APPENDIX C: Case Study Narratives and Examples of the FEP Process

BUILDING EFFECTIVE FISHERY ECOSYSTEM PLANS:
A REPORT FROM THE LENFEST FISHERY ECOSYSTEM TASK FORCE

Appendix C

CASE STUDY NARRATIVES AND EXAMPLES OF THE FEP PROCESS

Groundfish and Habitat in New England

This case study focuses on the Gulf of Maine region in New England, in the Northwest Atlantic larger marine ecosystem, governed by the Northeast Fisheries Management Council (NEFMC).

Background of Fisheries System Topic

One ecologically and economically important finfish fishery in the Gulf of Maine is the multispecies groundfish fishery, with iconic species like cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). Other important fisheries include the herring (*Clupea harengus*) fishery and the American lobster (*Homarus americanus*) fishery. Groundfish consume both lobsters and herring, and have strong effects on lobster behavior (i.e., reduce their movement and restrict them to shelter habitat; McMahan et al. 2013). Meanwhile, herring is used as bait in the lobster fishery (Grabowski et al. 2010), connecting these two fisheries through this anthropogenic linkage.

There has long been tension among these three fisheries. The groundfish fishery is convinced that the herring fishery both catches groundfish as bycatch and causes groundfish schools to disperse when they catch herring near groundfish schools. Both the lobster and groundfish fisheries supported the federal management efforts to limit the herring fishery through gear restrictions (banned mid-water trawls in favor of purse seining), limits to harvest in specific sections, and seasonal spawning closures in the nearshore waters of the Gulf of Maine that coincide with the peak of the lobster fishing season in summer. The lobster fishery supported these measures in spite of the fact that it made it more challenging for the herring fishery to land the fish that the lobster fishery needs for bait, and it potentially increased the proportion of herring that was landed for human consumption instead of bait. There are also issues around groundfish fishermen landing lobsters (allowed in Massachusetts, but not in Maine) and the limited ability of fishermen to move among fisheries to match the ebbs and flows of different species. The groundfish fishery is extremely stressed, and wants greater access to and certainty in catch levels looking out into the near to midterm (3-5 years). Emergency actions shutting down the groundfish fishery and the annual assessments are causing the industry both severe economic hardship and inducing high levels of stress.

Summary of Management Activity Related to Steps in the FEP Process Loop

The Ecosystem Status Report of the Northeast Shelf Large Marine Ecosystem (Ecosystem Assessment Program 2012) was completed in 2012 and contains descriptions of components of the fishery system, including climate, physical pressures, primary and secondary production, invertebrates, fish, protected species, and anthropogenic factors. This report also includes time-series data on components of the system and indicators (integrative ecosystem measures).

There is EBFM activity related to the groundfish fishery (including cod) and habitat. A strategic objective adopted by the New England Fishery Management Council from the Essential Fish Habitat mandate was – "describe and identify essential fish habitat for the fishery based on the guidelines established by the Secretary under section 305(b)(1)(A), minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat," (NEFMC 2016; Grabowski et al. 2014; Magnuson-Stevens Fishery Conservation and Management Act 2007). Based on this objective, more specific objectives were identified related to EFH and on-going work on groundfish habitat in the NEFMC's Omnibus Habitat Amendment 2. Specifically: "The first groundfish-specific purpose of this amendment is to improve protection for juvenile groundfish and their habitats (Purpose D). Success at younger ages can have positive productivity benefits for managed resources, and therefore action is needed to protect the habitats important for juvenile groundfish, particularly for commercially valuable species. A second groundfish-specific purpose of this amendment is to identify seasonal closed areas in the Northeast Multispecies FMP that would reduce impacts on spawning groundfish and on the spawning activity of key groundfish species, because the protection of spawning fish is needed to sustainably manage stocks (Purpose E)" (NEFMC 2016).

A management strategy evaluation process was used to evaluate various fisheries closures that may impact groundfish habitat based on the objectives above. Specifically, a Swept area seabed impacts model (SASI) was developed to evaluate different gear-types in terms of adverse effects on fish habitat (Omnibus Habitat Amendment 2 Appendix D; Grabowski et al. 2014). The SASI model highlighted areas vulnerable to fishing gear and this information was paired with analyses on juvenile habitat and adult spawning habitat of cod and other groundfish. Based on this information, a Closed Area Technical Team identified potential management strategies in the form of possible alternative closed areas. Information on all the spatial management alternatives (including the preferred strategies) are detailed in the Habitat Omnibus Amendment II Volume 3 (under review at the time this report). The alternative spatial management strategies were then evaluated through impact analysis to determine the potential impacts of each strategy on habitat, human community, protected resources (protected species), managed resources, fisheries, and cumulative impacts (Omnibus volumes IV and V). Alternative spatial management strategies were then voted on by the council (Grabowski per. comm.). There was also additional public comment and public hearings on the Omnibus amendment. As of July 2016, the amendment document and accompanying EIS is undergoing final review. Final NMFS approval and rulemaking will occur later this year.

Butterfish, habitat, and Fisheries Interactions in the Mid-Atlantic

This case study focuses on Butterfish and longfin inshore squid fisheries and habitat of butterfish, in the Mid-Atlantic region of the Northeast United States, governed by the Mid-Atlantic Fisheries Management Council.

Background of Fisheries System Topic

Butterfish (*Peprilus triacanthus*) in the mid-Atlantic is primarily a bycatch species and butterfish bycatch caps have constrained the fishery for longfin inshore squid (*Doryteuthis pealeii*). There is a high degree of habitat overlap between butterfish and squid and technical measures, e.g., minimum mesh size, have been only partly successful in reducing bycatch. The butterfish stock was determined to be overfished in the 2003 stock assessment, but the trends in the 2003 assessment conflicted with trends observed in the following assessment in 2009. One problem with the stock assessment of butterfish is that the degree of overlap between the stock and the trawl surveys is variable depending on environmental conditions – leading to attempts to quantify this in the most recent stock assessment (see below). The 2009 stock assessment resulted in a determination that fishing mortality rates had been extremely low in recent years and could not account for the apparent decline in butterfish biomass. However, the biological reference points estimated from this assessment were rejected by the assessment review panel as a basis for management (Northeast Fisheries Science Center 2010). As a result, the industry was faced with a situation in which it was widely acknowledged that fishing mortality rates on butterfish were extremely low, yet the rebuilding plan continued to call for tight caps on butterfish bycatch in the squid fishery. This situation led to reduced economic benefits to squid fishermen and distrust of the assessment by the industry.

