

PugetSoundPartnership

our sound, our community, our chance

DISCUSSION PAPER SPECIES AND BIODIVERSITY TOPIC FORUM

JULY 11, 2008

Puget Sound Partnership

Introduction to the Topic Forum Discussion Papers

As part of the development of the 2020 Action Agenda, six topic forum discussion papers were prepared to provoke and inspire enduring community conversation and critical thinking about the specific problems facing Puget Sound, and the strategies and actions needed to overcome the threats we face. The information from the topic forums was used to help answer two of the four questions of the Action Agenda: a) What is the status of Puget Sound's health and what are the biggest threats to it?; and b) What actions should be taken that will move us from where we are today to a healthy Puget Sound by 2020?

The papers represent the first effort in the region to comprehensively synthesize and document what we know about the Sound's problems, solutions that work, our current approach to solving problems, and what approaches we need to continue, add, or change. These papers address broad science and policy questions, providing an overview of each topic that looks at the Puget Sound ecosystem, from the crest of the Cascades to the Strait of Juan de Fuca, and documenting the basis of our conclusions and recommendations. They were fundamental to establishing strong connections between science and policy as we developed the 2020 Action Agenda.

For five of the topics (human health, land use and habitat, species and biodiversity, water quality, and freshwater quantity), the Partnership commissioned small groups of science and policy experts to prepare a draft discussion paper as a starting point. 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 to 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. The intent of the papers is to focus on identifying problems and solutions, rather than specific details about implementation.

The authors were instructed to review available information and prepare a brief overview of the key issues pertaining to each topic. The draft papers were produced in March 2008, reviewed by a broad audience, and discussed at individual topic forums held in April and May 2008. More than 500 people attended the topic forums, and dozens more provided comments online. During the review period, more than 1,200 pages of public comment were received from 229 people or entities. The Partnership, in conjunction with the papers' authors, reviewed and considered all of the comments as we prepared these revised discussion papers. Summarized comments and responses are included as appendices to the papers.

Following this public process, the Partnership Science Panel conducted a peer review of the five papers focused only on the science questions. The peer review addressed: 1) Do the conclusions in the paper have strong analytical support, and what is the nature of that support (e.g., multiple lines of evidence are offered; empirical data, analyses, or model results are available; documentation of rationale underpinning key points is clear)?, 2) What are key uncertainties or gaps in understanding, and how might these be addressed in future work?, and 3) Given reviewer assessment and characterization of the certainty in the paper's content, what guidance can be offered for how this information can be fruitfully used as part of the scientific basis of the Partnership's work? The general conclusion of the Science Panel and reviewers was that the topic forum papers were a good start at synthesizing information, particularly given the time available and length of the papers. In general, future improvements could include: more thorough discussion and inclusion of some topics (particularly climate change); inclusion of more recent and pertinent peer-reviewed literature and less use of gray literature; consistency and clarification of terms; and more treatment of terrestrial ecosystems. The schedule for developing the Action Agenda in late 2008 did not allow time for revisions to topic forum papers following peer review. However, the peer review summaries were evaluated by Partnership staff when considering what portions of the topic forum papers to incorporate into the Action Agenda. The Science Panel concluded that the topic forum process was useful and a version of the process should be conducted in the future.

A sixth paper on human well-being/quality of life was also prepared as a complement to the other five. This interdisciplinary topic is a very new area of work for the Puget Sound region. The paper presents a summary of the human dimensions and quality of life considerations associated with Puget Sound ecosystem recovery as articulated by the Partnership's work products developed in support of completing the 2008 Action Agenda. The human well-being paper also provides an initial human dimensions framework for moving forward.

The discussion papers are intended to be both comprehensive and brief, providing a synthesis of existing, readily available information and an initial list of recommendations for moving forward to achieve the Partnership's six main goals. Work to refine topic forum papers and to integrate the products from the respective topic forums within an ecosystem management framework will be an ongoing effort of the Partnership. In reading the discussion papers, several concepts should be considered:

- **The discussion papers provide an overview of the topic**, summarizing and synthesizing existing documentation. These papers are intended to provide a framework for future management strategies, but are not intended to address in detail all available data on the topic.
- **The Partnership identifies priority actions that are based on science.** People concerned with the future of the Puget Sound ecosystem express a wide range of opinion about the Sound's problems and suggest literally hundreds of ideas for how to solve them. This was evidenced by the broad range of opinions expressed during the topic forum process. Our continuing goal is to find reasonable consensus on the general nature and magnitude of the documented threats to Puget Sound, so that we have a better chance of prioritizing durable and effective solutions.
- **The papers mainly focus on the Sound as a whole.** We know that there are variations in information availability, type and extent of threats, and workable solutions in different parts of our region. The action area profiles in the Action Agenda help highlight local issues.
- **The discussion papers were used to develop cross-topic priorities for the Action Agenda.** A number of key themes emerged from the topic forum process and helped define priorities for management strategies and specific actions.
- **The recommendations to the Partnership in the papers represent the conclusion of the authors based on their expertise and comments received. The recommendations were considered by the Partnership, but should not be interpreted as a Partnership endorsement.** This was an intentional design of the topic forum process.
- **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 more fully explained in the Action Agenda. By addressing the system-wide needs, we will be able to more effectively focus the education/outreach, funding, and adaptive management and monitoring strategies.

The Partnership greatly appreciates the level of interest and participation that reviewers showed by attending topic forums and providing thorough, thoughtful comments. The comments that we received have greatly expanded and deepened the overall level of discussion, and moved our knowledge forward on these topics. We are committed to continuing this level of engagement.

DISCUSSION PAPER

SPECIES, BIODIVERSITY AND THE FOOD WEB IN PUGET SOUND

Contributing Authors

The following individuals contributed tremendous time, energy, thought, and effort to creating this paper:

- Lynne Barre, National Oceanic and Atmospheric Administration
- Dr. Ken Currens, Northwest Indian Fisheries Commission
- Sarah Gage, Washington Biodiversity Council
- Dr. Joe Gaydos, SeaDoc Society
- Mary Mahaffy, United States Fish and Wildlife Service
- Wayne Palsson, Washington Department of Fish and Wildlife
- Prof. Charles “Si” Simenstad, University of Washington

Laura Blackmore and Laila Parker of Cascadia Consulting Group, Inc. provided consulting support.

Preface

This discussion paper was available for public review in April 2008. The paper was intended to serve as an overview of the Species, Biodiversity and Food Web in Puget Sound, and to provide background discussion for the topic forum workshop, which was held on May 1, 2008. More than 80 people attended the workshop. Numerous comments were received on this topic; summarized comments and their responses are included as an appendix to this document. Many comments were received requesting additional detailed information on a variety of issues and concerns. Because the topic forum paper is intended to be an overview of the topic, providing a framework for management priorities, the paper has not been substantially revised to provide additional detail. Such refinement will occur through several ongoing efforts conducted by the Partnership; concepts presented in this paper will be built upon during ongoing and future Partnership efforts. The discussion paper has been revised to incorporate new information that was introduced through the topic forum process, resulting in a more comprehensive assessment of the issue.

This discussion paper provides a broad overview of scientific literature that describes the status of and threats to biodiversity, species, and the food webs in the Puget Sound basin, and the effectiveness of management approaches designed to ameliorate those threats. The paper also describes the approaches that a wide variety of organizations are taking to protect species, biodiversity, and the food webs, and identifies new priorities for action. The Puget Sound Partnership will refine these priorities, and the framework presented here, in future phases of Action Agenda development.

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 Individually and taken as a whole, the flora and fauna of the Puget Sound region contribute extensively to its uniqueness and the ecological, economic and cultural values held by the Puget Sound community.

This section of the discussion paper provides a broad overview of the scientific literature describing the status of and threats to species, biodiversity, and the food webs in the Puget Sound basin.

Key Findings from Previous Efforts

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

The Puget Sound basin is home to a wide diversity of species that depend upon marine, estuarine, freshwater, and terrestrial environments. Given this biodiversity, it is challenging to select “key” species. The National Oceanic and Atmospheric Administration (NOAA) is leading work to develop indicators for Puget Sound, including a list of indicator species. However, at the time of development of this paper, that work is incomplete. Therefore, in this section we discuss the abundance, productivity, spatial distribution, and diversity of three species generally acknowledged to be “key” indicator species in the Puget Sound basin: Chinook salmon, Pacific herring, and golden paintbrush. Pacific herring are a fundamental part of the marine food web, while Chinook salmon are a key species in the marine and freshwater food webs. Golden paintbrush is often used as an indicator of the health of prairie habitat in the Puget Sound lowlands. Chinook salmon and golden paintbrush are both listed as threatened species under the Endangered Species Act.

