PugetSoundPartnership

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INITIAL DISCUSSION DRAFT

SPECIES AND BIODIVERSITY TOPIC FORUM

APRIL 14, 2008

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Puget Sound Partnership

Introduction to the Topic Forum Discussion Draft

The attached topic forum discussion draft is one of five papers designed to provoke and inspire a long-term, community conversation and critical thinking about the specific problems facing Puget Sound, and the strategies and actions needed to address the threats we face. These papers and your comments will be used to help create the 2020 Action Agenda. Background on the topic forum process and how this information will be used can be found on our website at www.psp.wa.gov in the Action Agenda Center.

These initial draft papers are the first effort in our region to synthesize and document what we know about the problems, solutions that work, our current approach to solving problems, and what approaches we need to continue, add, or change. This is hard work that has not been done before. It means 1) looking at Puget Sound ecosystem from the crest of the Cascades to the Strait of Juan de Fuca, 2) providing sources to back up our statements and conclusions, and 3) establishing links between science and policy.

The discussion papers are DRAFT. They do not yet represent an opinion or position of the Partnership. We very much appreciate your interest and expertise in reviewing this initial work. The Partnership asked a small group of science and policy experts to prepare this draft discussion paper as starting place for the discussion. As you read this paper and prepare to participate in one of the five upcoming workshops, participate in an online discussion, or submit specific comments, the Partnership requests that reviewers keep this context in mind.

- The Partnership will be identifying priority actions that are based on science. There is currently a wide range of opinion about the problems and literally hundreds ideas for solutions. Our hope is that if we can agree on the documented threats to Puget Sound in terms of magnitude and impact, we will have a better chance of creating priority and durable solutions.

- The papers mainly focus on the Sound as a whole. We know that there are variations in problems and solutions in different parts of our region. The action area profiles that we are also preparing will highlight local issues.

- The papers are organized to logically step through three initial questions (two are science and one is policy) that build to a rational conclusion (the fourth question) about the strategies and actions that we will need continue, add, or change as a region. The design is intentional so that 1) our policies are based on science and 2) scientists and policy experts talk to one another.

- These initial papers will contribute to a synthesis paper that will describe links between each of the topic areas. Reviewers may want to read more than one paper to begin to see the links across our individual interests and concerns. The papers reach different types of conclusions for where to focus efforts, and in some cases the suggested solutions are far-reaching. Before we get to a synthesis paper (and workshop), we want the initial papers to be as accurate as we can in the time that we have available.

- The intent of papers is to focus on WHAT the problem is and WHAT solutions are needed, rather than HOW to implement specific solutions. For example, we know that we will need to do more to protect habitat and concentrate growth into urban areas. There are many ways to accomplish this task and different methods will be needed around Puget Sound. We will create the "how" with those who have to implement the solutions.

- The papers intentionally do not focus on the need for more education/outreach, new funding strategies including creative incentives, and a coordinated monitoring and adaptive management program. The Partnership knows that these three aspects are critical to long-term success and is using other processes to address them. That work is linked to the development of the action agenda. By addressing the system-wide needs, we will be able to more effectively focus the education/outreach and funding.

- The Quality of Life "topic", or Partnership goal, is not yet represented in these papers, but will be part of our subsequent work to synthesize across the topics.

You may comment on the draft papers by attending in the topic forum workshop, participating in the online discussion at www.psp.wa.gov, or submitting a comment via email or in writing. When reviewing the papers, please consider the following questions:

- Current knowledge: Have we accurately described what we know and don't know about the status of and threats to this topic in the Puget Sound region and the certainty of our knowledge? Have we missed any major documented findings?

- Effectiveness of tools: Have we accurately characterized what is certain and uncertain about the effectiveness of the tools available to address threats to this topic? Have we missed any major documented findings?

- Current strategies: From a topic perspective, have we accurately characterized what we are now doing to address threats? Have we missed any major programs or projects?

- Strategies to continue, add, or change: Given the status of and threats to the topic, effectiveness of the tools available, and current strategies to address threats, have we accurately captured the strategies we should continue, add or change? Have we missed any strategies and actions we should continue, add or change to address the threats (not just good ideas)? What sources have informed your thinking?

- Establishing criteria: Are the proposed criteria for prioritizing topic-specific actions appropriate and sufficient? Are there other criteria to consider?

- Measuring progress: Have we identified appropriate measures to assess progress toward goals for this topic? Have we missed any key measures of progress?

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INITIAL DISCUSSION DRAFT PAPER

SPECIES, BIODIVERSITY AND THE FOOD WEB IN PUGET SOUND

Science Question 1 (S1): Status of Species, Biodiversity, and the Food Web in Puget Sound

The Puget Sound basin, with its varied terrestrial, freshwater, and marine habitats, is a highly productive and diverse ecosystem. The Sound's waters support numerous residential and migratory marine species, including over 150 species of marine birds, 230 species of fish, 20 mammal species, over a thousand species of plants and algae, and numerous invertebrates and microbes.[1] Upland species, including mammals, reptiles and amphibians, birds, fish, invertebrates, plants, and microbes, also play an important role in the ecosystem.[2]

Key Findings from Previous Efforts

A. Abundance, productivity, spatial distribution, and diversity of key species

To briefly summarize the broad range of Puget Sound species, we can loosely group species by general habitat type and trophic levels. For these purposes, we consider marine, estuarine, freshwater, and upland habitats. We can also consider the major trophic levels as *primary producers* which fix energy, primarily from the sun; *lower trophic species* which mostly consume primary producers; and *upper trophic species* which consume primary producers and lower trophic species. We acknowledge that this grouping vastly oversimplifies ecological structure and function.

Information about the abundance, productivity, spatial distribution, and diversity of species that are *examples* of each group are presented below, with the understanding that there is great variability and overlap between the groups, and that there are far more species in the Puget Sound basin than we can discuss in this short paper.

- Marine primary producers: Phytoplankton is the foundation of Puget Sound's pelagic food chain. Its distribution is highly variable, with maximum abundances in the summer. Long-term status and trends are not well known.[3,4]
- Marine lower trophic species: Forage fish – including herring, sand lance, anchovies, and surf smelt – are important prey for a wide variety of marine animals.[5] Many of the estimated 19 herring stocks in Puget Sound have declined in the past few years, with the exception of those in central/southern Puget Sound.[5]
- Marine upper trophic species: Populations of several marine mammals are stable or increasing, such as harbor seals and Steller sea lions.[6] However, Southern Resident orcas (killer whales) are in serious decline: As of October 2007, there were 87 documented Southern Resident orca individuals, compared to historical estimates of 140 to 200 individuals.[7]
- Estuarine primary producers: Eelgrass, found in bays, coves, and estuaries, supports complex food webs and provides habitat for many species.[8] Data suggest eelgrass declines in Hood Canal as well as variability in the extent of eelgrass beds in northern Puget Sound, the Whidbey Basin, and the San Juan Islands.[3]
- Estuarine lower trophic species: Amphipods primarily live on eelgrass, eating diatoms, bacteria, and algae, and are food for fish species. Little is known about their distribution, abundance, or diversity.[3]
- Estuarine upper trophic species: The great blue heron nests close to tidal shorelines and forages within the Sound's estuaries and marine waters. Population estimates are variable as colonies are difficult to locate and

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often abandoned. Some estimates suggest the population has increased by more than 20 percent since the 1970s.[3]

- Freshwater primary producers: Cottonwoods in riparian zones provide nutrient inputs and shade for aquatic systems, but populations appear to be dwindling due in part to water diversions that have altered hydrology. [9]
- Freshwater lower trophic species: Three freshwater mussel species are found in Puget Sound rivers. Each population is thought to be declining, but little is known about their distribution or abundance.[9]
- Freshwater upper trophic species: The Puget Sound ecosystem supports an estimated 200 salmon stocks, which are born, spawn, and die in the Sound's tributary rivers. Puget Sound Chinook salmon, Hood Canal summer-run chum salmon, Puget Sound steelhead, and bull trout are listed as threatened under the federal Endangered Species Act.[3]
- Upland primary producers: Old-growth forests once covered much of upland Puget Sound, but European settlers cleared the majority of these forests by the end of the 19th century.[10] These forests support species associated with aquatic habitats such as marbled murrelet and osprey.
- Upland lower trophic species: The Beller's ground beetle is found at a small number of isolated bog sites. Although the population is thought to be at risk of local extinction, its status and trends are largely unknown.[9]
- Upland upper trophic species: The modification of Puget Sound lowland prairies has corresponded to declines in many species, [11] including the coast gopher snake which appears to be extirpated in western Washington.[12]

There are many valuable ways to use "key" species or species composition to assess the condition of an ecosystem. The index of biological integrity (IBI) and ecopath are two examples of approaches commonly used to assess whether habitats are supporting species composition, diversity, and functional organization that is comparable to that of natural habitat of the region.[13,14] These approaches use species or groups of species that are sensitive to anthropogenic stressors at the ecosystem scale to assess ecosystem health.

B. Food web status

Other than descriptive studies of nearshore food web linkages and structure in northern Puget Sound and the eastern Strait of Juan de Fuca[15], and preliminary investigations of food web sources using biogeochemical tracers,[16] our understanding of marine and estuarine food webs is limited to target consumers (e.g., juvenile salmon in estuarine and nearshore Puget Sound environments).[17] Recent work modeling historic shifts in food web structure in Puget Sound and establishing baseline conditions and indicators among the Sound's fishes gives us a better understanding of the food web.[18]

Marine-derived nutrients are spread from salmon carcasses throughout the riparian and upland food webs by predators and scavengers.[19] In turn, riparian vegetation provides insects and plant matter to the freshwater food web.[20]

Changes in species composition associated with urbanization and declines in species such as Chinook salmon and killer whales may be indications that the food web in Puget Sound has changed in a fundamental way. [21] Harvest practices may have shifted the species and population dynamics, for example by preferentially removing adult individuals, thus affecting food web dynamics.[22]

Fundamental data are still needed on many basic food web elements, such as phytoplankton productivity. Indicators of marine and freshwater food web status could include predator-to-planktivore and other ratios. [23],[24]

C. Status of biodiversity

Puget Sound hosts a wide variety and number of species and communities; some rare, others highly productive. This biodiversity is threatened by declines in the abundance and productivity of many species. As of 2008, 21 species in the region were listed by the federal and/or state governments as threatened or endangered (see

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Memorandum P1). Assessments of Puget Sound biodiversity are rare, with perhaps the most prominent being the Puget Sound Ecoregional Assessment prepared by The Nature Conservancy and partners.[25] This work highlights areas of the Sound that are understood to both support significant biodiversity and to be vulnerable; due to limitations on data for marine biodiversity, this work focuses on upland areas. See sample map of priority landscapes in Appendix 2.