Summary of FEP Process Activity and Tools

There is ongoing work by the Mid-Atlantic Fisheries Management Council (MAFMC) to inventory the fishery system and system-level ecosystem approaches, including information related to forage fish (such as butterfish) and climate. This work is part of the councils EAFM Guidance Document development that was initiated in 2011

(MAFMC 2015). As of April 2016, there was a first draft of the full guidance document that includes trends in indicators such as temperature and landings and a conceptual model of habitat interactions in the Mid-Atlantic.

Work to develop a strategic vision and strategic objectives that broadly relate to the case study topics was completed in 2013 and presented in the MAFMC Strategic Plan (MAFMC 2013). The vision statement decided on is: "*Healthy and productive marine ecosystems supporting thriving, sustainable marine fisheries that provide the greatest overall benefit to stakeholders*," (MAFMC 2013). This vision, other goals, and a comprehensive strategic plan were developed through the "Visioning and Strategic Planning Project". This project was initiated at a time when all MAFMC managed fisheries were rebuilt and no longer overfished, leading to some flexibility to cultivate the council's management strategies (MAFMC 2012). This planning strategy included a "large-scale stakeholder outreach effort" (MAFMC 2012) and input was collected from stakeholders through surveys, port meetings (roundtable sessions), and position letters, with more than 1,500 participants (MAFMC 2012). This effort was initiated in order to gain a full understanding of the system from stakeholder information and to broaden stakeholder involvement (only a small percent of stakeholders participated in the management process previously; MAFMC 2012). Stakeholder involvement included members from commercial and recreational fisheries, environmental organizations, seafood users, scientists and researchers, and more. The vision statement itself was developed based on questions to stakeholders about how they envision "successful" fisheries in the Mid-Atlantic.

One activity related to EBFM is the use of environmental data in the butterfish stock assessment (Adams et al. 2015), leading to a single species harvest control rule with an ecosystem consideration. There was a specific Term of Reference for the stock assessment that required the assessment scientists to consider oceanographic factors and include them in the assessment model if possible. Through an academic-industry-NOAA collaborative process, key environmental drivers of butterfish spatial distribution were identified and used to estimate the annual overlap between the stock and the trawl survey. Specifically, bottom temperature was used to define the availability of butterfish to the NEFSC trawl survey by measuring overlap between their thermal habitat and the trawl survey footprint. This thermal niche model determined annual estimates of availability of butterfish to the trawl survey, but in the end, a constant availability (from the model) was used because there was relatively little interannual variability in availability (62-75%). This information was directly incorporated into the 2014 assessment, which concluded that the stock is not overfished (and never was) and that overfishing is not occurring. While this difference in estimated stock status cannot be attributed to the use of environmental data, the inclusive process by which the environmental data was brought into the assessment resulted in greater confidence in the assessment by industry.

One tactical tool not currently in use is habitat modeling to identify areas of high butterfish bycatch that squid fishermen can avoid. Preliminary investigation suggests that the habitat preferences of the two species are too similar to reliably separate them by habitat.

Atlantic Menhaden

This case study focuses on the forage fish Atlantic menhaden. The present-day fishery is concentrated in the Mid-Atlantic, specifically in coastal, nearshore, and estuarine regions. Management of Atlantic menhaden is governed by the Atlantic States Marine Fisheries Commission (ASMFC).

Background of Fisheries System Topic

Atlantic menhaden (*Brevoortia tyrannus*) constitutes the biggest fishery in the Mid-Atlantic large marine ecosystem. This species has historically contributed from 100,000 to above 700,000 tons annually. Menhaden is a key forage for other managed species in regional fisheries and are important prey for seabirds and marine mammals. Products from the menhaden reduction fisheries supply feeds to livestock and aquaculture industries on a global scale and products from the bait fisheries on menhaden supply bait to other managed fisheries (e.g., crabs, lobster). Menhaden spawn offshore but juvenile production is dependent on estuarine nurseries.

The Atlantic menhaden has been referred to as "the most important fish in the sea," highlighting its role in supporting predators in the ecosystem and potentially having an important role in improving or affecting water quality through its filtering activities. So-called "localized depletion" of menhaden concerns recreational fishermen who believe predator availability is controlled by local abundance of menhaden, and this led to a cap on menhaden catch in the Chesapeake Bay. A single company catches and processes most menhaden. Additionally, a single, large facility processes the Atlantic menhaden catch from the Atlantic reduction fishery. Human health supplements (omega-3 products) are a relatively new product of the menhaden industry.

Menhaden in the Chesapeake Bay are managed as a part of the coastwide menhaden stock- the assessment of menhaden and its coastwide reference points and management include the Chesapeake component of the fishery. However, special regulations on fishing are imposed in Chesapeake Bay, including a cap on total catch. Local regulations abound in the Bay—e.g., purse seines are not allowed in Maryland waters, but are the major fishing gear used in Virginia to catch menhaden. The ASMFC has allocated menhaden among the states that have historically fished them and the biggest allocation is to Virginia, with a large part of that state’s allocation coming from catches in Chesapeake Bay (>50,000 tons annually in recent years).

Summary of Management Activity Related to Steps in the FEP Process Loop

The Chesapeake Bay FEP is one system inventory that includes information on Atlantic menhaden (Chesapeake Bay Fisheries Advisory Panel 2006) (alternatively The Ecosystem Status Report for the Northeast Shelf Large Marine Ecosystem also is a relevant system inventory for this case study).

