Scientific and Statistical Committee
Ecosystem-Based Management Subcommittee Report

Pacific Fishery Management Council
Online Meeting

November 5, 2024

The Scientific and Statistical Committee's Ecosystem-based Management Subcommittee (SSC-ES) met via webinar November 5, 2024 to review new forage indicators that may potentially inform future annual Ecosystem Status Reports (ESRs) to the Pacific Fishery Management Council (PFMC) on the state of the California Current Ecosystem. The SSC-ES reviewed two topics: a.) a coastwide index of abundance for krill and b.) a Dungeness crab megalopae index. Dr. Kristin Marshall (SSC-ES chair) chaired the meeting.

A. Coastwide krill abundance index

Elizabeth Phillips (NWFSC) presented a summary of krill abundance and distribution estimated from acoustic data collected during the Joint Integrated Ecosystem Acoustic-Trawl Survey for Pacific Hake between 2007 and 2023. Krill are a major forage group for a wide range of fish and marine mammal species and are a vital link between lower and upper trophic levels (e.g., phytoplankton and whales, respectively). A better understanding of patterns in the vertical, temporal, and spatial distribution of krill in the northeast Pacific should provide an important addition to the California Current Ecosystem Status Report.

Dr. Phillips summarized the process of translating raw acoustic data to location-specific estimates of krill relative density (Nautical Area Scattering Coefficient, NASC) and then to generalized maps of krill abundance and distribution. Surveys span from Point Conception, CA, to Dixon Entrance, AK, and include waters between the 50m and 1500m isobaths. Surveys are conducted in odd years (2007-2023) between mid-June and mid-September during daylight hours. The krill detected and classified using this acoustic approach are dominated by two species, *Thysanoessa spinifera* (more common in the central and northern survey areas in shallower habitats) and *Euphasuia pacifica* (more common in the southern areas and in offshore habitats). These two krill species cannot be discriminated using acoustic backscatter alone (i.e., their frequency responses overlap), so the krill data represent abundance and distribution of both species.

The acoustic proxy used as an indicator of krill density (NASC) indicated a more than 4-fold variation in krill among years, with 2015 notably lower than other years due to a very low biomass of krill south of central Vancouver Island, British Columbia, Canada. Despite this year-to-year variation, some persistent hotspots of high krill biomass are evident along the coast (e.g., near the Juan de Fuca eddy system and just north of Cape Mendocino, CA). Additionally, the relative distribution of krill with depth is relatively consistent among years. Depths shallower than 15m cannot be reliably used for determining krill NASC.

The krill acoustic proxy is the most spatially extensive data source for krill on the U.S. west coast, offering an excellent opportunity for connecting krill to other ecosystem components. Krill are a major prey item for many other species (e.g., Pacific hake, baleen whales) and this time series may prove invaluable in understanding the distribution, size, and growth of krill predators. There is also considerable potential value in better understanding the oceanographic drivers of krill abundance and distribution. Some particularly valuable future research avenues include studies of finer scale patterns of krill in response to environmental drivers (e.g., canyons and oceanographic fronts), separating the krill biomass into component species to understand species-level patterns in abundance and distribution, predicting future patterns of krill biomass using oceanographic models, and understanding spatio-temporal overlap between krill and their predators. Beyond krill, the acoustic methodology used here, perhaps paired with environmental DNA or other concurrently collected information, has the potential to be extended to identify and quantify other species groups such as myctophids.

The SSC-ES is very supportive of using this krill indicator in the Ecosystem Status Report and encourages further development of both the indicator itself and potential connections to other ecosystem components. There is enormous potential for this indicator to be helpful in advancing our understanding of both krill and the other ecosystem components connected to krill. The SSC-ES also notes that many other indicators for krill in different regions are either reported in the CCIEA or available elsewhere, and recommends that a more comprehensive review of the strengths and weaknesses of various krill indicators be considered in the future.

B. Dungeness crab megalopae abundance

Alan Shanks (Oregon State University) and Leif Rasmuson (Oregon Department of Fish and Wildlife) provided an overview of ongoing monitoring efforts and a body of literature and analyses related to ongoing monitoring of Dungeness crab megalopae (the last pelagic larval stage) abundance. This research was developed to better understand the mechanisms for cross-shelf movement of crab megalopae, which has been shown to relate strongly to tidal cycles and internal waves. Recently, the monitoring time series has also demonstrated potential to inform the Dungeness crab fishery with respect to the strength of incoming year classes, based on observed correlations between catch rates of megalopae in light traps and commercial landings four years later (adult male crabs typically recruit to the fishery at approximately 4 years of age, females are neither targeted nor retained in the fishery). Crab megalopae are also important components of the coastal ocean food web, particularly in years when abundance is high.

