Center for Independent Experts (CIE) Independent Peer Review for the Recruitment Processes Alliance Research in the Southeastern Bering Sea

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Executive Summary

A panel from the Center of International Experts (CIE) carried out a review on the applied research being undertaken in the southeastern Bering Sea by the Recruitment Processes Alliance (RPA) operated jointly by the Alaska Fisheries Science Center (AFSC) and the Pacific Marine Environmental Laboratory of NOAA. The primary goal of the RPA is to provide mechanistic understanding of the factors influencing recruitment of walleye pollock, Pacific cod, arrowtooth flounder, Chinook salmon and chum salmon, focusing on factors influencing their first year of ocean life. This has been achieved mainly through seasonal (spring, summer, autumn) field surveys, process-oriented research, and biophysical ecosystem models.

I found the survey methodology and analytical approaches applied to date to be sound and reasonable. Indeed, the PRA's research on marine fish recruitment is impressive and exceeds any such effort I know of anywhere in the world. They have shown that for walleye pollock and Pacific cod, survival in the first year of life determines recruitment, and that survival during the first winter is linked to amount of stored energy by the fall with high energy leading to increased potential for survival. This energy is supplied by large zooplankton prey containing high quantities of lipids, which are most prevalent during cold years. The modeling effort both from the physical, biological and fisheries perspectives is state-of-the-art and should continue, especially in regards to future conditions under climate change. Publication describing the FEAST model is recommended.

As regards to the various surveys, I strongly support RPA's plan to continue deployment of the current meter array in the Bering Sea and the biophysical sampling done in conjunction with the moorings. I concur that a change in the spring larval surveys is needed to improve the distributional and abundance indices for pollock, but I think that the present sampling grid could be modified and an adaptive strategy adopted. The spatial scale of the larvae in both the along- and across-shelf directions should be determined through autocorrelation analysis and the results used to determine the appropriate sampling resolution on the spring survey. The summer survey should be converted to mainly an acoustic survey, but the surface tows should continue to maintain collection of the data that established the energy content-recruitment relationships. The increased acoustic data collections may require additional personnel for processing these data in order to provide the data in a timely manner. I recommend separate summertime surveys for the salmon and groundfish based upon their different spatial distributions obtained during past surveys. The pollock industry should be approached to see if they would be willing to help finance the vessel required to undertake the salmon survey. I strongly recommend that environmental data be continued to be collected on all surveys. While the survey and analyzed data are provided to management and can influence decisions, further work is required to incorporate the results into Ecosystem Based Fisheries Management.

Background

To enhance and focus the research on fish recruitment by the US National Marine Fisheries Service (NMFS) of NOAA, a Recruitment Processes Alliance (RPA) was formed in 2011 between two major NMFS programs within the Alaska Fisheries Science Center (AFSC) and across line offices (between NMFS and the Pacific Marine Environmental Laboratory of NOAA's Oceans and Atmospheric Research unit). The two programs were the Ecosystem Monitoring and Assessment (EMA) Program and the Fisheries Oceanography Coordinated Investigations (FOCI) Program. EMA is run out of the AFSC's Auke Bay Laboratory in Juneau, Alaska, while the FOCI is located in Seattle, Washington, and is composed of the AFSC's Resource Assessment and Conservation Engineering (RACE) Division and the Recruitment Processes Program plus part of PMEL's Ocean Environment Research Division (OERD). Each Program is actively involved in ecosystem and stock assessment surveys, as well as research on recruitment processes. The purpose of forming the RPA was to: 1) reduce uncertainty in individual stock assessment models of important commercial fish species by providing predictions of recruitment success, and 2) provide the North Pacific Fishery Management Council with data on seasonal fisheries, environmental and biological indices and annual syntheses necessary to apply an ecosystem approach to the management of fisheries in Alaska's large marine ecosystems (LME's; Gulf of Alaska, Bering Sea/Aleutian Islands). The RPA was broadened in 2013 to include representatives from other AFSC groups including the Resource Energetics and Coastal Assessment (RECA), the Status of Stocks and Multispecies Assessment (SSMA) and Resource Ecology and Ecosystem Modeling (REEM) Programs. The RPA collectively executes joint ecosystem and fisheries applied research to enhance NOAA's understanding of physical, chemical, and biological interactions within the LMEs and to seek the linkages between ecosystem and environmental variability and change. Of particular interest are the factors that influence recruitment of walleye pollock, Pacific cod, and arrowtooth flounder, as well as Chinook and chum salmon, with a focus on the processes operating during the first year of life. Except for arrowtooth flounder, they are commercially important species. Arrowtooth flounder has been included because of its potential important role in the ecosystem, especially as a predator on pollock and cod.

RPA field programs form a large and important component of their work and are mainly based upon seasonal fish and oceanographic (ecosystem assessment) surveys taken either every year or now in some cases every second year. These observations are combined with laboratory experiments and modeling to determine the impact of climate and ecosystem function on critical life history periods. The seasonal surveys are conducted from spring through autumn with no winter surveys. Spring surveys provide data on initial spin-up conditions over the eastern Bering Sea shelf, production of zooplankton prey, and production of fish eggs and larvae. Summer-early autumn surveys collect data on condition and provisioning of age-0 juveniles prior to winter onset. Autumn surveys are intended to provide data on declining prey abundances, and winter onset conditions.

The CIE review was commissioned to assess the work of the RPA in the Eastern Bering Sea by examining the methodology being used, the data collection and analyses techniques, and the various products from the seasonal (spring, summer and autumn) field surveys and other process-oriented research. Of particular note, they wanted the panel to comment on the RPA's recent

change to the larval cruise in the spring and the proposed change to the summer trawl survey design in terms of what these changes will mean to the overall program.

Reviewer's Role in the Review Activities

The review panel consisted of four members covering expertise in fisheries assessment (Dr. John Simmonds, UK), acoustics and survey design (Dr. Paul Fernanades, Scotland), ecosystem based fisheries management (Dr. Tony Smith, Australia) and physical oceanography, climate change and their impact on food webs (myself). The meeting of the panel with RPA scientists and management was chaired by Dr. Mike Sigler from the NMFS in Juneau, Alaska, and was held at the AFSC at Sandy Point in Seattle from July 21-24, 2015. The main RPA team leaders were Drs. Janet Duffy-Anderson (AFSC, Seattle) and Ed Farley (AFSC, Auke Bay Laboratory, Juneau). Prior to this meeting we were provided with a list of around 30 papers that highlight the main work of the Alliance in regards to recruitment processes in the eastern Bering Sea. Most of these were previously published although some are new, being either in press or in review. During the course of the meeting we were provided with some additional papers and reports, including the most recent Ecosystem Considerations Report (Zador, 2014) that is provided annually to the North Pacific Fisheries Management Council. The panel was instructed that it did not have to review all of these papers, but rather to become familiar with their main conclusions. In addition we were provided with documents stating the review objectives, the panel's Terms of Reference (ToRs), and a preliminary Agenda for the meeting.

During the first day of the meeting the panel was provided a brief introduction by Mike Sigler including going through the ToRs, the charge to the panel, a brief overview of the work of NOAA Fisheries and the AFSC, and how and why the RPA was formed. The rest of the day focused upon the physical oceanography and the lower trophic levels in the southeastern Bering Sea. It began with presentations by Phyllis Stabeno and Carol Ladd (PMEL, Seattle) on the climate, physical oceanography, sea ice dynamics, nutrients and long-term physical and chemical monitoring program. This was followed by Lisa Eisner and Jeff Napp (AFSC, Seattle) presenting information on the phytoplankton and zooplankton including the effects of climate, oceanography and nutrients on the plankton biomass and production. The remaining time in the morning was spent on modelling, the first by Kerim Aydin (AFSC, Seattle) on lower trophic modelling forecasting and the second by Al Hermann and Nick Bond (PMEL, Seattle) on physical projection modelling both on the short term (seasonal) and long term (multi-decadal). In the afternoon Janet Duffy-Anderson presented the historical and current sampling program for oceanography and lower trophic sampling, followed by a discussion on the sampling methodology, which was moderated by Mike Sigler.

The second day was dedicated to groundfishes and modeling their dynamics. Janet Duffy-Anderson presented the ichthyoplankton ecology for walleye pollock, Pacific cod and arrowtooth flounder, which was followed by Elizabeth Siddon (AFSC, Juneau) who talked about the juvenile ecology for the 3 species. Ron Heintz (AFSC, Juneau) presented studies on pollock showing prewinter conditioning of age-1 was a reasonable estimator of age-3 recruitment. This is one of the main findings for the RPA. In the last presentation of the morning, Ivonne Ortiz presented more on trophic modelling using the FEAST model, including a discussion of the parameter estimates for the model. In the afternoon, the focus switched to sampling procedures and survey

design. Janet Duffy-Anderson began by going through the ichthyoplankton sampling designs discussing the historic seasonal surveys (spring, summer, autumn), the recent changes in the spring larval cruise and planned changes to the summer survey. She also discussed the analyses and products coming from the survey. Ed Farley then took the panel through the juvenile surveys and the potential changes to them. Both presentations were followed by open discussions where the panel could ask questions and provide comments.

