Marine Fish – Introduction

Species known as “forage fish” play a critical role in Alaska’s marine ecosystems and coastal areas. They are the principal link between primary and secondary producers (e.g., phytoplankton and zooplankton) and apex predatory species (e.g., seabirds, marine mammals, and large fishes). These species often also constitute important dietary or ecological components for terrestrial-oriented species. Consumption of these marine fishes by terrestrial predators in the intertidal zone provides sustenance for those species (e.g., crows feeding on sand lance) and indirectly spreads nutrients into the terrestrial system. Consumption of forage fish by marine predators, such as seabirds that return to shore, helps sustain the birds, brings nutrients to coastal terrestrial systems, and plays a part in longer food chains that include species that prey upon seabirds and sea ducks or their young, including humans.

Critical habitat for forage fish species that are important in terrestrial ecosystems can be divided into intertidal habitats and shallow pelagic habitats. Intertidal habitats are used temporarily on a seasonal basis by embryonic, larval, juvenile and adult stages of some key forage fish species for shelter, feeding and rearing, and spawning. Meanwhile, shallow pelagic habitats are used year-round by other key forage species. Both habitats serve as important nursery areas for forage fish.

The CWCS features a suite of forage fish species known to be critical for healthy ecological function in each of these 2 habitat categories; these fish are regarded as indicator species. Prior research on forage fish shows that the species selected are either: a) the locally dominant prey biomass in many Alaska nearshore areas, or b) a frequent component of Alaskan predator diets. Their conservation needs are representative of the needs for many other nearshore and intertidal species. Since none of the featured forage fish species are commercially harvested, management actions will likely focus on habitat protection rather than on organism protection.

Habitat protection is especially crucial in forage fish nursery areas because the early life history stages of forage fishes are often more sensitive to a broad range of pollutants than are adult stages. In addition, for Alaskan waters, recirculation and nearshore vertical stratification (largely due to density differences from the input of freshwater) can result in concentration of terrestrial or nearshore-sourced pollutants. This is in contrast to areas with lower freshwater input where estuarine circulation helps remove or dilute pollutants.

Because human activity often concentrates in nearshore coastal areas, aquatic input of petroleum hydrocarbon compounds, sewage, and industrial or household chemical waste to these most sensitive of marine areas is also potentially high. Given the critical ecological role of forage fish, conservation actions designed to protect the key species and habitats shown on the following templates will likely benefit not only other species of forage fish, but also other marine species more widely recognized as valuable to human society.

Forage Fish Occurring in Intertidal/Shallow Subtidal Areas

A. Species group description

Common name: Intertidal/shallow subtidal forage fish (esp. Pacific sand lance, capelin, eulachon, Pacific sandfish; and intertidal fish [e.g., sculpins, pricklebacks, and gunnels]); some members of this group are also called small schooling fish (see definition found in *Forage Fishes in Marine Ecosystems*, 1997)
Scientific names: *Ammodytes hexapterus, Mallotus villosus, Thaleichthys pacificus, Trichodon trichodon,* and Cottid, Hemipterid, Rhamphocottid, Stichaeid, and Pholid families*)*

B. Distribution and abundance

Range:
Global range comments: Circumpolar (capelin, intertidal fishes); Northeast Pacific (intertidal fishes)
State range comments: Gulf of Alaska and Bering Sea (eulachon, Pacific sandfish), and throughout coastal Alaska (Pacific sand lance, capelin, sculpins, pricklebacks, and gunnels)

Abundance:
Global and state abundance comments: unknown
State abundance comments: unknown[1]

[1] Pacific sand lance and capelin may dominate local assemblages by biomass; the listed species and groups are key species serving important trophic roles in the transfer of energy to larger predators, such as marine birds and mammals and commercially important fish.