The strategic vision for the menhaden fishery involves maintaining a valuable and sustainable menhaden fishery while avoiding damage to the ecosystem and menhaden-dependent predators. Specifically, from ASMFC (2012): "*The goal of Amendment 2 is to manage the Atlantic menhaden fishery in a manner that is biologically, economically, socially and ecologically sound, while protecting the resource and those who benefit from it."* This strategic vision was developed over multiple years and the original statement was very focused on the menhaden fishery and its yield. Through pressure from multiple stakeholders, mainly recreational fisheries and environmentalists, the strategic vision was broadened and the ASFMC gradually accepted and included ecosystem-level objectives that currently make up the vision statement (see ASMFC 2004). In addition to this vision statement, broad level objectives for the fishery can be found in the most recent stock assessment (SEDAR 2015).

Two relevant ecosystem-related management strategies exist for menhaden. Within the stock assessment for menhaden, a predation mortality value derived from a Multispecies Virtual Population Analysis provides a measure of age-specific natural mortality, leading to a single-species harvest control rule/strategy with an ecosystem consideration. Alternatively, in the Chesapeake Bay, there is a management strategy that caps the catch at 87,200 metric tons (mt) (SEDAR 2015), a measure enacted by ASMFC to reduce the probability of localized depletion of menhaden (ASMFC 2005).

An Atlantic Menhaden Technical Team and the Biological-Ecological Reference Points subgroup identified performance indicators for menhaden including environmental indicators, indices of forage abundance, and prey: predator ratios (SEDAR 2015). This team also worked on developing ecosystem reference points (ERPs) but stated that without explicit goals from the board, they could not recommend a ERP to adopt (SEDAR 2015 Appendix E). However, an inclusive set of performance indicators was identified and the BERP subgroup is proceeding with development of model and MSE-like analysis to test different harvest control rules. The BERP indicator and reference point work and recommendations in SEDAR 40 led the ASMFC to develop ecosystem objectives (ASMFC memorandum - 2015). Fundamental objectives such as "sustain menhaden to provide for predators" were identified. This work is on-going and not currently used in management.

In addition, there is ongoing research outside of ASMFC to develop ecosystem indicators and ecosystem reference points for Atlantic menhaden through a Lenfest-funded project, based on a coastwide Ecopath with Ecosim modeling approach. Additionally, the ASFMC recently launched a socio-economic study for Atlantic menhaden (ASMFC 2016).

Red Tide Impacts on Gag Grouper in the Gulf of Mexico

This case study focuses on the Gag grouper (*Mycteroperca microlepis*) fishery in the Gulf of Mexico, specifically from the coast to the continental shelf edge of the marine ecosystem, primarily in the eastern half of the Gulf. This region is governed by the Gulf of Mexico Fishery Management Council and the Florida Fish and Wildlife Conservation Commission.

Background of Fisheries System Topic

Gag grouper is a 2nd-level priority species (the stock(s) are designated as overfished OR stock(s) are undergoing overfishing or in need of an assessment) in the Gulf of Mexico and one of the more important reef fish species exploited in the eastern Gulf (second only to red grouper). There are three types of fisheries for Gag grouper: a commercial fishery, a recreational fishery, and a for-hire fishery (charter- and headboat), with the recreational fishery having overwhelmingly large catch. Because Gag is part of a multi-species reef fish complex, the targeted species in this group (e.g., gag) results in significant bycatch of other economically important reef fishes (e.g., red snapper *Lutjanus campechanus*, scamp *Mycteroperca phenax*, red grouper *Epinephelus morio*). Bycatch mortality (e.g., due to size limits, season) exceeds the landed catch because fish often occur at depths that preclude recovery from baro-trauma. Prey of Gag grouper includes some economically important species as well (e.g., vermilion snapper). Gag are piscivorous top-level predators as adults on offshore reefs, but primarily crustacivores as juveniles in seagrass habitat. There is continued research focused on offshore spawning sites of gag grouper, but no attention paid to two other essential habitats: open water (important for larval stages) and seagrass beds occupied by juvenile Gag.

Finally, harmful algal blooms or red tide events in the West Florida Shelf likely cause increased mortality for gag grouper. Particularly, a severe event in 2005 coincided with a sharp decline in gag grouper abundance indices. However, the mechanism behind how red tide causes mortality in gag is not known (direct toxicity or indirect impact) (SEDAR 2014).

Summary of Management Activity Related to Steps in the FEP Process Loop

The Ecosystem Status Report for the Gulf of Mexico (Karnauska et al. 2013) summarizes components of the fishery system. This report also presents status and trends for individual species, fisheries and environmental components/indicators such as data on trends of red tide events. This report is part of the Integrated Ecosystem Assessment work for the Gulf of Mexico and a DPSER conceptual model was used to select indicators that "reflect the status of key drivers, pressures, states, ecosystem services, and responses in the ecosystem" (Kelble et al. 2013).

Management is still single-species management, with little of no direct consideration of ecosystem-level concerns except for those relevant to red tide, which led to a single species management strategy with an ecosystem consideration. An additional source of mortality was added to the Gag grouper stock assessment in the Gulf of Mexico because of the large mortality caused by a red tide event in 2005 (SEDAR 2014). Red tide was modeled as a fishing fleet removing Gag and picked up as "discard" rather than "directed fishing mortality", doubling mortality predicted in the previous SEDAR (10). There is also ongoing work by the Integrated Ecosystem Assessment working group (presented in the gag stock assessment) on red tide severity indices (from remote sensing data and FWRI's Harmful Algal Bloom database), that could be used as environmental covariates in the stock assessment model (SEDAR 2014). However, these indices are not currently used. Additionally, there is continued monitoring of red tide events with the goal to be able to forecast potential problems from red tide and determine how it actually affects fish.

Pacific Sardine and Temperature

This case study focuses on the Pacific Sardine fishery in the California Current ecosystem in the Northeast Pacific, managed by the Pacific Fishery Management Council.