During day 3, the morning focus was on ecosystem based fishery management (EBFM) issues for the Bering Sea. Anne Hollowed (AFSC, Seattle) gave an introductory talk on what EBFM means to those working in the Bering Sea. She discussed the North Pacific Fisheries Management Council and the various laws and restrictions the Council and NOAA need to abide by. She also mentioned some of the opportunities for providing actionable advice. Kerim Aydin then talked about how NOAA incorporates ecosystem science into management. This was followed by Jim Ianelli (AFSC, Seattle) who presented what and how ecosystem information is used in single-species and multi-species stock assessments and management strategy evaluations. The last two talks of the morning were on other ways that NOAA is providing ecosystem information to the management. The first was by Stephani Zador (AFSC, Seattle) who edits the Ecosystem Considerations Report to the Council. She took the panel through the process of developing the report and what kinds of information it contains. Finally, Ellen Yasumiishi (AFSC, Juneau) presented some of the products produced for management, including ecosystem indicators and species report cards. In the afternoon, the panel was provided with information pertaining to salmon. Jim Ianelli began with a discussion of management of salmon resources and how the survey information is used. Ed Farley then presented an overview of the early life ecology of Chinook and chum salmon in the Bering Sea, and how the physical oceanography and lower trophic levels influence the early life stages of the salmon. Kerim Aydin took the panel through the modelling of Chinook salmon in the FEAST model including the modeling concepts and parameter estimation procedures. Ed Farley then discussed the historical and current sampling program for salmon in the Bering Sea, the analysis and products from the survey data and the planned changes to the surveys. This was followed by a discussion between NOAA scientists and the panel of what options might be available for the survey design along with possible advantages and disadvantages of what the various options are.

The fourth and final day of the meeting was a question and answer session with some of the main NOAA scientists and the review panel. The time was broken into approximate equal time sessions, the first session encompassed ocean physics, the lower trophic levels, and modelling. The second session was on fish, both groundfish and salmon, with the discussion mainly focused upon the proposed changes to the surveys, and particularly on the merits of acoustics versus traditional net sampling. The final session was on the applications to EBFM. Upon completion of the morning session, Mike Sigler, as moderator, thanked the panel for their various questions and comments through the four days and stated that he looked forward to the written reports. Janet Duffy-Anderson and Ed Farley also thanked the review panel for their comments and discussion points. The formal meeting was then closed.

After lunch on the final day, the review panel met for a closed session where we discussed some general points and then went through the ToRs to ensure that we were in agreement as to what these meant. Completing this, the panel said their good-byes and dispersed.

Summary of Findings

Below are my comments and recommendations in regards to each of the Terms of Reference (ToRs). No consensus recommendations were discussed by the panel so that each panel member could answer each of the ToRs as we saw fit. Given my particular expertise, I have provided more comments regarding the physical oceanography and lower trophic levels and their relationship with fish recruitment than on the survey designs and acoustics. However, I do provide my thoughts on these latter, but I am confident that the other reviewers will provide a more thorough and comprehensive review than I am able to on these latter points. I end with comments on the review process itself and some thoughts not particular related to any specific ToR.

Terms of Reference

1) *Review background materials and documents that detail the ecosystem and fishery survey design and methods, and data analysis methods and results for:*
   a. *Joint walleye pollock, Pacific cod, and arrowtooth flounder surveys;*
   b. *Chinook salmon and chum salmon survey*
   c. *Joint bio-physical oceanographic survey component (ecosystem).*

   The amount of background material and documents provided was extensive and somewhat overwhelming. I did peruse many of the papers and reports to become familiar with their results and methods, although I must admit that I only read a selection of them in any detail. I shall not provide a review of this material as most of the papers have already been reviewed and commented on through the publication process. I would like to say upfront that the amount of effort focused towards recruitment by the RPA and its predecessors as well as the quality of the research is impressive. This was espoused by all of the reviewers and we could not think of a single example that would surpass the work by NOAA and its scientists in effort, scope or results, anywhere in the world's oceans. The closest example we thought of might be on krill in the Southern Ocean as part of the CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources). Even that, however, did not match the NOAA effort in the Bering Sea. The scientists and managers are to be congratulated for the work they have carried out and the results they have accomplished. It should be pointed out that they have benefitted greatly from the funding as part of BEST and BSIERP (Bering Sea Ecosystem Study and Bering Sea Integrated Ecosystem Research Program) by the National Science Foundation (NSF) and the North Pacific Research Board (NPRB), respectively. The NOAA managers also should be congratulated on their forward thinking and providing the internal resources to accomplish what has been achieved to date. Comments on the surveys, methodology and analyses techniques are provided in response to the other terms of reference. Having said that, there is still more work to do, especially in incorporating the results from the work of the RPA into fisheries management and the assessment process.

2) *Evaluate the historic, spring and late summer ecosystem and fishery survey designs, methods, and analytical approaches including data preparations and quantitative analyses to estimate the nutritional and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)*

I have treated each of the surveys separately and have included comments on the spring mooring survey as well, although the ToR does not specifically ask for this.

(a) The first spring survey, of approximately 15 days duration, occurs in late April-early May during which the moorings are recovered and redeployed. The moorings provide measurements of currents, temperature, salinity, oxygen, nitrates, ρCO_2, fluorescence, and zooplankton biovolume. In addition, oceanographic data are collected between the moorings along the 70 m isobath in the middle domain to determine the transition zone between the strongly stratified waters to the south and the relatively weakly stratified waters to the north (Fig. 1). Also, some across-shelf transects are run to establish the habitat gradients for the fish and zooplankton. Data collected during the along and across-shelf transects include temperature, salinity, nutrients, chlorophyll-a, small and large zooplankton and microzooplankton. It was noted that, in some years, ice can limit the extent of the cross-shelf transects, especially on the inshore end.

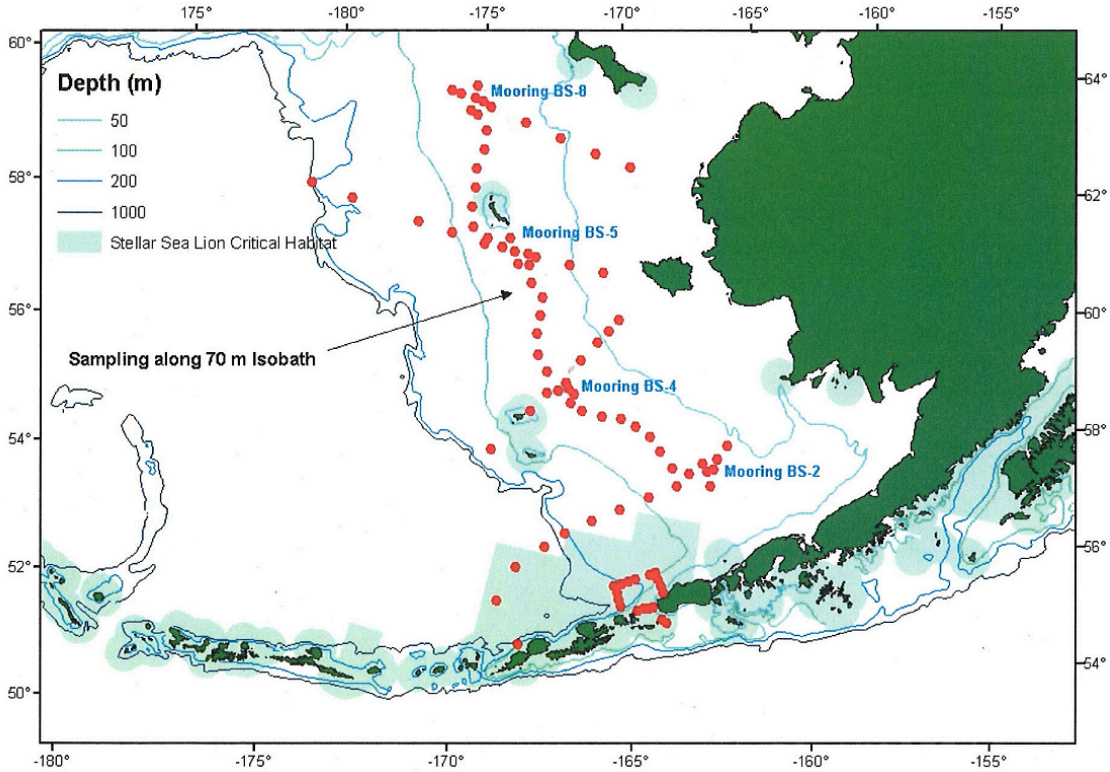

Fig. 1. The location of the four moorings and oceanographic stations taken during the spring mooring redeployment cruise including the along-shelf transect along the 70 m isobaths, some cross-shelf transects, and the box north of Unimak Pass.