Trends: Much annual variation but trends unknown
Global trends: Capelin and Pacific sand lance trends variable with climate in North Atlantic; for other species, trends are unknown
State trends: Unknown for all

References: Alaska Sea Grant College (1997); Brown (2002); Mecklenburg et al. (2002); Robards et al (1999)

C. Problems, issues, or concerns for species group

- These are key species that play a critical role in Alaska's marine ecosystems. They are the primary link between primary and secondary producers (e.g., phytoplankton and zooplankton) and apex predatory species (e.g., seabirds, marine mammals, and large fishes); however, data on the forage fish species currently are sparse. This paucity of data and understanding of intertidal/shallow subtidal fish reduces the ability to link effects of climate change and other environmental changes on forage fishes with changes in the apex communities that are of both social and economic importance (e.g., whales, birds, commercially harvested fishes).
- Susceptible to adverse effects from degradation of subtidal and intertidal substrates or beaches (substrates used for spawning and burrowing habitat; exact substrate is species-specific).
- Susceptible to habitat modification (jetties, etc).
- Anthropogenic and natural changes to riverine and estuarine hydraulics and morphology can impact eulachon and many other forage fish species.
- Susceptible to subtidal, intertidal, estuarine and riverine pollution.
- Lack of swim bladder in some species, benthic orientation, and/or shallow water distribution makes standard acoustic survey and some net sampling techniques difficult.
- Capelin, Pacific sand lance, and Pacific sandfish have been and could again be considered for a possible commercial fishery in Alaska; the potential effects to these populations are unknown.
- Very little is known about distribution, abundance, and life history.

D. Location and condition of key or important habitat areas

- Pacific sand lance: For spawning and burrowing, subtidal areas as well as protected and semi-protected clean fine substrate beaches within their range; condition unknown but currently thought to be pristine over much of the range.
- Capelin: For spawning, subtidal areas as well as exposed or semi-protected clean fine substrate beaches within their range; condition unknown but currently thought to be pristine over much of the range.
- Eulachon: For spawning, rivers within their range; condition unknown but currently thought to be pristine over much of the range.
- Pacific sandfish: Juveniles and nonspawning adults prefer soft to sandy subtidal substrate; at the time of spawning, they deposit egg clusters on nearshore rocky areas or rock ledges with modest currents.
- Intertidal fish (e.g., sculpins, pricklebacks, gunnels): Need substrates (living or not) for nesting, brooding, rearing; pricklebacks may be a primary colonizer in periglacial environments that consist of high amounts of glacial silt.
- In general, status and condition of all these habitats is unknown.

References: Baxter (1997); Love (2002); Marliave (1981); Pahlke (1985); Robards et al. (1999); Robards and Piatt (2004).

E. Concerns associated with key habitats

- See Section C, above
- Anthropogenic and natural (e.g., earthquake, uplift) changes to shore habitats
- Pollution (including eutrophication, outfalls, sedimentation)
- Spilled pollutant (e.g. oil transport, toxic plume) pathways parallel the food pathway for these species; mechanisms that produce important spawning and rearing habitats are the same mechanisms that transport spills to them
- Climate change; change in storm patterns, sea level rises and change in sea ice distribution
- Interaction with exotic species (e.g., new predators, disease, parasites), including as a result of increased vessel traffic and associated ballast water discharge
- Dredge and fill

F. Goal: Conserve and manage intertidal/shallow subtidal forage fish populations throughout their natural range to ensure sustainable use of these resources.

G. Conservation objectives and actions

Objective A: Sustain populations of the indicated intertidal/shallow subtidal forage fish species within their natural range of abundance.

Target: Level trend (recognizing potential for large inter-annual variability) in annual abundance of each sampled species as measured over a ten-year cycle.

Measure: Trend analysis of abundance in intertidal/shallow subtidal forage fish species using annual measurements over a ten-year cycle, based on information from the baseline survey sites.

Objective B: Maintain the quality and quantity of coastal habitat needed to sustain intertidal/shallow subtidal forage fish populations within their natural range of abundance.

Target: Maintain 100% of the very good-to-pristine condition habitat required to maintain viable sustainable populations of each intertidal/shallow subtidal forage fish stock.

Measure: A baseline map of available intertidal/shallow subtidal forage fish habitats against which to compare future monitoring results.

(Issues and conservation actions below apply to one or both objectives.)