Background of Fisheries System Topic

The Pacific sardine (*Sardinops sagax*) fishery was the largest in terms of catch for any of the species included in the PFMC CPS (Coastal Pelagic Species) FMP in the California Current system, till the closure of the fishery in 2015. Sardine are prey for predatory fish in the west coast groundfish, salmon, halibut, and migratory species (including albacore) fisheries, leading to potential trade-offs between fisheries. Sardine are also prey for other marine species, including protected marine mammals and seabirds.

Sardine recruitment is related to ocean conditions, with specifically higher recruitment in warm ocean conditions (related to PDO). The current sardine harvest control rule addresses these issues. General pelagic harvest control is set to be:

Harvest Target Level = (BIOMASS-CUTOFF) x FRACTION x DISTRIBUTION (Hill et al. 2014). The CUTOFF term is the lowest estimated value of biomass, below which no fishing is allowed (to protect the stock when biomass is low). Recently in 2015 the fishery was shutdown because it's believed to have dropped below this level. The FRACTION term is set at anywhere between 5-20% based on temperature for the previous 3 years since sardine productivity is higher in warmer ocean conditions (higher FRACTION with higher temperatures). There is also a maximum allowable catch that is set at 200,000 mt so that there is never extremely high catch levels in case there is an error in biomass estimation. Max catch and cap on catch help to allow for (or buffer for) continued prey for sardine predators. This harvest control rule also assumes 87% of the stock is in US waters (to deal with management across countries).

Summary of Management Activity Related to Steps in the FEP Process Loop

The Pacific Coast Fishery Ecosystem Plan summaries information on the entire California Current ecosystem and includes information on Pacific sardine and the relationship with sea surface temperature (PFMC 2013a). Within this FEP, there is a summary of ecosystem goals across Fishery Management Plans (FMPs). One broad goal or objective for Coastal Pelagic species (including sardine), is to "Provide adequate forage for dependent predators" (PFMC 2013). Additionally, there is an Integrated Ecosystem Assessment (IEA) for the California Current that includes status and trends of specific components (Levin et al. 2013).

The harvest control rule stated above that includes the temperature related term, was decided on based on a recent management strategy evaluation. The strong relationship between sea surface temperature (originally at Scripps pier) and recruitment was established in a management context by Jacobsen and MacCall (1995) during work on the sardine assessment (later approved by the SSC). In later assessments, it became apparent that the pattern between Scripps sea surface temperature and sardine productivity no longer held (Kevin Hill pers. Comm., McClatchie et al. 2010, Lindegren et al. 2012). Work by McClatchie et al. 2010 also showed a relationship between California Cooperative Oceanic Fisheries Investigations (CalCOFI) sea surface temperature and sardine productivity. After the deficiency of Scripps pier temperature as a predictor was identified by stock assessment scientists and the SSC, the Pacific Fishery Management Council convened a workshop to determine a new initial set of management strategies (PFMC 2013b). This workshop included members of the SSC, the PFMC CPS Advisory subpanel, the PFMC CPS management team, and other scientists. Hurtado-Ferro and Punt (2014) took the management strategies identified in the 2013 workshop and performed a management strategy evaluation using an age-structured population model of Pacific Sardine as the operating model and evaluating the performance of the strategies based on different performance criteria or indicators, such as variance of catch, mean catch, SSB, and more (see Hurtado-Ferro and Punt 2014 for all criteria and strategies). Strategies tested included using the previous temperature indicator, the new temperature indicator (CalCOFI temperature), and various levels of the cut-off value. After the MSE was reviewed, the control rule that included the use of CalCOFI temperature was selected (see PFMC 2014b). The continued use of the 150,000 mt cut-off management strategy was included in the selected strategy.

There was/is continued monitoring of the relationship between temperature and sardine productivity in the stock assessment and through this monitoring it was originally discovered that the relationship between Scripps pier temperature and sardine productivity no longer held. Moving forward, there is no formal re-evaluation of the temperature-recruitment relationship from year to year, but monitoring of these factors in the stock assessments can show when there is deviation from the pattern.

Interacting Protected Species in the Pacific (Killer whale and Chinook Salmon)

This case study focuses on protected salmon species (particularly Chinook, *Oncorhynchus tshawytscha*) in the Northeast Pacific (California Current to S.E. Alaska, including Puget Sound) and protected marine mammal predators that prey on salmon. Salmon fisheries on the West Coast are managed by the Pacific Fisheries Management Council, in cooperation with the Pacific Salmon Commission, which provides guidance on the international Pacific Salmon Treaty between the U.S. and Canada. Marine mammal populations are managed by NOAA Fisheries.

Background of Fisheries System Topic

Pacific salmon fisheries on the US West Coast primarily target Chinook, Coho (*Oncorhynchus kisutch*), and Pink Salmon (*Oncorhynchus gorbuscha*) and 17 species are listed as threatened or endangered under ESA. Fisheries sectors include ocean commercial fisheries, recreational fisheries, and tribal (commercial, subsistence, and ceremonial) fisheries. Salmon management over the past several decades has focused on controlling and mitigating the 4 H’s: harvest, hatcheries, hydropower dams, and habitat.

Potential conflicts between fisheries and marine mammals center on Chinook salmon, southern resident killer whales (*Orcinus orca*), and pinnipeds (primarily harbor seals (*Phoca vitulina*) and California sea lions (*Zalophus californianus*)). Southern resident killer whales are listed as endangered under the U.S. Endangered Species Act, and pinnipeds are protected by the Marine Mammal Protection Act (MMPA). Since its inception in 1972, many MMPA-protected pinnipeds on the West Coast have been increasing rapidly. The effects of pinniped and killer whale predation on Pacific salmon are not currently addressed by fisheries management. Additionally transboundary/trans-country salmon migration complicates management because an individual salmon can travel through the ocean waters of two countries and four U.S. states during its life-time, and may be subject to fishing or predation in any of those areas.

