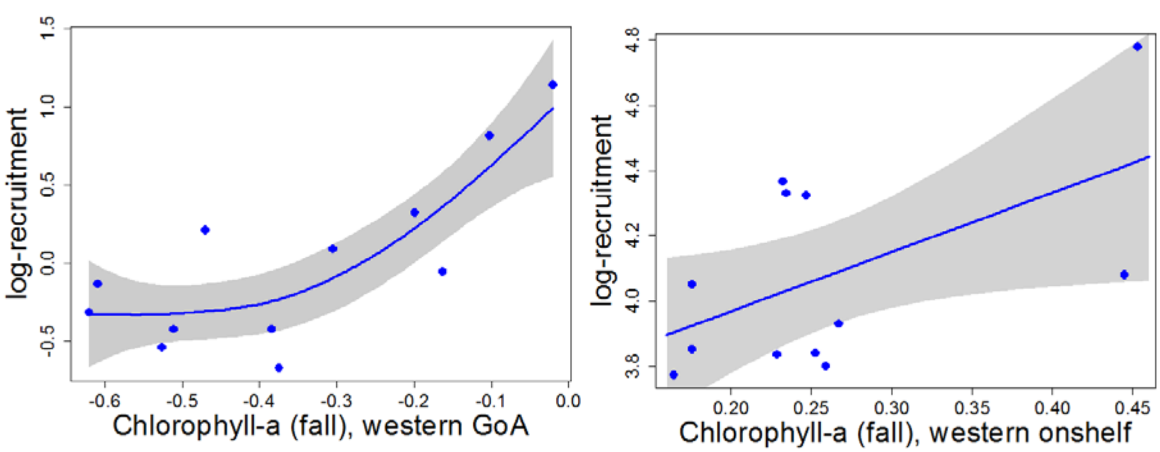

Figure 3. Correlation between chlorophyll-a anomalies in the western GOA with recruitment of sablefish (left, $r^2 = 0.68$, $p = 0.004$) and Pacific ocean perch (right, $r^2 = 0.30$, $p = 0.064$), 1998-2009.

In the SEM analysis of sablefish and POP recruitment, all a priori hypotheses were rejected for both species. In the exploratory phase, sablefish recruitment showed potentially significant relationships to winter PDO and freshwater discharge conditions during year 2 of their early life-history. POP recruitment showed potentially significant relationships to NPGO, winter NOI, and March upwelling conditions during years 0 and 1 of their early life history.

Objective 1f)
Available time series of recruitment from 1977 to 2008 suggest two separate modes of variability: sablefish, walleye pollock, and Pacific cod show similar recruitment trends with 1977 being somewhat of an outlier that had high recruitment of all 3 species. Recruitment of Pacific ocean perch and arrowtooth flounder shows a distinctly different pattern from the other three species (as evident in the separation between the arrows in Fig. 4) and are positively correlated with each other.

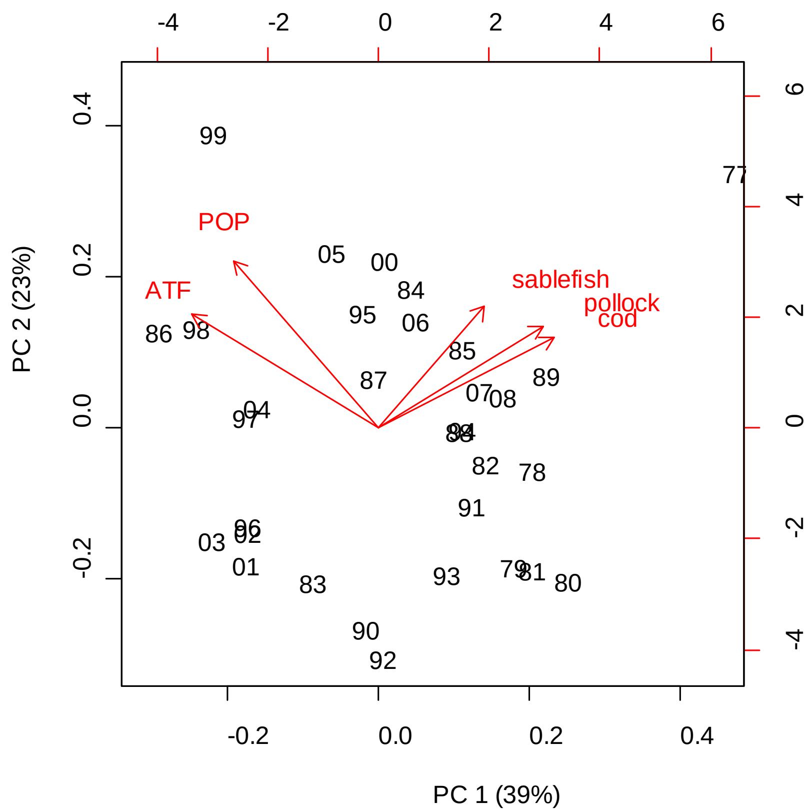

Figure 4. First two principal components of recruitment time series of five fish species in Gulf of Alaska. Arrows reflect correlations between individual time series and principal components (loadings) and distinguish two groups, which are also evident in a cluster analysis.

Objective 2)
No results to date

Related papers submitted or in preparation

Doyle, M.J. and Mier, K.L. 2012. A new conceptual framework for evaluating the early ontogeny phase of recruitment processes among marine fish species. *Canadian Journal of Fisheries and Aquatic Sciences* 69: 2112-2129. [this work was funded independently of NPRB but some of the results are being incorporated into the retrospective early life history work for the GOA project]

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, or GOAIERP special issue of DSR if appropriate.