D. Deficiencies in our current knowledge

Nothing is known about the abundance, productivity, distribution, and diversity of thousands of Puget Sound species. Others have been extensively studied, in most cases due to their cultural or commercial importance, and of these cases we know enough to show that many are declining.[3] Yet there are still gaps in our knowledge of well-studied species such as the orca or salmon, as well as our knowledge of the connections between species. Several recent reports have characterized the major areas needing further research, including:

- *The Northwest Straits Overview – A Science Gap Report*, prepared for the Northwest Straits Commission by the Washington Sea Grant Program's Office of Marine and Environmental and Resource Programs, 2000.
- *Protection and Restoration of Marine Life in the Inland Waters of Washington State* (West, 1997, 2004).[22]
- *Reconnaissance Assessment of the State of the Nearshore Ecosystem: Eastern Shore of Central Puget Sound, Including Vashon and Maury Islands (WRIAs 8 and 9).*[4]
- Species recovery plans for listed species including Southern Resident killer whales,[7] Puget Sound Chinook salmon,[26] Hood Canal summer-run chum salmon, [27] marbled murrelets,[28] and golden paintbrush.[29]
- *Puget Sound Update* reports issued periodically (e.g., see Reference 3).

These reports identify several common areas in which more effort is needed to recover declining species and protect biodiversity and the food web:

- Identify the most immediate needs for species conservation and recovery, whether identifying the most pressing threats to Hood Canal summer chum survival,[27] or the status, distribution, and function of unclassified microbes, fungi, invertebrates, and fishes. [1,3,8]
- Improve our understanding of the Puget Sound food web, such as rates of transfer between levels of food chains, and whether and when the net community metabolism changes from being autotrophic to heterotrophic.[30]
- Develop appropriate frameworks to assess and manage biodiversity, whether through using the index of biological integrity (IBI) approach[31] or developing a comprehensive habitat map of the seafloor.[25]

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Threats to Species, Biodiversity, and Food Web Status in Puget Sound

A. Documented threats to abundance, productivity, spatial distribution of key species

There is general agreement that habitat alteration, climate change, impacts to surface and ground water quantity, pollution, harvest, cultured species, and invasive species all threaten native species, food web status, and biodiversity.[1] There are both anthropogenic and natural drivers of these threats, described by one author as climate, ocean conditions, the global economy, scarcity of and competition for natural resources, human population growth, and lifestyle preferences.[32] These threats may act synergistically, and there is great uncertainty regarding the degree to which stressors most affect a given population, or which are the most important to address for recovery.[7]

Forces outside Puget Sound's borders, such as runoff from the Fraser River, changes to migratory birds' breeding and wintering grounds, or airborne mercury particles originating in Asia,[1, 3] are important but are not considered in detail here. In addition, the limits of our understanding of species' life characteristics, the interactions between species, and the nature of the risks they face, all can hamper our management of, and so threaten, Puget Sound species, food web, and biodiversity.

Habitat Alteration

Conversion and modification of marine, estuarine, and upland ecosystems have reduced habitat for Puget Sound species. Port development, beach armoring, and other shoreline modifications have changed the nature of one-third of all Puget Sound shorelines,[33] with major modifications to estuaries such as the Duwamish.[34] Beach modification threatens critical spawning habitat for surf smelt and Pacific sand lance.[3] Population growth and suburban sprawl have accelerated the fragmentation of upland habitat, as forests and wetlands are converted to homes, businesses, and roads. Agriculture has also modified wetland and forest habitats essential to many species' survival.[8]

Climate Change

Sea level rise associated with climate change is expected to increase erosion and landslides and to diminish estuarine habitat. Changes in oceanographic processes such as circulation, mixing, and stratification, as well as water temperatures and chemistry, are expected to influence salmonids and other marine life. Increases in marine water temperatures may affect plankton diversity, distribution, and abundance, driving changes in other species' composition and abundance in the marine food web.[35] Climate change and higher temperatures may already be limiting populations of Pacific cod.[36] Changes in early spring temperatures are expected to lead to mismatches in insect development and host plant flowering, affecting the reproductive success of the populations and possibly leading to extinctions.[37] Warmer air temperatures apparently have led to a lengthening of the period of summer stratification in Lake Washington, which in turn affects the timing of phytoplankton and zooplankton blooms, disrupting the interaction between predator and prey at the base of the food chain.[35] These expectations incorporate our best estimates of future changes, combined with our understanding of the impacts of these changes on species and ecosystems, and are thus full of uncertainties.

Surface / Ground Water Impacts

Freshwater inputs from rivers and creeks, and groundwater seepage from banks and bluffs, are important habitat-forming processes in the nearshore.[4] Low streamflows and stormwater peak flows affect many rivers and streams in the Puget Sound region. The lack of sufficient streamflows during key spawning times, combined with high water flows that degrade critical spawning habitats, limits the recovery of threatened salmon species in several river basins in Puget Sound.[1] In the future, balancing the water needs of fish populations and community growth will likely be increasingly difficult.

Pollution

Human activities on the shores of Puget Sound and in factories across the globe contribute metals, toxins, nutrients, pathogens, and xenobiotics (chemicals found in organisms but not expected to be produced by or present in them) to the Sound.[3] Accumulation of toxins in the food web is thought to be a major driver in the declining health and reproductive capacity of top-level predators such as orcas.[7] Chemical contamination of sediments and water has been documented to directly and indirectly result in suppressed reproduction, disruption of homing, higher rates of liver disease, and the feminization of some male fishes.[38] Eutrophication, or low oxygen levels due to increased nutrient loading, can cause direct mortalities of marine fish species.[39] Oil spills and chronic small-scale oil discharges pose toxicological risks to orcas, birds, and other marine life.[7,40]

Harvest

Over-harvest of rockfish and Pacific hake has been identified as a risk factor to those populations.[36, 41] Harvest is an identified threat to ESA-listed populations of Chinook salmon in Puget Sound. In the mid-1980s, the median exploitation rate of Puget Sound Chinook stocks was 85 percent; in the mid-1990s the median exploitation rate dropped to 45 percent.[42] The decline of pinto abalone populations has also been attributed to over-harvest.[22] The impacts of harvest on non-target species, such as scoters and harlequin ducks, are uncertain.[43] Harvest may have cross-trophic impacts, as predators experience declines in important prey.[7] Harvest also may indirectly impact non-target species such as other fishes, birds, and porpoises which are unintentionally captured (by-catch).[22,44 ,45] In

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addition, derelict, lost, and abandoned fishing gear in Puget Sound persists for decades, killing marine mammals, birds, fish, and shellfish.[46]

Cultured Species

The culture of Pacific salmon in hatcheries is a recognized risk to threatened salmon in Puget Sound,[42] and a potential threat to depressed rockfish populations as a result of increased predation.[22] Hatchery fish, by interbreeding with wild fish, may lower the fitness of those populations to survive and reproduce successfully in the wild.[47] Hatchery fish may heighten risks such as disease and overharvest,[26] and contribute higher concentrations of PCBs up the food chain than do wild fish.[7] Atlantic trout and salmon may escape from private hatcheries (i.e., netpens in saltwater) and compete with native species.[48] Shellfish aquaculture methods, pervasive in some areas of Puget Sound,[49] modify beaches and the lower intertidal zone, but impacts on populations or the ecosystem have not been well studied. Species culture, from agricultural forestry to aquaculture, may contribute pollutants to the environment (e.g., herbicides and antibiotics) and facilitate introduction of invasive species (e.g., the invasive dwarf eelgrass, *Zostera japonica,* was shipped along with Japanese oysters for cultivation).[50]

Invasive Species

In the U.S., invasive species are the second most common threat to imperiled and federally listed species, following habitat degradation and loss.[34] In the Puget Sound basin, purple loosestrife, *Spartina* spp*., Sargassum muticum*, knotweed, Scotch broom, and other invasive species threaten native ecosystems and species.[51] Invasive, non-native species can compete with or feed on native species, and may introduce diseases. Spartina, a non-native perennial grass, has been shown to be transforming estuarine intertidal habitats.[52]

Human Disturbance

Many species, such as orcas and birds, suffer from human disturbance and noise both below and above water, often resulting from people who wish to enjoy observing wildlife. Vessel effects, including those of whale-watching boats, were listed as one of the primary threats in the listing of Southern Resident killer whales.[7] Intertidal invertebrate communities can suffer from the effects of clam harvesting and trampling.[53] Nesting waterbirds are particularly sensitive to disturbance from wildlife-watching humans, and often abandon their nests either temporarily or permanently, endangering the survival of their young.[54]

Natural Forces/Variability

Species and biodiversity are also susceptible to natural forces, including hazards such as earthquakes, tsunamis, storms, floods, and wildfires; natural hypoxia, algal blooms, or forest succession; natural variations in rainfall, ocean currents and temperatures, snowmelt, air temperature, and climate; and disease.[34] Anthropogenic threats may accelerate, amplify, or act synergistically with natural forces, reducing organisms' resiliency to natural threats. For example, anthropogenic factors and climate change influence disease risk in terrestrial and marine ecosystems.[55] Although they have not been well studied in the marine biota of Puget Sound, diseases do exist that have the ability to affect multiple taxa including ecosystem engineers such as *Zostera marina*, Pacific herring, and social species such as killer whales.[56]

B. Main gaps in our understanding of threats

There is much we do not know about the forces that threaten species survival, or about how the interactions between natural and anthropogenic stressors affect populations and alter food webs and biodiversity.[57] We do not understand the cumulative effects of stressors and major drivers, the magnitude of impacts from individual stressors, or the relative importance of threats.[4]

Perhaps the largest gap is in our understanding of the impacts of climate change on biodiversity and species. Current predictions incorporate our best estimates of future changes in the Northwest weather regime, based on global-scale models, combined with our understanding of the impacts of these changes on species and ecosystems.

