Marine Invertebrates – Introduction

Marine ecosystems worldwide are being altered by human disturbances such as overfishing (Botsford et al. 1997; Jackson et al. 2001; Pauly et al, 2002; Myers and Worm 2003) coastal shoreline development, climate change, and eutrophication (Howarth et al. 2000; Rabalais et al. 2002), and these impacts are beginning to be felt in Alaska. Achieving sustainability of resources, economies, coastal communities and the ecosystems in which these are all embedded requires conservation strategies that acknowledge the complex social and ecological interactions that drive marine ecosystem dynamics (Scheffer et al. 2001; Walker et al. 2002). The focus of this template is on the approach that will be used for conservation planning, one that encompasses the ecological relationships among multiple species and habitats.

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Nearshore Soft Benthic Ecosystems

This ecosystem extends from the intertidal to the shallow subtidal (+ 6 m to –30 m) and includes eelgrass, mud, sand and gravel habitats. We identified 2 species assemblages of concern: 1) intertidal and shallow subtidal bivalves and 2) eelgrass-associated invertebrates. An ecosystem-based approach to the conservation of these assemblages would acknowledge the complex food web interactions between structure forming plants (e.g., *Zostera marina*), stabilizing algae (e.g., *Enteromorpha, Cladophora*, diatom films), nongame bivalves (e.g., *Macoma* spp., *Serripes* spp., *Clinocardium* spp., *Mactromeris* spp. Tellina *spp., Nucula* spp. and *Yoldia* spp.), harvested bivalves (e.g., *Protothaca staminea, Saxidomus giganteus, Panopea abrupta*), sediment bioturbators such as infaunal polychaetes and epifaunal gastropods, generalist predators (e.g., dungeness crabs and sunflower stars), bottomfish that inhabit this "nursery" ecosystem (e.g., sand lance, sand sole, starry founder, juvenile salmonids), shorebirds (e.g., sandpipers, ducks and geese) that depend on secondary consumers (shrimp, worms, small bivalves) as a primary source of food, and finally, marine mammals (e.g., harbor seals, sea otters and gray whales) that also forage in this ecosystem.

Some ecosystem dynamics to consider:

- Freshwater and nutrient inputs from upstream watersheds influencing nearshore water and sediment chemistry (i.e., hypoxia) and sediment grain size
- Oceanic nutrient inputs from offshore upwelling and marine derived nutrients from returning salmonid species
- Water filtration rates
- Sedimentation vs. erosion rates
- Bacterial activity and detrital cycling
- Benthic pelagic coupling and microbial decomposition
- Biofilms (diatoms) stabilizing nearshore sediments

Eelgrass Invertebrates

A. Species group description

Common name: eelgrass-associated invertebrates
Scientific names: a variety of invertebrates associate with eelgrass *Zostera marina* including: eelgrass shrimp *Hippolyte clarki*, hydroids *Obelia* spp., snails *Lacuna* spp., caprellid amphipods, Dungeness crab *Cancer magister*, helmet crab *Telmessus cheiragonus*, kelp crabs *Pugettia* spp., horse clams *Tresus capax,* sea cucumbers *Parastichopus californicus*, spionid polychaetes, nudibranches including *Melibe leonina* (Kozloff 1993; Ricketts et al. 1985)

Selection criteria: Eelgrass beds are among the most productive ecosystems on the planet. The invertebrates associated with eelgrass play a key role in transferring energy from the eelgrass to higher trophic levels (Nelson and Waaland 1997; Johnson et al. 2003).

B. Distribution and abundance

Range: (McRoy 1966; McRoy and Helfferich 1977)
Global range comments: *Zostera marina* is discontinuous from the Sea of Okhotsk and Japan, the Baltic Sea, the Mediterranean Sea, the North Pacific as far south as Agiopampo Lagoon, Mexico
State range comments: North to Port Clarence, west to Atka Island, the Gulf of Alaska including the Southeast Panhandle

Abundance:
Global abundance comments: Unknown
State abundance comments: Unknown

Trends:
Global trends: Generally declining
State trends: Unknown

C. Problems, issues, or concerns for species group

- Eelgrass invertebrates act as a crucial link in transferring energy from eelgrass production to higher trophic levels (Shirley 2003)
- The distribution of eelgrass across the state is poorly known and the associated invertebrate assemblages are also poorly documented
- Eelgrass is vulnerable to destruction from turbid water and fishing gear
- Pesticides used in mariculture can directly affect eelgrass-associated invertebrates (Thayer et al. 1975; Griffin 1997)
- Many of the associated invertebrates are dependent upon the eelgrass environment and are severely impacted by the disappearance of eelgrass beds (Stauffer 1937).
- Disease (Rasmussen 1977; Levinton 1982)

D. Location and condition of key or important habitat areas

Unknown. An evaluation of location and condition of this habitat is needed.

E. Concerns associated with key habitats

- Light availability is an important factor limiting eelgrass growth; the amount of light reaching eelgrass can be influenced by human activities, such as sediment loads caused by logging and streamside activities.
- Eutrophication is regarded as a major factor of eelgrass bed declines because it stimulates the overgrowth of epiphytic algae (Huges et al. 2004).
- High nutrient input from fertilizers, sewage, and fish waste can result in excessive epiphyte growth on eelgrass blades that can also deprive eelgrass of light.
- Pesticides used to control invertebrates in mariculture operations may also kill the invertebrates in nearby eelgrass beds (Thayer et al. 1975; Griffin 1997).
- Coastal development has been the primary cause of widespread seagrass loss (Short and Wyllie-Echeverria 1996).

- Physical disturbance via commercial fishing gear (Stephan et al. 2000; National Research Council 2002; Trush and Dayton 2002) has been identified as a significant source of seagrass habitat destruction. Trawling, dredging and raking for bay scallops (Fonseca et al. 1984), mussels (Neckles et al. 2005), and hard clams (Peterson et al. 1983) have been found to damage eelgrass beds (Johnson 2002).
- Other activities such as dredging (Thayer et al. 1984), and associated construction of boat docks and harbors (Burdick and Short 1999) significantly impact eelgrass habitats.
- On-bottom shellfish aquaculture in close proximity to eelgrass beds can lead to habitat destruction as farmers access their beds. Geoduck mariculture may also affect eelgrass beds.