Examining the abundance, productivity, spatial distribution, and diversity of key species can be valuable because key species can serve as indicators of the health of the Puget Sound ecosystem. These four characteristics of species populations reflect important determinants of their health and sustainability, and are considered necessary to a full description of their status.³

It is important to state clearly here that the discussion below is possible because Chinook salmon, Pacific herring, and golden paintbrush are well-studied species in the Puget Sound basin. While this data is usually available in recovery plans for listed species, this data is not available for hundreds, if not thousands, of other native and non-native species known to inhabit the basin.

Chinook salmon (*Oncorhynchus tshawytscha*)

The Puget Sound Salmon Recovery Plan⁴ summarizes information on abundance, productivity, spatial structure, and diversity for Puget Sound Chinook salmon. The information in this section is drawn from that Plan.

Spatial Structure: The Puget Sound Technical Recovery Team analyzed Chinook salmon data and identified 22 independent populations of Chinook in Puget Sound. These populations are distributed around the Sound. The Elwha and Dungeness populations border the Strait of Juan de Fuca, while the Skokomish and Mid-Hood Canal populations return to the Hood Canal. Eastern Puget Sound boasts eighteen independent populations, ranging from the Nooksack populations in the north to the Nisqually in the south. Scientists estimate that historically there were 30 to 37 populations of Chinook in Puget Sound.

Diversity: The Puget Sound Technical Recovery Team also summarized information about genetic diversity among Chinook, and identified six major genetic clusters of Chinook salmon in Puget Sound, as follows:

1. Strait of Juan de Fuca Chinook salmon
2. Nooksack River early-returning Chinook salmon
3. Skagit and North Fork Stillaguamish Rivers Chinook salmon
4. Snohomish and South Fork Stillaguamish Rivers Chinook salmon
5. Central and southern Puget Sound and Hood Canal late-returning Chinook salmon
6. White River early-returning Chinook salmon

Puget Sound Chinook have lost some of their historic genetic diversity as a result of the loss of eight to fifteen populations. Many of these lost populations were early-returning runs. In addition, hatchery fish heavily influence the genetic structure of several populations.

Abundance and Productivity: Table 1, reproduced from the Recovery Plan, shows recent abundance and productivity data for the 22 populations of Chinook salmon in Puget Sound. Abundance in this table is defined as the geometric mean of naturally spawning Chinook populations. The productivity estimates are the number of adult offspring that return and spawn successfully from a single parent spawner. A productivity estimate of 1.0 means that the population is replacing itself; productivity estimates less than 1.0 are highlighted in purple. Productivity estimates were not available for 2000-2004.

Table 1: Puget Sound Chinook Salmon Population Abundance and Productivity Data

Populations	1986-1990			1994-1998			2000-2004	
	Geometric Mean	% Hatchery Contribution	Productivity	Geometric Mean	% Hatchery Contribution	Productivity	Geometric Mean	% Hatchery Contribution
North + Middle Fork Nooksack	140	21%	1.29	263	67%	0.45	4,232	94%
Nooksack	243	7%	0.60	181	35%	1.20	303	46%
Lower Skagit	2,732	1%	0.59	974	1%	3.15	2,597	2%
Upper Skagit	8,020	2%	0.69	6,388	1%	1.60	12,116	4%
Upper Cascade	226	0%	0.88	241	0%	1.34	355	1%
Lower Sauk	888	0%	0.61	330	0%	2.35	825	0%
Upper Sauk	720	0%	0.57	245	0%	1.35	413	0%
Suiattle	687	0%	0.40	365	0%	1.20	409	0%
North Fork Stillaguamish	699	0%	0.92	862	35%	0.94	1,176	31%
South Fork Stillaguamish	257	0%	1.31	246	0%	1.22	205	0%
Skykomish	3,204	14%	0.52	3,172	52%	0.82	4,759	39%
Snoqualmie	907	12%	1.23	1,012	33%	1.68	2,446	14%
Sammamish	388	41%	0.28	145	74%	2.72	243	69%
Cedar	733	9%	0.51	391	17%	0.97	412	21%
Green/Duwamish	7,966	62%	0.50	7,060	71%	1.00	13,172	34%
White	73	56%	7.51	452	82%	1.49	1,417	28%
Puyallup	1,509	15%	1.86	1,657	40%	0.67	1,353	31%
Nisqually	602	3%	4.22	753	21%	1.38	1,295	25%
Skokomish	1,630	69%	0.48	866	69%	0.34	1,479	80%
Mid Hood Canal	87	26%	1.41	182	26%	1.31	202	46%
Dungeness	185	83%	0.12	101	83%	0.70	532	83%
Elwha Nat Spawners	2,055	34%	0.46	512	61%	1.03	847	54%
Elwha Nat+Hat Spawners	3,887	34%	0.67	1,679	61%	1.27	2,384	54%

As the table shows, abundance of Chinook varies substantially by population. The Upper Skagit and Green/Duwamish populations were the only two that have had average runs exceed 10,000 spawners in recent

years. Other populations have had experienced critically low abundance in the last 20 years, such as the Nooksack, Sammamish, Cedar, Dungeness, South Fork Stillaguamish and Mid-Hood Canal populations. It is also important to note that of the 12 populations that exceeded 1,000 natural spawners between 2000 and 2004, only the two Skagit populations are believed to have a low percentage (less than 5%) of hatchery fish spawning naturally. The other ten rely more on hatchery fish that spawn in the wild.

In 2003, the National Marine Fisheries Service calculated the long term productivity trend for naturally spawning populations, and found that the trend was flat. This finding is an improvement over the trend calculated in 1998, which showed productivity declining by 1.1 percent. However, the presence of hatchery fish on the spawning grounds complicates these calculations.

Summary: Given these data, the Puget Sound Salmon Recovery Plan concludes that few Puget Sound Chinook salmon populations are viable currently. Scientists estimate that populations of salmon with high percentages of natural spawners are concentrated in the Skagit and Stillaguamish river basins, which is a significant reduction in spatial structure compared to historic conditions. As noted previously, Puget Sound has lost several populations of early-run Chinook, decreasing the species' genetic diversity. Except for the Skagit system, all populations are at a small fraction of their historical abundance, and the productivity of many populations is below replacement value or declining.

[Pacific Herring \(*Clupea pallasii*\)](#)

The 2007 Puget Sound Update: Ninth report of the Puget Sound Assessment and Monitoring Program⁵ summarizes information about the spatial structure, diversity, and abundance of Pacific herring. The information in this section is drawn from that report, unless otherwise noted.

Spatial Structure: Pacific herring spawn in 19 areas of Puget Sound. These spawning grounds are fairly well dispersed around the Sound, with locations in Whatcom, Skagit, San Juan, Island, Snohomish, King, Thurston, Jefferson, Mason, Kitsap, and Clallam counties.⁶ The *2007 Puget Sound Update* groups these stocks into three categories: Straits, South/Central, and North.

Genetic Diversity: Based on timing and location of spawning activity, the Washington Department of Fish and Wildlife (WDFW) has identified 19 stocks of Pacific herring. According to the WDFW Forage Fish website, other stock-specific features, such as pre-spawner holding area behavior, unique age structures, and distinctive spawning timing support the geographically-based stock definitions.⁶ The Cherry Point stock is genetically distinct from other Puget Sound and British Columbia herring stocks.

Abundance and Productivity: In 2002, the total abundance of Pacific herring in Puget Sound reached a (recent) peak of 17,700 tons. The biomass of the south/central Puget Sound stocks, which increased between 1997 and 2002, drove this peak. The northern herring stocks have remained at lower abundance levels, primarily due to the critical status of the Cherry Point herring stock. The Cherry Point herring stock has varied over time from about 3,000 tons to almost 15,000 tons between 1973 and 1995. In 2000 the stock reached a low of only 808 tons, but had risen to about 2,000 tons in 2005.