Salmon and killer whales are iconic organisms in the Pacific Northwest and both have high non-monetary value in the region. Killer whales also support a lucrative whale watching industry in the San Juan Islands of Washington. Predation interactions create the potential for salmon fisheries to conflict with social goals. While a waiver of the moratorium on take of California sea lions has been granted to haze and remove individuals predating on returning salmon near Bonneville Dam on the Columbia River, whether more general culling of pinnipeds would be socially acceptable is an open question.

A considerable amount of ecosystem management already occurs to benefit Pacific Salmon recovery (freshwater and habitat restoration, and modifications to dam operations and hatchery practices). However, salmon management could benefit from an investigation of changing natural mortality rates from increasing predators. Currently, the assessment model for salmon has assumed a fixed natural mortality rate through time, despite the significant increases in pinniped populations.

Summary of Management Activity Related to Steps in the FEP Process Loop

The Pacific Council's Fishery Ecosystem Plan provides general information on direct and indirect interactions between fisheries and marine mammals on the West Coast. The FEP also mentions the importance of salmon in the diets of endangered killer whale (PFMC 2013a). NOAA's Integrated Ecosystem Assessment (IEA) for the California Current includes salmon and marine mammals as key ecosystem components, with multiple indicators for each (Levin et al. 2013. The marine mammal indicators currently focus on pinniped species and have not yet been expanded to cetaceans.

The Pacific Council's Salmon Fishery Management Plan does not have specific objectives for managing salmon fisheries in light of their importance as prey to marine mammals. However, protected species in marine waters are managed by NOAA Fisheries, and objectives/goals stemming from the killer whale recovery plan (mandated by the Endangered Species Act) include: "Ensure adequate habitat to support a recovered population of Southern Resident killer whales. Habitat needs include sufficient quantity, quality, and accessibility of prey species," (NMFS 2008).

NOAA Fisheries and the Department of Fisheries and Oceans (DFO) Canada convened an independent scientific review panel to evaluate the effects of salmon fisheries on southern resident killer whales (Hilborn et al. 2012). The panel reviewed science that suggested that Southern Resident Killer whale survival and fecundity rates were correlated with indices of Chinook abundance (Hilborn et al. 2012, Ward et al. 2009). The panel also evaluated simulations of a salmon population model that closed all ocean fishing on Chinook, and concluded that even complete cessation of fishing would increase Chinook abundance by a maximum of 25 percent. The panel concluded that the effects of this small change in Chinook abundance would be difficult to predict, but would be unlikely to translate to increased prey (or survival or fecundity) for killer whales. Instead, Chinook abundance is more strongly influenced by freshwater habitat and ocean conditions than by fishing mortality.

Alaska groundfish and avoiding ecosystem overfishing

This case study focuses on the Alaska Groundfish fishery in the Bering Sea and Aleutian Islands, managed by the North Pacific Fishery Management Council.

Background of Fisheries System Topic

Main Bering Sea fisheries consist of high-volume walleye pollock (*Gadus chalcogrammus*) fisheries, and other groundfish fisheries, including Pacific halibut (*Hippoglossus stenolepis*), sablefish (*Anoplopoma fimbria*) and Pacific cod (*Gadus macrocephalus*). Many of these fisheries are rationalized as ITQs or cooperatives and the fleet is socially heterogeneous consisting of non-Alaska residents, non-indigenous Alaska residents, and indigenous Alaska residents. Most groundfish fisheries also are conducted by multiple commercial sectors defined by gears or vessel characteristics. Climate is a widely known driver of population and community dynamics particularly at decadal scales. Walleye Pollock recruitment is related to annual-scale climate variation that affects timing of sea ice melt and water temperatures. Food web interactions are also considered important in this ecosystem and have implications for fisheries. A recent outburst of arrowtooth flounder (*Atheresthes stomias*) populations is thought to have reduced Walleye Pollock recruitment over the past 15 years (see Ianelli et al. *in press*). Previous declines of ESA listed western Aleutian stocks of Steller sea lion (*Eumetopias jubatus*) were thought by some to stem partly from competition with

Pollock fisheries (though also atka mackerel [*Pleurogrammus monopterygius*] and pacific cod), leading to fishery closures in feeding grounds surrounding Steller sea lion rookeries in the western Aleutians. However, this hypothesis for sea lion declines is controversial, and other hypotheses include: 1) environmental change, 2) predation by killer whales, 3) disease, 4) contaminants, 5) anthropogenic effects including direct and incidental mortality, and 6) combinations of all of the above. Available data do not point to any single hypothesis as being the most likely.

Species use across sectors has generated recent controversy. For instance, the bycatch of Chinook salmon (*Oncorhynchus tshawytscha*) and halibut in the trawl sector might reduce returns and opportunities for subsistence, recreational and directed commercial fisheries for these species. Because of the total cap on groundfish removals at 2 million metric tons per year, high quotas for pollock will reduce opportunities for fisheries in other groundfish sectors. In the Bering Sea, many fishermen express concerns about the high costs of entry into many commercial groundfish fisheries. The cod jig fishery is an entry-level fishery that has become increasingly popular because it is open to entering fishermen in this region.

Summary of Management Activity Related to Steps in the FEP Process Loop

The Ecosystem Considerations Report for the Alaska Regions (Bering Sea/Aleutian Islands, Gulf of Alaska, and Arctic) stemmed from the groundfish FMPs (Arctic, BSAI, and Gulf) (NPFMC 2015a) and contains ecosystem assessment and ecosystem status and trends and indicators for each region in Alaska. The goal of this annual report is to compile results from multiple research efforts and provide an ecosystem context for fishery management decisions. The Ecosystem Considerations Report began in 1995 when the NPFMC Groundfish Plan Team provided a separate document to the SAFE report on ecosystem considerations for the Groundfish fishery. In following years, additional elements were added to the report including bycatch effects, information on seabirds and mammals, essential fish habitat, oceanographic changes, and trends in ecosystem-based management. In 1999 a proposal was put forward to begin to include information on ecosystem status and trends and indicators.