F. Goal: Conserve and manage eelgrass-associated invertebrate populations throughout their natural range to ensure sustainable use of these resources.

G. Conservation objectives and actions

Objective: Sustain species diversity, population density and size structure of eelgrass-associated invertebrate populations within historic levels throughout the natural range of eelgrass beds.

Target: Identify and then sustain a diversity of species, and density and size structure of eelgrass-associated invertebrate assemblages that is similar to historical conditions.

Measure: Species diversity and population density and size structure.

Issue 1: The distribution and population status of eelgrass beds and associated fauna is unknown in most parts of the state.

Conservation actions:

a) Identify remote sensing technologies, including advanced satellite imagery that may allow for large-scale mapping and monitoring of eelgrass beds statewide.
b) Train local community groups to monitor species.

Issue 2: There is a lack of information on species diversity associated with eelgrass habitats.

Conservation action: Select 2–3 representative eelgrass beds from across the state for intensive monitoring of the population status of the bed and species diversity of associated fauna assemblages. Beds would be selected based on the location of previous studies, such as Izembek Lagoon, Sitka Sound, and Kachemak Bay.

Issue 3: Future increased mariculture in the state may have a negative effect on eelgrass-associated invertebrates.

Conservation actions:

a) Locations selected for mariculture sites should continue to avoid areas of eelgrass.
b) Monitor pesticides used in mariculture areas to determine their persistence and potential for impacts to the surrounding environment.

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

State and federal agencies, the university, industry, Native entities and NGOs should coordinate to establish a monitoring plan within the next 2 years that would begin annual monitoring with evaluation at 5-year intervals.

I. Recommended time frame for reviewing species status and trends

Evaluate the strategy after 3 years and then 5 years after that.

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Intertidal and Shallow Subtidal Bivalves

A. Species group description

Common name: intertidal and subtidal clams
Scientific names: *Macoma* spp., *Serripes* spp., *Clinocardium* spp., *Tellina* spp., *Nucula* spp., *Yolida* spp. and *Mactromeris* spp. are several nongame species. Commercially and recreationally harvested clams found in the same habitat include the Pacific little neck clam, *Protothaca staminea* and butter clam *Saxidomus giganteus* and geoduck (*Panopea abrupta*).
Selection criteria: This is an important group of invertebrates as they are abundant in soft sediment areas and are prey for many other higher trophic level invertebrates, birds, fishes, and mammals (Fukuyama and Oliver 1985; Bodkin et al. 2002; Dean et al. 2002). The loss of these animals may affect populations of many other species, including some commercially important and subsistence species.

B. Distribution and abundance

Range:
Global range comments:
State range comments: Present throughout most state waters intertidally and subtidally

Abundance:
Global abundance comments: Probably locally abundant in areas not affected by pollution, intense fishing pressure, or sea otter predation
State abundance comments: Probably locally abundant in areas not affected by pollution, intense fishing pressure, or sea otter predation

Trends:
Global trends: Unknown
State trends: Unknown

C. Problems, issues, or concerns for species group

- In general, lack of data within this group is a problem; better quantitative information on distribution and abundance is needed
- Lack of reproductive information; there is some reproductive information for a few species available in the literature
- This is an important group of animals since they are prey for many other invertebrates, birds, fishes, and mammals; the loss of these animals may affect populations of many other species, including some commercially important and subsistence species
- Unknown impact of contaminants or of diseases
- Effect of climate change through water temperature effects on clams and their prey unknown

D. Location and condition of key or important habitat areas

Intertidal and subtidal soft sediment areas. Key areas include upper Cook Inlet, Copper River Delta and other large tidal wetlands for *Macoma* spp., which are a key prey species for wintering or migrating shorebirds (Bob Gill, USGS, personal communication). Other key areas for clams include the Aleutian Islands, Bristol Bay, Prince William Sound, and for *Serripes* spp., areas of the Chukchi Sea.
An evaluation of location and condition of key habitats is needed—currently unknown.

E. Concerns associated with key habitats

- One potential threat is loss of intertidal habitat from commercial and residential development
- Another potential concern is pollution

F. Goal: Conserve and manage clam populations throughout their natural range to ensure sustainable use of these resources.

G. Conservation objectives and actions

State conservation and management objectives and actions:

Objective: Develop targets for and sustain species diversity, population density and size structure throughout its distribution.

Target: Identify and then sustain a diversity of species, and density and size structure of those species that are reflective of productive populations.

Measure: Species diversity and population density and size structure.

Issue 1: Unknown spatial and temporal variability and extent of distribution.

Conservation action: Assess spatial variability of habitat and populations.

Issue 2: Trawling or other fishing gear impacts.

Conservation actions:

a) In collaboration with federal agencies and coastal communities, set aside areas to protect this benthic habitat from on-bottom fishing impacts.
b) Promote development of innovative technologies and alternative fishing gears and methods to minimize destructive effects of fishing gear.

Issue 3: Lack of information on life history (growth and longevity).

Conservation action: Identify and apply methods to age and measure growth rates. May apply methods used on other clam species for this group of clams.

Issue 4: Trophic dynamics are unknown and may affect growth and survival.

Conservation action: Quantify and identify interaction strength with other components of ecosystem of other associated species (predator and prey).

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

State and federal agencies, universities, Native entities and NGOs should coordinate to establish a monitoring plan within the next 2 years that would begin annual monitoring with evaluation at 5-year intervals.

I. Recommended time frame for reviewing species status and trends

Evaluate the strategy after 3 years and then 5 years after that.