The mooring and early spring survey data have provided valuable information on the physical oceanography and early season biology in the southeastern Bering Sea. The mooring at M2

has been in place since the mid-1990s and has clearly shown the interannual variability in thermal regime from cold to warm periods (high and low ice years, respectively) and back again. The plankton data have allowed descriptions of the species compositions over the shelf, their spatial distributions, and information on phenology, as well as how these vary interannually. The physical data have helped to show that sea ice sets the stage for the temperature and in turn the biology, the importance of the cold pool, and that the physical oceanography in the north and south Bering Sea differ. For example, while the south has relatively high variability between warm and cold years, the north experiences less variability and is almost always cold with extensive ice. This, together with model results, indicates that in the future under warming scenarios there will most likely still be ice in the north while in the south it will form later, leave earlier and be less extensive. The long-term moorings have been most influential in support of understanding the physical dynamics and their effect on the lower trophic levels, especially primary production and zooplankton. I am fully in support of the RPA's plan to continue the deployment of these moorings, and the survey conducted in associated with the recovery and redeployment of the moorings.

Knowledge gaps noted at the end of the physical oceanographic presentation by Phyllis Stabeno and Carol Ladd included the source of the general northward flow over the shelf and through the Bering Strait, which affects both the thermal conditions in the Bering Sea and ultimately its biological production. (Note while ToR8 deals with gaps in knowledge, I have reserved the response largely to those not mentioned by the presenters and instead have provided comments on the those of the presenters within the present ToR). Although not on the list of key papers of the RPA, Danielson et al. (2014) (Stabeno, a member of the RPA, was one of co-authors on this paper) has already contributed greatly to improving the understanding of how the flow over the Bering Sea responds to wind forcing. It describes how the different currents over the Bering Sea Shelf contribute to the outflow through Bering Strait as a function of wind direction. This was primarily a modeling study, but the conclusions are supported by available current meter data. They found that the interannual variability in the flow through Bering Strait was largely governed by meridional sea surface elevation gradients set up by large-scale steric height changes over the Aleutian Basin caused by variations in Ekman suction within the North Pacific Western Subarctic Gyre. Ekman suction is when cyclonic winds induce net divergence and upwelling through Ekman transport. At synoptic to monthly time scales, the response in Bering Strait was a combination of local wind forcing and remotely forced continental shelf waves propagating from the northwest along the Siberian coastline, and the southeast along the Alaskan coast. The authors noted that the atmospheric conditions that increase transport through Bering Strait at annual time scales act to reduce the transport at synoptic scales. Further work to confirm the model results are encouraged, including better resolution of the model winds and the use of satellite imagery to measure the variability in sea level elevation gradients, albeit recognizing the difficulty in obtaining good sea level data in the presence of ice. Another identified gap, also related to the circulation, was the flow through the Aleutian Islands into the Bering Sea. I concur and think that improved quantitative estimates of the mean flow and its variability are needed, as well as the fate of the waters from the Gulf of Alaska that make it through into the Bering Sea. The main focus should be on Unimak Pass, which to my knowledge is one of the main passages, if not the most important one. For example, what percentage of the Gulf of Alaska waters flowing through the Aleutians moves onto the Bering Shelf versus the amount that enters and remains in the Basin? In regards to the circulation through the Aleutians, it would be interesting to

examine the difference in flow during warm (low ice) and cold (high ice) years. Although a large mooring program to monitor the flow through Unimak Pass is probably prohibitively expensive and difficult given the intense currents in the area, the flow and its variability could be explored using presently available models in combination with satellite imagery of sea surface height data, if it has not been done already. Another possibility is the establishment of sea level gauges on either side of the pass to monitor the flow variability (see Garrett and Petrie, 1981 for an application in the Gulf of St. Lawrence). The last knowledge gap identified by the presenters was related to nutrients, in particular their origin and replenishment mechanisms. Improved knowledge of the flows through the Aleutian Island would also likely contribute information on nutrient fluxes into the Bering Sea from the Gulf of Alaska. I believe that investigations into the role of eddies at the slope between the shelf and the basin in producing shelf-basin water exchanges are warranted. Such exchanges could be very important for nutrient concentrations, as well as fluxes of zooplankton and ichthyoplankton onto or off the shelf. Satellite imagery of the number and frequency of eddies could be combined with past or future strategically-placed moorings along the shelf break or in the Aleutian Canyon to provide information on the effect of eddies on the shelf-basin exchanges. The physical oceanographic survey data may also provide some insights if obtained at the same time as an eddy or eddies are present. I therefore recommend a process study on the role of eddies on the water exchange between the basin and the shelf in the southeast Bering Sea and their impact on nutrients, larval drift, plankton and ichthyoplankton.

While the spring mooring survey does not add greatly to the nutritional and behavioral ecology of the various target species, it and the mooring data provide valuable background information on the physical oceanography and plankton and contribute significantly to the Ecosystem Consideration reports.

(b) The spring larval survey between 2001 and 2011 was held annually and consisted of sampling for roughly 12 days on a grid of 15 km spacing north of the Aleutians. It included four major across-shelf transects extending approximately 400 km from the deep basin onto the shelf to the inner domain (Fig. 2). This survey captured one major spawning area for both pollock and Pacific cod as well as Bering Canyon, an area known as a spawning site for arrowtooth flounder. In 2012, the survey undertook a major change, as it was extended to 20 days duration and spatially covered an area beyond the Pribilof Islands to about 60°N (Fig. 2). The spatial separation on the new grid was similar to the previous grid, i.e. around 15 km. The surveys are now conducted biennially on odd years. The spatial change was mainly motivated by known pollock distributions, in particular to capture the Pribilof Island spawning areas as well as continuing to sample the spawning regions north of the Aleutian Islands. Still, it does not extend far enough to include the Zhemchug spawning area for pollock, which is farther north just outside the present sampling grid. The survey also apparently does a good job sampling the larvae of Pacific cod, although similar to the pollock there is a known population of spawning cod to the north of the grid located to the west of St. Lawrence Island (Neidetcher et al., 2014). It was unclear from the presentations just how well arrowtooth flounder ichthyoplankton were sampled. Arrowtooth spawn along the slope and this area has poor coverage with low priority sampling or some slope regions where there is no intended sampling. However, additional surveys have been carried out (3 times between 2002 and 2010) targeting arrowtooth flounder as well as some other species with a focus more along the

slope region and the area off the Pribilof Islands. In addition to the larvae, the spring larvae surveys also provide valuable information on the zooplankton prey field for the larvae.

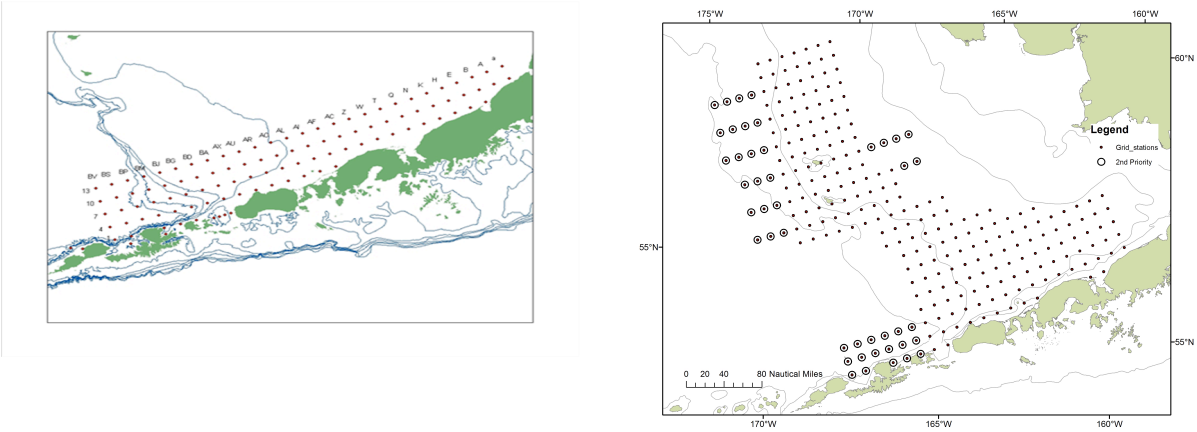

Fig. 2. The location of the spring larval survey stations annual from 2001-2011 (left panel) and from 2012 sampled biennially on odd years (right panel).