The research effort began in 1997, with light traps used to attract and capture pelagic crab megalopae as they prepare to settle to nearshore benthic habitat in the spring. Initial sampling included multiple traps deployed throughout different parts of the Coos Bay estuary as well as the open coast, and it was quickly recognized that catch rate patterns were similar in both the open coast and throughout the estuary, but with lower catch rates further up the estuary. As early data indicated a strong correlation between megalopae catch and commercial landings 4 years later, the Oregon Dungeness Crab Commission has continued to support this monitoring and research effort since 2006, with the University of Oregon using the monitoring program as a research opportunity for undergraduate students.

Much has been learned about the oceanographic drivers (primarily related to tidal cycles) and fine-temporal scale variability in catch rates, while annual catches from the monitoring program have been shown to vary by several orders of magnitude. The data indicate that megalopae catches decline substantially during strong El Niño events, and that the largest catches occur during negative PDOs, with factors such as upwelling and timing of the spring transition also influencing catch rates. The mechanisms behind these patterns are thought to be primarily related to large scale ocean processes having an influence on larval survival, and consequently interacting seasonal cycling of transport patterns that enable the survivors to be transported onshore by internal tides.

The relationship between megalopae abundance and the catch of age 4 crabs four years later does not resemble a typical spawner-recruit relationship, as the variability in megalopae catches is far greater than those of landings (factor nearly 3000 versus factor of 5). There is evidence for density dependent processes, as the number of recruits per megalopae drops with increasing abundance. However, the researchers have developed a somewhat unusual predictive model, in which two separate regressions are used depending on a threshold of catch rates, representing separate relationships between megalopae catch and subsequent fishery catches relative to whether megalopae catches were above or below a given abundance threshold. This approach appears to predict the observed commercial catch reasonably well, however, distinct patterns have appeared during large marine heatwaves relative to non-heatwave years. The model also appears to perform far better for prediction of Oregon adult crab catches than other states, and while it also performs reasonably well for California catches, it performs poorly for Washington catches. The biogeographic barrier and coastal ocean dynamics associated with the Columbia River plume may relate to these observations.

To the extent the Council community may be interested in indicators of future crab fishery performance, despite the fact that this fishery is not managed by the PFMC, the SSC-ES recommends exploring a finer scale geographic evaluation between megalopae catches and subsequent fishery landings. Similarly, more monitoring in other regions of the coast to better understand and evaluate regional variability in megalopae catches could be insightful (some relatively recent megalopae monitoring efforts that might help to inform such questions were also discussed). The relationship between megalopae abundance and subsequent crab fishery landing appears different in the period prior to, during, and after the large marine heatwave, which may limit the utility of the indicator for forecasting fishery performance. The SSC-ES and the proponents acknowledged the need to better understand both physical and biological dynamics (particularly density-dependent processes related to crab numbers, such as cannibalism, and potentially how metabolism may vary during large marine heatwaves) with respect to recruitment processes following settlement of megalopae.

The SSC-ES supports the inclusion of the megalopae index in future Ecosystem Status Reports as an indicator of forage availability. During years of high abundance, megalopae could represent an important trophic transfer of energy to nearshore ecosystems. However, it was not clear how important such pulses of forage may be to higher trophic level predators or to the food web due to the highly episodic nature within seasons and the high degree of year-to-year variability among seasons.

Appendix A. SSC Ecosystem Subcommittee Member Participants

Dr. Cheryl Barnes, Oregon State University & Oregon Department of Fish and Wildlife, Newport, OR

Dr. John Field, National Marine Fisheries Service Southwest Fisheries Science Center, Santa Cruz, CA

Dr. Chris Free, University of California, Santa Barbara, Santa Barbara, CA

Dr. Dan Holland, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle, WA

Dr. Galen Johnson, Northwest Indian Fisheries Commission, Olympia, WA

Dr. Kristin Marshall (SSC Ecosystem-Based Management Subcommittee Chair), National Marine Fisheries Service Northwest Fisheries Science Center, Seattle, WA

Dr. Tommy Moore, Northwest Indian Fisheries Commission, Forks, WA

Dr. Matthew Reimer, University of California Davis, Davis, CA

Dr. William Satterthwaite, National Marine Fisheries Service Southwest Fisheries Science Center, Santa Cruz, CA

Dr. Ole Shelton, National Marine Fisheries Service Northwest Fisheries Science Center, Seattle, WA