The Strait of Juan de Fuca stocks also have low abundance. In particular, the Discovery Bay stock has decreased significantly and steadily since reaching a high of 3,200 tons in 1980, and now averages between 200 and 250 tons annually. Similarly, the Dungeness/Sequim Bay stock has very low abundance.

No estimates of the productivity of Pacific herring stocks were found in the course of the literature review undertaken for this project.

Summary: Most Pacific herring stocks in Puget Sound declined between 2000 and 2005. The northern and Straits stocks exhibit a long-term decline, while the central and south Sound stock declines are part of a variable trend of stock increases and decreases.

Golden Paintbrush (*Castilleja levisecta*)

The United States Fish and Wildlife Service finalized the recovery plan⁷ for this prairie plant in 2000. The information in this section is drawn from that plan and from the subsequent Five-year Review (2008).

Spatial Structure: Golden paintbrush populations exist in Washington and British Columbia. Eleven known populations remain, of which nine are in Washington. All nine of these populations are in the Puget Sound basin. There are five populations in Island County, three in San Juan County, and one in Thurston County. Historically, the species was reported from more than 30 sites in the Puget Sound region (including British Columbia) and extending as far south as the Willamette Valley of Oregon. The species was last observed in 1937 in Oregon and is presumed extirpated from Oregon.

Diversity: Because most of the remaining golden paintbrush populations are small – both in terms of numbers of individuals and area covered by the population – they are vulnerable to demographic events.

Abundance and Productivity: The table below contains population information from the Five-year Review (2008)⁸ for the nine remaining populations of golden paintbrush found in Puget Sound. As the table shows, just three of the populations have more than 1,000 individual plants, which is the recovery threshold for the species. Most populations are much smaller. The population trend is increasing at just two locations, where grassland management has been ongoing. The other populations are declining, stable, or unknown.

Table 2: Abundance and Productivity of Golden Paintbrush Populations in the Puget Sound Basin

Site Name	County	Population Size	Year	Area	10-Year Trend
Rocky Prairie Natural Area Preserve (NAP)	Thurston	>9,000	2008	ca. 12 acres	stable
Naas/Admiralty Inlet NAP	Island	145	2008	ca. 1 acre	stable
Fort Casey State Park	Island	1,700	2008	<1 acre	increasing
West Beach	Island	97	2008	<1 acre	declining
Forbes Point	Island	247	2008	<1 acre	stable
Ebey's Landing	Island	601	2008	ca. 1 acre	declining
False Bay	San Juan	495	2008	<1 acre	increasing
Davis Point	San Juan	0	1998	<1 acre	Presumed extirpated
San Juan Valley	San Juan	>5,000	2003	1 acre	Last monitored in 2003 - unknown
Long Island	San Juan	154	2002	<1 acre	unknown

Summary: The spatial distribution of golden paintbrush is significantly reduced from its historical range. Only three of the nine known populations in the Puget Sound basin meet or exceed the recovery threshold of 1,000 individuals.

It is important to reiterate here that while there is general agreement that the three species discussed in this section are important as indicators of their food webs and habitats, they are not the only species that can be considered “key” to the ecology of the Puget Sound basin. We have chosen to discuss these species partly due to the agreement on their significance, but also partly because data exist about them. Similar data do not exist for hundreds, if not thousands, of species in the basin. In many instances, assessment information about individual species exists for

one or more of the four status attributes, but scientists and managers have not determined the levels of abundance, productivity, spatial structure, or diversity that are sufficient to meet ecosystem goals. In other words, for most species, answering the question of 'how much' of any of those attributes are required for a certain level of ecosystem performance or function usually has not been addressed.

The abundance, productivity, spatial structure, and diversity information described above for these key species illustrates how this information can be useful. For Chinook salmon, scientists have used the information to determine whether the populations are viable or not. Managers can use it to determine whether recovery goals have been met. In addition, comparing this information to historical conditions imparts a sense of the scale of the changes in populations of these key species, two of which form crucial links in Puget Sound food webs and one of which serves as an indicator of the loss of an entire ecosystem (prairie or grassland). And, of course, tracking this information over time provides trend data. All three of these key species are in decline.

Assessing and reporting the status of individual species typically focuses on that species' persistence, and not how the abundance, productivity, spatial structure and diversity relate to other ecosystem roles that species can play, such as providing food, predation, competitive interactions, habitat structure, or nutrients to food webs. For example, the recovery goals for Chinook salmon in Puget Sound were developed based on modeled estimates of how many salmon would be needed for each population so that it would persist into the future and be able to sustain desired levels of commercial and recreational harvest. The recovery goals did not specify how many salmon would be needed to meet other ecosystem needs, such as providing food for orcas or marine-derived nutrients to riparian communities in watersheds where salmon spawn and decomposing carcasses are an important nutrient source.

B. Food web status

Puget Sound does not have one food web. Rather, there are many food webs in the Puget Sound basin, ranging from marine to estuarine to freshwater aquatic to terrestrial. Within each of these four categories, there are many smaller food webs (or food chains). It is important to note that the marine, estuarine, freshwater, and upland food webs are not discrete and independent, but rather are strongly linked by "organic matter sources, physical proximity, exchange of water, and organisms that change habitats during the course of their life cycles."⁹ Food webs also vary spatially and temporally, and some species occupy multiple places or serve multiple purposes in the food webs.⁹ An excellent example of these phenomena is Chinook salmon, which link all four major food web categories (marine to upland¹⁰) and occupy multiple roles in these food webs depending on their life history stages.

Other than descriptive studies of nearshore food web linkages and structure in northern Puget Sound and the eastern Strait of Juan de Fuca,¹¹ and preliminary investigations of food web sources using biogeochemical tracers,¹² our understanding of marine and estuarine food webs is limited to target consumers (e.g., juvenile salmon in estuarine and nearshore Puget Sound environments).¹³ 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 slightly better understanding of the marine and estuarine food webs.^{14,15} The *Sound Science* report presents a highly readable description of what is known about the Puget Sound food webs, providing general information about primary producers, herbivores and detritivores (including benthic infauna), mid-level consumers and top-level predators.⁹ However, fundamental data are still needed about many basic elements of the marine and estuarine food webs, such as phytoplankton and zooplankton productivity.

Even though our understanding of the marine and estuarine food webs is limited, there are many indications that the food webs have altered significantly from historical conditions. As described above, populations of Pacific herring and Chinook salmon are dramatically reduced from their historic abundance levels, and early runs of Chinook salmon have been lost. A model of changes in the South Puget Sound food web between 1970 and 1999 showed that the biomass of dabbling ducks, diving ducks, dogfish, flatfishes, hake, resident coho salmon, herring, lingcod, loons and grebes, pacific cod, pollock, rockfishes, and skates and rays had declined during that interval.¹⁵ Assemblages of marine birds and waterfowl differ along an urban shoreline gradient progressing from more to less urbanized in Puget Sound.¹⁶ Harvest practices may have shifted species and population dynamics, for example by preferentially

removing adult individuals, thus affecting food web dynamics.¹⁷ Tidelands, critical areas for energy exchange through transfer of nutrients and sunlight, have been altered dramatically, and the increase in human population around the Sound has heightened the input of nutrients to the Sound.⁹

We were not able to locate summaries of the status of the terrestrial and freshwater aquatic food webs of the Puget Sound basin. However, the lack of studies indicates that our knowledge of the health of terrestrial and aquatic food webs of this region is limited, similar to our knowledge of the marine and estuarine food webs. Also similar to the marine environment, there are indications that the terrestrial food webs have altered significantly from historical conditions. The *King County Biodiversity Report 2008*, for example, discusses the fact that urbanization and various forms of development have altered the lowland areas of the county severely.¹⁸ These habitat changes in the lowlands, and the changes in species composition that accompany them, are likely to have altered the terrestrial and freshwater food webs there.

In summary, although we have some data about specific species in the Puget Sound food webs, and can illustrate links between some species of cultural or economic importance, there is no assessment of the condition or functioning of the Puget Sound food webs. However, our knowledge that many species are declining in abundance and/or productivity strongly suggests that the food webs have been altered significantly from historical conditions.