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Deep Benthic Ecosystems

Deep benthic ecosystems extend from –30 m to the deep marine trenches found off the Alaskan shelf. Our featured species assemblage of deep sea corals, tunicates and sponges occur on both soft and hard substrates. As biogenic habitat, this species assemblage offers structure, an important ecosystem service, to a wide variety of juvenile bottomfish, shrimp, and crab species, many of which are commercially important in Alaska. Turnover rates of primary production and the dispersal of phytoplankton, governed by regional and local oceanic currents, have obvious ramifications given that phytoplankton is the primary food source for this filter feeding assemblage. Other key trophic interactions pertinent to this ecosystem include those between primary and secondary producers in the pelagic ecosystem above. Reciprocal relationships among benthic epifauna (e.g., crab, shrimp, scallops), infauna (e.g., polychaetes, bivalves) and demersal fish (e.g., sablefish, lingcod, Pacific cod, black rockfish, halibut) are also germane. Commercially harvested invertebrates in this ecosystem include the weathervane scallop *Patinopecten caurinus*, king crab, Dungeness crab, Tanner crab, snow crab and shrimp.

Some ecosystem dynamics to consider:

- Spatiotemporal dynamics between nutrient upwelling, phytoplankton and zooplankton production
- Shifts in oceanographic regimes (i.e., Pacific Decadal Oscillation)
- Benthic pelagic coupling and microbial decomposition
- Role of biogenic habitat in fish and invertebrate population dynamics

Corals, Tunicates, and Sponges

A. Species group description

Common names: cold water corals, black coral, gorgonian corals, stony corals, sea whips, sea pens, and sponges. A high diversity of species make up this assemblage, many of which are currently undescribed.
Scientific names: Phylum Cnidaria
Octocoral Families: Corallidae, Isididae, Paragorgiidae, Pennatulidae, Primnoidae
Hexacoral Families: Antipathidae, Oculinidae, Caryophylliidae
Hydrocoral Family: Stylasteriidae
Phylum: Urochordata class: Ascidiacea
Phylum: Porifera

B. Distribution and abundance

Range:
Global range comments: Temperate benthic habitats
State range comments: The regional extent of this species assemblage is unknown; however, in Alaska they have been documented in the Aleutian Islands (e.g., Andreanof Islands) (Heifetz 2002), Bering Sea, Gulf of Alaska and Southeast Alaska (Heifetz et al. 2003) and other areas (see Etnoyer and Morgan 2003).

Abundance:
Global abundance comments: Unknown
State abundance comments: Percent cover of corals ranged from 5% on low relief pebble substrate to 100% on high relief bedrock at depths of 150–350 m (Heifetz 2002). Other species are common on soft bottom substrate, and populations may be patchy, making it difficult to assess impacts (Heifetz et al. 2003).

Trends:
Global trends: Although quantitative assessment has not been done, assemblages of corals and sponges are likely to have become increasingly impacted since the onset of commercial benthic trawling.
State trends: same as above

C. Problems, issues, or concerns for species group

Known concerns and threats
- High potential for localized depletion due to mobile fishing gear impacts on the seafloor (e.g., trawling, longlining, pot fisheries). The species composing this assemblage are often slow-growing and very long-lived. Consequently, population recovery after impact is likely to be very slow.
- These organisms create biogenic habitat structure that has been documented to be very important habitat for variety of other organisms (e.g., flatfish, rockfish, cod, etc.). Their absence can reduce the survival rates and slow the recovery of commercially harvested species (Lindholm, Walters and Kitchell 2001).
- Many corals and sponges are a specific food source for rare nudibranchs (e.g. *Tochuina tetraquetra*) that feed on only one or several species of corals or sponges. Loss of the coral or sponge species would be detrimental to these nudibranchs.

- A lack of data exists on the range extent of corals and sponges and their associated species.
- Population dynamics are unknown.

Potential or suspected threats

- Climate change and how it alters oceanic temperature, salinity and circulation patterns (i.e., alteration of potential food sources and larval recruitment)
- Impact of disease is unknown
- Lack of information on the effects of natural disturbances
- Offshore dredging impacts

D. Location and condition of key or important habitat areas

These corals and sponges are found in benthic habitat on both soft and hard rock substrates. In areas impacted by fishing gear (heavily trawled areas) these habitats can be very degraded; however, in undisturbed areas, these habitats are often in very good condition.

E. Concerns associated with key habitats

- Habitat alteration due to trawling, longlining and pot fisheries
- Lack of information on the effects of natural disturbances

F. Goal: Conserve and manage assemblages of corals and sponges throughout their natural range to ensure sustainable use of these resources.

G. Conservation objectives and actions

Objective A: Sustain species diversity, population density, and size structure throughout its natural range within historic levels.

Target: Identify and then sustain a diversity of species, and density and size structure of those species in known areas of population density that is similar to historical conditions.

Measure: Species diversity, population density and size structure of assemblages in known areas of population density across their natural range.

Target: Distribution of species is greater than 90% of the historical distribution within state waters (experts in this group recommend that it go beyond state waters).

Measure: Percentage of known historical distribution.

Objective B: Research the ecological role of corals and sponges in providing sufficient structural habitat for associated species (commercially important bottomfish species have higher survival rates in areas with complex bottom topography [Lindholm 2001]).

Target: Identify or develop a species association index, a measure of the utility of sponges and corals as habitat by key species.

Measure: Species association index.

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

Issue 1: Habitat alteration and localized declines of corals due to trawling and or other mobile fishing gear impacts. In Alaska, anthropogenically induced disturbance to these benthic epifauna is most evident in heavily fished areas (Heifetz 2002; Heifetz et al. 2003).

Conservation actions:

a) In collaboration with federal agencies and coastal communities, set aside areas to protect this benthic habitat from on-bottom fishing impacts.
b) Support an international agreement between Canada, the United States and Russia to establish an international offshore protected area.
c) Promote development of innovative technologies and alternative fishing gears and methods to minimize destructive effects of fishing gear.

Issue 2: Lack of information on the taxonomy of corals and sponges.

Conservation actions:

a) Inventory and collaborate with government agencies, such as NOAA, universities, and local nongovernmental organizations.
b) Train observers and commercial fishermen in species identification and collection of unknown species for taxonomic identification (e.g., molecular methods).