Issue 1: There is a paucity of information about intertidal/shallow subtidal forage fish species and their habitats, and a lack of commitment to long-term monitoring.

- Generally, very little appears to be known about intertidal/shallow subtidal forage fish distribution, abundance, life history, and habitat requirements/use.
- Few documented baselines exist (especially outside Southcentral and Southeast Alaska) against which to compare future population or habitat monitoring results.
- There is limited information available on how habitats change naturally over time; difficult to separate anthropogenic from natural (climate, uplift, etc.) variability in loss/degradation/gain of habitats.
- Likely sources of “traditional knowledge” about intertidal/shallow subtidal forage fish abundance and habitat use have not been determined.

Conservation actions:

a) Establish a network of monitoring sites.
b) Determine minimum number of sites needed for statewide index (see draft network).
c) Annually survey forage fish populations by conducting recruitment surveys at index locations around the coast, and report decadal trends in the scientific and popular literature; conduct recruitment surveys via airplane or boat, or use beach seine and other net sampling techniques, and conduct intertidal transect surveys for intertidal species.
d) Determine the ecosystem function at the specific monitoring sites through collaboration with other agency projects (e.g., salmon, halibut, seabird, marine mammal diet surveys). (This entails evaluating the flow of energy through the system and what dictates or regulates that flow, as well as the stability and resiliency of the system [i.e., if perturbed will the system return to its former composition or resume a new state with different energy flow rates and forcing regulators].)
e) If there is extensive overlap among sites recommended by the different expert groups, consider putting together an LTER proposal at a designated site.
f) Develop ecological trophic interaction models for comparing among sites and over time based on data collected in Conservation Action (d), above. (This work delineates predator/prey relationships and defines feeding/predation/ consumption rates either in numeric or energetic currency. This is a critical and necessary part of mapping energy flow in ecosystem function.)
g) Establish a baseline map of available habitats used by intertidal/shallow subtidal forage fish against which to compare future monitoring results.
h) Add known forage fish habitat to NOAA’s environmental sensitivity index maps.
i) Map known, and survey and map unknown, intertidal/shallow subtidal forage fish habitat.
j) Develop a trend analysis of habitat use by intertidal/shallow subtidal forage fish using annual measurements over a 10-year cycle, based on information from the baseline survey sites.
k) Develop a trend analysis of the amount and quality of habitat, using annual measurements over a 10-year cycle, based on information from the baseline survey sites.
l) Prioritize and link known habitat requirements for forage fish to existing coastal habitat maps; use literature values (densities, etc.) to extrapolate what potential population levels could be.
m) Measure and map the rate of change (loss/gain) of key habitats.
n) Measure and map the rate of change in percentage overlap of fish distribution with mapped habitat.
o) Develop multiple methods to link habitat use to abundance.
p) Collaborate with community leaders to identify and tap sources of local and/or traditional knowledge familiar with local forage fish abundance and habitat use.

Issue 2: There is a paucity of public knowledge and understanding about, or interest in, intertidal/shallow subtidal forage fish and their habitats.

- Little knowledge by the public about forage fish distribution, abundance, life history, and habitat (especially among those not traditionally using or observing forage fish species)
- Lack of public understanding of the importance of forage fish and forage fish habitat in the ecosystem

Conservation actions:

a) Develop a public citizenry in Alaska that is well educated about the importance of forage fish assemblages and their habitats as a key element in Alaska's marine ecosystems and understands how forage fish form a linkage between comprehensive research on climate change and trends in apex predator populations.
b) Establish information and education interchange mechanisms (active hands-on websites).
c) Establish citizen education and information exchange programs directed, at a minimum, to key monitoring sites.
d) Integrate intertidal/shallow subtidal forage fish and their habitat needs into existing fish curricula, including homeschooling.
e) Involve local residents in planning and conducting sampling and monitoring programs.
f) Mentor local leaders regarding benefits and importance of the program.

Issue 3: Education programs lack flexibility, with budget and time constraints limiting options to incorporate new material or customize it for the local area; outreach/start-up funding is needed (over and above the normal allocation for education) for field sampling equipment, travel, and salary for additional human resources needed to begin and maintain the program. Homeschooling curricula needs to be considered since homeschooling is widespread in Alaska, especially in more remote areas.

