Final Report of the Indices Working Group Workshop: 13-14 June 2001

Prepared by J.D. Schuamcher and C. Ferrar

1.0 Workshop Attendees

IWG: Al Hermann, Anne Hollowed, Nancy Kachel, Allen Macklin, Bern Megrey, Jeff Napp, Jim Schumacher, Alan Springer, and Phyllis Stabeno.

IWG members not able to attend: Nick Bond, Jim Ianelli, Pat Livingston, Sigrid Salo and Terry Whitledge.

Also attending: Tom Wilderbuer, Ron Reed, Peggy Sullivan, Kerim Aydin and Cathy Ferrar (Rapporteur)

2.0 Introduction

The intent of this Report is to provide a summary of the results of discussions related to the various presentations (see Appendix A for the Agenda). As such, most of the information presented and the detailed discussion topics are omitted. The most important information for the success of the IWG is given in **Section 4.0 Key Points and Action Items from General Discussions.** This Section provides specific steps to be undertaken, a definition of which strata are to be used and when the next meetings are to be held.

To provide a focus for the IWG and this workshop, Allen Macklin reiterated the theme of the Southeast Bering Sea Carrying Capacity (SEBSCC) program. "The goal of the (SEBSCC) is to document the role of juvenile pollock in the eastern Bering Sea ecosystem, to examine the factors that affect their survival, and to develop and test annual indices of pre-recruit (age 1) abundance (from the SEBSCC Concept Paper, July 1995).

Allen also provided a background of the IWG's purpose developed at the SEBSCC Principal Investigators meeting held this past January. Based on the best understanding of ecosystem dynamics, the IWG will identify potential single- or multi-parameter constructs or indices (e.g., wind mixing, time of spring bloom, stratification plus cold pool presence) that lead to development of survival indices (which also provide input to the NMFS stock assessment model) and/or models of juvenile pollock for use by fisheries scientists at AFSC/NMFS. As a product, the group will create a matrix (the "Anne" matrix in honor of Anne Hollowed) that provides the availability of these constructs by time and appropriate geographic domain. The group will share relevant findings with the Pribilof and Overall Synthesis groups.

In accord with the SEBSCC goal and the charge to the IWG, the purpose of the workshop was to:

1. present status of indices development,
2. determine how to best match the spatial domain of physical/biological indices,
3. determine the next steps in indices development/analysis, and
4. develop a time-line for progress.

Objective (2) grew from an email discussion regarding the difference in the spatial extent of the NMFS strata and the smaller boxes defined by physical phenomena (e.g., the hydrographic and current domains and the corresponding transition zones or fronts). Pat Livingston posed a question regarding how to resolve the mismatch between the spatial extent of physical and biological strata. The solution suggested was to:

1. Sort physical and biological observations by strata;
2. Establish subsets of these observations for the boxes defined within strata;
3. Compare the time-series within the boxes to those for the entire strata;

4. Present results of these comparisons at the workshop in June.

The boxes were defined so that the physical observations would represent a distinct domain (geographical region) and not become less well defined due to incorporation of data from transition regions. The above approach will allow us to see how important the geographic distinction is to the physical environment. On the other hand, we did not want to lose too many biological observations so that data from the entire strata are generally used. This approach would permit an evaluation of how important including all data from a given stratum is to either of the ensuing time series.

The strategy of the workshop was to hear and discuss presentations of physical and biological components of the ecosystem, including spatial variation in their attendant indices. The intent was to have all participants assist in identifying the next steps in development and refinement of a given index.

3.0 Presentation of Results

Ice, Nutrients and Atmospheric Indices: Phyllis Stabeno presented results from the ice (Sigrid Salo was at sea) and atmospheric indices research (Nick Bond at a Gordon Conference), together with some information regarding potential indices for nutrients (Terry Whitledge was involved in field operations). The ice concentration results are presented in some detail in order to highlight the rich nature of the original time series and of the inherent spatial variability that exists over the shelf.

The concentration of ice was determined for each of the boxes as represented on the Proposed Unequal Area Strata or Boxes (April. A brief description of patterns of ice concentration in each of the areas follows.

Area 7: (the shelf north of St. Matthew Island) Ice remains for a long period, occurs earlier and retreat is latest of all the Areas. The date of last ice is typically about June 15 with the ice disappearing over a fairly long time scale (about 1 month from full to no coverage). Most of the change among years occurs on the interannual time scale rather than decadal.

Area 2b: Some decadal period in the ice coverage and disappearance occurs quicker than in Area 7.

Area 2a: very similar to 2b.

Area 4: Ice concentration shows the greatest variability here of all the boxes. There is similarity in ice concentration with patterns in 2a. There appears to be little difference between these two boxes in the length of time that the ice remains; the major difference is the later arrival of ice in Area 4.