The Aleutian Islands FEP is also a system inventory for this region, but also contains a system-wide risk assessment (NPFMC 2007). This FEP has a non-quantitative risk assessment (following classic risk assessment defined in NRC 1983 and EPA 1992 but qualitative) that looks at the ecological and economic impacts (low, medium, high, or unknown) of different activities (vessel traffic, change in fishery habitat, oil and gas activities, and more) based on the professional judgment of the Aleutian Islands Ecosystem Team and consensus judgment of the Ecosystem Team members.

For Alaska fisheries (and our Alaska groundfish case study), there is a broad ecosystem vision statement that states: "*Vision Statement – The Council envisions sustainable fisheries that provide benefits for harvesters, processors, recreational and* *subsistence users, and fishing communities, which (1) are maintained by healthy, productive, biodiverse, resilient marine ecosystems that support a range of services; (2) support robust populations of marine species at all trophic levels, including marine mammals and seabirds; and (3) are managed using a precautionary, transparent, and inclusive process that allows for analyses of tradeoffs, accounts for changing conditions, and mitigates threats*," (NPFMC 2014). This statement was developed by the Ecosystem Committee for the North Pacific Fishery Management Council, brought on partly by input from stakeholders that the council did not previously have a vision statement or ecosystem objectives (pers. Comm. Bill Tweit).

The Groundfish FMPs have multiple high level ecosystem related objectives including: "*Preserve food web*" and "*Incorporate ecosystem-based considerations into fishery management decisions, as appropriate*." Also more specific objectives about avoiding impacts to seabirds and mammals: "*Maintain or adjust current protection measures as appropriate to avoid jeopardy of extinction or adverse modification of critical habitat for ESA-listed Steller sea lions*," (NPFMC 2015b). The full list of 45 objectives (some ecosystem focused and others more single species focused) come from the 2004 council review of the BSAI/GOA groundfish fisheries (the Alaska Groundfish Programmatic Supplemental Environmental Impact Statement - PSEIS) and the groundfish management policy described in that report. Various components related to the objectives were analyzed based on the impacts of fishery management alternatives on those components. For example, one major objective is "Avoid impacts to Seabirds and Marine Mammals," and as part of the PSEIS (NMFS 2004), different fisheries management alternatives were analyzed for direct/indirect impacts on seabirds and marine mammals.

For Alaska's Bering Sea/Aleutian Islands groundfish fisheries, total catch of groundfish in the region can't exceed a 2 million mt catch cap. Acceptable Biological Catch (ABCs) are set for each stock separately, and then Annual Catch Limits (ACLs) are set so that they all total ACLs don't sum to above 2 million (only partially based on the ecosystem state). This cap was put into place in order to limit fleet capacity and avoid ecosystem overfishing (NPFMC 2015b). The OY (optimum yield) of 2 million mt value was chosen based on 85% of historical annual summed MSY estimates (1.4 to 2 million mt) (NPFMC 2015b). In the programmatic supplemental environmental impact statement, multiple alternative harvest management policies for groundfish were considered and the preferred strategy chosen was the 2 million mt. cap.

Contrasting fish and invertebrate fisheries and species interactions in the Western Scotian Shelf, Canada

This case study focuses on the Scotian Shelf, specifically the Western Scotian Shelf (North Atlantic Fisheries Organisation Division 4X), managed by Fisheries and Oceans Canada (DFO) in the Maritimes Region.

Background of Fisheries System Topic

There are several considerations for the Western Scotian Shelf fisheries, which include fisheries for groundfish, pelagic fish and invertebrates. Groundfish are harvested with trawl, gillnet or longline gear as part of a multi-species groundfish fishery, mostly targeting pollock (*Pollachius virens*), haddock (*Melanogrammus aeglefinus*) and cod (*Gadus morhua*), which is primarily caught as bycatch now, due to its low abundance. There are technical interactions, with by-catch species such as American plaice (*Hippoglossoides platessoides*), white hake (*Urophycis tenuis*), yellowtail flounder (*Pleuronectes ferruginea*), witch flounder (*Glyptocephalus cynoglossus*), winter flounder (*Pseudopleuronectes americanus*), halibut (*Hippoglossus hippoglossus*), and redfish (Sebastes spp.). Herring (*Clupea harengus*), the main forage fish species in the area, are over-fished, and prey for many of the groundfish, as well as seabirds and mammals. There is also concern about the unrecorded landings of herring used for bait in lobster (*Homarus americanus*) fishery. The main invertebrate fisheries are for scallop (*Placopecten magellanicus)* and lobster, some by-catch of groundfish, especially flatfish, in the former. Finally, there is an offshore lobster fishery and a large pelagic fishery, including bluefin tuna (*Thunnus thynnus*) and swordfish (*Xiphias gladius*). Currently groundfish and herring stocks are depressed, but invertebrate stocks (scallop and lobster) are doing well.

Herring are prey for many groundfish, as well as marine mammals, seabirds and large pelagic predators such as tunas. They also are dependent on zooplankton for food, and are likely predators of ichthyoplankton and cod and other groundfish eggs, although this has not been quantified in this area. Groundfish biomass is generally low, due to excess fishing, but may also be related to predation and environmental change.

Fisheries and Oceans Canada (DFO) uses Integrated Fisheries Management Plans (IFMP s) to guide the conservation and sustainable use of marine resources. An IFMP is developed to manage the fishery of a particular species in a given region. They combine the best available science on a species with industry data on capacity and methods for harvesting that species, and include social, cultural and economic objectives. The latter can reflect the aboriginal right to fish for food and social and ceremonial purposes, and also recognize the economic contribution that the fishing industry makes to Canadian businesses and many coastal communities. Ultimately, the economic viability of fisheries depends on the industry itself. However, the department is committed to managing the fisheries in a manner that helps its members be economically successful while using the ocean's resources in an environmentally sustainable manner. Key issues are the decline in traditional groundfish fisheries and decline in the herring fishery.