Issue 3: Unknown spatial and temporal variability and extent of distribution of coral species.

Conservation actions:

a) Collect local ecological knowledge from trawl fishermen on the magnitude and extent of bycatch.
b) Assess spatial variability and distribution of habitat and populations.

Issue 4: Lack of information on life history (reproduction, growth, and longevity)

Conservation action: Identify and apply methods to age and measure growth rates in corals and sponges.

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

Current efforts to designate Habitat Area of Particular Concern (HAPC) for living substrates, such as corals and sponges, through the Magnuson-Stevens Fishery Conservation and Management Act should be coordinated among management agencies and completed. Collaboration with federal agencies, universities, local coastal communities, and local NGOs is essential to effective monitoring of the resource.

I. Recommended time frame for reviewing species status and trends

Evaluate the strategy after 3 years and then 5 years after that.

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Salt Marsh Ecosystems

Coastal salt marsh ecosystems are tidal wetlands broadly defined by halophytes, plants that are adapted to saline soils (e.g., spike grass *Distichlis spicata*, salt marsh sand spurry *Spergularia marina*, creeping alkali grass *Puccinelia phryganodes*, Bear sedge *Carex ursina*, pickleweed). Salt marsh ecosystems occur at the mid point between high and low tides where the flood of seawater prevents the establishment of terrestrial vegetation. Low marshes may be inundated by each high tide, whereas high marshes are covered by seawater only a few times during the growing season. In this ecosystem we identified a very broad species assemblage: salt marsh-associated invertebrates. The extensiveness of this species group reflects the paucity of information on it yet our appreciation that it is a critical source of food to an incredibly wide variety of marine and terrestrial species. Migratory shorebirds use this ecosystem extensively, as do numerous land-based mammals, including bears, beavers, muskrats, river otters, raccoons and deer. Burrowing filter feeders that inhabit this ecosystem include many species of clams, cockles, and polychaete worms. Epifauna include gastropods, crabs, and oysters. Larval and juvenile stages of many fish and invertebrate species thrive in this protected system yet spend much of their adult life elsewhere. Consequently, these ontogenetic shifts in habitat associations suggest that there are strong ecological connections to the other marine ecosystems identified in this report. Furthermore, because this system represents a transition zone between land and sea, the ecological connections among species templates produced by the marine, terrestrial, and freshwater expert groups are likely very high for this ecosystem.

Some ecosystem dynamics to consider:

- Ontogenetic shifts in habitat associations
- Decomposition, detritus cycling, bacterial production
- Salt excretion and water storage
- Absorption of freshwater runoff
- Siltation rates vs. erosion rates
- Filtration and degradation of nitrogenous and phosphorous waste
- Land-based nutrient subsidies

Salt Marsh-Associated Invertebrates

A. Species group description

Common name: salt marsh-associated invertebrates
Scientific names: examples of salt marsh-associated invertebrates include marine annelid worms, such as the lugworm (*Arenicola pacifica*), and marine gastropods, such as the Sitka snail (*Littorina sitkana*).
Selection criteria: Salt marsh habitats are very productive systems (Mitsch and Gosselink 1993; Begon et al. 1996). The invertebrates associated with salt marshes play a key role in transferring energy from marshes to higher trophic levels (Graca et al. 2000; Peterson and Howarth 1987).

B. Distribution and abundance
(species assemblage unknown; therefore, range, abundance, trends unknown)

Range:
Global range comments:
State range comments:

Abundance:
Global abundance comments:
State abundance comments:

Trends:
Global trends: Generally declining
State trends: Unknown

C. Problems, issues, or concerns for species group

- In general, lack of data within this habitat is a major problem. An inventory of salt marsh-associated species, along with quantitative information on distribution and abundance, is needed.
- This is a very important habitat for variety of other plants and animals. The loss of this habitat with its associated organisms may affect populations of many other species, including some commercially harvested species.

D. Location and condition of key or important habitat areas

Unknown; an evaluation of location and condition of this habitat is needed.

E. Concerns associated with key habitats

- A key threat is loss of this habitat through commercial and residential development
- Loss from filling
- Pollution threats
- Alteration of habitat due to trawling in subtidal areas is a potentially important issue

F. Goal: Conserve and manage salt marsh species assemblages throughout their natural range to ensure sustainable use of these resources.

G. Conservation objective and actions

Objective: Develop targets for, and sustain species diversity, population density and size structure of, salt marsh-associated invertebrates throughout the natural range of salt marshes in Alaska state waters.

Target: Identify species and then attain the diversity of species, and density and size structure of those species, that is reflective of productive populations of invertebrates associated with salt marsh habitats.

Measure: Species identification, diversity, population density and size structure of salt marsh-associated invertebrate assemblages.

Issue 1: Unknown spatial and temporal variability and extent of distribution.

Conservation action: Assess spatial variability of salt marsh habitat and associated invertebrate populations.

Issue 2: There is a lack of information on the species that are associated with salt marsh habitats.

Conservation actions:

a) Inventory species.
b) Train observers in species identification and collection of unknown species for taxonomic identification (including using molecular methods).

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

State and federal agencies, universities, Native entities, and NGOs should coordinate to establish a monitoring plan within the next 2 years that would begin biannual monitoring with evaluation at 5-year intervals.

I. Recommended time frame for reviewing species status and trends

Evaluate the strategy after 3 years and then 5 years after that.

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Pelagic Ecosystems

The pelagic ecosystem encompasses the water column beyond –30 m over both hard and soft substrates. We identified zooplankton species (euphausiids, copepods, jellyfish, ctenophores, invertebrate and fish larvae) as a primary invertebrate species assemblage of concern. Reciprocal relationships among phytoplankton, zooplankton, pelagic forage fish (e.g., herring), upper level fish predators (e.g., pollock), seabirds (e.g., shearwaters, albatross species, storm-petrels) and marine mammals (baleen and toothed whales) encompass some of the key trophic interactions of this system.