The historic survey that focused on the narrow strip north of the Aleutians was positioned to provide good information to assess the influence of egg and larval fluxes through Unimak Pass and the movement of arrowtooth flounder larvae spawned on the continental slope onto the shelf. Also it captured cod and pollock spawning aggregations north of the Aleutian Islands. However, a more detailed and extensive assessment of the distribution and abundance of pollock larvae and young required a much expanded grid (Fig. 2). Still, even this new grid failed to fully resolve the eastern boundaries of the pollock distribution. While the RPA is not necessarily tasked with providing abundance estimates, it is attempting to understand the mechanisms responsible for understanding recruitment dynamics so that some index, at least, of the changes in abundance and distribution are needed. This means ensuring adequate sampling of the population. To achieve this, I would recommend an adaptive sampling strategy. Expanding the grid where and when needed could be achieved by eliminating extraneous stations, e.g. by deleting stations where there is a low probability of finding larvae and stratifying in those areas of high abundance. This could be based on either results from earlier surveys where no or few larvae are ever found, or on known environmental conditions the larvae and young do not inhabit. Another method to trim the number of stations is to examine the spatial autocorrelation from historical survey data from which one can determine the typical spatial scale of the concentrations of larvae and young pollock. The autocorrelation analysis should be performed separately for the along- and across-shelf directions, because it is expected that the along-shelf direction is likely to have a larger spatial scale than the across-shelf direction. For example, perhaps running every second across-shelf transect could provide essentially the same information as the present grid. Any time saved through reducing the number of stations could be used to extend the boundaries of the grid if the sampling warranted. That is, sampling could continue through high concentrations beyond the present grid boundaries until low concentrations were found, with the spacing of the stations determined by the autocorrelation analyses. Acoustics could also be used on this survey to assess predator-prey overlap including the potential for cannibalism. As mentioned previously the arrowtooth flounder spawn in the slope region and given that some, if not the majority, of

their larvae would likely be carried by the residual flow northwards along the slope, it seems to me that the present sampling grid would not be ideal for monitoring this species.

As previously mentioned, pollock spawn to the north of the new grid and so the larvae from this aggregation are not presently sampled. This could potentially cause difficulties if strategic sampling were adopted. For example, if high concentrations were found in the most northern stations on the present grid, and they therefore extended the grid until the northern boundary of the larvae was resolved, they might sample the Zhemchug population in some years and not in others. Any abundance indicator estimated from the data could then be biased. While proper sampling of the northern spawning population may be beyond the present capabilities of the spring larval survey given time restrictions, I would recommend a special study to focus on this northern component and track its spatial extent. Perhaps one or two surveys could be combined together with modeling studies to determine the extent of mixing of larvae or young with those from farther south. Or is it that the northern spawned larvae are all transported farther north by the prevailing currents and hence do not mix with the more southern spawning populations? In such a case, my concerns would not be warranted but it would be good to know definitively.

These surveys, under an adaptive strategy, could provide adequate data on the relative abundances and distributions of pollock and Pacific cod. However, I do not feel they are adequate to provide similar information for arrowtooth flounder.

(c) The BASIS (Bering Aleutian Salmon International Survey) summer collections began in 2001 to address questions related to sockeye salmon, which at the time had returns that were well below forecasted levels. Up through 2007, the surveys were conducted aboard contracted vessels, and since 2008 have been carried out aboard the NOAA research vessel *Oscar Dyson*. The geographic coverage included much of the southeastern Bering Sea (Fig. 3) and also included the northern Bering Sea up to Bering Strait (not shown). The oceanographic measurements taken were temperature, salinity, oxygen, phytoplankton collections, microzooplankton from Niskin bottle samples, and other zooplankton from bongos and Juday nets. The use of the Juday nets were part of a collaborative study with Russians who traditionally use this net, with the idea to compare samples taken on the eastern and western sides of the Bering Sea. Fish were sampled from surface trawls and included young-of-the-year pollock and cod, as well as the salmon. It is from the BASIS data that the relationships between zooplankton, energy content of age-1 pollock, and recruitment at age-3 have been established. Also, the effects of energy content of young Pacific cod on its recruitment levels were determined from the surface tow results during this survey. I fully agree that the analytical approaches the RPA has undertaken to estimate the nutritional and behavior ecology of walleye pollock are appropriate.

The physical, chemical and plankton data collected during the summer survey have provided valuable insights, including relationships with young pollock and Pacific cod. They have shown that during cold (warm) periods the number of large (small) zooplankton with higher (lower) lipid content increases. This, together with the decline in abundance of pollock during warm years, contributed to the revision of the Oscillating Control Hypothesis and supported the present view that it is the amount of energy that the young pollock have in the fall that determines their probability of survival during their first winter. It was also noted that the

timing and taxonomic characteristics of primary production are of greater importance than its magnitude for the survival and growth of large zooplankton. One of the results that intrigued me was the relationship between silicates and pollock growth. Length of the pollock increased from 0 to 6 µM of silicate, after which the length remained relatively constant (or a slight decline) with increasing silicate concentrations. It was argued that high stratification and low wind mixing leads to low surface nutrients as indicated by low Si that in turn reduces summer diatom production, producing longer food webs and less efficient energy transfer to the fish. Part of my fascination with this result is that I recently reviewed a paper internally that was hypothesizing silicate reductions as a cause of distributional changes of a certain species in the Northeast Atlantic. I recommend that the research into the role of silicate in the changes in pollock growth should be pursued further and extended to determine if a similar relationship is found for cod.

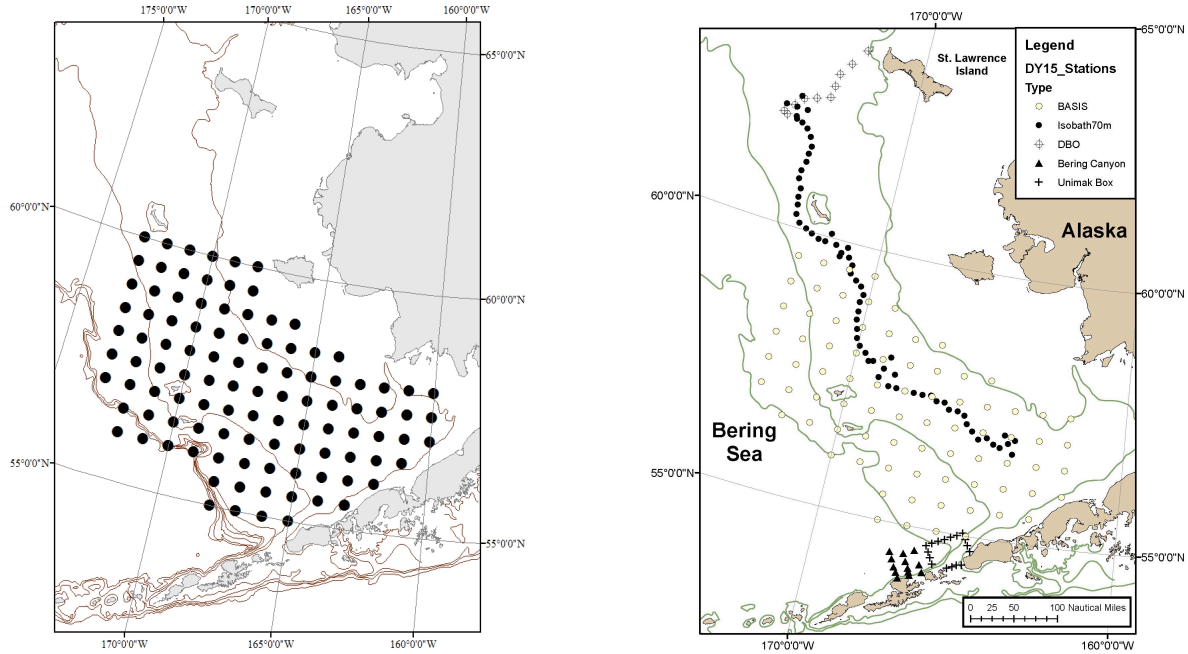

Fig. 3. The summer survey station locations over the southeastern Bering Sea (left panel) and the new proposed station locations (right panel).

Lisa Eisner, near the end of her presentation, highlighted a number of areas where there were uncertainties related to the plankton and where more research was needed. While not all of her comments relate to the summer survey, still I think it is appropriate to comment on them here. I will not discuss all of the uncertainties but want to mention three that I definitely feel are the most important and where more research is needed. The first of these is on euphasiids. These zooplankton comprise an important component of the young pollock diet, especially during cold years. In spite of this, knowledge of their abundance is poor. I would recommend further effort be expended on euphasiids with special attention given to estimating their abundance, and what controls the variability in their abundance. I understand that they can avoid nets, but perhaps acoustics in combination with nets can help to provide better estimates

of euphasiid populations. The second large uncertainty was in ice algae, their nutritional value and how much is consumed by the pollock. A short-term directed study could provide this valuable information although it may have to be during a few different years, preferable at least one cold and one warm year to see if there are substantial differences in both the ice algae nutrition and what is consumed by pollock under different thermal regimes. The third uncertainty is the relative importance of the summer and fall blooms in ultimately providing the energy required to help the pollock obtain the necessary energy reserves to help them make it through their first winter. Investigations into this are needed (see below for some suggestions for what might be done).