C. Status of biodiversity

Puget Sound hosts a wide variety and number of species and communities, some rare, others common. 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 government(s) as threatened or endangered (see Memorandum P1). Several species, such as Chinook salmon and Lake Washington kokanee, have disappeared from parts of their historical ranges.^{4,19} Others, such as western pond turtles, have disappeared from the Puget Sound region entirely.²⁰ The Tacoma pocket gopher is globally extinct.²¹

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.²² 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.) The Washington Biodiversity Council found that Washington “has experienced a dramatic loss of its native biodiversity over the last 100 years and faces significant threats in the future.”²³

The *King County Biodiversity Report 2008* characterizes biodiversity in that county as moderately healthy, noting that while some habitats have been dramatically altered, others remain largely intact. Some habitats and species in the county are declining, while others show signs of recovery.¹⁸ The fact that biodiversity can be characterized as moderately healthy in the most populous county in the state is a hopeful sign for biodiversity in the Puget Sound basin.

D. Deficiencies in our current knowledge

As the foregoing suggests, there are significant gaps in our current knowledge of species, the Puget Sound food webs, and biodiversity.

Species: Nothing is known about the abundance, productivity, distribution, and diversity of thousands of Puget Sound species. In addition, there are very few analyses of what levels of abundance, productivity, spatial structure, or diversity are necessary for certain ecosystem functions, such as population persistence or provision of food for other species. As a result, we cannot gauge the health or status of these 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.⁵ 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. Little is known about early life history stages of many species, even those for which there is good data about adults.

Food Webs: Our knowledge of food webs in the Puget Sound basin is centered primarily on species of cultural or economic importance. We know that the food webs are very complex, with complicated linkages between species, but do not know enough about these linkages to understand the effects of human actions on the food webs.⁹ We also lack basic data, such as the primary productivity of Puget Sound's marine areas, or the food webs for terrestrial birds.²⁴ Lastly, we lack the data to assess the health of the Puget Sound food webs.

Biodiversity: Very little is known about the biodiversity of Puget Sound's marine environment, particularly the deep water zones.

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).¹⁷
- *Reconnaissance Assessment of the State of the Nearshore Ecosystem: Eastern Shore of Central Puget Sound, Including Vashon and Maury Islands (WRIAs 8 and 9)*.²⁵
- Species recovery plans for listed species including Southern Resident killer whales,²⁶ Puget Sound Chinook salmon,⁴ Hood Canal summer-run chum salmon,²⁷ marbled murrelets,²⁸ and golden paintbrush.⁷
- *Puget Sound Update* reports issued periodically (e.g., see Reference 5).

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

- **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. ^{1,5,23} As mentioned previously, little is known about the abundance, productivity, spatial structure, and diversity of thousands of species in the Puget Sound basin. Finally, without analyses of "how much is enough" for species-status attributes, it is difficult to set goals and design strategies to achieve them.
- **Improve our understanding of the Puget Sound food webs**, such as rates of transfer between levels of food chains, and whether and when the net community metabolism changes from being autotrophic to heterotrophic.²⁹ Developing this understanding will be critical to our ability to predict the effects of human actions on the food webs, which can change rapidly in response to our activity.⁹
- **Develop appropriate frameworks to assess and manage biodiversity**, whether through using the index of biological integrity (IBI) approach³⁰ or developing a comprehensive habitat map of the seafloor.²²

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.³¹ 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.²⁶

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,^{1,5} 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 threats they face, all can hamper our management of, and so threaten, Puget Sound species, food webs, 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,³² with major modifications to estuaries such as the Duwamish.³³ Beach modification threatens critical spawning habitat for surf smelt and Pacific sand lance.⁵ Population growth and suburban sprawl have accelerated the fragmentation of upland habitat, as forests, prairies, and wetlands are converted to homes, businesses, and roads. Habitat fragmentation leads to the loss of habitat and wildlife corridors, and as areas are paved over and forest patches grow smaller, can lead to decreases in the biodiversity of freshwater benthic fauna and birds.^{34,35} Agriculture has also modified wetland and forest habitats essential to many species' survival.²³ (Please see the Land Use/Habitat Protection and Restoration paper for more information about habitat alteration.)

Climate Change

Sea level rise associated with climate change is expected to increase erosion and landslides and to decrease 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 webs.³⁶ Climate change and higher temperatures may already be limiting populations of Pacific cod.³⁷ 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.³⁸ 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.³⁶ While there are uncertainties related to the amounts of future emissions that will affect climate change, and the climate system's sensitivity to changes in emissions, scientists project that climate change will have significant effects on the species, food webs, and biodiversity of the Puget Sound basin.⁹

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.²⁵ 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 Given the hypothesis that Puget Sound's human population will increase significantly in the coming decades, balancing the water needs of fish populations and humans will likely be increasingly difficult. (Please see the Water Quantity paper for more information about this topic.)

Pollution

Human activities on the shores of Puget Sound and in industrial centers 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.⁵ These contaminants make their way into biota in the Puget Sound basin via a number of pathways including stormwater, point-source and non-point source discharges with potentially serious results. Pesticides applied to oyster growing areas affect the ability of anadromous cutthroat trout to swim effectively, and trout exposed to these pesticides suffered higher rates of predation from lingcod.³⁹ Nutrients in wastewater and in runoff can lead to toxic algal blooms⁴⁰ or to closures of shellfish growing areas.⁴¹ Eutrophication, or low oxygen levels due to increased nutrient loading, can cause direct mortalities of marine fish species.⁴² Toxic chemicals in stormwater can adversely affect fish health, and non-point source pollution can degrade the biological integrity of the aquatic communities that support productive fish populations. Contaminants in stormwater have led to an increase in

pre-spawn mortality among coho in urban streams in Puget Sound.⁴³ Concentrations of PBDE (flame retardants) in Puget Sound harbor seals have risen 1500 percent since 1984, and are now twice as high as the concentrations of PBDE in harbor seals from the Strait of Georgia. Total concentrations of PCBs in Puget Sound herring stocks are four to nine times higher than those in Georgia Basin stocks.⁴⁴ Accumulation of these and other 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.²⁶ 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.⁴⁵

Oil spills and chronic small-scale oil discharges pose toxicological risks to orcas, birds, and other marine life.^{26,46} Studies have shown that even relatively small oil spills from vessels that are not commercial oil carriers have resulted in tens to hundreds of oiled birds washing ashore, and each spill can kill an estimated hundreds to thousands of birds. While major oil spills are rare events in Puget Sound (and the United States), small spills from vessels that are not commercial oil carriers are likely to continue to be a major threat to seabirds and other marine life.⁴⁷

In addition, litter and detritus can harm Puget Sound species. Derelict fishing gear can trap, wound, or kill marine species and degrade marine ecosystems and sensitive habitats, among other adverse effects.⁴⁸ The Northwest Straits Marine Conservation Initiative estimates that there are approximately 4,000 derelict fishing nets in Puget Sound.⁴⁹ A recent study shows that at an average rate of entanglement, each net could entangle 92 invertebrates, 13 fish and seven seabirds each month.⁵⁰ Other types of debris, such as small pieces of plastic or cigarette filters, can kill wildlife that eats them.⁵¹ Lead poisoning from consuming lead shot and fishing weights is a leading cause of death for wild trumpeter and tundra swans in Whatcom County.⁵²

Harvest

Over-harvest of rockfish and Pacific hake has been identified as a risk factor to those populations.^{37,53} Over-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.⁵⁴ The decline of pinto abalone populations has also been attributed to over-harvest.¹⁷ Harvest may have cross-trophic impacts, as predators experience declines in important prey.²⁶ Harvest also may indirectly impact non-target species such as other fishes, birds, and porpoises which are unintentionally captured (by-catch).^{17,55,56} The impacts of harvest on non-target species, such as scoters and harlequin ducks, are uncertain.⁵⁷ Most fishing methods and gear inadvertently impact species or species forms (e.g. hatchery or wild forms) that were not intended to be handled or harvested because the methods are not completely selective for the targeted species.