Summary of Management Activity Related to Steps in the FEP Process Loop

Fisheries and Oceans Canada produce State of the Ocean Reports for the different regions in Canada (FEPs are not used by DFO). The State of the Ocean Report for the Scotian Shelf, including the Western Scotian Shelf, covers a range of topics including ocean acidification, climate change and its effects on ecosystems, habitats and biota, Scotian Shelf in context, at-risk species, marine habitats and communities, trophic structure, ocean noise, waste and debris, invasive species, and water and sediment quality (http://www.dfo-mpo.gc.ca/science/coe-cde/soto/scotian-eng.asp). The State of the Ocean reports as well as the Ecosystem Status and Trends Report for the Gulf of Maine and Scotian Shelf (Worcester and Parker 2010) have time series data on many components/indicators in this system. There is ongoing work to assess risk to ecologically and biologically significant areas in the Western Scotian Shelf and other regions, but these assessments are not complete (see DFO 2014).

Within the DFO Regional Oceans Plan for the Maritimes Region (that includes the Scotian Shelf) there is the following broad vision statement for the region: "*Healthy marine and coastal ecosystems, sustainable communities and responsible use supported by effective management processes,"* (DFO 2014b). For individual species or fisheries in this case study (herring, groundfish, lobster, and scallop), each has an IFMP with specific goals or objectives. Within the lobster management plan for example, there are goals related to broader ecosystem impacts including: "Control unintended incidental mortality of North Atlantic right whales," and "Manage area disturbed of bottom habitat," (DFO 2011). Overarching all fisheries in the region are the following conservation and social objectives (see DFO 2013 as an example):

1. Productivity: Do not cause unacceptable reduction in productivity so that components can play their role in the functioning of the ecosystem.
2. Biodiversity: Do not cause unacceptable reduction in biodiversity in order to preserve the structure and natural resilience of the ecosystem.
3. Habitat: Do not cause unacceptable modification to habitat in order to safeguard both physical and chemical properties of the ecosystem.

Social, cultural and economic objectives

4. Culture and Sustenance: Respect Aboriginal and treaty rights to fish.
5. Prosperity: Create the circumstances for economically prosperous fisheries.

Finally, a Multispecies Virtual Population Analysis model (MSVPA) was developed to explore mortality of herring by predators (Guenette and Stephenson 2012), but this information and the model are not in use by management.

Interacting Fisheries in the Baltic Sea

This case study focuses on the Eastern Baltic Sea (ICES SD 25-32) for which Total Allowable Catches are scientifically advised by the International Council for the Exploration of the Sea (ICES) and management decisions are made by the European Union.

Summary of Fisheries System Topic

Eastern Baltic Sea fisheries are mainly focused on demersal cod (*Gadus morhua*) (bottom/pelagic trawling, gillnets) and pelagic forage fish, herring (*Clupea harengus*) and sprat (*Sprattus sprattus*). Cod and forage fishes strongly interact ecologically through (1) cod top-down predation and (2) sprat and herring predation on cod eggs. Furthermore, there is competition for zooplankton food between sprat and herring. Cod overfishing has hence in recent history caused a strong sprat increase. The large sprat stock depressed cod recruitment through egg predation and top-down control of zooplankton. Additionally, sprat density-dependent growth reductions have been observed in herring and sprat. Reduced herring growth and condition may negatively influence herring recruitment. All species, but especially cod, are strongly dependent (mainly species recruitment) on the physical oceanographic environment. Recent environmental conditions have resulted in distribution changes leading to a spatial mismatch on species interactions.

The social dimension of this case study includes the balance between economic optimization and equity aspects between sectors (demersal vs. pelagic) and regions. Socio-cultural preferences that may affect management decisions are local preference for resource species (cod in the south vs. sprat in the north). There are furthermore cultural differences in management goals reflected by a restoration/protection focus in Sweden versus an economic/exploitation focus in countries such as Poland.

Summary of Management Activity Related to Steps in the FEP Process Loop

System inventories for the Baltic Sea have been conducted within different ICES initiatives. The ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB) conducted what they called Integrated Trends Assessments (ITAs) of the various sub-systems of the Baltic Sea. These include multivariate analyses of time-series encompassing abiotic (nutrients, hydrography, fishing pressure) as well as plankton (phyto- and zooplankton) and fish (pelagic and demersal) time-series. Results for the Central Baltic are published in Möllmann et al. (2009) and analyses for multiple sub-systems in Diekmann & Möllmann (2010), and are irregularly updated within WGIAB. Furthermore, within ICES groups, there is development of ecosystem overviews for all European marine regions. The ecosystem overview for the Baltic Sea is in progress but will be published on the ICES website (http://www.ices.dk/community/advisory-process/Pages/Ecosystem-overviews.aspx).

Broad ecosystem goals for the region can be found in the Common Fisheries Policy (CFP) and the Marine Strategy Framework Directive (MSFD). The Common Fishery Policy of the EU was reformed in 2014 and now has the goal that, "Fish stocks should be brought up to healthy levels and be maintained in healthy conditions"(COM 2013). The CFP strives to develop ecosystem-based fisheries management by applying an MSY approach: "Fish stocks should be exploited at maximum sustainable yield levels. These levels can be defined as the highest catch that can be safely taken year after year and which maintains the fish population size at maximum productivity." Further elements of the CFP reform towards an ecosystem approach are (i) the stepwise implementation of a discard ban ("landing obligation") and (ii) efforts towards a stronger regional stakeholder involvement ("regionalization") to enhance compliance with management decisions. Overall, management of Baltic fish stocks is still single-species. However, presently a multi-annual ("long-term") management plan for multiple Baltic fish stocks is promoted within the legislative process of the EU. While not including a real multi-species MSY approach, F_{MSY} values are intended to be set within ranges that implicitly account for multi-species management goals. In addition minimum levels of the spawning stock biomass are set for conservation purposes.