3) *Evaluate the planned change in trawl survey design for the late summer survey design (surface trawl with midwater acoustics to oblique trawl with acoustics), methods, and analytical approaches including data preparations and quantitative analyses to estimate the nutritional and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)*

4) *Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of transitioning the late summer survey from surface trawl with midwater acoustics to an oblique trawl survey, particularly regarding its potential to provide comparisons between historical and future nutritional and behavioral ecology of target species.*

In discussions with the other reviewers, we felt that there is a great deal of overlap in ToRs 3 and 4 so I have elected to answer them together.

The planned change in the trawl survey design for the late summer includes biennial surveys on even years in the Bering Sea and will be limited to depths greater than or equal to 50 m. These changes were a result of a shift in focus towards pollock. In particular, there is a change to sampling more offshore in order to capture age-0 fish (Fig. 3) and the use of acoustics to better resolve their vertical distribution. The geographic shift means that there will be little to no surveys conducted within the inner domain with sampling covering the middle and outer shelf domains, consistent with what is known about the distribution of young pollock and will capture Pacific cod as well. The survey also will sample along the 70 m isobath similar to the spring mooring deployment cruise and will occupy the DBO (Distributed Biological Observatory) stations in Region 1 (Bering Sea, southwest of St. Lawrence Island) (Fig. 3). The plan is to replace surface trawls and mid-water acoustics with oblique trawls and acoustics.

It is clear that oblique trawls will not provide the same or comparable information to that of the surface trawls. The oblique hauls integrate over the water column. The acoustic data will provide information within the water column, but will miss the near surface layer as the acoustic transducer is located a few meters below the sea surface at the bottom of the ship's hull. Those reviewer's more knowledgeable about acoustics than I suggested that the summer survey should be turned into a mainly acoustic survey with strategic net hauls to assess what species the acoustic data are targeting where large concentrations are observed with the acoustics. This makes sense to me, and I would recommend that these be undertaken. However, I think that the surface trawls should be maintained given their importance in supplying the data that established the condition-recruitment relationship for pollock (Heintz

et al., 2013) and for cod (Farley et al., 2015). These results are some of, if not, the primary results of the work of the RPA, and thus the surface net data should be maintained unless a comparable relationship can be established using other data. I do not think that information on fish size, diet, and energetic content for the fish should be affected by the new survey design as long as there are sufficient net samples taken. The proposed new sampling, especially if moving to a mainly acoustic survey, should improve the relative abundance, distribution and biomass estimates of the pollock. Based on the information we received, it would appear that Pacific cod should also be well-sampled in the survey area. For both species it will still not sample the northern most aggregations. The limited number of stations at the shelf break region would again suggest to me that arrowtooth flounder may still be under-sampled if the new proposed grid is adopted. Size, diet and energetic content data for arrowtooth could be obtained with appropriate trawling. Certainly diet data should be collected to help determine the role of arrowtooth flounder as a predator on pollock and cod. Comparison of the size, diet and energetic content data for arrowtooth flounder from previous and whichever survey design is chosen should in large part be comparable. The relative abundance and biomass estimates may be comparable but will require further analysis to confirm this. One method might be to compare the estimates from the different survey designs using results in overlapping areas. This might then be converted to an index to convert estimates from one survey to the other. However, if these overlapping areas in the two different survey designs do not cover a significant portion of the population of one or more of the targeted species, the results from the different surveys may not be comparable.

Part of the reason to switch to biennial surveys, as I understand it, is not only financial (and to alternate between the Bering Sea and the Gulf of Alaska in different years), but the recent phenomena of having several continuous years of either warm or cold conditions, referred to by some of the presenters as *stanzas*. The survey changes make sense if the recent variability pattern will continue, and if one cold (warm) year is much like the next cold (warm) year. However, in terms of the fish, it was shown that in 2007, which was a relatively cold year, the average energy density of an individual pollock was high, but their growth was lower than in other cold years and so the overall energy content was less. This, it was concluded, was the cause of the reduced survive rate during their first winter compared to other cold years. If this year was one of the years that the survey was not run, then it might have been concluded that energy density rather than total energy was the most important factor influencing survival through the first winter. Thus, sampling every second year could result in missing important results or it may take longer to discover these relationships. From a statistical point of view, reducing the number of samples (i.e. years) may, at first, lead to the conclusion that this will extend the time over which it will take to confirm statistical relationships. The statistical significance of such relationships depends upon the degrees of freedom, which is commonly based upon the number of points in the time series. However, using the total number of points in the time series assumes that each of the points are statistically independent, or in other words the autocorrelation function is near zero for all lags. Often, geophysical and fisheries time series are highly autocorrelated (there is persistence in the data, i.e. one year is much like the next). In such cases, one needs to determine the number of *independent points* to calculate statistical significance (see for example, Pyper and Peterman, 1998). The number of independent points in the time series is equal to or less than the number of total points and depends upon the magnitude of the autocorrelation function. The higher the autocorrelation (i.e. more persistence) in the time series, the fewer the number of independent points and

hence the longer the time series needs to be in order to confirm statistical relationships. For ocean temperatures in the southeastern Bering Sea with the present pattern of variability, it is likely that sampling biennially does not adversely affect the number of independent points. If true, this would mean that whether the samples are collected annually or biennially, it would take a similar amount of time to produce a statistically significant result (this of course needs to be confirmed by a proper analysis). However, it is not clear what the autocorrelation function is for other variables such as salinity, mixed-layer depth, nutrients, chlorophyll-a, zooplankton and fish, and what affect, if any, the switch to biennial sampling will have on these variables in terms of the number of independent points for these time series. Such analyses need to be performed to be aware of what it means in terms of confirming any relationships statistically.

5) *Evaluate the potential of the spring and late summer ecosystem and fishery survey designs and analyses, or an alternative, to (i) be applied to coupled biophysical-individual based modeling and trophic modeling approaches currently in use, ii) resolving mechanistic linkages among ecosystem components, and (iii) be applied to management and conservation of walleye pollock, Pacific cod, and arrowtooth flounder within an Ecosystem Based Fishery Management approach.*

(i) The physical and biophysical modeling efforts undertaken as part of RPA are impressive and state-of-the-art. The physical modeling have made great strides and now include future model scenarios, which are necessary for highlighting potential impacts on food webs under climate change. Continued work on these models is encouraged. The end-to-end trophic model is also what I think of as state-of-the-art. However, given its importance within the work of the Alliance, I would recommend that the developers of trophic model publish an initial paper describing the FEAST component and the philosophy behind it, its calibration, and some test results as soon as possible. It certainly seems, based on the presentations we heard, as if there is enough material to do this. I understand that a paper is in preparation, but was surprised to learn that one is not yet out (unless I am mistaken). I understand that the model keeps changing and being modified, but still a primary publication is needed for a thorough review of the methodology and for the oceanographic community to access its potential for addressing particular hypotheses and model uncertainties. What will the model do well and what will it not? Having said this, I do believe that the potential is there to apply the data from the modified spring and late summer ecosystem and fishery surveys to the model, whatever the choice of the final survey designs will be. These data should be able to help better parameterize the model and provide essential information to calibrate the model and validate (or not) its results. Given that improvements to models usually occur as a result of "getting things wrong", finding out that the model is not performing well is not always a bad thing as it should lead to improved model parameterization or adding additional processes until the predictions better match the observations. To improve the model will require constant communication between the modelers and the observationalists. The latter can ensure the modelers are interpreting the observations correctly and that the model results are capturing the data (and possibly for the correct reasons). The modelers on the other hand can inform those taking the observations where best to collect data and at what frequency to maximize efficiency, and capture the critical information in order to help improve the models.

(ii) It was clear from the information presented to the panel that the survey results have, and are continuing, to provide insights into the mechanistic linkages amongst ecosystem components. The highlight of the Alliance's research to date, the relationship between total energy at the beginning of autumn determining the survival rate of pollock during the first winter, which is ultimately linked to recruitment levels at age-3 is a prime example of insights the survey data can provide. Similar results in terms of the relationship between size, diet and energetic status were found for Pacific cod (Farley et al., 2015) indicating that common mechanisms potentially regulate gadid recruitment in the southeastern Bering Sea. Monitoring of these relationships needs to continue in order to place them on stronger statistical grounds as they are presently only based on around a decade of data for pollock and slightly less for cod. In this regard, the new design for the summer survey (from which the energy-survival-recruitment relationships were established) needs to ensure that the same or comparable data that established the relationships can continue to be collected in the coming years. A few other examples where the survey data have been instrumental in generating mechanistic understanding and testable hypotheses include the revision of the Oscillating Control Hypothesis (Hunt et al., 2013), the temperature effect on the diets and condition of pollock (Heintz et al., 2013), and relationship of pollock recruitment to the growth of chum salmon (Yasumiishi et al., 2015). There is no reason to think that such results and others will not continue into the future based on the survey data.