Cultured Species

The culture of salmon in hatcheries is a recognized risk to threatened salmon in Puget Sound,⁵⁴ and a potential threat to depressed rockfish populations as a result of increased predation.¹⁷ Hatchery fish, by interbreeding with wild fish, may lower the fitness of those populations to survive and reproduce successfully in the wild.⁵⁸ Salmon may escape from private hatcheries (i.e., netpens in saltwater) and compete with native species.⁵⁹ Hatchery fish may heighten risks such as disease (including viral hemorrhagic septicemia⁶⁰) and overharvest,⁴ and contribute higher concentrations of PCBs up the food chain than do wild fish.²⁶ Sea lice, a potentially lethal parasite, were nearly nine times more abundant on wild juvenile pink and chum salmon near salmon farms holding adult salmon than in areas distant from salmon farms in British Columbia.⁶¹ The National Marine Fisheries Service identified three issues associated with net pens as posing high risk to Puget Sound: the impact of fish feces and uneaten feed on the environment beneath net pens, the impact on benthic communities of accumulated heavy metals in sediments below net pens, and the impact of pharmaceuticals and pesticides on non-target organisms. However, these risks vary depending on site conditions – such as the level of flushing at the site – and government regulation for the use of specific therapeutic compounds.⁶²

Shellfish aquaculture methods, pervasive in some areas of Puget Sound,⁶³ modify beaches and the lower intertidal zone, but impacts on populations or the ecosystem have not been well studied. A recent review of the ecosystem-level effects of shellfish aquaculture determined that while more study is needed, the available literature indicates that intensive shellfish aquaculture may divert materials to benthic food webs, alter coastal nutrient dynamics, and have cascading effects on estuarine and coastal food webs.⁶⁴ In particular, the effects of geoduck aquaculture on the benthic environment and fauna, the food webs, water quality, and aesthetics are a current concern but very few studies have been conducted to examine them.⁶⁵

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).⁶⁶ In addition, many species grown for aquaculture in Puget Sound are invasive species, such as Manila clams, Mediterranean mussels, Pacific oysters,⁶⁷ and Atlantic salmon.

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.⁶⁸ Invasive, non-native species can have a wide variety of adverse effects on native species and habitats, including competing with or feeding on native species, reducing the resilience of ecosystems, changing local habitats, affecting flood patterns, and introducing diseases. Invasive species enter the Puget Sound basin through a number of pathways: importation of seeds, plants, fruits, and vegetables; in ballast water discharges from ships; in soil brought in with nursery stock; on commercial and recreational boat hulls; on travelers' clothes and shoes, cars, and airplanes; in solid waste and soil dumped as fill in wetlands; and from people who release exotic pets and plants "into the wild."⁶⁹

In the Puget Sound basin, purple loosestrife, *Spartina* spp., *Sargassum muticum*, knotweed, Scotch broom, and other invasive species threaten native ecosystems and species.⁷⁰ *Spartina*, a non-native perennial grass, has been shown to be transforming estuarine intertidal habitats.⁷¹ Studies demonstrate a link between domestic animals (including feral cats and rodents), freshwater runoff, and transmission of the potentially fatal disease *Toxoplasma gondii* to river otters in the San Juan Islands⁷² and southern sea otters in California.⁷³ Invasive species are a threat to more than a quarter of the plant species in Washington that are of conservation concern.⁷⁴

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.²⁶ Intertidal invertebrate communities can suffer from the effects of clam harvesting and trampling.⁷⁵ 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.⁷⁶

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.³³ 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.⁷⁷ 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.⁷⁸

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.⁷⁹ 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.²⁵ For example, we do not comprehensively understand the magnitude of threats from individual invasive species, or the distribution of invasive species infestations.⁶⁹

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. 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.³⁸ However, scientists project that these effects are likely to be significant and wide-ranging.⁹

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 webs, 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."⁸⁰

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.

More scientific work is required to analyze the question of "how much is enough" for the majority of species in the Puget Sound basin. Defining thresholds for abundance, productivity, spatial structure, and diversity for key species will enrich the definition of a healthy Puget Sound, and enable the Partnership to measure the health of species, biodiversity, and the native food webs.

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

The current condition varies by species, and in many cases is not known. For example:

- Many Puget Sound species are meeting or exceeding reference conditions. Most groundfish and Pacific herring stocks are in good condition, as are intertidal invertebrates. (However, several important Pacific herring and groundfish populations have undergone substantial declines.) Many managed species are providing productive and rewarding harvest opportunities including intertidal clams, geoducks, Dungeness crabs, sea urchins, and sea cucumbers.⁵ Harbor seals have been steadily increasing in population since the early 1970s, and their population size is very close to its upper limit within the carrying capacity of Puget Sound.⁸¹ Species that respond well to disturbance, such as the western scrub jay and the American robin, have increased in numbers in

recent years.²³ 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.⁸²

- The status of many of the thousands of plant and animal species in the Puget Sound region is not known.
- Twenty-one species are listed as threatened or endangered by the state and federal governments, and the state government lists 157 species of concern.
- 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.²⁶
- Many other formerly abundant species are declining, such as the pinto (northern) abalone, sea ducks, grebes and loons, rockfish, Pacific cod, Pacific whiting (hake),⁸³ and Lake Sammamish kokanee.¹⁹
- Given the declines in many species, it is likely that the native food webs of Puget Sound are significantly altered from their historical condition.

1 References

- ¹ Puget Sound Partnership, 2006. *Sound Health, Sound Future: Protecting and Restoring Puget Sound*.
- ² Washington Biodiversity Project website, http://www.biodiversity.wa.gov/ecoregions/puget_trough/puget_trough.html
- ³ McElhany, Paul, Ruckelshaus, Mary H., Ford, Michael J., Wainwright, Thomas C., and Bjorkstedt, Eric P. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Department of Commerce, Seattle, Washington. http://www.nwfsc.noaa.gov/assets/25/5561_06162004_143739_tm42.pdf
- ⁴ Shared Strategy Development Committee, 2005. *Puget Sound Salmon Recovery Plan, Volume 1*. Plan adopted by the National Marine Fisheries Service (NMFS) January 19, 2007.
- ⁵ Puget Sound Action Team, 2007. *2007 Puget Sound Update: Ninth Report of the Puget Sound Ambient Monitoring Program*.
- ⁶ Washington Department of Fish and Wildlife, 1997. Forage Fish website. <http://wdfw.wa.gov/fish/forage/herring.htm>. Accessed June 5, 2008.
- ⁷ U.S. Fish and Wildlife Service, 2000. Recovery Plan for the Golden Paintbrush (*Castilleja levisecta*). U.S. Fish and Wildlife Service, Portland, Oregon. 51 pp.
- ⁸ Washington Department of Natural Resources, 2008. Golden Paintbrush (*Castilleja levisecta*) 5-year review: Summary and Evaluation. Prepared for the U.S. Fish and Wildlife Service, Region 1, Portland, Oregon. 51 pp.
- ⁹ Sound Science: Synthesizing ecological and socioeconomic information about the Puget Sound ecosystem. 2007. Mary H. Ruckelshaus and Michelle M. McClure, coordinators: prepared in cooperation with the Sound Science collaborative team. U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration (NMFS), Northwest Fisheries Science Center. Seattle, Washington, 93 p.
- ¹⁰ Naiman, R.J., Bilby, R.E., Schindler, D.E., and Helfield, J.M., 2002. Pacific Salmon, Nutrients, and the Dynamics of Freshwater and Riparian Ecosystems. *Ecosystems* (2002) 5: 399-417.
- ¹¹ Simenstad, C. A., B. S. Miller, C. F. Nyblade, K. Thornburgh, and L. J. Bledsoe. 1979. *Food web relationships of northern Puget Sound and the Strait of Juan de Fuca: A synthesis of the available knowledge*. EPA DOC Research Report EPA-600/7-79-259 (Also Fish. Res. Inst., Univ. Wash., Seattle, WA. FRI-UW-7914).
- ¹² Simenstad, C. A., and R. C. Wissmar. 1985. $\delta^{13}\text{C}$ evidence of the origins and fates of organic carbon in estuarine and nearshore marine food webs. *Marine Ecology -Progress Series* 22:141-152.
- ¹³ Brennan, J. S. K. F. Higgins, J. R. Cordell, and V. A. Stamatiou, 2004. *Juvenile salmon composition, timing, distribution, and diet in marine nearshore waters of central Puget Sound in 2001-2002*. King County Department of Natural Resources and Parks, Seattle, WA. 164 pp.; Duffy, E. J. 2003. *Early marine distribution and trophic interactions of juvenile salmon in Puget Sound*. M.S. thesis, University of Washington, Seattle, WA.
- ¹⁴ Reum, J. C. P., 2006. *Spatial and temporal variation in the Puget Sound food web*. M.S. thesis, University of Washington, Seattle, WA.