Conservation action: Integrate intertidal/shallow subtidal forage fish and their habitat needs into existing fish curricula, including home schooling.

Issue 4: Lack of public support can jeopardize efforts to implement conservation measures.

Conservation actions:

a) Involve local residents in planning and conducting sampling and monitoring programs.
b) Mentor local leaders regarding benefits and importance of the program.

<u>**Issue 5**: Policies for better maintaining intertidal/shallow subtidal forage fish stocks and their habitats may be needed.</u>

- The public appears to have a low awareness of how their activities can adversely affect the marine ecosystem; coastal communities with rocky intertidal zones accessible by road are especially hard hit by beach foragers, algae gatherers and school educational groups during low tide periods.
- Capelin, Pacific sand lance, and Pacific sandfish have been and could again be considered for a possible commercial fishery in Alaska, and the potential effects to these populations from fishing are unknown; future fisheries would need to be regulated in a way that incorporates ecosystem considerations, such as considering predator needs in quota decisions.

Conservation actions:

a) Develop approaches to mitigate adverse impacts from beach foragers and educational groups to beaches, road-accessible rocky intertidal zones, and rocky reef habitats used by rockfish juveniles (regulations, enforcement, coastal zone planning, beach preserve designations).
b) Develop standards for managing vessel ballast water to avoid introduction of nonindigenous species (see state's Invasive Species plan for overlapping strategies that would benefit forage fish).
c) If fisheries are begun on capelin, Pacific sand lance, or Pacific sandfish, ensure that harvest regulations are based on broader ecosystem considerations such as predator needs.

H. Plan and time frames for monitoring species and their habitats

Within the next 2 years, state and federal agencies in coordination with appropriate partners (e.g., universities, NGOs, tribal governments, village councils) to develop an annual monitoring plan with evaluation at 5-year intervals; see objectives above.

I. Recommended time frame for reviewing species status and trends

Review at 3, 7, and 12 years.

J. Bibliography

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Nearshore Occurrence of Pelagic Forage Fish

A. Species group description

Common name(s): Myctophids, prowfish, and Arctic cod
Scientific names: Myctophidae, *Zaprora silenus*, and *Boreogadus saida*

B. Distribution and abundance

Range:
Global range comments: Circumpolar (Arctic cod); North Pacific (myctophids, prowfish)
State range comments: Coastal glacial fjords and shelf edge (myctophids); broadly distributed (prowfish); associated with jellyfish aggregations as juveniles (Arctic cod; possible associations for myctophids, prowfish); North Bering, Chukchi and Beaufort Seas (Arctic cod)

Abundance:
Global abundance comments: Unknown
State abundance comments: Unknown (myctophids, prowfish, Arctic cod); Myctophids may dominate local assemblage by biomass; in the Beaufort Sea region, Arctic cod are locally the most abundant marine species; occurrence of any or all 3 species may represent a healthy marine ecosystem; prowfish are commonly caught in the juvenile fish assemblage near shore.

Trends: Unknown
Global trends: Arctic cod trends in the North Atlantic are better understood than those in the North Bering, Chukchi, Beaufort, and Bering Seas; trends in the Chukchi and Bering Seas are variable and generally related to recruitment events.
State trends: Unknown for all

References: Abookire et al. (2002); Alaska Sea Grant College (1997); Bradstreet and Cross (1982); Mecklenburg et al. (2002); Roseneau and Herter (1984); Springer et al. (1984)