The trophic model can also help examine and test mechanistic linkages between climate and physical oceanography with the plankton and fish, and amongst the various trophic levels themselves. However, to adequately assess which hypotheses the model might be able to investigate requires knowing more details about FEAST and the model methodology as well as some results. One of the advantages of such models is their ability to consider various factors in combination. This is especially important for non-linear processes where the outcome can be quite different from expectations. Model testing can be used to investigate different hypotheses and also to consider different forcing functions separately and together. The ability of the models to represent reality will depend upon their temporal and spatial resolution, and if these can match the important scales in nature. This, of course, will depend upon the environmental factor, trophic level, species and/or hypothesis being considered.

(iii) I believe that the data from the spring and late summer ecosystem and fishery surveys and their analysis have great potential for management and conservation applications within an Ecosystem Based Fishery Management approach. While I understand that direct application within fisheries assessment process has not yet been achieved, I believe it eventually will, especially if the predictions of recruitment from the index of total energy content continue to stand the test of time. It might be worthwhile in the meantime to compare the results of using those recruitment predictions with the results based on whatever recruitment estimates were actually used. What would have been the difference in the assessment results? Would the energy content derived recruitment have improved the assessments?

Although not yet used in the assessment process, the survey data that has been collected and analyzed are used in other ways. The Ecosystem Considerations Report provides environmental, fish and fisheries information from the surveys of relevance to management such as annual conditions and trends pertaining to general productivity, physical characteristics such as temperature and salinity, and biological characteristics, such as the

status of jellyfish in the Bering Sea. Comments are provided on the factors contributing to the trends and changes, and the possible implications for management. Also included is a list of Ecosystem Status and Management Indicators such as information on fish habitats and non-target species for which the surveys can provide some input. The report is provided and discussed by the Bering Sea planning team and the information passed on to the Science and Statistical Committee of the Alaska Fisheries Council and in turn to the Council's Advisory Panel that makes recommendations on fish quotas. The survey information can also help to identify possible broad-scale changes (potential regime shifts) if and when changes are observed across multiple trophic levels. They could provide a relatively early warning of a major change.

Data from the summer survey on Alaska Chinook salmon could potentially be used for important management decisions. The bycatch of Chinook salmon in the pollock fishery, if high enough, can result in significant limitations to the pollock catches, thereby cutting into the profits of the pollock fishery. The salmon indices calculated from the surveys could determine if a cap on the pollock fishery is required, and if so, what the size of the cap should be (see further discussions under ToR 6). Another potential management use of the survey data is on the selection of possible fishery closure areas. These might be imposed, for example, in spawning areas if particular stocks are threatened or to prevent bycatch of certain species.

6) *Evaluate the potential of the late summer ecosystem and fishery survey design and analysis, or an alternative, to incorporate these data in a western Alaska Chinook salmon the estimation of an 'abundance based cap' for prohibited species catch within the Bering Sea walleye pollock fishery in comparison to the proposed 'abundance based cap' using estimates of adult western Alaska Chinook salmon returns as proposed within the North Pacific Fishery Management Council.*

Ed Farley provided a clarification to this ToR. He indicated that in essence they are asking if the juvenile Chinook salmon index developed from survey data would be a useful tool for the North Pacific Fisheries Management Council to consider when determining abundance based caps for Chinook salmon bycatch. As background, Chinook salmon has been declining since the early 1980s. Causes of the decline are unknown, but questions have arisen as to the relative importance of climate versus bycatch in the decline. The bycatch peaked in 2007 and has declined since then. Still, there is concern about the bycatch of Chinook salmon by the pollock fishery, and abundance based caps have been put in place such that if the number of salmon drops below 250,000, then the bycatch is limited to 60,000 and if the salmon abundance continues to remain below 250,000 for 3 out of 7 consecutive years the bycatch limit will be further reduced. I think that the western Alaska Chinook salmon index has the potential for determining abundance based caps for the bycatch by the pollock fishery, but will require further confirmation of the relationships with stronger statistical reliability.

7) *Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of:*

a. *separate Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling*
b. *joint Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling, particularly regarding their*

potentials to: i) evaluate the nutritional and behavioral ecology of Chinook salmon, walleye pollock, Pacific cod, arrowtooth flounder, and ancillary forage species; ii) put that information into the context of their biotic and abiotic environments; and iii) characterize their roles in the eastern Bering Sea Ecosystem. Provide specific recommendations for short- and long-term improvements to anticipated compromises associated with spring and late summer ecosystem surveys.

Rather than answer (a) and (b) separately I will compare and contrast the separate versus joint surveys together in my response. I also assume that issues (i), (ii) and (iii) refer to both (a) and (b), and not just (b).

Based on the BASIS survey information, it appears as if the salmon distributions are located on the inner domain and extend up into the northern Bering Sea while a greater percentage of the pollock and Pacific cod are located in the middle and outer domains of the southeastern Bering Sea. For this reason, I would recommend separate surveys for salmon and for pollock, cod and arrowtooth flounder. This would likely increase the costs over and above a joint survey. Given the potential of financial losses to the pollock fishery if there are high bycatches of salmon, it was suggested that the industry might be willing to pay for a vessel to carry out a separate salmon survey. This option should be explored, which would significantly reduce the costs of separate surveys. Separate surveys would likely increase the costs to NOAA for personnel to carry out the surveys. Assuming that a similar number of people are required on the ship to undertake each of the surveys, separate surveys would require between 1-2 times the total number of person days on a joint cruise, depending on how long the joint cruise would take compared to two separate survey cruises.

Yearly surveys obviously provide more data, and perhaps more importantly they will allow sooner notification of any significant changes in regards to the fish or the environment. I have already discussed the effects of yearly versus biennial surveys in terms of obtaining enough data to confirm statistical significance of any relationships (see last paragraph under ToRs 3 and 4) and this does not need to be repeated here. I would recommend carrying out an analysis of the existing annual survey data by selecting the data from every second year and compare the mean and variability of the abundance, diets and nutritional condition for Pollock, cod, and arrowtooth flounder as well as salmon, where available. This will provide both a comparison to assess what the effect of sampling yearly or biennially will be and give a quantitative estimate of the uncertainty associated with the less frequent sampling. This should be performed and assessed before any permanent long-standing decision on annual or biennial surveys is taken.

I believe that ecosystem sampling is needed whether there are separate or joint surveys, annual or biennial. Given that one of the main objectives is to provide mechanistic understanding of the relationships between climate and fish recruitment, ecosystem data should be collected during the same cruise as the fish data. This allows direct comparisons between the fish and the measures of environment and estimation of fish-weighed environment. For example, are the fish that are captured in the nets randomly distributed with respect to their environment, such as temperature, or are they selecting a preferred temperature range? This could only be answered with data collected during the surveys.

Nutritional and behavioral ecology of Chinook salmon, walleye pollock, and Pacific cod will be obtained whether the surveys are joint or separate, annual or biennial assuming adequate coverage of Bering Sea in a joint survey. More frequent sampling certainly has the potential for increasing the amount of information, but analyses need to be done to confirm this (see comment above regarding statistical significance). For arrowtooth flounder, the proposed new sampling, assuming adequate number of bottom trawls, will provide information on the nutrition and diets, but I do not think that the present sampling provides enough information to adequately determine the behavioral ecology of this species. Of particular interest is the role of arrowtooth as a predator on the young pollock during the winter season.

Little was presented during the meeting on forage fish compared to the main groundfish species and salmon. However, Andrews et al. (in review) does provide information on capelin and herring. Based on that paper, the full BASIS survey grid (north and south Bering Sea) does capture these species of forage fish and their distribution does appear to depend upon temperature conditions. Diet and nutritional data analysis have been and could continue to be collected. The data also provide some information on the behavioral ecology although more data from different seasons are needed (if not already available) to understand their life cycle.

The work of the RPA has gone a long way in linking the context of their biotic and abiotic environments. The Oscillating Control Hypothesis is one prime example of this, which captures the difference in phytoplankton and zooplankton productivity on walleye pollock during cold, high ice years, and warm, low ice years. Other examples include temperature effects on energy content of fish, phenology of the spring blooms, and size of the zooplankton and the influence of wind and transport on the distribution of eggs and larvae, to mention just a few. In this regard, they have been helped by the relative high environmental variability during the period of sampling with a number of cold years and a number of warm years, thereby providing contrast between periods. The recent shift from a cold period back to a warm year will help to confirm if the biological conditions observed during the earlier warm period will return.

The survey data and the stories they have been able to tell from them have helped to characterize, at least partially, their roles in the eastern Bering Sea Ecosystem.