There are multiple ongoing, not completed, projects within ICES and the Baltic related to EBFM. For the Baltic Sea a new ICES initiative (Workshop on developing integrated advice for Baltic Sea ecosystem-based fisheries management - WKDEICE) has been tasked to show how to integrate environmental and socio-economic information into advice. The group works on developing ecosystem indicators (abiotic/biotic) and how these can be included in short-term stock projections. Furthermore, socio-economic model simulation will be conducted. The overall goal of this process is to develop single and multi-species F_{MSY} options for the interacting species of cod, herring and sprat.

Previous efforts within ICES evaluated multi-species F_{MSY} but they are presently not considered due to uncertainties inherent in the multispecies model and cod input data (ICES 2013). Finally, there are a number of papers that have done MSEs for the Baltic Sea with respect to management plans, expected climate change effects, eutrophication, or economic considerations, but these have not been conducted within the operational management setting, only sometimes in relation to an ICES group (e.g. Bastardie et al. 2010, Gårdmark et al. 2013, Niiranen et al. 2013, Voss et al. 2014). On the other hand, management strategies from sprat and herring stock assessments include predation mortality parameters from MSVPA models, leading to single-species ecosystem consideration management strategies (ICES 2015).

Small Pelagic Fishery and Ecosystem Impacts in Australia

This case study focuses on the Small Pelagic Fishery (SPF) covering much of Eastern and Southern Australia and managed by the Australian Fisheries Management Authority (AFMA) (federally managed, not state managed).

Summary of Fisheries System Topic

The small pelagic fishery comprises commercial mid-water and bottom trawl fisheries targeting four low- to mid-trophic level species (Australian sardine *Sardinop sagax*, blue mackerel *Scomber australasicus*, jack mackerel *Trachurus declivis*, and redbait *Emmelichthys nitidus*). Product from this fishery is mainly used for fish feed (aquaculture), with only a limited amount used for direct human consumption (high volume low value product). There are multiple conservation concerns surrounding this fishery. Specifically, there is concern about the fishery impact on predators of SPF species including seabirds and marine mammals (trophic-mediated impact including through localized depletion of prey) and concern about the accidental catch of protected species by the commercial fishery (direct mortality from fishing).

Additionally, there is a recreational fishery for Southern Bluefin Tuna (*Thunnus maccoyii*) (SBT) off the East Coast of Tasmania, within the area of the SPF. The recreational and charter fishery mostly targets Tuna but also some other large pelagic species such as swordfish (*Xiphias gladius*). A commercial SBT fishery is managed by AFMA but the recreational fisheries are generally controlled by the states. There are social concerns related to the interactions between the recreational SBT fisheries and the small pelagic fisheries. One concern is the impact of SPF fishery on prey of SBT and therefore potential impacts on the abundance and distribution of Tuna that would adversely affect recreational fishing opportunities and experience.

Summary of Management Activity Related to Steps in the FEP Process Loop

Ecological risk assessment (ERA) is used to inform management of all federally-managed (and many state-managed) fisheries in Australia and a comprehensive ERA was done for the SPF fishery in 2007 (Daley et al. 2007). This ERA used a hierarchical approach with three levels: 1) remove activities that are determined to have low impact (Scale Intensity Consequence Analysis), 2) semi-quantitative prioritization process for species and habitats impacted by fishing (Productivity Susceptibility Analysis), 3) quantitative modeling based analysis (further prioritization and cumulative impact analysis).

The Australian public raised further concerns about risks posed by the SPF fishery. Particular concerns about the impact of the SPF on predators, protected species, other parts of the ecosystem, and other fisheries arose during 2012 when one of the license holders (quota owners) brought in from overseas a very large factory trawler (later dubbed a "super trawler") to fish its quota. Environmental and recreational fishing groups launched a media campaign against the use of this vessel and this led to widespread public disquiet. The federal government intervened and eventually banned the vessel all together. A description of these events can be found in Tracey et al (2013).

These events also coincided with a heightened public awareness about the trophic impacts of fishing "forage fish" including several of the species targeted in the SPF (sardine, Jack mackerel) due to publications such as the Lenfest report (Pikitch et al. 2012) and the publication of the Marine Stewardship Council criteria for assessing the sustainability of low trophic level species to take account of trophic impacts (MSC 2014).

It was this constellation of factors that led AFMA to review the SPF harvest strategy in 2013, with a particular focus on determining target and limit reference points that took account of impacts on predators of the target species in the SPF, as well as more general impacts on the food web. This review was undertaken and the results reported in Smith et al (2015) and led to a new harvest strategy for the fishery, adopted in 2015 (AFMA 2015).

The review of the SPF harvest strategy was undertaken by a group of fishery scientists and involved considerable interaction with AFMA and with stakeholders in the fishery, both in the initial design phase of the review, and during its course. The scientific group initially suggested using the MSC criteria for assessing low trophic level fisheries as objectives/performance indicators for management strategy evaluation for the review and this suggestion was endorsed by the Resource Assessment Group for the fishery, and by AFMA management. Adopting MSC criteria was seen as adopting a credible international standard.

The MSC criteria and guidelines allow the use of credible ecosystem models to evaluate impacts of fishing LTL species on other parts of the food web. The criteria for determining acceptable impact are that:

1. No other species is impacted by more than 70%
2. No more than 15% of other species or groups are impacted by more than 40%

The SPF review used an existing Atlantis ecosystem model tuned to the particular circumstances of the SPF (Smith et al 2015) to evaluate management strategies that would meet these operational objectives and performance indicators. The analysis concluded that harvest rates that achieved a target stock size of B50 (50% of unexploited biomass) met this performance criterion (no species or group was impacted by more than 40%) (Smith et al. 2015). Note that B50 was the status quo target stock size for the fishery before this analysis (corresponding to the maximum economic yield (MEY) target for all AFMA managed fisheries). Note that in the absence of availability of an ecosystem model for this specific ecosystem, the "safe" target stock size would likely have been set at a more conservative 75% of unfished biomass, in line with guidance from MSC and the Lenfest Forage fish report and similar to the reference point used for krill fishing by CCAMLR.

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