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While new empirical data on climate change impacts continue to inform these projections, uncertainties in the data and model assumptions make it difficult to forecast effects precisely.[37]

Current Status of Puget Sound Biological Life Compared to 'Healthy' Condition

A. What is the definition of healthy condition?

In its 2006 report, the precursor to the current Puget Sound Partnership described a healthy Puget Sound: "Puget Sound forever will be a thriving natural system, with clean marine and freshwaters, healthy and abundant native species, natural shorelines and places for public enjoyment, and a vibrant economy that prospers in productive harmony with a healthy Sound".[1] In terms of species, biodiversity, and the food web, a healthy Puget Sound will have "healthy and sustaining populations of native species in Puget Sound, including a robust food web", with the following related outcomes:

"1. Terrestrial, aquatic, and marine species exist at viable levels into the future and biodiversity of the overall ecosystem is naturally maintained.
2. Invasive species do not significantly reduce the viability of native species and the functioning of the food web.
3. The harvest of fish, wildlife, shellfish, and plant species is balanced, viable, and ecosystem-based."[58]

A healthy Puget Sound is dynamic and resilient. Conditions may naturally change over time through random events or large-scale catastrophic or climatic events, from tsunamis to multi-decadal climate oscillations, but a healthy Puget Sound will be resilient enough to respond to these changes.

B. Where does the current condition meet, exceed, or not meet these reference conditions?

The status of many of the thousands of plant and animal species in the Puget Sound region is not known. Many key species do not meet the definition of healthy. For example:

- Twenty-one species are listed as threatened or endangered by the state and federal governments.
- Cultural icons such as orcas are in serious decline. As of October 2007, there were 87 documented Southern Resident orca individuals, compared to historical estimates of 140 to 200 individuals.[7]
- Many other formerly abundant species are declining, such as the pinto (northern) abalone, sea ducks, grebes and loons, rockfish, Pacific cod, Pacific whiting (hake), and Lake Sammamish kokanee.[59]

However, many Puget Sound species are meeting or exceeding reference conditions. Populations of California sea lions and Steller sea lions have increased by about 5 percent and 10 percent annually, respectively. Most groundfish and Pacific herring stocks are in good condition, as are intertidal invertebrates. Many managed species are providing productive and rewarding harvest opportunities including intertidal clams, geoducks, Dungeness crabs, sea urchins, and sea cucumbers.[3] Harbor seals have been steadily increasing in population since the early 1970s, with current inland waters of Puget Sound supporting a population of approximately 14,000 individuals.[3] Species that respond well to disturbance, such as the western scrub jay and the American robin, have increased in numbers in recent years.[8] And, in a positive sign of the success of conservation efforts, the bald eagle was recently removed from the federal list of threatened species, and the brown pelican has been proposed for delisting.[60]

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Science Question 2 (S2): Management Approaches Addressing Species, Biodiversity, and the Food Web

What we know, from a scientific standpoint, about the effectiveness and certainty of management approaches aimed at addressing threats to key species, biodiversity, and the food web

A. What are the main scientific findings relating to management approaches and their documented effectiveness?

Management approaches designed to address key threats to species, biodiversity, and the food web have been in place for decades. Despite the monitoring, land-use, harvest-management, and other approaches tried over the years, species – and thus the food web and biodiversity – continue to decline in Puget Sound. Currently, Washington State agencies list 157 species in the Puget Trough Ecoregion[i] as species of concern.[1]

The Land Use and Habitat, Water Quality, and Water Quantity Topic Forums are addressing the effectiveness of management approaches aimed at reducing threats such as habitat alteration, pollution, and surface and groundwater diversion. This memorandum focuses on approaches designed to address the decline of specific species, and to manage harvest, invasive species, and cultured species. It also examines management approaches more broadly, and highlights those management approaches that are thought to be most effective. For the purposes of this paper, a management action is considered "effective" if it accomplishes its goal, whether that goal is to protect a species, its prey, biodiversity, or the food web.[2]

Species Plans

Species conservation and recovery plans are prepared for species listed as threatened or endangered under the federal Endangered Species Act (ESA) and/or by the Washington Department of Fish and Wildlife (WDFW).[ii] These recovery plans have had some stunning successes at bringing back individual species, such as the delisting of the bald eagle in 2007,[3] or the proposed delisting of the brown pelican in 2008.[4] A study by the Center for Biological Diversity shows that listed species with recovery plans in place for two or more years were significantly more likely to be improving and less likely to be declining than species without such plans in place. Furthermore, species with critical habitat designated for two or more years were more than twice as likely to be improving, and less than half as likely to be declining, as species without critical habitat designations.[5] The authors identified critical habitat designations as part of these plans as a key factor for recovery success, and noted that implementation of the plan (as measured by expenditures) appeared to be positively correlated with species recovery.

Management plans have also been developed for other Puget Sound species which are not listed as threatened or endangered. For example, the harvest of geoduck is managed under the Commercial Geoduck Fishery Management Plan, as well as on a local basis through cooperative agreements with relevant Tribes.[6] Groundfish and forage fishes are managed under the Puget Sound Groundfish Management Plan and the Forage Fish Management Plan, respectively.[7] An analysis of recovery plans suggests that such multi-species plans are less effective at ensuring species recovery than individual recovery plans,[5] and the Groundfish Management Plan has had mixed results. Trends in species status information suggest some successes, such as the slight improvements in the

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[i] Please note that the Puget Trough Ecoregion extends north into British Columbia and south into Oregon, and therefore may contain species of concern that do not occur in Puget Sound.

ii State law (WAC 232-12-297) requires conservation of listed species through preparation of recovery or management plans, which direct WDFW to address the threats to listed species. The Fish and Wildlife Commission has the authority to classify wildlife as endangered or protected under RCW 77.12.020. Species classified as endangered are listed under WAC 232-12-014, as amended. Species classified as protected are listed under WAC 232-12-011, as amended.

number of groundfish and forage fish stocks in good condition during recent years.[8] However, a recent review of the Groundfish Management Plan identified gaps in the plan that may be hindering conservation efforts,[9] and as the result of a petition NMFS is currently reviewing the status of Puget Sound rockfish in consideration of an ESA listing.

Large-scale habitat conservation plans (HCPs) developed recently by state agencies are landscape-based and include provisions for multiple species.[10] However, the intent of HCPs is to protect sensitive species and their habitat while allowing certain activities to continue,[11] rather than to serve as a comprehensive plan for recovery.

There are many other management plans for harvested species and some wildlife species, but the majority of Puget Sound species are not managed under plans, and our understanding of the status and trends of those species is limited.[8]

Harvest Management

Many species in the Puget Sound basin are subject to harvest for commercial, recreational, or cultural purposes. Further detail on these regulations can be found in Memorandum P1. WDFW and WDNR regulate harvest of non-fish marine species, in some cases in partnership with treaty Tribes. Timber harvest is guided by the 1994 Northwest Forest Plan, the Washington Forests and Fish Law, and several Habitat Conservation Plans. Harvest of some non-timber forest products is regulated by the DNR.

Many Puget Sound Indian Tribes have reserved rights to harvest a variety of species, including fish and shellfish. As established through treaties and case law, Tribes and Washington State share authority and responsibility for managing fish and shellfish harvests. Federal and Washington State agencies, Tribes, and citizen groups have developed fish management plans and recovery plans which address harvest, hatchery, and habitat impacts on species such as the Puget Sound Chinook and the Hood Canal summer-run chum.[12] Tribes and Washington State share responsibility for managing fish and shellfish harvests.

Harvest management has resulted in a decrease in the overall harvest mortality of wild Chinook salmon in Puget Sound,[13] and can prevent overharvest of many species, such as halibut, salmon, geoduck, sea urchins, sea cucumbers, and other invertebrates.[14,15] Management of some species according to the precautionary principle (see "Other Management Approaches" below) has been implemented, but not evaluated for effectiveness. For example, groundfish harvest for live fish markets has been prohibited, as has the commercial harvest of seaweed and any fishing for six-gill sharks.[16,17,18] An additional benefit of harvest management is that required catch and population abundance data can be useful species-status information for purposes other than harvest management.