Doyle, M.J., Coyle, K., and others? (in prep). Provisional title: Early life history phenology among Gulf of Alaska fish species in relation to seasonality in the zooplankton - implications for larval fish feeding, growth and survival. Considering submission to GOAIERP special issue of DSR.

Shotwell, S.K., Hanselman, D.H., Belkin, I.M., (*In Press*). Toward biophysical synergy: Investigating advection along the Polar Front to identify factors influencing Alaska sablefish recruitment. Deep-Sea Res. II (2012), http://dx.doi.org/10.1016/j.dsr2.2012.08.024

Waite, J.N. and Mueter, F.J. (in review). Spatial and temporal variability of chlorophyll-a concentrations in the coastal Gulf of Alaska, 1998-2011, using cloud-free reconstructions of SeaWiFS and MODIS-Aqua data. Submitted to Progress in Oceanography January 2013.

d. Describe integration activity.

The retrospective group met in Seattle for the 2013 PI meeting and F. Mueter, J. Waite, K. Shotwell, and M. Doyle presented and integrated summary of current findings that incorporated long-term environmental and biological data to help shed light on the unusual chlorophyll event in the spring of 2011. Coordination with the modeling group occurred during the PI meeting to discuss indices based on model output that would be useful to generate as potential explanatory variables in modeling recruitment variability. Principal Investigators and J. 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. K. Shotwell and several other scientists at the AFSC are currently proposing a revamped stock specific ecosystem section, which includes a report card of relevant indicators for that species. This information was presented to the September 2012 Plan Team during the sablefish assessment. The team requested a full report and examples for September 2013. Upon approval of this section, there is potential for inclusion of many GOA Project results for the five focal species within the SAFE documents. Finally, Franz Mueter participated in a conference call with Kris Holderid and Tammy Neher to coordinate data acquisition and analyses between the Gulf Watch Alaska program and GOA IERP.

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

Coffin B and Mueter F. 2013. Environmental covariates of sablefish and Pacific ocean perch (POP) recruitment in the Gulf of Alaska. Poster at the 2013 GOA-IERP Meeting, Seattle, WA

Doyle, M.J. Five posters, one per species: “Building early ontogeny pelagic exposure profiles for GoA IERP species based on historical ichthyoplankton data.” Focus species: Pacific cod, walleye pollock, sablefish, rockfish, and arrowtooth flounder, GOA-IERP PI meeting, Seattle, WA, March 2013.

Mueter F, Waite J, Doyle M, Shotwell K, Rand K, Ormseth O, and Coffin B. 2013. The Gulf of Alaska: The long(ish) view. GOA-IERP PI Meeting, Seattle WA, March 2013.

g. Education and outreach

None to date

4. PROGRESS STATUS

We have continued to make good progress and have largely completed the tasks scheduled for the current reporting period. Data analyses are ongoing, several manuscripts are close to completion, and a new manuscript is currently under review at Progress in Oceanography. These analyses will provide time series indices of physical and lower-trophic level variability to be used in analyses of recruitment trends of our focal species. Analyses of upper trophic level variability, including recruitment trends of focal species, are in the beginning stages and we will be outlining potential manuscripts over the next several months.

5. FUTURE WORKPLAN and DATA DELIVERY

Workplan

What	*Who*	*Start and end dates*	*Other key dates*
Continue to collaborate with the modeling group as requested to provide information and data relevant to the development of the target species IBMs.	**Miriam Doyle**	April 1 – September 30 2013.	
Continue to collaborate with members of the Retrospective group to link ichthyoplankton time-series to time-series of recruitment and environmental variables, and to develop manuscript(s) from such synthesis.	**Miriam Doyle**	April 1 – September 30 2013.	
Complete early life history synthesis manuscript (Doyle, in prep) through internal review and submission to NOAA Professional papers (or also considering for submission to GOAIERP special issue journal).	**Miriam Doyle**	April 1 – September 30 2013.	
Collaborate with Ken Coyle and other interested zooplankton experts on preparation of the “Seasonality and larval trophic ecology manuscript” (Doyle and Coyle/others, in prep).	**Miriam Doyle**	April 1 – September 30 2013.	December 2013 submission deadline.
Analysis of groundfish survey data (catch-per-unit-effort from bottom trawl and longline surveys for multiple species)	**Franz Mueter / Jason Waite / Kalei Shotwell**	August 1, 2012 – December 31, 2013	

(1b)			
Analysis and characterization of spatial patterns (East-West comparison) across environmental variables and across all trophic levels.	**Franz Mueter, Jason Waite, Brendan Coffin, Kalei Shotwell**	February 1, 2013 – December 31, 2013	
Integrated analysis of time series data across multiple trophic levels	**Jason Waite**	April 1, 2013 – December 31, 2013	

Data delivery.

GOAIERP Data Delivery Table		
Data type for delivery	Delivery Month & Year	Person sending data, with email address
Seabird and marine mammal diet and abundance data used for analysis of trends in eastern and central/western GOA	June 30, 2012	Jason Waite jwaite3@alaska.edu
Groundfish survey data (catch-per-unit-effort from bottom trawl and longline surveys for multiple species) used for analysis of trends in coastal GOA	June 30, 2013	Franz Mueter fmueter@alaska.edu