The above are the four Areas with the most extensive ice.

Area 6: The concentration of ice changes immensely each year. This Area is dominated by interannual variation and it has distinctly less ice than the other areas. In some years there is little or no ice at all.

Area 8: (Contains mooring site 4) The concentration of ice here shows large variability in percent of concentration. The time maximum concentration varies throughout the years - one year it occurred in January while in another year it occurred about May 1^{st}

Area 3: (contains mooring site 2) We know the most about what is occurring at this location from the long term moored instruments. Interannual variability is the dominant energy in the spectrum of ice concentration here.

Area 1: Although this area is in a region where ice can form locally, there is huge interannual variability in the concentration of ice, which provides a most surprising result

Pribilof I: Some of the variation in ice concentration occurs because of the influence of the islands on regional/tidal currents. St. George Island typically has minimal ice compared to St. Paul Island. The patterns of ice concentration are very distinct from other areas. For example, in area 7 there is ice 5-6 months of year while there may be none at all around the Pribilof Islands.

Area 5: The warmer slope waters bathe this area and ice is a transient feature. There were significant concentrations in the early 1970's (cold period), and after the regime shift of 1976/77 ice was an infrequent visitor to this area. The dominant energy of this area occurs in the year-to-year variability.

The amount of nutrients over much of the shelf of the southeastern Bering Sea does not vary significantly from year to year. Winter conditions appear to bring much of the shelf back to reasonably high concentrations of nutrients. Nutrients can be, however, depleted in a given year. Area 8 (and perhaps 4) may benefit from a more continuous flux of nutrients due to advection. There appears to be two blooms (ice associated and spring) at mooring site 4. Given what we know about the nutrient cycle and the sparseness of observations over most of the shelf, development of indices related to nutrients is not reasonable at this time.

The basic data set for the development of atmospheric indices was from the NCEP reanalysis, which is a combination of model results and observations. As noted in the ice concentration observations, there are spatial variations among the areas. The data that were presented were grouped in summer (mid-May through July) and winter (January through March). In many of the time series there has been an increase in variability with time and it would be useful to quantify that. The need was identified to develop multi-parameter indices, e.g., a wind mixing index (wind stress to the 3/2 power) combined in some manner with an index of water column stratification. As with ice, an important question was over what time period do we average the series/index? For the biological (e.g., first feeding, predator-prey) and physical (e.g., ice cover, mixing) processes that go on in the ecosystem, what is the appropriate time with emphasis on those processes we know to directly impact survival of young pollock? While the entire time series could be a member of the Anne Matrix, such value-added indices would allow the incorporation of our combined knowledge.

Nancy Kachel presented some results from her examination of physical oceanographic parameters. As with the other physical features, spatial variation is great among the boxes. She examined how enlarging a given box might enhance the number of observations that could be used to develop indices. By enlarging area 3 the data set was expanded by nearly 50%. Her results were based on the data available in the EPIC database at PMEL. The trawl survey bottom temperature data and some other sets must be added to the database in order to generate a more complete set of indices. Examples of Physical Ocean Parameters could include primarily those derived from temperature such as the temperature of the surface and bottom layers, the integrated water column temperature and sharpness of the thermocline [dT/dz]. Using salinity is more challenging since there are much less data, however, salinity likely acts as a proxy for nitrate and the integrated water column salinity provides some measure of onshelf flux/ice melt.

Summary of Discussion on Indices Related to Physical/Chemical Phenomena

1. A single index of ice concentration or wind-derived quantities is not valid for the entire SEBSCC study area. Since time series observations exist, indices will be created for each box within the strata.
2. The change in solar radiation (adequate light for the initiation of primary production) must be modeled in order to develop an index of potential primary production (time/duration) in each box. Such an index would provide the start time for the period during which ice concentration is important to processes that influence survival of larval through age-0 pollock, i.e., and a multi-parameter index.
3. Another step in the evolution of ice indices is the development of a numerical ice index rather than 8 or 9 spatial distributions. One form this could take is a series of ice concentration times time (integration under the curve of ice concentration), with the time period being related to the first day when light is sufficient to start primary production. An equivalent metric might be the concentration of ice between March 20 and May 15th (given that the light is adequate to begin primary production in all areas on 20 March), or that quantity weighted by the light availability curve. Another niche in the Anne Matrix would contain the date of last ice in an area.
4. Examine the variability in the NCEP derived time series using covariance analysis techniques.
5. Develop "wind mixing" indices. While the entire time series could become niches in the Matrix, indices for "critical periods" would have added value. The time of last "storm" and start of "storms" in fall (plus storms in summer that may drive prolonged production in the vicinity of the inner front) should also be Matrix elements.