Many harvest quotas do not consider the other ecosystem services that species provide.[19] For example, salmon harvest quotas are based upon spawning escapement goals, forecasted run sizes, and exploitation rates. While these quotas consider survival and recovery of salmon, they do not consider the number of salmon necessary to feed Southern Resident killer whales, bald eagles, California sea lions, and other predators. The Puget Sound Salmon Recovery Plan recommends more concerted efforts to integrate harvest, hatchery, and habitat management.[20]

In other cases, harvest quotas are set too high or not set at all. Studies have identified harvest as a risk factor for rockfish, Pacific hake, and pinto abalone populations in Puget Sound.[21,22,23] Harvest of birds, non-timber forest products, such as maple for guitars, salal or moss for floral arrangements, and bark for medicines, is not always subject to regulation and, if regulated, is often inadequately and inconsistently enforced.[24] The ecological impacts of this minimally-managed harvest are not well assessed, but some of the harvest species are slow-growing (e.g., moss) and others are essential for forest nutrient cycling (e.g., mushrooms).[25]

Marine Protected Areas (MPAs), including marine reserves, are increasingly proposed as an enforceable fishery management tool.[26,27] Research on the effectiveness of MPAs for economically valuable, mid-trophic level species

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suggests that bigger reserves, and reserves which account for species' dispersal ranges, are better at protecting species.[26] Apostolaki et al. modeled the effects of marine reserves on spawning stock biomass and short and long-term yields, and found that reserves could benefit overexploited stocks of low-mobility species, as well as, to a lesser extent, underexploited stocks and high-mobility species. They found greatly increased resilience to overfishing within reserves.[27] Marine reserves established in Puget Sound by WDFW appear to have some benefit to rockfish and lingcod; however benefits to species outside the reserve have not been demonstrated.[28] MPAs have had mixed effectiveness for marine mammals and marine predators.[26]

Cultured Species

The Washington State Department of Agriculture is responsible for managing aquaculture, while authority over fish hatcheries is shared between federal, state, and tribal authorities. The Department of Natural Resources and the Forest Practices Board manage forest culture operations.

The effectiveness of these management efforts varies between culture practice and impacted species. For example, captive breeding of members of threatened or endangered populations can prevent extinctions and help with reintroductions.[29] Cultured salmon benefit human well-being by maintaining tribal culture and providing commercial and recreational benefits.[29,30,31] On the other hand, salmon hatcheries appear to limit the genetic diversity and alter the life histories of wild salmon,[13] and have been identified as a potential threat to depressed rockfish populations.[23] New species such as lingcod or geoduck are being cultured or considered for culture without extensive research into potential impacts, while cultured species continue to be a vehicle for introducing invasive species.[32]

Invasive Species

Invasive non-native species are among the top threats to imperiled species nationally.[1] In Puget Sound, purple loosestrife, *Spartina* spp*., Sargassum muticum*, knotweed, Scotch broom, and other invasive species threaten native ecosystems and species.[33] Taking early measures to avoid invasive non-native species appears to be significantly more effective than post-invasion eradication, as once established, some invasive species are virtually impossible to completely eradicate. Early action to remove species while infestations are small is more effective (and less costly) than removing them after they have infested large areas.[34]

Ecosystem-Based Management

Despite the effectiveness of many of the approaches described above, such as single-species recovery plans, the Puget Sound ecosystem has continued to decline. One indicator of this decline is that government agencies in the Georgia Basin-Puget Sound ecosystem continue to add to their lists of species of concern: Between 2002 and 2004, fourteen species were added to these lists. The total number of species on the combined lists – 63 – is indicative of ecosystem decay.[35]

To arrest this decline, many scientists suggest focusing on ecosystem-based management, which accounts for the linkages between species and addresses system-wide factors of decline. The U.S. Ocean Policy Commission and the Pew Ocean Commission both called for a shift to ecosystem-based management, and NOAA is following their lead by conducting an Integrated Ecosystem Assessment (IEA) of Puget Sound, with plans for a future U.S. West Coast IEA.[30,31,36]

A recent paper[37] describes the principles that ecosystem-based management approaches for the ocean generally include:

1. Define the spatial boundaries of the marine ecosystem to be managed.
2. Develop a clear statement of the objectives of ecosystem-based management.
3. Include humans in characterizations of marine ecosystem attributes and indicators of their response to change.

4. Use a variety of strategies to hedge against uncertainty in the ecosystem response to ecosystem-based management approaches. These strategies can include regulations, incentives, rewards, marine reserves, and others.
5. Use spatial organizing frameworks such as zoning for coordinating multiple management sectors and approaches.
6. Link the governance structure with the scale of the ecosystem elements to be managed under an ecosystem-based management approach.

Ecosystem management is designed to protect ecosystem structure, functioning, and key processes, formed on concepts such as:

- Changes in the abundance of any species can have unintended consequences in the ecosystem. For example, increased abundance of pinnipeds such as harbor seals and California sea lions in Puget Sound (due to their protection under the Marine Mammal Protection Act) has negatively affected populations of Pacific herring and may be inhibiting recovery of several fish species, including Pacific hake, walleye pollock, and Pacific cod. Similarly, the return of the bald eagle may be responsible for the unusually high mortality of common murre nestlings at Tatoosh Island.[23]

- Dramatic variability is to be expected, thus a long-term focus is necessary. The abundances of species are inherently difficult to predict, especially over longer time periods, in part because they may change abruptly and with little warning. For example, decadal-scale changes such as the North Atlantic Oscillation or the Pacific Decadal Oscillation can abruptly and unexpectedly alter ecosystem dynamics and species abundances.[38]

- Ecosystems are not infinitely resilient.

- Ecosystem services are nearly always undervalued.

Although many scientists call for a shift to ecosystem-based management and some management agencies have adopted it in principle, ecosystem-based management has been implemented only rarely. Little is known about its effectiveness in action.[37]

Management on the ecosystem scale is expected to be most effective if it is undertaken through coordinated action across agencies with a clear plan. The U.S. Government Accountability Office (GAO) reviewed the Chesapeake Bay Program, and found that the program lacks a comprehensive, coordinated implementation strategy, and that some of the partners' efforts or plans are inconsistent with each other or perceived as unachievable by program partners. The GAO questioned the program's ability to effectively coordinate restoration efforts and manage its resources. [39]

In contrast, Washington has found successes in locally-based, multi-stakeholder management processes. For example, Marine Resource Councils appear to effectively raise awareness of and mobilize local support for conservation and increase voluntary compliance with conservation goals.[40]]

Other Management Approaches

Two approaches to managing the uncertainty associated with species, biodiversity, and the food web that are championed by many in the conservation community are the precautionary principle[41] and adaptive management.[42]

The **precautionary principle** encourages policies that protect human health and the environment in the face of uncertainty.[43] It is based on taking precautionary measures on activities that raise threats to human health or the environment, even if all the cause and effect relationships have not been fully established scientifically.[44].[45] Kriebel et al. (2001) describe the precautionary principle to have four central components: "taking preventative action in the

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face of uncertainty; shifting the burden of proof to the proponents of an activity; exploring a wide range of alternative to possibly harmful actions and increasing public participation in decision making."[43] The State of California has adopted the precautionary approach as a starting point for addressing 19 fish species.[46]

Adaptive management, designed to deal with uncertainty, is considered by some as a method to implement the precautionary principle.[47] Adaptive management occurs through an iterative process in which management approaches are developed and applied, their impacts are monitored and assessed, and management approaches are modified based on findings. In practice, it may take many years for adaptive management of a given ecosystem to accurately measure and document the effectiveness of management techniques. While adaptive management is widely supported in concept, in practice it is often less effective than expected, due in many cases to the complexity of the human institutions and ecosystem being managed.[42]

The National Research Council has identified a continuum of management actions: protection, restoration, enhancement and rehabilitation. Mitigation, particularly compensatory mitigation, can adopt any of these approaches to minimize or eliminate a net impact. Protection is identified as the most effective management approach. Restoration is most effective when pursued with the goal of recovering natural ecosystem processes that maintain and reestablish natural biodiversity and complex ecosystems, but it requires integrated, coordinated efforts to address all ecosystem components at an appropriate scale. Mitigation, the least effective approach because it seldom involves true restoration and often attempts highly-uncertain ecosystem creation, can alleviate some detrimental effects of ecosystem loss but rarely achieves full restoration.[48]

B. How is the effectiveness of management techniques measured and documented?

While a number of agencies and groups monitor species' abundance or health in the Puget Sound ecosystem, little of this monitoring is done with the goal of informing modifications in management approaches.[49]

For example, the Puget Sound Assessment and Monitoring Program (PSAMP) has been monitoring key indicators of water and sediment quality, nearshore habitat, shellfish beds, and the health of fish, seabirds, and marine mammals for almost 20 years. While PSAMP has provided a wealth of information on species health, abundance, diversity, and distribution, these data are not well-linked to management objectives or approaches.[50]

The Washington Department of Fish and Wildlife monitors a network of 18 marine reserves in Puget Sound for research purposes. Scuba divers estimate fish densities, measure individual fish, and identify and quantify lingcod nesting activity.[8] While these data do have relevance for the impacts of harvest on species, benefits for species or overall population management outside the reserves have not been demonstrated.

Washington's Forum on Monitoring has begun implementing a statistically-designed multi-agency evaluation of the effectiveness of watershed recovery efforts for salmon through a program of intensively monitored watersheds.[51] Baseline data were collected in 2004-2005; other results have not yet been published.[52]

One very important step in evaluating the effectiveness of management techniques is clearly articulating goals and choosing indicators. For example, the GAO review of the Chesapeake Bay Program found that the program's monitoring efforts were weakly tied to assessments of progress toward identified goals.[39] Identified goals may not necessarily benefit the ecosystem as a whole; as discussed above, the effectiveness of harvest and/or hatchery management is usually discussed in the context of the managed species, but management impacts on other species in the ecosystem are usually not addressed.

C. *From a scientific standpoint, which approaches have been documented to have the most effective results relative to abundance, productivity, spatial distribution, and diversity?*

Management approaches which appear to more effectively protect and promote species, biodiversity, and food web status include aggressively preventing species invasion, taking an ecosystem approach to management, and prohibiting or limiting harvest in set-aside areas.