C. Problems, issues, or concerns for species group

- These are key species that play a critical role locally at local sites in Alaska's marine ecosystems; in glacial fjords, myctophids are a critical food source for many species; in the Arctic, Arctic cod play a critical role in the marine ecosystem and for human consumption.
- These species are susceptible to subtidal pollution (all 3 species) and, for Arctic cod, waste products from offshore drilling.
- These species are susceptible to climate change in regards to changes in sea ice (Arctic cod) and glacial ice (myctophids).
- Whatever may adversely affect jellyfish (*Cyanea* and *Chrysaora*) in the Chukchi and Beaufort Seas may in turn have a detrimental effect on *Boreogadus*.
- In general, recovery time for Arctic and/or ice-dependent species and their habitats may be much longer than in more temperate climates; however, a population rebound could be very rapid in the Arctic for a species such as cod (B. Wilson, personal communication).
- Effective oil spill cleanup in ice-affected waters is still unproven.
- The presence of ice, affinity to ice structure (for Arctic cod, myctophids), and/or shallow water distribution make(s) standard acoustic survey and some net sampling techniques difficult.
- A lack of harvest data (Arctic cod) exists and potential impacts of harvest on the population are unknown.
- Very little is known about distribution, abundance, life history, and habitat use and requirements.

D. Location and condition of key or important habitat areas

For all, habitat requirements are largely unknown. Prowfish may need living cover (e.g., jellyfish aggregations) for rearing (i.e., refuge from surface feeders); juvenile Arctic cod may require jellyfish aggregations when ice cover is limited. In general, status and condition of these habitats is unknown.

References: Alaska Sea Grant College Program (1997); Brodeur et al (1999); Purcell et al. (2000)

E. Concerns associated with key habitats

- See Section C, above
- Concentration of pollutants from anthropogenic sources (e.g., in the Arctic for Arctic cod)
- Pollution (including increased ship traffic, cruise ship dumping and offshore oil development)
- Spilled pollutant (e.g. oil transport, toxic plume) pathways parallel the food pathway for these species; mechanisms that produce important spawning and rearing habitats may be the same mechanisms that transport oil spills to them

- Climate change; change in storm patterns, sea level rises and change in sea ice distribution
- Interaction with exotic species (e.g., new predators, disease, parasites)
- Dredge and fill (Arctic cod)

F. Goal: Conserve and manage nearshore pelagic forage fish populations to ensure sustainable use of these resources.

G. Conservation objectives and actions

Objective A: Maintain populations of the indicated nearshore pelagic forage fish species at their current levels.

Target: Level trend in annual abundance variation from the mean of each sampled species as measured over a 10-year cycle.

Measure: Trend analysis of abundance in nearshore pelagic forage fish species, using annual measurements over a 10-year cycle, based on information from the baseline survey sites.

Objective B: Maintain the quality and quantity of coastal habitat resources needed to sustain nearshore pelagic forage fish populations at their current levels.

Target: 100% of the very good-to-pristine condition habitat required to maintain viable populations of each forage fish stock.

Measure (1): Establish habitat requirements for species (e.g., salinity, temperature, prey) and produce a baseline map of available habitats used by nearshore-occurring pelagic forage fish against which to compare future monitoring results.

Measure (2): Trend analysis of the amount and quality of habitat, using annual measurements over a 10-year cycle, based on information from the baseline survey sites. For myctophids and Arctic cod this would focus first on defining optimal habitat conditions (oceanographic conditions that produce optimal plankton and food resources), then connecting these conditions to the forcing factors such as storm frequency, water temperature, salinity and timing/frequency of water stratification; for adult prowfish, it would focus on rocky, bouldery areas with cover.

(Issues and conservation actions below apply to one or both objectives.)

Issue 1: There is a lack of harvest data for Arctic cod, and potential impacts on the population from harvest are unknown.

Conservation action: Develop and conduct harvest assessment for Arctic cod.

Issue 2: There is a paucity of information about nearshore-occurring pelagic forage fish species and their habitats, and a lack of commitment to long-term monitoring.

- Very little is known about nearshore-occurring pelagic forage fish distribution, abundance, life history, and habitat requirements/use.
- With some notable exceptions (e.g., industry-sponsored work in the nearshore Beaufort Sea, near Prudhoe Bay), little documented baseline exists against which to compare future population or habitat monitoring results.

- There is limited information available on how habitats change naturally over time; it is difficult to separate anthropogenic from natural (climate, uplift, etc.) variability in loss/degradation/gain of habitats.
- Sources of "traditional knowledge" about forage fish abundance and habitat use have not been determined.