- ¹⁵ Preikshot, D. and Beattie, A., 2001. *Fishing for answers: analysis of ecosystem dynamics, trophic shifts and salmonid population changes in Puget Sound, WA, 1970-1999*. Fisheries Centre Research Reports 2001, Volume 9 Number 6. Available at <http://www.fisheries.ubc.ca/publications/reports/9-6.pdf>.
- ¹⁶ Rice, C.A., 2007. *Evaluating the Biological Condition of Puget Sound*. PhD thesis, University of Washington, Seattle, WA.
- ¹⁷ West, J. E., 1997, 2004. *Protection and Restoration of Marine Life in the Inland Waters of Washington State*. Puget Sound/Georgia Basin Environmental Report Series No. 6.
- ¹⁸ King County Department of Natural Resources and Parks, 2008. King County Biodiversity Report 2008. LAB: Local Action for Biodiversity, an ICLEI Initiative. Enhancing Urban Nature through a Global Network of Local Governments. Available at <http://www.kingcounty.gov/environment/animalsAndPlants/biodiversity.aspx>.
- ¹⁹ Berge, H.B., and K. Higgins, 2003. *The current status of kokanee in the greater Lake Washington Watershed*. King County Department of Natural Resources and Parks, Water and Land Resources Division. Seattle, WA. 50 pp.
- ²⁰ Hays, D. W., K. R. McAllister, S. A. Richardson, and D. W. Stinson. 1999. Washington state recovery plan for the western pond turtle. Washington Department of Fish and Wildlife, Olympia. 66 pp.
- ²¹ Stinson, D.W, 2005. *State of Washington: Status Report for the Mazama Pocket Gopher, Streaked Horned Lark, and Taylor's Checkerspot*. Washington Department of Fish and Wildlife Program, 145 pp. Available at <http://wdfw.wa.gov/wlm/diversty/soc/status/prairie/prairie.pdf>.
- ²² Floberg, J., M. Goering, G. Wilhere, C. MacDonald, C. Chappell, C. Rumsey, Z. Ferdana, A. Holt, P. Skidmore, T. Horsman, E. Alverson, C. Tanner, M. Bryer, P. Iachetti, A. Harcombe, B. McDonald, T. Cook, M. Summers, and D. Rolph, 2004. *Willamette Valley-Puget Trough-Georgia Basin Ecoregional Assessment, Volume One: Report*. The Nature Conservancy, with support from the Nature Conservancy of Canada, Washington Department of Fish and Wildlife, Washington Department of Natural Resources, Oregon State Natural Heritage Information Center and the British Columbia Conservation Data Centre.
- ²³ Washington Biodiversity Council, 2007. *Washington Biodiversity Conservation Strategy: Sustaining Our Natural Heritage for Future Generations*. Available at: <http://www.biodiversity.wa.gov/council/docs.html>.
- ²⁴ Pearson, Scott, 2008. Personal communication to Mary Mahaffy, May 2008.
- ²⁵ Williams, G.D., et al., 2001. *Reconnaissance Assessment of the State of the Nearshore Ecosystem: Eastern Shore of Central Puget Sound, Including Vashon and Maury Islands (WRIAs 8 and 9)*. J.S. Brennan, Editor. Report prepared for King County Department of Natural Resources, Seattle, WA.
- ²⁶ National Marine Fisheries Service, 2008. *Recovery Plan for Southern Resident Killer Whales (Orcinus orca)*. National Marine Fisheries Service, Northwest Region, Seattle, WA.
- ²⁷ Hood Canal Coordinating Council, 2007. *Hood Canal and Eastern Strait of Juan de Fuca Summer Chum Salmon Recovery Plan*.
- ²⁸ U.S. Fish and Wildlife Service, 1997, *Recovery Plan for the Marbled Murrelet*; U.S. Fish and Wildlife Service, 2003, *5-year Status Review of the Marbled Murrelet*.
- ²⁹ Hopkinson, C. S., and J. J. Vallino, 1977. *The relationships among man's activities in watersheds and estuaries: A model of runoff effects on patterns of estuarine community metabolism*. Estuaries and Coasts 18: 598-621.
- ³⁰ Deegan, L. A., J. T. Finn, S. G. Ayzajian, C. A. Ryder-Kieffer and J. Buonaccorsi, 1997. *Development and validation of an estuarine biotic integrity index*. Estuaries and Coasts 20: 601-617.
- ³¹ Lackey, R. T., 2004. *A salmon-centric view of the twenty-first century in the western United States*. pp. 131-137. In: P. Gallagher and L. Wood (eds), *Proceedings of the World Summit on Salmon*, Simon Fraser University, Burnaby, BC, Canada; Lackey, R. T., 2005. Economic growth and salmon recovery: an irreconcilable conflict? *Fisheries*. 30(3): 30-32
- ³² Washington Department of Natural Resources, undated. *Summary of Key Findings – ShoreZone Inventory*.
- ³³ Washington Biodiversity Council, 2007. *Washington's Biodiversity: Status and Threats*.
- ³⁴ Alberti, M., and Marzluff, J.M., 2004. Ecological resilience in urban ecosystems: Linking urban patterns to human and ecological functions. *Urban Ecosystems*, 7: 241-265.
- ³⁵ Morley, S.A., 2000. Effects of urbanization on the biological integrity of Puget Sound lowland streams: Restoration with a biological focus. Master's thesis, University of Washington. Available at: <http://depts.washington.edu/cuwr/research/morley.pdf>.
- ³⁶ Mote, P. W., A. K. Snover, L. Whitely Binder, A. F. Hamlet, and N. J. Mantua, 2005. *Uncertain Future: Climate Change and its effects on Puget Sound – Foundation Document*. Climate Impacts Group, Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington.
- ³⁷ Gustafson, R. G., W. H. Lenarz, B. B. McCain, C. C. Schmitt, W. S. Grant, T. L. Builder, and R. D. Methot, 2000. *Status review of Pacific hake, Pacific cod, and walleye pollock from Puget Sound, Washington*. NOAA Technical Memorandum NMFS-NWFSC-44.