- Taking early measures to avoid problematic invasive non-native species appears to be significantly more effective than post-invasion eradication in promoting species abundance, productivity, spatial distribution, and diversity.[20]
- Harvest management can effectively maintain or enhance the status of the target species.[13] Revised harvest quotas which reflect the needs of other species in the ecosystem are expected to have more widespread benefits.
- Single-species recovery approaches, such as those under the ESA, can effectively restore the target species.[3, 4] In addition, the in-depth focus on ailing species can uncover hidden problems, such as the effects of DDT on eggshells. However, single-species recovery plans do not account for effects on other species, or on the ecosystem as a whole.
- Comprehensive management approaches addressing ecosystem and harvest needs are more certain to benefit the ecosystem than current single-species harvest management approaches.[5]
- There is strong scientific consensus that ecosystem-based management will more effectively ensure healthy, intact, and resilient ecosystems with diverse and abundant species.[38]

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Policy Question 1 (P1): Policy Approaches to Address Species, Biodiversity, and the Food Web in Puget Sound

A. Threats being addressed by existing regulations or management programs

Puget Sound's growing human population poses multiple threats to marine, estuarine, and upland ecosystems. Habitat alteration, climate change, impacts to surface and ground water quantity, pollution, harvest, cultured species, and invasive species will continue to put marine, estuarine, freshwater, and upland ecosystems and species at risk.[1,2]

Agencies and organizations use many policy approaches to manage or reduce threats in Puget Sound, including incentives, education, voluntary stewardship, regulations, plans, and programs. The Partnership recently requested these organizations to submit summaries of their Puget Sound-related activities; the inventory of these activities demonstrates the great breadth of programs and numbers of people working on the behalf of Puget Sound species, biodiversity, and the food web. A non-exhaustive sampling of these is provided below, organized by threat.

In addition, it is important to note that many agencies and multi-stakeholder groups have created management plans to address single species, multiple species, or even all of Washington's biodiversity. These plans typically contain provisions to address multiple threats. Examples of these plans and programs include the Washington Biodiversity Conservation Strategy, the Puget Sound Salmon Recovery Plan, the Pacific Region Seabird Conservation Plan, the Northwest Forest Plan, the Pacific Salmon Treaty, state and federal species recovery programs, and the Washington Department of Fish and Wildlife's (WDFW) Comprehensive Wildlife Conservation Strategy and Priority Habitats and Species Program. Regulations that address multiple threats to species, biodiversity, and the food web include (but aren't limited to) the Growth Management Act, the Coastal Zone Management Act, the Forest and Fish Act, and the Clean Water Act.

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Habitat Alteration

- The federal Endangered Species Act (ESA) focuses on protecting and recovering species and the ecosystems that support them. Under ESA, species may be listed as threatened or endangered and can be afforded legal protections. The ESA provides the legal foundation for the development of recovery plans for listed species. It allows incidental take of listed species. Federal agencies are required to consult with the U.S. Fish and Wildlife Service and the National Marine Fisheries Services about their activities. Non-federal entities can develop voluntary Habitat Conservation Plans (HCPs) before taking actions on their land which may incidentally harm ("take") a threatened or endangered species. The ESA also requires the federal government to identify and designate critical habitat for any listed species.[3] The National Environmental Policy Act requires federal agencies to consider the environmental effects of their proposed actions, and reasonable alternatives to those actions, as part of their decision-making processes.[4]
- Tribes around Puget Sound work to restore and enhance habitat in their treaty areas to reverse the decline of species and other natural resources. [5, 6]
- Several Washington State agencies are completing ecosystem-based, multi-species HCPs under the Endangered Species Act. The Washington Department of Natural Resources (DNR) is developing an HCP for aquatic lands[7] and WDFW is developing multi-species HCPs for wildlife management areas and for Hydraulic Project Approvals.[8] Since 1997, DNR has managed its timber lands under an HCP.[9] These HCPs provide the opportunity to synthesize data on the distribution and other metrics on key fish and wildlife species in the Puget Sound region. Like its federal counterpart, the Washington State Environmental Policy Act (SEPA) requires state and local agencies to include the environmental consequences of an action in their decision-making process.[10]
- Cities and counties implement Comprehensive Plans, Shoreline Master Programs, Critical Areas Ordinances, zoning laws, and other regulations which have provisions to protect species habitat from development and

disturbance. For example, Whatcom County and Bainbridge Island include provisions for forage fish spawning in their Critical Areas Ordinances.[11] Cities and counties must also comply with SEPA. Eleven Puget Sound-basin local governments have adopted transfer of development rights programs to protect open space and guide development.[12] The City of Seattle also has an HCP for the Cedar River Watershed, designed to protect both the City's water supply and habitats for 83 species of fish and wildlife in the watershed.[13]

- Citizens and non-profit organizations monitor birds, fish, beaches, and streams in an effort to inform scientists and managers about ecosystem conditions and potential threats to these resources. Examples are numerous but include Washington State University Extension's Beach Watcher program, the Puget Sound Alliance's Sound Watcher program, the Salmon Watchers program, and many others.

Please see the Land Use/Habitat Topic Forum initial discussion draft papers for more information about how habitat alteration is being addressed in Puget Sound and the effectiveness of these approaches.

Surface / Ground Water Impacts

- The Washington Department of Ecology (Ecology) has established or is working to establish instream flow rules in all 12 Puget Sound watersheds except San Juan (WRIA 2) and Island (WRIA 6), to protect and preserve instream resources and values such as fish, wildlife, and recreation.[14] Ecology also is charged with implementing the Water Resources Act of 1971.[15]
- Citizens, local governments, state agencies, and Tribes are working together in several Water Resource Inventory Areas across Puget Sound to develop watershed management plans that address surface and groundwater quantity.
- Local governments and water purveyors develop water system plans detailing future water supply and conservation measures.

Please see the Water Quantity Topic Forum initial discussion draft papers for more information about how surface and groundwater impacts are being addressed in Puget Sound and the effectiveness of these approaches.

Pollution

- Tribes monitor water quality across Puget Sound.[16]
- The federal Clean Water Act regulates point sources of water pollution such as factories and wastewater treatment plants, and provides for management of non-point sources such as agricultural runoff.
- The Washington Department of Ecology implements the Clean Water Act and is responsible for monitoring and regulating water quality state-wide.
- Counties and cities in Puget Sound have adopted Ecology's 2001/2005 *Stormwater Management Manual for Western Washington.*[17]

Please see the Water Quality Topic Forum initial discussion draft papers for more information about how pollution is being addressed in Puget Sound and the effectiveness of these approaches.

Harvest

- Treaty tribes and state agencies share responsibility for managing fish and shellfish harvests. The federal government, Washington State agencies, Tribes, and citizen groups have developed fish management plans and recovery plans which address harvest, hatchery, and habitat impacts on species such as the Puget Sound Chinook, bull trout, Hood Canal summer-run chum, and many food fish.
- State government agencies also regulate harvest of non-fish species. Commercial harvest of kelp and seaweed from aquatic lands is prohibited with specific exemptions, while recreational harvest is permitted by

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WDFW and WDNR.[18] Recreational and commercial harvest of shellfish is permitted by WDFW.[19] WDNR manages geoducks in partnership with WDFW and treaty Tribes.

- **Federal, state, tribal, and county** governments in Washington collaborated with those in Oregon and California to develop the 1994 Northwest Forest Plan, with the goal of producing timber while protecting and managing related species.[20] Similarly, the federal, state, tribal, and county governments and private forest landowners worked together to create the Washington Forests & Fish Law and its HCP to allow timber harvest while still protecting streams and salmon.[21] Federal, state, and private forest landowners have worked together to create three major HCPs on private timber lands.[22]
- **The Washington DNR** issues permits for harvest of specialized non-timber forest products including Christmas trees, native ornamental trees, evergreen foliage, cedar products and salvage, mushrooms, and cascara bark.[23]
- **The Washington Department of Fish and Wildlife** has established a series of marine reserves to protect iconic or reference habitats and species.[24] WDNR has established Aquatic Reserves to protect habitats.

Invasive Species

- **Washington State and federal agencies are working with their counterparts in Oregon, California, Alaska, and British Columbia** to address invasive species across political boundaries. WDFW manages aquatic nuisance species, focusing on non-native invasive mussels.
- A number of **Tribes** in the Puget Sound basin are actively involved in addressing non-native invasive species, including *Spartina* spp. and knotweed.[25]
- **The Washington Invasive Species Council** provides policy level direction, planning, and coordination for combating invasive species and preventing introductions, and will release a strategic plan in June 2008. High-profile invasive species, such as tunicates and *Spartina* spp., are actively managed by state agencies.[25]
- **The Washington State** Ballast Water Management Act of 2000 (as amended) requires vessels to manage ballast water in ways to reduce the introduction of invasive species to receiving waters.[26] The Washington Ballast Water Workgroup is working with industry representatives to meet requirements in that Act.
- **Citizens** monitor for invasive species such as tunicates and European green crab. [27]

Human Disturbance

- The federal **Marine Mammal Protection Act** prohibits disturbing or harassing marine mammals.[28] Similarly, the ESA prohibits harassing, harming, pursuing, collecting, or capturing listed species.[29]
- **The Washington Governor** recently signed a bill requiring all vessels to stay at least 300 feet away from orcas.[30]
- **WDFW** publishes management recommendations for priority species that include provisions to reduce human disturbance. For example, the recommendations for great blue herons include buffers from all human activity of at least 820 feet between February 15 and July 31.[31]
- **Local programs** such as the Seattle Aquarium's Beach Naturalist program train volunteers to teach beach-goers how to admire intertidal life without harming it.[32]

B. Threats not being addressed, and why

Despite many good efforts, including but not limited to those described above, **all of the stressors outlined above continue to threaten** species, the food web, and biodiversity. As the human population of Puget Sound grows by 1.5 million over the next 20 years, it is likely that threats such as pollution, reductions in water quantity, disease, and habitat loss and degradation will intensify.