Ecosystem dynamics to consider:

- Spatiotemporal dynamics between nutrient upwelling, phytoplankton and zooplankton production
- Shifts in oceanographic regimes (i.e. pacific decadal oscillation)
- Benthic pelagic coupling and microbial decomposition

Zooplankton

A. Species group description **Common name**: zooplankton, jellyfish, ctenophores, larvae **Scientific names:** a variety of planktonic invertebrates including copepods *Neocalanus* spp., *Calanus* spp., *Acartia* spp., *Psuedocalanus* spp., *Oithona* spp., *Metridia* spp., *Podon* spp., *Evadne* spp., chaetognaths *Sagitta elegans*, euphausiids, amphipods, pteropods, cladocerans, cnidarian medusae, ctenophores, meroplankton (benthic invertebrate larvae, fish larvae), and others **Selection criteria:** Zooplankton are an essential link in the food chain and provide food for many seabirds, fishes, and marine mammals.
B. Distribution and abundance **Range**: Global range comments: Widely distributed State range comments: Widely distributed **Abundance**: Global abundance comments: Unknown State abundance comments: Unknown **Trends**: Global trends: Unknown State trends: Unknown

C. Problems, issues, or concerns for species group

- Great importance as food for invertebrates, fishes, seabirds, and marine mammals
- Dramatic seasonal, interannual and decadal-scale variability documented
- Importance of specific species unknown
- Lack of data on distribution and abundance, with the exception of studies conducted by UAF, Institute of Marine Science on some of the dominant copepods

Potential and/or suspected threats

- Pollution from oil spills, oil and gas platforms, sewage outfall, forestry and mining runoff, anthropogenic and natural heavy metals
- Contamination from pollution sources (oil spills, oil platform discharge)
- Pesticide introduction from forestry, agriculture, and mariculture activities
- Fish harvesting may alter trophic cascades and result in dramatic changes in plankton communities
- Climate change; changes in ocean temperature may affect distribution, abundance, and community composition

D. Location and condition of key or important habitat areas

Unknown; an evaluation of location and condition is needed.

E. Concerns associated with key habitats

- Pollution from oil spills, sewage discharge, mining and forestry runoff
- Fish harvest may alter community composition

F. Goal: Maintain the ecological function of zooplankton populations throughout their natural range to ensure sustainable use of these resources.

G. Conservation objectives and actions

Objective: Sustain species diversity, population density and size structure within historic levels.

Target: Identify and then sustain a diversity of species, and density and size structure of those species that is similar to historical conditions.

Measure: Species diversity and population density and size structure.

Issue 1: There is a fundamental lack of information on importance of zooplankton in diets of seabirds, fishes, and marine mammals.

Conservation action: Compile existing information on role of zooplankton in diets of seabirds, fishes, and marine mammals. Assess temporal and spatial variation in the role of individual zooplankton species as diet.

Issue 2: Seasonal, interannual, and decadal-scale changes in zooplankton can impact the abundance of other species.

Conservation action: Develop a long-term monitoring program in various locations throughout the state. The California Cooperative Oceanic Fisheries Investigation (CalCOFI) program is one such model.

Issue 3: Increases in mariculture in the state could potentially have a negative effect on zooplankton diversity and abundance through the use of pesticides.

Conservation action: Monitor the use of pesticides in mariculture operations to determine their persistence and unintended impacts on the surrounding environment and zooplankton.

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

Management agencies, university researchers, local coastal communities, and local NGOs will need to coordinate to ensure that a monitoring program is developed and deployed.

I. Recommended time frame for reviewing species status and trends

Evaluate the strategy after 3 years and then 5 years after that.

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Nearshore Rocky Reef Ecosystems

Nearshore rocky reef ecosystems include both intertidal and shallow subtidal rocky reef species assemblages (+4 m to –30 m). An ecosystem-based approach to the conservation of nearshore rocky reef ecosystems would include conservation actions that address the threats to food web dynamics among reef fish predators (greenlings, rockfish, lingcod, cabezon), marine invertebrates predators (octopus, sea stars, Muricidae gastropods), small cryptic reef fish (e.g., sculpins, warbonnets, pricklebacks, and gunnels), scavengers (red rock crabs), deposit feeders (sea cucumbers), grazers (urchins, chitons and limpets), filter feeders (mussels *Mytilus* spp., barnacles *Semibalanus and Balanus*, giant rock scallop *Crassadoma* once *Hinnites)*, structure-forming anemones such as *Metridium*, and primary producers (*Alaria* spp., *Nereocystis*, *Laminaria* spp.). Seabirds (Black Oystercatchers, guillemots, kittiwakes, Rock Sandpipers, Glaucous-winged Gulls, Herring and Mew gulls, Bald Eagles, Northwestern Crows, Common Ravens) and mammals that forage in this system (American mink, sea otters, river otters, American martens, black bears, harbor seals) can have direct and indirect effects on the species mentioned above, some of these interactions being more critical to system dynamics than others.

While stressing the importance of considering the complex associations among algal and animal rocky reef food web dynamics, we have identified the northern abalone, gumboot chiton and black leather chiton as 3 featured species of concern representative of this ecosystem. These specific species were identified because of known demographic limitations in the case of the northern abalone and localized declines in the case of the two chitons.

Some ecosystem dynamics to consider:

- Top-down effects of keystone predators
- Kelp production and its contribution to secondary consumers, both directly via invertebrate grazers and indirectly via filter feeders consumption of detritus
- Terrestrial subsidies via freshwater runoff
- Marine subsidies via upwellings, seabird colonies, sea lion and seal rookeries
- Interaction between upwellings, regional and local oceanographic currents, and larval dispersal and delivery

Benthic Grazers
Katharina tunicata and *Cryptochiton stelleri*

A. Species group description

Common name: black Katy chiton, black leather chiton, bidarki, Urriitaq in Alutiiq
Scientific name: *Katharina tunicata*
Selection criteria: This competitive dominant benthic grazer is known to govern the community dynamics and productivity of temperate rocky intertidal ecosystems (Detheir and Duggins 1984; Paine 1992, 2002). *K. tunicata* remains an important traditional subsistence food source for coastal Native Alaskans (Stanek et al. 1982; Fall and Utermohle 1999; Chugachmiut 2000) and is a prey item for sea otters and various seabirds (O'Clair and O'Clair 1998). As a result, there have been noticeable declines in the density and size structure of this chiton in some areas. Lastly, *K. tunicata* is representative of a broad array of other rocky intertidal benthic species located on surf-swept rocky shores.