- ³⁸ Lawler, J. J. and M. Mathias, 2007. *Climate Change and the Future of Biodiversity in Washington*. Report prepared for the Washington Biodiversity Council.
- ³⁹ Labenia, J.S., Baldwin, D.H., French, B.L., Davis, J.W., and Scholz, N.L., 2007. Behavioral impairment and increased predation mortality in cutthroat trout exposed to carbaryl. *Marine Ecology Progress Series*, Vol. 329: 1-11.
- ⁴⁰ Washington State Department of Health, Division of Environmental Health, Office of Shellfish and Water Protection, 2007. Biotoxin Program website. <http://www.doh.wa.gov/ehp/sf/BiotoxinProgram.htm>. Accessed June 9, 2008.
- ⁴¹ Washington State Department of Health, Division of Environmental Health, Office of Shellfish and Water Protection, 2007. Growing Area Classification Program website. <http://www.doh.wa.gov/ehp/sf/grow.htm>. Accessed June 9, 2008.
- ⁴² Palsson et al, in press
- ⁴³ McCarthy, S.G., Incardona, J.P., and Scholz, N.L., 2008. Coastal Storms, Toxic Runoff, and the Sustainable Conservation of Fish and Fisheries. *American Fisheries Society Symposium* 64:000-000, 2008.
- ⁴⁴ US Environmental Protection Agency, 2006. Puget Sound Georgia Basin Ecosystem Indicators: Toxics in Harbor Seals. http://www.epa.gov/region10/psqb/indicators/harbor_seals/what/index.htm. Accessed May 30, 2008.
- ⁴⁵ West, J., and S. O'Neill. 1998. *Persistent pollutants and factors affecting their accumulation in rockfishes* (Sebastes spp.) *from Puget Sound, Washington*. In: Puget Sound Research '98 Proceedings. Puget Sound Action Team, Olympia, WA; O'Neill, S. M., and J. E. West, 2001. *Exposure of Pacific herring (Clupea pallasii) to persistent organic pollutants in Puget Sound and the Georgia Basin*. Puget Sound Research 2001. Puget Sound Water Quality Action Team, Meydenbauer Center, Bellevue, WA; Meador, J. P., 2002. *Use of tissue and sediment-based threshold concentrations of polychlorinated biphenyls (PCBs) to protect juvenile salmonids listed under the US Endangered Species Act*. Aquatic Conservation: Marine and Freshwater Ecosystems 12:493-516; Lomax, D. 2004. *Further survey results on xenoestrogen exposure of benthic fish in Puget Sound*. In T.W. Droscher and D.A. Fraser (eds). Proceedings of the 2003 Georgia Basin/Puget Sound Research Conference.
- ⁴⁶ Tenyo Maru Oil Spill Natural Resource Trustees, 2000. *Final Restoration Plan and Environmental Assessment for the Tenyo Maru Oil Spill*. Available at <http://www.r1.fws.gov>
- ⁴⁷ Helm, R.C., Ford, R. G., and Carter, H.R., 2006. The Oil Pollution Act of 1990 and Natural Resource Damage Assessment. *Marine Ornithology* 34: 99-108.
- ⁴⁸ Washington Department of Fish and Wildlife, 2003. Derelict Fishing Gear Removal Project website. <http://wdfw.wa.gov/fish/derelict/>.
- ⁴⁹ Northwest Straits Foundation, 2007. *Derelict Fishing Gear Priority Ranking Project*. Report prepared for the Northwest Straits Marine Conservation Initiative.
- ⁵⁰ Natural Resources Consultants, Inc., 2008. *Rates of Marine Species Mortality Caused by Derelict Fishing Nets in Puget Sound, Washington*. Report prepared for: Northwest Straits Initiative.
- ⁵¹ National Oceanic and Atmospheric Administration, 2007. *Marine Debris Facts*. <http://marinedebris.noaa.gov/marinedebris101/documents/101MDFacts.pdf>.
- ⁵² Degernes, L., Heilman, S., Trogdon, M., Jordan, M., Davison, M., Kraege, D., Correa, M., and Cowen, P., 2006. Epidemiologic investigation of lead poisoning in trumpeter and tundra swans in Washington State, USA, 2000-2002. *Journal of Wildlife Diseases*, 42(2), pp. 345-358.
- ⁵³ Stout, H. A., B. B. McCain, R. D. Vetter, T. L. Builder, W. H. Lenarz, L. L. Johnson, and R. D. Methot. 2001. *Status review of copper rockfish (Sebastes caurinus), quillback rockfish (S. maliger), and brown rockfish (S. auriculatus) in Puget Sound, Washington*. NOAA Technical Memorandum NMFS-NWFSC-46.
- ⁵⁴ Good, T. P., R. S. Waples, and P. Adams, 2005. *Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead*. NOAA Technical Memorandum NMFS-NWFSC-66.
- ⁵⁵ National Marine Fisheries Service, 2006. *Harbor Porpoise (Phocoena phocoena): Washington Inland Waters Stock*.
- ⁵⁶ Melvin, E. F. and J. K. Parrish (eds), 2001. *Seabird bycatch: Trends, roadblocks, and solutions*. Proceedings of the Symposium Seabird Bycatch: Trends, Roadblocks, and Solutions, February 26-27, 1999, Blaine, Washington, Annual Meeting of the Pacific Seabird Group. University of Alaska Sea Grant AK-SG-01-01.
- ⁵⁷ Kraege, D., 2007. *Final Report: Impacts of Hunting on Scoter Numbers in Northern Puget Sound*. Report to the Wildlife Health Center, SeaDoc Society.
- ⁵⁸ Araki, H., B. Cooper, M.S. Blouin, 2007. Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild. *Science* 318(5847) pp. 100-103.
- ⁵⁹ Volpe et al., 2000. *Evidence of Natural Reproduction of Aquaculture-Escaped Atlantic Salmon in a Coastal British Columbia River*. *Conservation Biology* 14(3): 899-903
- ⁶⁰ Meyers, T.R. and Winton, J.R., 1995. Viral hemorrhagic septicemia virus in North America. *Annual Review of Fish Diseases*, Volume 5, pages 3-24.

- ⁶¹ Morton, A., Routledge, R., Peet, C., and Ladwig, A., 2004. Sea lice (*Lepeophtheirus salmonis*) infection rates on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*Oncorhynchus keta*) salmon in the nearshore marine environment of British Columbia, Canada. *Canadian Journal of Fisheries and Aquatic Sciences*, 61 (2): 147-157 (2004).
- ⁶² Nash, C.E. (editor), 2001. The net-pen salmon farming industry in the Pacific Northwest. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-49, 125 p.
- ⁶³ Simenstad, C. A. and K. L. Fresh, 1995. *Influence of intertidal aquaculture on benthic communities in Pacific Northwest estuaries: Scales of disturbance*. *Estuaries* 18(1), Part A:43-70
- ⁶⁴ Cranford, P., Dowd, M., Grant, J., Hargrave, B., and McGladdery, S., 2003. Ecosystem Level Effects of Marine Bivalve Aquaculture. In: Volume I: A Scientific Review of the Potential Environmental Effects of Aquaculture in Aquatic Ecosystems. *Canadian Technical Report of Fisheries and Aquatic Sciences* 2450, p. 51-84.
- ⁶⁵ Straus, K.M., Crosson, L.M., and Vadopala, B., 2008. *Effects of Geoduck Aquaculture on the Environment: A Synthesis of Current Knowledge*. Report prepared for Washington Sea Grant, available at http://www.wsg.washington.edu/research/geoduck/literature_review.html.
- ⁶⁶ International Union for Conservation of Nature, *Global Invasive Species Database*, <http://www.issg.org/database/welcome/>.
- ⁶⁷ Boersma, P.D., Reichard, S.H., and Van Buren, A.N., eds. *Invasive Species in the Pacific Northwest*. Seattle and London: University of Washington Press.
- ⁶⁸ Wilcove, D.S., Rothstein, D., Dubow, J., Phillips, A., and Losos, E., 1998. Quantifying Threats to Imperiled Species in the United States. *BioScience*, Vol. 48, No. 8 (Aug., 1998), pp. 607-615.
- ⁶⁹ Washington Invasive Species Council, 2008. *Invaders at the gate: Washington State 2008 Invasive Species Council Strategic Plan*. Available at: http://www.rco.wa.gov/invasive_species/default.htm.
- ⁷⁰ Boersma, P. D., S. H. Reichard, and A. N. Van Buren (eds), 2006. *Invasive species in the Pacific Northwest*. University of Washington Press, Seattle, WA; Britton-Simmons, K. H., 2004. *Direct and indirect effects of the introduced alga, Sargassum muticum (Yendo), in subtidal kelp communities of Washington State, USA*. *Marine Ecology Progress Series* 277:61-78; Lim, P. 2003. *Pathways and Regulation of Aquatic Nuisance Species into British Columbia's Waterways*. Proceedings of the 2003 Georgia Basin Puget Sound Research Conference.
- ⁷¹ Williams, S. L. and E. D. Grosholz, 2008. *The Invasive Species Challenge in Estuarine and Coastal Environments: Marrying Management and Science*. *Estuaries and Coasts*; Hacker, S. D. D. Heimer, C. E. Hellquist, T. G. Reeder, B. Reeves, T.J. Riordan, and M.N. Dethier. 2002. *A marine plant (Spartina anglica) invades widely varying habitats: potential mechanisms of invasion and control*. *Biological Invasions* 3: 221-217; People for Puget Sound, 2005. *Invasive Spartina in Puget Sound, A Citizens' Handbook*. Mount Vernon, WA. 31 pp.
- ⁷² J.K. Gaydos, P.A. Conrad, K.V.K. Gilardi, G.M. Blundell, and M. Ben-David, 2007. Does Human Proximity Affect Antibody Prevalence in Marine-Foraging River Otters (*Lontra canadensis*)? *Journal of Wildlife Diseases*, 43(1), pp. 116-123.
- ⁷³ Miller, M.A., I.A. Gardner, C. Kreuder, D.M. Paradies, K.R. Worcester, D.A. Jessup, E. Dodd, M.D. Harris, J.A. Ames, A.E. Packham, and P.A. Conrad, 2002. Coastal freshwater runoff is a risk factor for *Toxoplasma gondii* infection of southern sea otters (*Enhydra lutris nereis*). *International Journal for Parasitology* 32 (2002) 997-1006.
- ⁷⁴ Bishop, A., A. Dotolo, M. Grady, A. Lillenthal, J. Panza, A. Varlamov and C. Wilson, 2005. *Threats to Biodiversity in Washington: A Report Prepared for the Washington Biodiversity Council*.
- ⁷⁵ Griffiths, J., M. N. Dethier, A. Newsom, J. E. Byers, J. J. Meyer, F. Oyarzun and H. Lenihan, 2006. *Invertebrate community responses to recreational clam digging*. *Marine Biology* 149:1489-1497; Jenkins, C., A. Olson, J. L. Ruesink, and M. E. Haas, 2001. *Watch Your Step: Impacts of Trampling on a Rocky Shoreline of San Juan Island, Washington*. Proceedings of the 2001 Puget Sound Research Conference.
- ⁷⁶ Carney, K.M. and W.J. Sydeman, 1999. *A Review of Human Disturbance Effects on Nesting Colonial Waterbirds*. *Waterbirds: The International Journal of Waterbird Biology* 22(1):68-79.
- ⁷⁷ Harvell, C. D., K. Kim, J. M. Burkholder, R. R. Colwell, P. R. Epstein, D. J. Grimes, E. E. Hofmann, E. K. Lipp, A. D. M. E. Osterhaus, R. M. Overstreet, J. W. Porter, G. W. Smith, and G. R. Vasta, 1999. *Emerging marine diseases-climate links and anthropogenic factors*. *Science* 285:1505-1510; Daszak, P., A. A. Cunningham, and A. D. Hyatt, 2001. *Anthropogenic environmental change and the emergence of infectious diseases in wildlife*. *Acta Tropica* 78:103-116; Harvell, C. D., C. E. Mitchell, J. R. Ward, S. Altizer, A. P. Dobson, R. S. Ostfeld, and M. D. Samuel, 2002. *Climate warming and disease risks for terrestrial and marine biota*. *Science* 296:2158-2162.
- ⁷⁸ Muehlstein, L. K., D. Porter and F. T. Short, 1988. *Labyrinthula sp., a marine slime mold producing the symptoms of wasting disease in eelgrass, Zostera marina*. *Marine Biology* 99: 465-472; Gaydos, J. K., K. C. Balcomb, III, R. W. Osborne, and L. Dierauf, 2004. *Evaluating potential infectious disease threats for Southern Resident Killer Whales (Orcinus orca): a model for endangered species*. *Biological Conservation* 117: 253-262; Kocan, R. M., P. K. Hershberger, N. E. Elder, and J. R. Winton. 2001. *Epidemiology of viral hemorrhagic septicemia among juvenile pacific herring and pacific sand lances in Puget Sound*,