The Land Use/Habitat, Water Quantity, and Water Quality Topic Forums are addressing habitat loss, water quantity, and water quality threats. This section discusses limitations to how threats posed by harvest management, cultured species, invasive species, and climate change are being addressed:

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- Threats to biodiversity and the food web posed by the culture of species are not comprehensively addressed. Culture sites such as forests or net pens can fragment habitat, the addition of cultured species into Puget Sound can adversely affect the food web,[33] and disease risk in hatcheries is elevated.[34]
- Harvest management rarely considers the impacts of harvest on species linked in the food web and on the ecosystem as a whole.
- The responsibility for management of many species rests with WDFW and the Tribes, while those species use public and private lands and waters managed by others. There is no framework to make cohesive ecosystem-based management evaluations or decisions across these authorities. This increases the potential for habitat fragmentation or management plans working at cross purposes. For example, WDFW has 18 marine protected areas but WDNR manages the aquatic lands underneath them and could lease the sites for other purposes. Conversely, WDNR has several large Aquatic Reserves, yet WDFW allows many types of harvest within those reserves.
- Harvest of non-timber forest products, such as salal, mushrooms, and cascara bark, is difficult to manage, and illegal harvest is a growing problem.[35]
- While programs to control noxious weeds have been in place in Washington for decades, the infrastructure to manage invasive animals, as well as funds to eradicate or control invasive species, are lacking. More dedicated management of invasive species in marine and estuarine environments has been identified as a pressing need.[36]
- Human disturbance, such as trampling along shorelines associated with recreational activities, can have significant effects on species.[37] While many parks and management agencies have issued guidelines designed to minimize these impacts, regulations and public education could more effectively protect refuges, hauled-out marine mammals, seabird colonies, rafting seabirds, shellfish, and others.
- The state and many local governments and citizens are beginning to take action on reducing greenhouse gas emissions, but climate change is expected to continue to impact species and biodiversity in coming decades.

There are many institutional challenges and barriers to addressing threats to species, biodiversity, and the food web. For example, authority to manage invasive species is fragmented, such that agencies frequently work in isolation to evaluate risks, develop prevention strategies, and control the threat of an invasive species. Even when regulatory authority is clear, agencies may lack flexible funding with which to tackle the problem.[25] In many cases, lack of resources or political will weakens management efforts and enforcement of existing laws, while in others our incomplete understanding of the problem precludes implementation of a truly effective management approach.[2] Management of these threats is also complicated by overarching drivers which are particularly difficult to address; e.g., climate, ocean conditions, the global economy, scarcity of and competition for natural resources, human population growth, and individual and collective lifestyle preferences.[38]

The institutional framework for managing marine ecosystems is complicated by issues of scale. While most biological management efforts occur at the state and federal level, many of the decisions that affect Puget Sound biota are made by local governments and individual residents and visitors.[39] Ownership across nearshore and upland systems is fragmented, and protection of aquatic environments is weakly correlated with ownership because of the fluid nature of the ecosystem and the mobility of many of the component species.[2] In addition, habitat loss and pollution outside of Puget Sound can affect migratory species that reside part-time in Puget Sound.[40]

Local governments are often constrained in enforcing laws protecting nearshore ecosystems, due to lack of resources and fears of legal challenges and political opposition.[41] Conflicting mandates complicate management at the state level: For example, the WDFW is funded in part by its management of resource harvest, yet it is simultaneously charged with species conservation.[42]

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C. Species plans to address population, abundance, distribution and/or diversity

Currently, Puget Sound species which have been listed as threatened or endangered by the state and/ or federal government include:[43]

- Puget Sound Chinook Salmon
- Hood Canal/E. Strait of Juan de Fuca Chum Salmon
- Bull Trout
- Northern Pacific Humpback Whale
- Puget Sound Steelhead
- Steller Sea Lion
- Southern Resident Orca
- Northern Sea Otter
- Marbled Murrelet
- Western Grey Squirrel
- Streaked Horned Lark
- Pacific Fisher
- Northern Spotted Owl
- Western Pond Turtle
- Mardon Skipper
- Taylor's Checkerspot
- Golden Paintbrush
- Water Howellia
- Grizzly Bear
- Mazama Pocket Gopher
- Gray Wolf

Recovery or conservation plans have been developed, or are being developed, for most of these threatened or endangered species.[44]

Other Puget Sound species which are not listed as threatened or endangered are managed under state plans. WDFW manages at least 80 species of groundfish and at least 8 species of forage fishes under the Puget Sound Groundfish Management Plan and the Forage Fish Management Plan.[45] The DNR manages geoduck harvests under the Commercial Geoduck Fishery Management Plan, and co-manages geoduck and intertidal shellfish harvests on a regional basis with the relevant Tribes.[46]

D. Species without plans or programs either in place or planned

There are thousands of marine, estuarine, freshwater, and upland species that are not managed through recovery plans, such as unclassified marine invertebrates and fishes. An estimated 157 species in the Puget Trough Ecoregion have been listed as species of concern by Washington State; the status of many others is unknown.[2]

E. Plans or programs in place to address food web status and biodiversity in the Puget Sound region

There is no real institutional structure for managing biodiversity or food webs.[39] The 2007 Washington Biodiversity Conservation Strategy contains a number of recommendations that, if implemented, should help to address biodiversity in Puget Sound. These include:

- Using the Ecoregional Assessment tool to guide prioritization of habitat conservation;
- Using incentive programs and technical assistance to support conservation among private landowners;
- Supporting local governments in managing growth and development, as well as existing laws, plans, and regulations;
- Improving mitigation programs;
- Conducting public outreach; and
- Establishing a Biodiversity Science Panel and a Biodiversity Data Partnership, as well as a Biodiversity Inventory to document all species in the state, and a Biodiversity Monitoring Plan to track the status of those species.

These recommendations were developed based on input and results from groups working to conserve biodiversity in Washington and beyond. For example, The Nature Conservancy has found that Ecoregional Assessments provide a

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common information base, identify additional data needs, and help to build partnerships essential to conservation.[47] Conservation incentive programs have proved to be a successful non-regulatory method to help private landowners steward their land.[39] A pilot citizen biodiversity stewardship project in Pierce County underscored the importance of local government support for biodiversity conservation.[48]

Additional work informing management at an ecosystem scale includes the Ecoregional Assessments conducted by The Nature Conservancy, the WDFW Wildlife Conservation Strategy, and an effort to improve ecosystem-based management through an Integrated Ecosystem Assessment of Puget Sound.[49] There is also significant research underway on better understanding of Puget Sound food webs,[50] but there are no existing management approaches directed toward food web goals.

F. Other types of plans or programs used in other locations to address species and biodiversity

A range of plans and programs are being used in marine, estuarine, freshwater, and upland ecosystems across the world to address species and biodiversity. For example:

- Many U.S. states adjoining marine waters or the Great Lakes have strategies for biodiversity conservation, including Oregon, California, Hawaii, Wisconsin, Maine, Delaware, Massachusetts, New Jersey, and Florida.[51]
- California's Marine Life Management and Protection Act directed the state to design and manage a network of marine protected areas in order to, among other things, protect marine life and habitats, ecosystems, and natural heritage, as well as improve recreational, educational and study opportunities.[52]
- Under the Georgia Basin Action Plan, Environment Canada, the British Columbia Ministry of Environment, and others conduct monitoring and biological stream assessments in four Georgia Basin watersheds, with the intent of providing needed information to sustain healthy aquatic environments in the Basin.[53]
- Ireland's National Biodiversity Plan calls for practices to conserve biodiversity such as the preparation of a National Integrated Coastal Zone Management Strategy, the development of a National Marine Biodiversity Resources Database, and enhanced surveys and research on marine biodiversity.[54]
- The National Strategy for the Conservation of Australia's Biological Diversity aims to protect biological diversity and maintain ecological processes and systems.[55] Australia also has created a set of national objectives and targets for biodiversity conservation to augment the National Strategy, and set targets for 10 priority outcomes.[56]
- In 2008, New Zealand released a final policy and implementation plan to protect its marine biodiversity by establishing a comprehensive and representative network of Marine Protected Areas.[57] The country also has a comprehensive, nationwide Biodiversity Strategy.[58]

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Policy Question 2 (P2): Needs Assessment and Actions: What are the Gaps?

Addressing the Threats to Species and Biodiversity in Puget Sound

A. Plans and programs which are on track to address identified threats, and why

In Memoranda S2 and P1, we identified a number of plans and programs that appear to be on track to address identified threats. These include the following:

- Management plans focused on individual species or groups of species can be effective at addressing multiple threats to those species. Perhaps the most famous example in Puget Sound is the delisting of the bald eagle, but other species' populations have improved under focused management. [1,2] Species recovery plans such as the Puget Sound Chinook Recovery Plan and multi-species and broader management plans such as the Washington Biodiversity Conservation Strategy identify many ways to address identified threats, although implementation of these plans is underfunded. The detailed recommendations for protection and restoration projects, improvements in management approaches, and targeted scientific inquiries contained in these plans will be a critical component of restoring the health of species, the food web and biodiversity in Puget Sound.

- Improved harvest management techniques have benefited their target species. For example, better harvest management has led to a decrease in the overall harvest mortality of wild Chinook salmon,[3] and can prevent overharvest of many species, such as halibut, salmon, geoduck, sea urchins, sea cucumbers, and other invertebrates.[4,5] Use of the precautionary principle to eliminate commercial harvest pressure on seaweed and sharks and other fishes has reduced pressure on and slightly improved groundfish stocks.[6] Efforts such as the Puget Sound and Coastal Washington Hatchery Reform Project[7] should also be on track to improve hatchery practices so that they contribute to recovery of species in Puget Sound.

- Protection of species works well. For example, the Marine Mammal Protection Act prohibits harassing or killing marine mammals. Since its passage, some populations of marine mammals have increased in Puget Sound.[8] Populations of bald eagles and peregrine falcons rebounded after DDT was banned.[9]

- An increased focus on human disturbance effects also will help address the threat that human disturbance poses to a variety of species. A new state law that requires vessels to stay 300 feet away from orcas is a step in the right direction. Local programs such as the Seattle Aquarium's Beach Naturalist program train volunteers to teach beach-goers how to admire intertidal life without harming it.[10]

- Swift action to avoid the introduction of non-native species is more effective than trying to eradicate established invasive species.[11]

- Multi-stakeholder groups have been shown to be effective at mobilizing local support for conservation and increasing voluntary compliance with conservation goals.[12] They also provide forums for collaboration between and among stakeholders and resource managers.