Common name: gumboot chiton, giant Pacific chiton, Chinese slipper, lady slipper, Urriitarpak in Alutiiq
Scientific name: *Cryptochiton stelleri*
Selection criteria: Although primarily found in the subtidal, individuals found in the low intertidal are a subsistence food item for coastal Alaska Natives. Recruitment rates of *C. stelleri* are low, making this species vulnerable to overharvest (O'Clair and O'Clair 1998). Indeed, there have been noticeable declines in the density and size structure of *C. stelleri* in some areas.

B. Distribution and abundance

Katharina tunicata
Range:
Global range comments: Kamchatka, through the Aleutian Islands, Alaska, to Southern California (O'Clair and O'Clair 1998)
State range comments: *Katharina* have been documented to be present in the Aleutian Islands, Amchitka and Shemya Island (Estes and Palmisano 1974, Simenstad et al. 1978), Southcentral and Southeast Alaska.

Abundance:
Global abundance comments: Densities and sizes vary:
1) 15–30/m^2 Tatoosh Island, WA (Paine 2002)
2) 28–52/m^2 San Juan Island, WA (Dethier and Duggins 1988)
State abundance comments: Densities and sizes vary:
1) 21–57/m^2 Torch Bay, AK (Detheir and Duggins 1988)
2) 0–60/m^2 Nanwalek and Port Graham, AK (Salomon 2003)

Trends:
Global trends: Varies depending on localized impacts
State trends: Varies depending on localized impacts

Cryptochiton stelleri

Range:

Global range comments: Japan through Aleutian Islands, Alaska, to southern California

State range comments: Aleutian Islands southward

Abundance:

Global abundance comments: Unknown

State abundance comments: Unknown

Trends:

Global trends: Varies depending on localized impacts

State trends: Varies depending on localized impacts

C. Problems, issues, or concerns for species group

Known concerns and threats

- Localized depletion due to subsistence harvest
- Localized depletion due to predation by sea otters, sea stars and other subtidal predators
- Lack of demographic data
- Recruitment limitation (especially in *Cryptochiton*) makes these chitons more susceptible to overharvest

Potential and/or suspected threats

- Pollution from oil spills, oil and gas platforms, sewage outfall, forestry and mining runoff, anthropogenic and natural heavy metals
- Contamination from pollution sources (oil spills, oil platform discharge)
- Disease – unknown impact
- Climate change; changes in ocean temperature may effect chitons directly by altering their spawning period and length (Himmelman 1978) and/or indirectly by affecting the production of their algal food sources and/or local current patterns which influence their metapopulation structure

D. Location and condition of key or important habitat areas

Both chiton species live on surf-swept rocky shores, in low intertidal and shallow subtidal rocky reef habitats. *Cryptochiton* is generally found subtidally to 20 m on both rocky and muddy substrate (O'Clair and O'Clair 1998). Both chitons are more commonly found on exposed outer coasts. Generally, the condition of the habitats in which these chitons are found is very good, although shoreline development and pollution from oil spills, sewage discharge and forestry and mining runoff can degrade such habitats.

E. Concerns associated with key habitats

- Shoreline development
- Localized trampling
- Pollution from oil spills, sewage discharge, mining and forestry runoff

F. Goal: Conserve and manage chiton metapopulations throughout their natural range to ensure sustainable use of these resources.

G. Conservation objectives and actions

Objective A: (*Katharina tunicata)* Sustain population density and size structure throughout its distribution at target levels.

Target: 20–30 reproductive chitons per square meter within its microhabitats (reproductive individuals are 35 mm and greater [Strathman 1987]).
Measure: Density of chitons in local population.

Target: Size structure distribution: maximum 130 mm – mininum 5mm, average 50 cm.
Measure: Size structure of chitons in local population.

Target: Sustain greater than 80% of known historical populations throughout natural range.
Measure: Percentage of known historical local populations sustained.

Objective B: (*Cryptochiton stelleri)* Sustain population density and size structure throughout its distribution.

Target: Identify and then sustain typical population density and size structure.
Measure: Density and size structure of chitons in local population.

Target: Sustain greater than 80% of known historical populations throughout natural range.
Measure: Percentage of known historical local populations sustained.

Issues and conservation actions for both *Katharina tunicata* and *Cryptochiton stelleri* appear below.

Issue 1: Because they are broadcast spawners, both *Katharina* and *Cryptochiton* require a minimum density for successful fertilization and reproduction. Consequently, these chitons are vulnerable to depensatory (Allee) effects. Furthermore, low densities of these grazers likely alter local macroalgal assemblages including gamma-aminobutyric acid (GABA) producing crustose coralline algae implicated with successful recruitment (Strathman 1987). Therefore, low densities of this species may indirectly impede local recruitment. Localized depletion due to harvest and interactions with other predators such as sea otters and seabirds has already been documented (Salomon 2003).

Conservation actions:

a) In collaboration with coastal communities, experiment with harvest policies (harvest and no harvest zones, seasonal harvest restrictions, minimum size limits, etc.) to estimate sustainable population sizes and population recovery rates for local habitats. Quantify interaction strength with other components of ecosystem.
b) In collaboration with coastal communities, establish areas where harvest of chitons is not allowed interspersed with areas where chiton harvest is allowed in order to maintain optimum density of reproductive individuals embedded within a functional ecosystem.