8) *Evaluate gaps and inconsistencies in process research, particularly regarding the potential of research practices to provide mechanistic information to Integrated Ecosystem Assessments and Ecosystem Based Fishery Management practices.*

- One of the major gaps is the lack of winter data. To overcome this, one possible way to obtain information on the winter environmental conditions is to deploy autonomous gliders, which could be directed to sample throughout the winter and even under the ice, if necessary. Data could include temperature, salinity, oxygen, currents (using an ADCP attached to the glider) and turbulence, as well as phytoplankton (fluorescence) and zooplankton (ADCP backscatter). The gliders could sample from the early autumn through the winter into the spring when the ship surveys begin. They could sample the autumn blooms and determine if the zooplankton abundance peak at this time predicted by the model is real. The gliders could also sample the spring bloom, how it develops and its relationship with winds and density stratification. While this would be greatly

beneficial in terms of the environment and lower trophic levels, the gliders would not provide any data on the fish (except a bit from the acoustic backscatter data). In particular, a major gap in knowledge to fill is the primary cause of the mortality of the young Pollock during the winter. Is it due to starvation or is it predation? If the latter, what species is the major predator? Ideally, a directed NOAA winter survey would be preferred, but even if a boat were available there is a strong possibility of very limited sampling due to heavy weather. To overcome this but still help answer these questions about sources of mortality, perhaps the fishing industry could be persuaded to collect samples of young pollock and cod for diet and condition analysis. Diet samples for arrowtooth flounder should be collected to help determine if it is indeed a major predator of young pollock and cod. Diet analysis on other potential predators should be undertaken to determine the relative importance of arrowtooth flounder on the mortality of young pollock and cod.

- Much less is known about arrowtooth flounder than pollock and Pacific cod. This is not surprising given there is not an important commercial fishery for this species. As stated earlier, its importance is more as a voracious predator. To obtain more information on this species, more directed surveys or a special study will be required. Given that the spawning of arrowtooth tends to be along the slope, more stations will be needed there. While it appears to me that the some of the arrowtooth eggs and larvae spawned along the slope would make it onto the shelf, many would be carried along the slope towards the northwest by the residual currents. Are these lost to the population, and if not, where do they end up and do they eventually migrate back to the spawning locations to the southeast? Initially, this could be explored with the use of models, but a combined study of modeling, Lagrangian transport using drifters, and a directed survey would, I think, be needed to ultimately determine where the arrowtooth are transported to and what might happen to them. However, the largest unknown I think is the importance of arrowtooth as a predator, in particular on the first year pollock and cod during the winter. This could be determined by obtaining winter samples for diet analysis (see comment above for suggested methods).
- Modeling results indicate a fall zooplankton bloom in response to a late phytoplankton bloom, but no surveys are being conducted late enough to test this. However, autonomous measuring devices could be deployed to test the results. First, backscatter from acoustic Doppler current profilers could be analyzed to determine if zooplankton abundances rise to take advantage of the fall phytoplankton blooms. Secondly, one could use gliders equipped with acoustics to assess the zooplankton concentrations. They provide an advantage over the current meter moorings in that it can obtain data over a larger spatial region.
- Ocean acidification, associated with the rising atmospheric CO_2 concentrations, is a concern especially for those organisms with calcite shells. Colder water regions are particularly vulnerable due the potential for higher pH levels. While the impact on the northern Bering Sea is potentially greater than the southeastern Bering Sea region because of the greater number of key calcifying prey organisms for higher trophic predators (seabirds and marine mammals in particular), it still may be important in the southeast, and more consideration should be given to this topic and especially the combined effects of ocean acidification with climate change and the pending warmer climate.

Other Thoughts

- As previously stated, the impetus spawned by the funding from BEST and BSIERP helped to advance the recruitment processes research within the RPA. With the completion of those programs and the push from NPRB to go to the Arctic, this means not only will there be less money to continue the research in the Bering Sea, but the staff will likely be drawn off in other directions (I was told that many of those working on the Bering Sea Program have joined in proposals for Arctic work). This is just an acknowledgement that without an influx of new money, it is likely that the rate of progress in the Eastern Bering Sea research will be slower, perhaps significantly so.
- The use of degree days as a measure of growth, rate to maturity, and size has been demonstrated for a number of fish, both marine and freshwater (Neuheimer and Taggart, 2007). I did not hear or see any studies that included investigating the possibility that degree days could explain life history characteristics such as growth or phenology. If this has not been done, then I would suggest exploring this environmental variable.
- The RPA should consider 3-D krigging of the physical, chemical and biological data if it is not being performed already. This could take advantage of data collected on random surveys or other surveys conducted in the Bering Sea. The most common form of krigging is 2-D (using the 2 horizontal dimensions), but adding the depth component would improve the interpolation scheme, for variables such as temperature and salinity. Interpolations could then be performed onto any grid if desired. Such interpolations could be use to extend gridded time series back in time using previously collected data. Krigging depends upon the correlation scales, which can vary in each dimension (along shelf, across shelf, with depth) and seasonally. These scales could be determined from the presently available NOAA surveys, except for the winter season when no surveys have been conducted.
- Seldom can just one variable account for the fluctuations in fish recruitment over time. Indeed, as impressive and convincing as the relationship between autumn condition and survival of pollock is in the work by Heintz et al. (2013) and others, it is important to recognize that in the coming years other factors become equally or more important than total energy content. For this reason, it is important to continue the monitoring of not only the total energy content but other environmental and biological factors as well.

Critique of the NMFS Review Process

The reviewers were asked to critique the review process. The different expertise of the review panel complemented each other and all had broad enough knowledge to understand and ask questions about the various aspects that were covered. I thought that Mike Sigler did an excellent job of guiding us through the review during the meeting and keeping us on track. He ensured that all necessary material that we had to review were provided adequate time to go through. He also allowed discussions to go on when significant progress was being made, but still kept us on time in regards to the agenda. The meeting presentations were very good and provided much of the pertinent information we required. One issue that I found a bit confusing was that the different surveys were sometimes referred to by different names, which at times made it difficult to follow exactly what survey was being discussed. Prior to the

meeting, the reviewers were provided with a rather long list of papers with the instruction that we did not necessarily have to read any of them in detail but should familiar ourselves with their conclusions. I think it would have been preferable and resulted in the reviewers, myself in particular, being better prepared if one or two primary papers per ToR had been identified to read and then provided a list of other papers we should become familiar with. My final comment on the review is in regard to the ToRs. Perhaps a bit more time could have been spent on these to make them (at least some) a bit clearer as to what was wanted. In addition, I felt there was significant overlap between some of ToRs which meant that they could have been combined. However, overall I was very pleased with the review process and congratulate the RPA for doing a good job in organizing and presenting the material. The program is truly an impressive research effort.

Conclusions and Recommendations

The major conclusions regarding the Fisheries Recruitment Processes Applied Research:

- The research that has been carried out by the RPA has been impressive and one of, if not the most comprehensive study, of recruitment worldwide.
- Statistical analysis of the late summer to early fall survey data has shown recruitment of pollock at age-3 to be dependent upon the amount of energy stored in the late fall at age-1, which suggests that survival during the first winter is critical in determining recruitment success. Further confirmation of the importance of the autumn energy content for recruitment has been provided for Pacific cod and strengthens the conclusion that this is a major breakthrough in terms of recruitment mechanisms. The RPA team is to be commended for this groundbreaking work.
- These results are based on only about a decade of observations and confirmation of the condition-recruitment relationships must be undertaken.
- The deployment of the current meter array in the Bering Sea and the associated biophysical sampling should be maintained on an ongoing basis.
- The spring larval survey should adopt an adaptive strategy to ensure adequate sampling of the distributions. Time required for such a strategy could be achieved by reducing the number of grid stations to the minimum required to produce a reliable index of abundance. Autocorrelation of the larval data in the along- and across-shelf directions should be undertaken using past data to determine the spatial scales and this information used to determine the appropriate grid sizes and which grid stations can be cut (if possible).
- It is recommended that the late summer survey be mainly an acoustic survey but with surface tows. To ensure timely delivery of the acoustic data will require additional processing capacity.
- Separate summertime surveys for the salmon and groundfish are recommended based upon their different spatial distributions.
- Environmental data should continue to be collected on all surveys.
- If the rate of advancement of the science is to continue at the pace over the last decade or more, it will require an influx of additional funds given the completion of the BEST and BSIERP programs that provided significant funding to the RPA.

- While results from the survey are being used to influence management through the Ecosystem Considerations report, species report cards, and various physical, chemical and biological indicators, the potential for greater influence and even direct considerations in the assessment process is high but more work is needed in this regard.