- Collaborative science programs such as the Hood Canal Dissolved Oxygen Program partner scientists and managers in strategic studies and recommending actions.

- Prevention and restoration efforts have proven successful. For example, oil-spill prevention efforts, such as the deployment of a tug in Neah Bay and increases in vessel inspections, have markedly decreased the

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number and volume of oil spills in Puget Sound since 1986.[13] The Northwest Straits Commission's Derelict Fishing Gear Removal Project is locating and removing lost fishing gear, which can harm humans as well as wildlife. The Commission estimates that hundreds of tons of derelict gear litter Puget Sound.[14] Collaborative efforts and groups such as the Puget Sound Nearshore Ecosystem Restoration Project and a wide variety of non-profits are taking a proactive approach to restoration.

B. Gaps between existing programs or plans and identified needs (what is missing from what we do now?)

Although many programs and management efforts are on track, Puget Sound lacks an ecosystem-based management framework to protect and restore marine, estuarine, freshwater, and terrestrial species, biodiversity, and the food web. As preliminary recommendations for the working group to consider, this ecosystem-based management approach should include the following:

- An institutional framework that includes all levels of government, tribes, scientists, and a wide variety of stakeholders. Successful implementation of an ecosystem-based management approach will depend upon all agencies and entities adopting the same form of ecosystem management. Strong leadership will be necessary to knit all the agencies and entities together into a cohesive planning and implementing body. This framework must develop a way to overcome the gaps between institutions – such as the fact that DNR manages the lands under WDFW's groundfish reserves, or that Ecology manages water rights but local governments manage growth – as well as modifying the mandates of institutions as necessary. For example, WDFW is charged with recovering priority species but is partly funded by hunting and fishing licenses; DNR manages aquatic and forest lands but must use them to generate funding. The framework also should include a focus on strengthening trans-boundary collaboration with Canada.

- A comprehensive approach to identifying and managing drivers of ecosystem change as well as threats to species, biodiversity, and the food web. Because there currently is no system for managing the food web, this approach would fill a major gap. This approach must also prioritize among actions to protect and restore species, biodiversity, and the food web, and hold entities accountable for implementation.

- A comprehensive science program to coordinate research and monitoring efforts. These efforts must include status and trends, cause and effect, validation, and effectiveness monitoring. The ecosystem-based approach should establish goals, outcomes, and indicators, and ensure that monitoring efforts "roll up" through an accurate model to create a picture of ecosystem health. Because ecosystem models are still in development, qualitative outcomes should be evaluated with respect to the principles of adaptive management and the precautionary principle. This monitoring program should maintain a balance between a focus on chosen indicators and research on aspects of the ecosystem that are not indicators.

- A dedicated, sustainable funding source for management efforts, the science program, and maintenance of the institutional framework.

Creating this ecosystem-based approach will require ingenuity and creativity to develop new tools and modify existing ones. It will require strong leadership and willingness to take risks.

What areas or issues need the greatest attention or action and why?

Creation of the ecosystem-based approach should begin immediately to organize and coordinate the myriad of actions necessary to recover species, biodiversity and the food web in Puget Sound.

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C. Actions which may need to be changed (programs or mandates that conflict, are not focused on key problems, overlap, or have some other inefficiency)

The ecosystem-based approach should serve as an umbrella under which many successful programs continue to promote species, communities, and biodiversity. Some may need to be changed somewhat to fit within the ecosystem perspective. For example:

- Species recovery planning efforts should continue and be nested within this approach. Restoring individual species within the food web requires the dedication and detailed investigation that species-recovery efforts generate. An ecosystem-based approach could suggest ways to broaden these efforts to consider the ecosystem services these species provide.

- Species-management efforts also should continue but be integrated across agencies and levels of government.

- Harvest management efforts also should continue. Nesting them within the ecosystem-based management approach will require evaluating harvest quotas and management practices to ensure that they help achieve ecosystem and food-web goals in addition to economic, cultural, and recreational goals.

- Similarly, culture-management efforts should continue but expand to consider the effects of culture on other species, biodiversity, habitat, and the food web.

- Efforts to manage specific threats, such as human disturbance or invasive species, should continue. Nesting them within this approach will require an examination of how they meet ecosystem goals.

- Scientific programs such as the Puget Sound Ambient Monitoring Program should continue but be adjusted as necessary to ensure they inform management decisions supporting the ecosystem-based goals and objectives, and support tracking indicators of progress toward goals and objectives.

Shifting to an ecosystem-based management approach would tie all of these efforts together and unite them in making progress toward a single set of goals. It also would drive us beyond our current focus on species toward a more comprehensive understanding of species interactions, the food web and biodiversity in the Puget Sound basin.

Which actions need the greatest attention?

All of these actions require attention, but the ecosystem-based framework must be created first.

Which criteria should be considered for prioritizing actions to address species, biodiversity, and the food web?

Developing an ecosystem-based approach to recovering Puget Sound's food web and biodiversity will require agreeing upon a set of goals and outcomes for the ecosystem, as well as indicators for tracking progress toward those goals. That effort also likely will generate a set of criteria for prioritizing actions to achieve the outcomes and goals.

In the meantime, some criteria to consider include the following:

- Urgency:
    - Is it urgent? Does it effectively address endangered or declining species?
    - Does it keep common species common or protect functioning ecosystems or habitats?

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- Effectiveness:
    - Does it affect multiple species, biodiversity or the food web?
    - Does it address the cause of the problem, rather than a symptom? Does it address multiple threats or limiting factors?
    - Can the effects of the action be discriminated from natural variability in the system?
    - Do we have a good sense that it's going to work, based on the science?
    - Can we evaluate this action so that it leads to adaptive management?
    - Does it lead to human behavior change that will improve ecosystem conditions?
    - Is it cost-effective?

- Steps towards ecosystem-based management:
    - Does the action improve coordination between and integration of managers, implementers, and scientists?
    - Does it amplify and/or integrate the scope(s) of existing efforts so that they contribute to ecosystem goals?
    - Does the action build our understanding of the ecosystem and/or limiting factors?
    - Does it consider sustainable species needs as well as human well-being?
    - Does it consider the precautionary principle, if its effects on the ecosystem are unknown?
    - Does the action inform citizens, scientists, and/or managers about species trends and corresponding appropriate actions?

A. Where should we start? Why?

Citizens, non-profit agencies, tribal and government entities, and multi-stakeholder groups have already poured tremendous effort into recovering species (and by extension, the food web and biodiversity) in Puget Sound. We should build on that good work.

That good work includes hundreds of suggested actions to address dozens of species. Rather than attempting to select among them, we suggest five areas in which to focus efforts initially:

1. Begin developing an ecosystem-based management approach to, and institutional framework for, recovering Puget Sound.

2. Take action where we know there is urgency: restore declining species and keep common species common. Implement existing species-recovery and multi-species plans. Create plans for other imperiled species and communities.

3. Protect or conserve habitats or areas with high biodiversity and high potential value to the food web.

4. Continue to build our understanding of the food web, threats to the food web and biodiversity, and the effectiveness of management actions so that we can manage adaptively. In particular, conduct research to build our understanding of trends, patterns, and mechanisms of change in species, biodiversity, and the food web.

5. Undertake a critical assessment of harvest and culture practices to see where they could be improved, particularly regarding maintaining harvested species' roles in the ecosystem and ensuring that culture practices protect the ecosystem.

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B. *What immediate or short-term actions (next biennium) are needed? What is the rationale?*

In the short-term, we need to create the ecosystem-based framework and take action where we know there is urgency.

Begin to design an ecosystem-based management approach:

1. Assemble partners for the ecosystem-based management approach, and begin work on identifying goals, outcomes, and indicators. NOAA's Integrated Ecosystem Assessment project should form the basis of this work. Find ways to incorporate existing efforts, such as the Washington Biodiversity Council's work to create a new institutional framework, and embed the Biodiversity Conservation Strategy as an organizing principle for natural resource agencies.

2. Develop and implement a funding strategy designed to create a stable, dedicated, long-term funding source for ecosystem-based management.

Rationale: An ecosystem-based approach is more likely to recover the Puget Sound ecosystem than a piecemeal approach. Stable funding is necessary to ensure success.

Take action where we know there is urgency:

- Implement the most urgent actions in existing plans, such as those for single species, multiple species, biodiversity, and invasive species. Emphasize actions that we know are effective or that can further our knowledge of effectiveness of management actions.

- Create and implement plans for imperiled species and communities.

- Prioritize and enforce existing regulations and start reviewing their effectiveness.

- Fix known problems with existing regulations.

- Assess marine, estuarine, freshwater, and terrestrial areas to find the representative and high quality areas.

- Protect known high quality and representative areas using a variety of tools and incentives.

- Take steps to prevent introduction of invasive species, and to remove them where already established and harming the ecosystem.

- Continue and expand efforts to minimize human disturbance effects on species and communities where they have been shown to be detrimental.

- Create and implement community-based social marketing programs to encourage behavior changes to protect biodiversity and the food web.

- Link the conceptual models developed for different parts of the Puget Sound basin into a network to identify the most relevant ecosystem indicators and guide overall ecosystem monitoring,[15] and to link drivers and pressures to changes in species or food web status.

- Select indicators and develop an understanding of species, biodiversity, and the food web as a baseline against which to monitor progress and manage adaptively.

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- Implement short- and long-term status and trends, effectiveness, validation, and other types of monitoring.

- Ensure that monitoring measures both natural variability and the effects of management actions.

Rationale: These actions should help prevent extinction, recover declining species, and protect biodiversity and the food web.