Issue 2: Intertidal and subtidal habitat degradation along with direct contamination can occur due to pollution from various sources. Watershed discharges, such as sewage (point and nonpoint sources), forestry, mining and agricultural runoff, may degrade chiton habitat.

Conservation actions:

a) Promote proper regulation of discharge from offshore oil and gas platforms.
b) Promote proper treatment of sewage to reduce nitrogen input levels and regulation of sewage flow rates to reduce particulates and turbidity levels that may be discharged during storm events.
c) Promote regulations and policies that ensure sewage settling fields/ponds in rural areas are located far enough away from streams to allow for adequate filtration to occur.
d) Document and promote regulations that limit elevated nutrient levels originating from the fish waste discharged by canneries and hatcheries.
e) Promote regulations that curtail or eliminate the commercial use of antifouling paint that contains tri-butyl tin.
f) Promote sustainable forestry and mining practices that reduce high turbidity and sediment flows.
g) Discourage the use of fertilizers and pesticides in reforestation and coastal agricultural and mariculture activities.

Issue 3: There is limited education and community involvement in research.

Conservation action: Community-based research should be prioritized for funding. Local communities can be trained to monitor chiton densities to ensure the sustainability of chiton populations and encourage local stewardship of the resource.

Issues 4: Growth rates, survival rates, and dispersal distances of both adults and larvae are unknown.

Conservation actions:

a) Conduct tagging studies on both adults and larvae; assess growth rate and recruitment patterns of *Katharina* and *Cryptochiton.*

b) Consider genetic studies and local current pattern research to help determine metapopulation dynamics.
c) Assess reproductive patterns relative to food resources and availability of food resources.

Issues 5: There is a high degree of spatial and temporal variability and an unknown extent of suitable habitat in Alaska.

Conservation action: Assess spatial variability of rocky reef habitat in Alaska.

Issue 6: Population trends are unknown in Alaska.

Conservation action: Collect local and traditional ecological knowledge to develop a time series of historical population dynamics. Archeological data from middens may also indicate how densities and sizes may have changes through time (Simenstad et al. 1978).

Issue 7: Trophic dynamics are unknown and may affect the growth and survival of these chitons. For example, predation on the gumboot chiton by predators such as sea otters, cabezon, and sunflower stars (*Pycnopodia helianthoides*) likely alters the distribution and abundance of *Cryptochiton* in conjunction with human harvest.

Conservation action: Research the relative role of natural predation versus fishing mortality in altering the density and size structure of *Katharina* and *Cryptochiton*. This mortality should be factored into the harvest policy experiments suggested above.

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

State and federal agencies, universities, Native entities, and NGOs should coordinate to establish a monitoring plan within the next 2 years that would begin annual monitoring with evaluation at 5-year intervals.

I. Recommended time frame for reviewing species status and trends

Evaluate the strategy after 3 years and then 5 years after that.

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Shallow Rocky Reef Ecosystem (0–20 meters)
Species: *Haliotis kamtschatkana*

A. Species description

Common Name: Northern abalone, pinto abalone, Alaskan abalone, Japanese abalone
Scientific name: *Haliotis kamtschatkana*

Selection criteria: The northern abalone is vulnerable to overharvest and has become commercially extinct in parts of its range (Washington and British Columbia) (Wallace 1999; Jamieson 2001; Adkins 2000). In Alaska, this species is at the northern limit of its ecological range, increasing its vulnerability to potential impacts (e.g., harvest pressure or changes in ocean temperatures). In some areas, expansion in the range of sea otters, a major abalone predator, may be increasing natural mortality. A combination of these factors could lead to northern abalone recruitment failures in Southeast Alaska. This species has been declared a “species at risk” in British Columbia, Canada, by Environment Canada and a “species of concern” in Washington state by the Washington Department of Fish and Wildlife. The concern identified to the south should not stop across international borders, particularly given that this species is at the end of its ecological range in Alaska.

B. Distribution and abundance

Range:

Global range comments: Sloan and Breen (1988) suggest that the northern abalone ranges from Icy Strait at the northern tip of Sitka Island, Alaska (approximately ≅58^{o} North) to Baja California (approximately (≅27.5^{o}N). However, O’Clair and O’Clair (1998) indicate that northern abalone exist from Yakutat, Alaska to Point Conception, California. The northern abalone range is also said to extend to northern Japan and parts of Siberia.

State range comments: Yakutat southward

Abundance:

Global abundance comments: The northern abalone is patchily distributed, and densities vary spatially depending on human harvest pressure, sea otter predation, local recruitment rates, and hydrodynamics forces. The following are several reported density estimates from British Columbia, Canada (SL = shell length; see papers for estimates of error):

1) Denman Island, BC all sizes: 0.06/m^2 , 90–110 mm SL: 0.02/m^2 (Lucas et al. 2002)
2) Barkley Sound, BC all sizes: 0.10/m^2 , 90–110 mm SL: 0.04/m^2 (Lucas et al. 2002)
3) Kitkatla, BC all sizes: 0.16/m^2 at McCauley Island, 0.05/m^2 at Goschen Island, 90–110 mm SL: 0.05/m^2 McCauley Island, 0.01/m^2 Goschen Island (Lucas et al. 2002)
4) Bere Bay, Malcom Island, BC all sizes: 0.04/m^2, Trinity Bay 0.03/m^2, Cormorant Island, BC 0.05/m^2
5) Higgins Pass, central coast of BC 0.43–0.52/m^2 (Cripps and Campbell 1998)

State abundance comments: Abundances vary spatially depending on human harvest pressure, sea otter predation, and local recruitment rates. No specific Alaskan abundance estimates are known.

Trends:

Global trends: The northern abalone is listed as "threatened" by COSEWIC (Jameison 2001) and is listed as "threatened" under the Canadian Species at Risk Act. In Washington state, the northern abalone is a candidate species for listing under the Endangered Species Act.