Conservation actions:

a) Establish a network of monitoring sites.
b) Determine minimum number of sites needed for statewide index.
c) If there's extensive overlap among sites recommended by the different expert groups, consider putting together an LTER proposal at a designated site.
d) Annually survey forage fish populations by conducting recruitment surveys via net sampling techniques and acoustics at index locations around the coast, and report decadal trends in the scientific and popular literature.
e) Determine the ecosystem function at the specific monitoring sites through collaboration with other agency projects (e.g., salmon, halibut, seabird, marine mammal diet surveys). (This entails evaluating the flow of energy through the system and what dictates or regulates that flow, as well as the stability and resiliency of the system [i.e., if perturbed will the system return to its former composition or resume a new state with different energy flow rates and forcing regulators].)
f) Develop ecological trophic interaction models for comparing among sites and over time based on data collected in Conservation Action (e), above; addresses first Issue bullet in template box C. (This work delineates predator/prey relationships and defines feeding/predation/consumption rates either in numeric or energetic currency. This is a critical and necessary part of mapping energy flow in ecosystem function.)
g) Establish a baseline map of available habitats used by nearshore-occurring pelagic forage fish against which to compare future monitoring results.
h) Map known, and survey and map unknown, nearshore-occurring pelagic forage fish habitat.
i) Develop a trend analysis of habitat use by nearshore-occurring pelagic forage fish using annual measurements over a 10-year cycle, based on information from the baseline survey sites.
j) Prioritize and link known habitat requirements for myctophids to existing coastal habitat maps; use literature values (densities, etc.) to extrapolate what potential population levels could be.
k) Measure and map the rate of change (loss/gain) of key habitats.
l) Measure and map the rate of change in percentage overlap of fish distribution with mapped habitat.
m) Develop multiple methods to link habitat use to abundance.
n) Collaborate with community leaders to identify and tap sources of local and/or traditional knowledge familiar with local Arctic cod abundance and habitat use.

Issue 3: There is a paucity of public knowledge and understanding about, or interest in, pelagic forage fish species occurring near shore and their required habitats.

- Little public knowledge about forage fish distribution, abundance, life history, and habitat (especially among those not traditionally using or observing forage fish species).
- Lack of public understanding of the importance of forage fish and forage fish habitat in the ecosystem.

Conservation actions:

a) Develop a public citizenry in Alaska that is well educated about the importance of forage fish assemblages and their habitats as a key element in Alaska's marine ecosystems, that has a higher awareness of how their activities can adversely affect the marine ecosystem, and that understands how information on forage fish can form a linkage between comprehensive research on climate change and trends in apex predator populations.
b) Establish information and education interchange mechanisms (active hands-on websites).
c) Establish citizen education and information exchange programs directed, at a minimum, to key Arctic cod monitoring sites.
d) Integrate nearshore pelagic forage fish and their habitat needs into existing fish curricula, including for home schooling.
e) Involve local residents in planning and conducting sampling and monitoring programs for Arctic cod (possible diet composition of subsistence harvest species such as seals); more difficult to involve locals for myctophids and prowfish.
f) Mentor local leaders regarding benefits and importance of the program.

Issue 4: Policies for sustaining forage fish stocks and their habitats is lacking.

- Arctic cod harvest could become an issue; it may need to be regulated in a way that incorporates ecosystem considerations such as predator needs in quota decisions.

Conservation actions:

a) Develop approaches to mitigate adverse anthropogenic impacts to nearshore waters (regulations, enforcement, coastal zone planning).
b) Develop standards for shipping regarding pollution, docking facilities, and transport/introduction of nonindigenous species (see state's Invasive Species Plan for overlapping strategies that would benefit forage fish).

H. Plan and time frames for monitoring species and their habitats

Within the next 2 years, state and federal agencies in coordination with appropriate partners (e.g., universities, NGOs, tribal governments, village councils) to develop an annual monitoring plan with evaluation at 5-year intervals; see objectives above.

I. Recommended time frame for reviewing species status and trends

Review at 3, 7, and 12 years.

J. Bibliography

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