Hydrodynamic Model (HDM): Al Herrmann presented results form the HDM, which showed good agreement between model and observed "larval" pollock trajectories. The mixing parameters used in the model appear to result in over mixing so that the physical property fields, which mirror those observed, are different in magnitude. It is apparent that results generated by the HDM are central to development of many indices since the model provides complete spatial fields (temperature, salinity, current, etc.) not available from observations. If fields generated by the model began to be produced in July, by the December Workshop a wealth of information should be available for use.

Summary of Indices Related Products From the HDM

1. It is vital to produce model results for as many years as possible back to 1972.
2. Primary products to be generated by the HDM include:
   a. Trajectories to be compared to those produced by OSCURS.
   b. Temperature fields and vertical stratification available for "preferred habitat" of age-0 vs. adults, where the preferred habitats are to be defined by AFSC scientists.
   c. Integrated volume fluxes where the regions, depth intervals and time periods are to be defined by both physical and biological IWG members.

3. The "mixing" parameters need to be adjusted to more closely mirror direct observations of water properties.

Biological Components of the Ecosystem: Presentations were made of information available on and potential indices related to plankton (Jeff Napp), fish (Anne Hollowed Tom Wilderbuer and Kerim Aydin (for Pat Livingston) and birds and marine mammals (Alan Springer). Clearly, both the plankton and the marine mammal/bird observations are very limited in spatial coverage. Where time series are available, they should be included in the Matrix. Analyzing data on plankton eating birds possibly can extend the zooplankton time series. Using these results, an index of adequate prey abundance for age-0 pollock could be developed, particularly for the Pribilof Island area and area 1 (which includes Cape Pierce). Looking at overall productivity of marine birds that primarily eat fish (i.e., red legged kittiwakes and murres), together with other diet information (diet varies, so one would have to identify a couple of months where it is somewhat consistent) may contribute (within the given temporal and spatial limits) to the integrated biological/physical matrix we're building. In general, however, it is likely that indices based on either plankton or marine mammals/birds will not play a major role in examination of factors influencing survival of young pollock.

The potential use of indices for examination of factors affecting trends in recruitment and behavior of fish other than pollock (i.e., flat fishes) is another benefit that may occur from developing indices. Anne presented data from the pollock recruitment time series, which is the basic data set against which indices will be tested. Further, she gave the following summary of factors that influence survival of pollock at various life history stages:

1. Success of stages through larval depends on:
   a. Hatching success which is related to water temperature and location of spawning
   b. First feeding success which is related to timing/extent of spring bloom (NPZ sequence), wind mixing (turbulence) which can affect both production and feeding success of larval pollock and features of the environment that concentrate larvae such as eddies and fronts.
   c. Transport of larvae to nursery areas, which depends on initial location and the strength of the currents.
2. Juvenile success depends on:
   a. Growth (must achieve size necessary to survive over winter), which depends on prey availability processes, which result in concentration (eddies/fronts) and temperature (index of metabolism).
   b. Avoidance of predation which depends on abundance and distribution of adult pollock and other groundfish, together with physical features (e.g., mixed layer depth, strength of vertical stratification) that could allow spatial separation between the juvenile pollock and their predators

Kerim Aydin (who works with Pat Livingston) presented results from predator-prey models. The food habits database contains information on all major fish species for the last 20 years for the eastern Bering shelf area. It was noted that Areas 1-6 are typically lumped together. Data includes stomach contents (from trawl surveys), where the fish was caught and its size. The summary of results from presentations and discussion is:

1. Develop time series for several of the boxes and compare to values calculated for the entire stratum.
2. Develop time series of spawning by strata for development/analysis of trajectories generated by the HDM (use age-0 surveys from the Oshuro Maru).
3. Develop time series of "predator modified" recruits to compare to impacts resulting from changes in other components of the environment.
4. Examine records of roe quality to estimate if spawn was early or late. This would provide an index of spawning time.
5. Examine the distribution of key species within a stratum.

4.0 Key Points and Action Items from General Discussions

Focus and Form: Bern Megrey made three important points: (A) all of the indices that are developed should be related to a general model, (B) that the functional response of young pollock to a given index must be known, and (C) that at the next work shop, which will be held in Seattle on 12-13 December (other dates will be considered), all the data sets should be available in the same format so that we all can play. There was a consensus that the Bering Sea switch model would provide the base upon which indices were added. An example of a functional response can be developed from the potential impact of wind-induced turbulence on success of larval pollock. Up to some magnitude, wind mixing may be beneficial while above that point the integrated affect is detrimental to larval survival.