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Appendix 2: CIE Statement of Work

External Independent Peer Review by the Center for Independent Experts

Review of Fisheries Recruitment Processes Applied Research in Support of Ecosystem Based Fishery Management of the Bering Sea Ecosystem

Scope of Work and CIE Process: The National Marine Fisheries Service (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: We request an independent CIE review of the ecosystem and fisheries recruitment processes applied research conducted at the NMFS's Alaska Fisheries Science Center (AFSC). Ecosystem and fisheries research has been conducted by various programs within the AFSC for over 30 years. Recently several of these programs came together to form the Recruitment Processes Alliance (RPA), which joins expertise, merges effort, and facilitates scientific exchange in the study of Arctic and North Pacific ecosystem functioning. The RPA, comprised of the Recruitment Processes program (the Ecosystems and Fisheries Oceanography Coordinated Investigations or EcoFOCI), the Ecosystem Monitoring and Assessment (EMA) program (the Bering Arctic-Subarctic Integrated Survey or BASIS), the Marine Acoustics and Conservation Engineering (MACE) program, the Resource Ecology and Ecosystems Modeling (REEM) program, and the Resource Energetics and Costal Assessment (RECA) program, as well as the members of the EcoFOCI Program that reside at the Pacific Marine Environmental Laboratory (PMEL). This effort is a unique collaboration among NMFS programs within the AFSC and across-line offices (National Marine Fisheries Service and Oceanic and Atmospheric) with a primary goal to provide mechanistic understanding of the factors that influence recruitment of walleye pollock, Pacific cod, arrowtooth flounder, Chinook salmon and chum salmon, focusing on factors influencing the first year of ocean life. To accomplish this, seasonal (spring, summer, autumn) field surveys and process-oriented research are conducted to inform single-species, multi-species, and biophysical ecosystem models. Survey methods rely on gridded net tows and selected use of acoustics to collect target species, with concurrent oceanographic and environmental sampling to estimate biological and physical oceanographic structuring forces. For this review, an impartial evaluation of the joint, RPA fisheries-oceanographic research of the Eastern Bering Sea will be conducted to evaluate the survey methodology and analytical approaches used to estimate relative abundance, distribution, biomass, and

physiological condition of target species, the biophysical environmental variables thought to structure recruitment of target species, and the incorporation of observed variables into ecosystem forecast models, Integrated Ecosystem Assessments (IEAs), and Ecosystem Based Fishery Management (EBFM) practices. The terms of Reference (ToRs) of the peer review are attached below.

Requirements for CIE Review:
Four CIE experts shall participate in a panel peer review in accordance with the SoW and ToRs herein. The review panel shall have the combined expertise and working knowledge in (1) recruitment processes surveys and design including fisheries-oceanographic plankton and trawl survey design, operation, sampling and analysis; (2) familiarity with ocean ecology of early life stages of groundfish and salmonid species, (3) field methods, including acoustics for process studies, and spatial sampling and analysis of distribution and abundance of young fish; (4) experience in Ecosystem Based Fishery management and/or Integrated Ecosystem Assessment; (5) climate-coupled single-species, multi-species, and biophysical models. Each CIE reviewer is requested to provide a separate and independent evaluation. The CIE reviewer's duties shall include (1) conducting pre-review preparations with document review; (2) participation in panel review meeting; and (3) completion of a CIE independent peer review report in accordance with the ToR and the Schedule of Milestones and Deliverables. The agenda for the Panel review meeting will be provided to reviewers along with background materials two weeks prior to the panel meeting. Each CIE reviewer's duties shall not exceed a maximum of 10 days to complete all work tasks of the peer review described herein.

Location/Date of Peer Review: Four CIE experts shall participate during a panel review meeting scheduled at the **AFSC in Seattle, Washington** to be held during the dates of **July 21-24, 2015.**

Statement of Tasks: Each CIE expert shall complete the following tasks in accordance with the SoW, ToRs and Schedule of Milestones and Deliverables specified herein.

Prior to the Peer Review: Upon completion of the CIE expert selection by the CIE Steering committee, the CIE shall provide the CIE expert information (name, affiliation, and contact details) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to each CIE expert. The NMFS Project Contact is responsible for providing the CIE experts with the background documents, reports, foreign national security clearance, and information concerning other pertinent information. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE experts participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE experts who are non-US citizens. For this reason, the CIE experts shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website:

http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to each CIE expert all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance with the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Panel Review: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs. Modifications to the SoW and ToR cannot be made during the peer review, and any SoW or ToR modification prior to the peer review shall be approved by the COR and CIE Lead Coordinator. Each CIE expert shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their tasks shall be focused on the ToRs as specified in the contract SoW.

The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer **shall complete** the independent peer review addressing each ToR as described in Annex 2.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables.**

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review;
2) Participate during the panel review meeting in **Seattle, Washington** during **21-24 July 2015**, and conduct an independent peer review in accordance with the ToRs (**Annex 2**);
3) No later than **7 August 2015**, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Dr. Manoj Shivlani, CIE Lead Coordinator, via email to mshivlani@ntvifederal.com, and to Dr. David Die, CIE Regional Coordinator, via email to ddie@rsmas@miami.edu. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE **shall complete** the tasks and deliverables described in this SoW in accordance with the following schedule.

29 June 2015	CIE sends the reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
6 July 2015	NMFS Project Contact sends the CIE Reviewers the pre-review documents
21-24 July 2015	Each reviewer participates and conducts an independent peer review during the panel review meeting
7 August 2015	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
21 August 2015	CIE submits the CIE independent peer review reports to the COTR
28 August 2015	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: This "Time and Materials" task order may require an update or modification due to possible changes to the terms of reference or schedule of milestones resulting from the fishery management decision process of the NOAA Leadership, Fishery Management Council, and the Council's SSC advisory committee. A request to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent changes. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on changes. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToR within the SoW as long as the role and ability of the CIE experts to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COR (Allen Shimada, via allen.shimada@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards: (1) the CIE reports shall have the format and content in accordance with **Annex 1**, (2) the CIE reports shall address each ToR as specified in **Annex 2**, (3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon notification of acceptance by the COR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COR. The COR will distribute the approved CIE reports to the NMFS Project Contact and regional Center Director.

Support Personnel:

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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. Each CIE independent report **shall be prefaced** with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of each peer review report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe using their own words, the review activities completed during the panel review meeting, including a detailed summary of findings, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. Each CIE independent peer review report shall be a stand-alone document for others to understand the proceedings and findings of the meeting, regardless of whether or not they read the summary report. Each CIE independent report shall be an independent peer review of each ToRs.

3. Each report shall include the appendices as follows:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership and other pertinent information from the panel review meeting.

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Annex 2: Terms of Reference (ToR) for the Center for Independent Experts Panel Review of the Fisheries Recruitment Processes Applied Research in Support of Ecosystem Based Fishery Management of the Bering Sea Ecosystem.

Each CIE reviewer **will conduct an independent peer review** addressing each ToR;

1) Review background materials and documents that detail the ecosystem and fishery survey design and methods, and data analysis methods and results for:
    a. Joint walleye pollock, Pacific cod, and arrowtooth flounder surveys;
    b. Chinook salmon and chum salmon survey
    c. Joint bio-physical oceanographic survey component (ecosystem).

2) Evaluate the *historic*, spring and late summer ecosystem and fishery survey designs, methods, and analytical approaches including data preparations and quantitative analyses to estimate the nutritional and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)

3) Evaluate the *planned change* in trawl survey design for the late summer survey design (surface trawl with midwater acoustics to oblique trawl with acoustics), methods, and analytical approaches including data preparations and quantitative analyses to estimate the nutritional and behavioral ecology of target species (e.g. size, diet, energetic content, relative abundances, distributions, and biomasses, and associated uncertainties.)

4) Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of transitioning the late summer survey from surface trawl with midwater acoustics to an oblique trawl survey, particularly regarding its potential to provide comparisons between historical and future nutritional and behavioral ecology of target species.

5) Evaluate the potential of the spring and late summer ecosystem and fishery survey designs and analyses, or an alternative, to (i) be applied to coupled biophysical-individual based modeling and trophic modeling approaches currently in use, ii) resolving mechanistic linkages among ecosystem components, and (iii) be applied to management and conservation of walleye pollock, Pacific cod, and arrowtooth flounder within an Ecosystem Based Fishery Management approach.

6) Evaluate the potential of the late summer ecosystem and fishery survey design and analysis, or an alternative, to incorporate these data in a western Alaska Chinook salmon the estimation of an 'abundance based cap' for prohibited species catch within the Bering Sea walleye pollock fishery in comparison to the proposed 'abundance based cap' using estimates of adult western Alaska Chinook salmon returns as proposed within the North Pacific Fishery Management Council.

7) Evaluate the tradeoffs, in terms of costs, benefits, and consequences, of:
    a. separate Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling

b. joint Chinook salmon and walleye pollock, Pacific cod, arrowtooth flounder surveys every year or every other year, with or without ecosystem sampling, particularly regarding their potentials to: i) evaluate the nutritional and behavioral ecology of Chinook salmon, walleye pollock, Pacific cod, arrowtooth flounder, and ancillary forage species; ii) put that information into the context of their biotic and abiotic environments; and iii) characterize their roles in the eastern Bering Sea Ecosystem. Provide specific recommendations for short- and long-term improvements to anticipated compromises associated with spring and late summer ecosystem surveys.

8) Evaluate gaps and inconsistencies in process research, particularly regarding the potential of research practices to provide mechanistic information to Integrated Ecosystem Assessments and Ecosystem Based Fishery Management practices.

Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

The following attended the panel review meeting during October 28-30. The NFMS Users group only attended in the afternoon of October 29th.

CIE Panel Members

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