C. What long-term actions are needed? What is the rationale?

Take action where we know there is urgency:

1. Continue to implement actions listed above.
2. If new species are listed, develop and implement recovery plans for them within the ecosystem context.

Rationale: These actions should help prevent extinction and recover declining species.

Begin to design an ecosystem-based management approach:

Continue to implement – and adjust as necessary – the ecosystem-based approach.

Rationale: An ecosystem-based approach is more likely to recover the Puget Sound ecosystem than a piecemeal approach. Stable funding is necessary to ensure success.

Protect important habitats:

Develop and implement methods to protect the marine areas of Puget Sound that support high levels of biodiversity (measured as species richness or productivity) or support rare species.

Rationale: Once we know which areas of Puget Sound are important for protecting biodiversity, we should protect them.

Build understanding of species, biodiversity, the food web, and the effectiveness of management actions:

1. Design a comprehensive research program to inform the ecosystem-based management approach. Draw upon the recommendations of many existing plans and studies to create this program. Include the monitoring programs mentioned in the previous section. To maximize effectiveness, existing monitoring programs will need to be integrated, and gaps between them identified and filled.

2. Conduct research to constrain and define the problem: what is the Puget Sound food web? This research should be designed to provide information about trends, patterns, and mechanisms of change in the food web, so that we can discriminate between natural and human-caused changes.

3. Develop and implement a rigorous monitoring program to evaluate the effectiveness of management actions that discriminates between natural variability and the effects of management actions.

Rationale: There are very large gaps in our knowledge, particularly of the food web in Puget Sound. A comprehensive, coordinated research program should help fill those gaps and help us understand what change is natural and what change is human-caused – and therefore where we should focus our management actions. Understanding which management actions really work is a key part of adaptive management.

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Undertake a critical assessment of harvest and culture practices:

1. Design and conduct an assessment of harvest and culture practices focused on the effects of current practices on the ecosystem, particularly on the food web and its supporting habitats.

2. Adjust harvest and culture practices as necessary to protect and restore the ecosystem.

Rationale: Current harvest practices protect their target species, but don't consider the links between those species and other species in the food web. Similarly, culture practices ensure the propagation of target species but don't consider their effects on the food web. This assessment will help align these practices with ecosystem goals.

How will we know we are making progress on species, biodiversity and the food web?

To know whether we are making progress, we must first understand where we are now. Our knowledge of species, biodiversity, and the food web varies dramatically depending on the species and the ecosystem, as described below.

Species: We know a great deal about some species, particularly those that are culturally or economically important, or that are listed under the Endangered Species Act. However, we know very little about thousands of other species, including primary producers such as phytoplankton. We will need to conduct research about these species to develop a baseline before we can know whether we are making progress. Clearly, we will need to choose among these species – it will not be possible to study them all in great depth.

Biodiversity: Our understanding of terrestrial biodiversity is fairly good at some trophic levels, and our understanding of freshwater aquatic biodiversity is less so. We know even less about marine biodiversity and the areas that are important to protect. We will need to develop a map of marine habitats and the biodiversity they support before we can measure improvements.

Food Web: Although we have some understanding of terrestrial and freshwater food webs, we know very little about Puget Sound's food web and more information about the terrestrial and freshwater food webs would be useful. Information about predator-prey interactions, the structure of the food web, and how plant and animal communities work together in the terrestrial, freshwater, estuarine, and marine environments is lacking. Before we can evaluate progress on increasing the resiliency of the food web, we need to understand what changes in the food web are natural and which are human-caused.

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A. What objectives should we consider to monitor progress?

Some objectives to consider include:

- No more species merit listing, and common species stay common.
- Populations of currently listed species are increasing or recovered.
- Ecosystems are representative of the natural state and variability of Puget Sound, and are sustainable as such. We should avoid management that seeks to isolate and "fix" naturally dynamic ecosystems in one "target" state.
- The food web contains robust, redundant nodes (such as important primary consumers) and pathways that maintain the ecosystem's resilience to natural and human-caused disturbances.
- We protect productive habitats as well as species-rich ones.

- We develop an independent, self-sustaining source of funding to support management and scientific programs.

B. What actions and outcomes would be important to monitor in evaluating progress on this topic?

Status and trend of ecosystem conditions

Monitoring should include:

- Trends in and status of species' abundance, productivity, spatial structure, and diversity
- Trends in and status of the food web
- Trends in and status of biodiversity (see Biodiversity Conservation Strategy, especially recommendations related to report card)

Status and trend of threats

Monitoring should include:

- Indicators of climate change, harvest and culture practices, and human disturbance
- Trends in and status of invasions of non-native species, and their effects on native species' abundance, productivity, spatial structure, and diversity (see draft Invasive Species Council Strategic Plan)

Implementation of programs

Monitoring should include:

- Progress toward adjusting harvest management and culture practices to account for ecosystem services
- Progress toward developing an ecosystem-based management approach
- Progress toward implementing actions

Implementers' compliance with program requirements

Monitoring should include:

- Effectiveness of efforts to improve the institutional framework for ecosystem-based management

Project, program, and/or strategy effectiveness (in achieving direct outcomes)

Monitoring should include:

- Effectiveness of management efforts, such as changes in harvest-management practices
- Effectiveness of enforcement, protection, and restoration actions

Research and other studies of the underlying assumptions about strategies and programs

As discussed above, a comprehensive research program is necessary to create a framework for understanding the food web, biodiversity, communities, and many species in Puget Sound. This program must include validation monitoring and a gap analysis, and quantify and evaluate threats and limiting factors.

Any monitoring program should be aligned well with the goals of ecosystem-based management, and at least some of the indicators selected should be useful for communicating outcomes or progress to the public and elected officials. In addition, the monitoring program should include tracking of some ecosystem characteristics that aren't selected as indicators, to ensure that we don't miss potentially important signals and new threats to the ecosystem.

C. What aspects of progress evaluation are most important to start immediately? Why?

The Puget Sound Partnership has identified outcomes for the ecosystem. A critical first step will be to transform those outcomes into more detailed metrics that can be measured. In addition, developing and implementing a

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comprehensive research program to deepen our understanding of Puget Sound's food web and biological communities is an important action to begin immediately. Lastly, we can begin to evaluate the effectiveness of existing management actions now to better inform our choices in the future, monitor implementation actions, and begin the development of an adaptive management plan.

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Appendix 1: Definitions

Biodiversity

Biodiversity is the full range of life in all its forms. This includes the ecosystems in which life occurs, the way that species and their habitats interact with each other, and the physical environment and the processes necessary for those interactions.

This definition includes all species found within the Sound, from tiny phytoplankton to towering Douglas firs. The definition also includes the interactions that sustain each species, such as predator-prey relationships, and the physical processes on which life depends, including chemical and nutrient cycling, water filtration, and climate regulation.[1]

Biological diversity can be considered at four principal levels or scales:

- Genetic diversity within and between species – that is, the unique genetic composition of individual members within a population or variety and the pattern of differences among populations or varieties;
- Species diversity, or an index of community diversity that accounts for both species richness and the relative abundance of species. Species richness is simply the number of species present in a community, but relative abundance measures the evenness of species numbers within a community;[2]
- Ecosystem structure, or the composition and organization of plant, animal and microorganism communities that interact with their environment as an ecological unit; and
- Landscape structure, or the spatial arrangement or patterns of clusters of interacting ecosystems that is repeated in similar associations of topography, vegetation cover, land use and cultural settlement.[3]

Three commonly accepted measures of biodiversity are richness, rarity, and representation.

- Richness, or the number of species present in an area, e.g., the Olympic peninsula's high number of species,[8]
- Rarity of species, communities, or ecosystems, characterized by population size, geographic range, and habitat specificity, e.g., the marbled murrelet which nests in old growth forests; and
- Representation, or the important species and communities that occur in a local area, e.g., the high biomasses of groundfish and forage fish found in deep water basins and water column habitats.

Other habitats and species contribute to biodiversity through their productivity, such as the shallow, sun-filled sand and mudflats that produce high prey levels and nursery habitats for invertebrates and fishes.

Food Web

A food web is a complex of interconnected food chains within and among ecosystems, where a food chain is a sequence of organisms on successive trophic levels that transfer energy and minerals from one to another as each provides food for the next (e.g., phytoplankton, zooplankton, larval fish, small fish, big fish, mammals). Primary producers fix organic matter and this energy is transferred to higher trophic levels through primary consumers (grazers) and carnivores. In estuarine ecosystems such as Puget Sound, many food web pathways also cycle through a heterotrophic pathway, where dead organic matter (detritus) is fed upon by primarily microbial decomposers; this energy moves up the food chain/web. Thus, the types and varieties of food chains and webs are as numerous as the species within them and the ecosystems that support them. The food web is analyzed based on

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knowledge of the food chains that make it up. This can be further complicated because through various life history stages and changes in distribution, any single species may occupy more than one tropic level within a food chain.[4]

Diversity

When referring to particular species, "diversity" is defined as in the NOAA Viable Salmonid Populations document: "…(D)iversity refers to the distribution of traits within and among populations. These range in scale from DNA sequence variation at single genes to complex life-history traits."[4]

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Appendix 2: Map of Priority Conservation Areas

The attached map is from:

Floberg, J., M. Goering, G. Wilhere, C. MacDonald, C. Chappell, C. Rumsey, Z. Ferdana, A. Holg, P. Skidmore, T. Horsman, E. Alverson, C. Tanner, M. Bryer, P. Iachetti, A. Harcombe, B. McDonald, T. Cook, M. Summers, D. Rolph, 2004. *Willamette Valley-Puget Trough-Georgia Basin Ecoregional Assessment, Volume One: Report*. Prepared by The Nature Conservancy with support from the Nature Conservancy of Canada, Washington Department of Fish and Wildlife, Washington Department of Natural Resources (Natural Heritage and Nearshore Habitat programs), Oregon State Natural Heritage Information Center and the British Columbia Conservation Data Centre.

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