Products for the Final Report: Workshop participants identified products that should be available either for reference or to be included in the Final Report from the IWG.

1. Quality controlled times series of the data sets on a meta-database and database.
2. A reasonably completed Matrix of indices which includes how and why the index was derived.
3. Comparison of output from the assessment model with and without indices.

Our schedule is to have a Draft Final Report by July and a Final by 15 September 2002.

What's Next? The next step is for the individual IWG members to continue their work related to indices. Clearly, it is extremely important that the various investigators interact with each other. For example, those compiling data and generating indices of the physical environment need to know from the fisheries scientists what are the critical time periods and/or locations (e.g., start points for generation of trajectories). The production of simulations from the HDM should become a focal point, a common ground between the various researchers. Finally, some of the physical scientists have concern that integrating fisheries data from all Areas and/or generating one number from each stratum may obscure important processes. For example, if most of the fish in Area 1 are located near the inner front (their distribution is strongly not homogeneous), then generating an index of the oceanic environment for the entire Area may show no linkage to fish survival.

Action Items: During the workshop, 5 major themes were generated for indices related to Physical Phenomena (PP), 4 for indices related to the HDM and 5 for indices related to fish (F). There also are several other actions items related to completion of the aforementioned 13 themes. From my interpretation of results from the workshop, I have generated the following list of ACTION ITEMS and have tentatively identified those responsible:

GENERAL

1. Begin constructing the Matrix on the SEBSCC web page (Allen Macklin).
2. To maintain momentum and foster communications, schedule an afternoon meeting of IWG members from AFSC and PMEL to compare results of the Action Items below. Late August early September should give individuals time to complete much of their products. (Allen Macklin, Phyllis Stabeno and Anne Hollowed).

PHYSICAL PHENOMENA

1. Develop light curves for each strata/box (Jeff Napp) and use time of adequate light for primary production to begin as initial time for ice indices.
2. Develop a numeric ice index for each box using results (from 1. above) and [ice concentration] x [time until region is ice free] (Sigrid Salo).
3. Generate wind-mixing indices and examine changes in variability of atmospheric phenomenon (Nick Bond). Note: while the daily average mixing time series could be made available, what is wanted in the Matrix are indices for critical periods whose definition requires input from biologists (Jeff Napp, Bern Megrey and others).
4. Develop time series of surface temperature, bottom temperature (cold-pool), mixed layer depth/thermocline depth and strength of thermocline (Nancy Kachel).
5. Develop time history of satellite color imagery (Sigrid Salo).

HDM

1. Hire someone (under "Indices" component, Phyllis Stabeno) to conduct model simulations.
2. Generate trajectories of "planktonic" life history stages of pollock (modeler, Al Herrmann). This effort requires input from biologists regarding spawning time/location (Anne Hollowed, Jim Ianelli, others). Compare trajectories to OSCURS output (Al Herrmann, Jim Ianelli).
3. Adjust mixing parameters (Al Herrmann, modeler).
4. Given information on the location of age-0 (from 2 above and any direct observations) and adult pollock "preferred habitats" (research presently being conducted by Troy Buckley, Gary Walters and Taina Honkalehto), simulate temperature and vertical stratification conditions (modeler) and generate an index of juvenile survival/abundance and adult abundance if appropriate (Pat, modeler, Phyllis and Anne Hollowed).

BIOLOGICAL COMPONENTS

1. Make available time series of marine mammals/birds (Alan Springer) and zooplankton (Jeff Napp).
2. Analyze data on plankton-eating birds to extend the zooplankton time series. Using these results, develop an index of adequate prey abundance for age-0

pollock for the Pribilof Island area and area 1 (which includes Cape Pierce)…Alan Springer and Jeff Napp.

3. Provide time series of recruitment, spawning biomass, distribution of age 1, distribution of age 2, distribution of age 3 and distribution of age 4+ pollock. Also provide any information on the winter spawning distribution as inferred from catch and scattered surveys, together with winter egg distribution in selected years (if possible). Finally, provide the distribution of piscivorous groundfish (cod and ATF) (Jim Ianelli).
4. Conduct a comparison of pollock abundance within a small box versus within an entire stratum (Sigrid Salo).
5. Examine the trawl survey data to determine if there are preferred regions within a given stratum (see HDM 4, above).

With regard to which strata to use, to be consistent with the Synthesis Group (Workshop, 31 July-2 August 2001), the following will be used: The strata which appear in the Hunt et al (submitted) paper (The eastern Bering Sea: A Review Of Data And New Hypotheses For Control Of Energy Flow Through The Ecosystem) will be used with physical data generally compiled and spatially average within the boxes of the unequal area presentation.