State trends: unknown

C. Problems, issues, or concerns for species

Potential and/or Suspected Threats

- Localized depletion due to harvest
    a) Mature individuals found in shallow water are easily accessible to harvesters, making abalone prone to localized depletion.
    b) Northern abalone larvae disperse over relatively short distances; this species may be particularly vulnerable to localized extirpations (Jamieson 2001).
- Recruitment limitation increases susceptibility to overharvest
    a) As a broadcast spawner, the northern abalone requires high densities to ensure successful fertilization. Consequently, it is susceptible to depensatory (Allee) effects.
    b) Food web dynamics may also hinder this species.
    c) GABA-producing coralline crusts induce settlement of larvae; therefore, a lack of browsing adults may reduce successful recruitment rates.
    d) Mucus trails of conspecifics may be an important cue to triggering settlement and metamorphosis (Sloan and Breen 1988).
- Pollution from oil spills, oil and gas platforms, sewage outfall, forestry and mining runoff, anthropogenic and natural heavy metals
- Pesticide introduction from forestry, agriculture, and mariculture practices

- Climate change; changes in ocean temperature may affect abalone directly by altering their spawning period and length and/or indirectly by affecting the production of their algal food sources and/or local current patterns, which influence their metapopulation structure
- Lack of demographic data
- Higher trophic level predation, range expansion of sea otters increasing natural mortality
- Disease
- Contamination from pollution sources (oil spills, oil platform discharge)

D. Location and condition of key or important habitat areas

Northern abalone are patchily distributed throughout their range on exposed and semiexposed coasts in close association with kelp beds (Sloan and Breen 1988). In its southern range, *H. kamtschatkana* is found strictly in the subtidal with most individuals located at 10–20 m depth; however, in its northern range it is found in the lower intertidal to 100 m depth (Sloan and Breen 1988). Juveniles are cryptic and are often found in habitats characterized by crustose coralline algae. Generally, these habitats are in good condition in Alaska.

E. Concerns associated with key habitats

- Kelp forest degradation due to pollution (sewage discharge, mining, forestry and agricultural runoff)
- Coastal development
- Shallow trawling

F. Goal: Conserve and manage northern abalone metapopulations throughout their natural range to ensure sustainable use of these resources.

G. Conservation objectives and actions

State conservation and management objectives and actions:

<u>Objective</u>: Develop targets for, and sustain the population density and size structure indicative of, sustainable northern abalone populations reflective of a viable metapopulation throughout their natural range in Alaska.

Target: Identify the population density and size structure indicative of sustainable northern abalone populations in Alaska.

Measure: Density and size structure of abalone in local populations.

<u>**Issue 1**: The northern abalone is vulnerable to overexploitation because of its sporadic recruitment, slow growth, longevity and late maturity, and sedentary nature.</u>

Conservation actions: In collaboration with coastal communities, establish "no harvest" areas (marine abalone reserves) interspersed with abalone harvest areas in order to sustain a minimum density of reproductive individuals embedded within a functioning ecosystem. Because juveniles are generally found deeper than adults, these marine reserve areas must encompass depths associated with juvenile rearing grounds (i.e. account for broader metapopulation dynamics). By maintaining egg production, genetic diversity, and functional food webs, marine abalone reserves could play an important role in abalone conservation (Shepard and Brown 1993).

Issue 2: Kelp forest degradation may be caused by "upstream," coastal and oceanic pollution. For example, watershed discharge such as sewage (point and nonpoint sources), forestry, mining and agricultural runoff may degrade abalone habitat (Tegner 1991).

Conservation actions:

a) Promote the regulation of discharge from offshore oil and gas platforms to reduce coastal habitat degradation and potential contamination of coastal food webs.
b) Promote regulation of sustainable forestry and mining practices in "upstream" watersheds to reduce the potential for high turbidity and sediment flows in aquatic ecosystems.
c) Promote proper reforestation practices to reduce the use of fertilizers and pesticides.
d) Promote the regulation of sewage treatment and flow rates to reduce particulates, turbidity levels and toxins that may be discharged during storm events; promote regulations that ensure that sewage settling ponds/fields in rural areas are located far enough away from streams to allow for proper filtration to occur.

Issue 3: Kelp forest degradation can be induced by shoreline development. Furthermore, abalone depend on high flow environments that are altered by shoreline development activities.

Conservation action: Promote regulations that reduce of the amount of shoreline hardening (e.g., sea walls), which can alter regional hydrodynamics.

Issue 4: Alaskan northern abalone die at a water temperature of 16–17^{o}C (Paul and Paul 1981).

Conservation action: Promote proper regulation and design of pulp and paper mills and steam power plants that use ocean water as a coolant.

Issue 5: Lack of demographic and trophic interaction information. Growth, survival, and recruitment rates, plus estimates on minimum viable population densities required for successful fertilization, are critical pieces of demographic information required to manage and conserve a species susceptible to depensatory effects.

Conservation actions:

a) Determine food web dynamics that contribute to natural mortality.
b) Estimate metapopulation dynamics with density and size structure surveys, plus tagging and local circulation pattern studies.

Issue 6: The species *Haliotis kamtschatkana* has not been entirely resolved (Sloan and Breen 1988) across its range; consequently, it remains unclear if we are dealing with one abalone species or a species complex.

Conservation action: Collaborate on research projects with international researchers on the genetic analyses of various northern abalone populations.

Global conservation and management objectives and actions:

Issue: Various concerns regarding northern abalone cross international borders. These animals are broadcast spawners subject to metapopulation dynamics, and the populations in Southeast Alaska may be dependent on Canadian recruits or visa versa. Additionally, scientists are interested in finding out how genetically unique the northern abalone species and populations are within the Pacific. A variety of other common concerns may be identified.

Conservation action: Collaborate with Japanese and Canadian government agencies and universities that are currently devising conservation strategies for the northern abalone.

H. Propose plan and time frames for monitoring species and their habitats

State and federal agencies, universities, Native entities and NGOs should coordinate to establish a monitoring plan within the next 2 years that would begin annual monitoring with evaluation at 5-year intervals.

I. Recommended time frame for reviewing species status and trends

Evaluate the strategy after 3 years and then 5 years after that.

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