Washington. *Journal of Aquatic Animal Health* 13:77-85; Hershberger, P. K., K. Stick, B. Buic, C. Carroll, B. Fall, C. Mork, J. A. Perry, E. Sweeney, J. Wittouck, J. Winton, and R. Kocan. 2002. *Incidence of ichthyophonus hoferi in Puget Sound fishes and its increase with age of pacific herring*. *Journal of Animal Health* 14:50-56.

⁷⁹ Aber, J., R. P. Neilson, S. McNulty, J. M. Lenihan, D. Bachelet, and R. J. Drapek, 2001. *Forest processes and global environmental change: Predicting the effects of individual and multiple stressors*. *BioScience* 51(9); Folt, C. L., C. Y. Chen, M. V. Moore, and J. Burnaford, 1999. *Synergism and antagonism among multiple stressors*. *Limnology and Oceanography* 44 (3/2).

⁸⁰ Puget Sound Partnership, 2008. *Working Draft Definition – What is a healthy Puget Sound?* Unpublished draft, 3/7/2008.

⁸¹ Jeffries, S., Huber, H., Calambokidis, J., and Laake, J., 2003. Trends and status of harbor seals in Washington State: 1978 – 1999. *Journal of Wildlife Management* 67(1): 208-219.

⁸² Federal Register: February 20, 2008, Proposed Rule. 73(34):9408-9433

⁸³ West, J. E., 1997, 2004. *Protection and Restoration of Marine Life in the Inland Waters of Washington State*. Puget Sound/Georgia Basin Environmental Report Series No. 6

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

This section of the discussion paper provides an overview of the scientific literature describing the effectiveness of management approaches used in the Puget Sound basin and elsewhere to reduce threats to species, biodiversity, and the food webs.

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 webs 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 webs and biodiversity – continue to decline in Puget Sound. Currently, Washington State agencies list 157 species in the Puget Trough Ecoregion¹ as species of concern.⁸⁴

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

¹ 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.

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 webs.⁸⁵

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).² These recovery plans have had some successes at bringing back individual species, such as the delisting of the bald eagle in 2007,⁸⁶ or the proposed delisting of the brown pelican in 2008.⁸⁷ 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.⁸⁸ 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.⁸⁹ Groundfish and forage fishes are managed under the Puget Sound Groundfish Management Plan and the Forage Fish Management Plan, respectively.⁹⁰ An analysis of recovery plans suggests that such multi-species plans are less effective at ensuring species recovery than individual-species recovery plans,⁸⁸ and the Groundfish Management Plan has had mixed results. Trends in species status information suggest some successes, such as the slight improvements in the number of groundfish and forage fish stocks in good condition during recent years.⁹¹ However, a recent review of the Groundfish Management Plan identified gaps in the plan that may be hindering conservation efforts,⁹² 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.⁹³ However, the intent of HCPs is to protect sensitive species and their habitat while allowing certain activities to continue,⁹⁴ 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.⁹¹

Harvest Management

Many species in the Puget Sound basin are subject to harvest for commercial, recreational, scientific or cultural purposes. Further detail on regulations governing these activities 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

² 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.

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.⁹⁵

Harvest management has resulted in a decrease in the overall harvest mortality of wild Chinook salmon in Puget Sound,⁹⁶ and can prevent overharvest of many species, such as halibut, salmon, geoduck, sea urchins, sea cucumbers, and other invertebrates.^{97,98} 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.^{99,100} 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.¹⁰¹ 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.¹⁰²

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.^{103,104,105} 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.¹⁰⁶ 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).¹⁰⁷

Marine Protected Areas (MPAs), including marine reserves, are increasingly proposed as an enforceable fishery management tool.^{108,109} Research on the effectiveness of MPAs for economically valuable, mid-trophic level species suggests that bigger reserves, and reserves that account for species’ dispersal ranges, are better at protecting species.¹⁰⁸ 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.¹⁰⁹ 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.¹¹⁰ MPAs have had mixed effectiveness for marine mammals and marine predators.¹⁰⁸

Cultured Species

The Washington State Department of Agriculture is responsible for managing aquaculture as well as agriculture, while the U.S. Fish and Wildlife Service, Puget Sound Indian tribes and nations, and the Washington State Department of Fish and Wildlife operate fish hatcheries.¹¹¹ 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.¹¹² Cultured salmon benefit human well-being by maintaining tribal culture and providing commercial and recreational benefits.^{112,113,114} On the other hand, salmon hatcheries appear to limit the genetic diversity and alter the life histories of wild salmon,⁹⁶ and have been identified as a potential threat to depressed rockfish populations.¹⁰⁵ 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.¹¹⁵

Invasive Species

Invasive non-native species are among the top threats to imperiled species nationally.⁸⁴ In Puget Sound, purple loosestrife, *Spartina* spp., *Sargassum muticum*, knotweed, Scotch broom, and other invasive species threaten native ecosystems and species.¹¹⁶ 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.¹¹⁷

Derelict Gear Removal

The Northwest Straits Initiative removes derelict fishing gear, including both nets and pots or traps, from Puget Sound. A recent cost-benefit analysis of the program demonstrated that removing this gear is cost-effective even when considering only the directly measurable monetized benefits of derelict gear removal – the commercial exvessel value of species saved from mortality over a one-year period. Indirect benefits, such as improved human safety, habitat restoration, removal of barriers to navigation and reduced pollution, were not considered.¹¹⁸ A recent study shows that at an average rate of entanglement, each of the estimated 4,000 nets in Puget Sound could entangle 92 invertebrates, 13 fish and seven seabirds each month.¹¹⁹

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 decline.¹²⁰

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. Ecosystem-based management represents a shift away from single-species or single-issue management toward a focus on these linkages. 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.^{113,114,121} The IEA will provide a formal synthesis and quantitative analysis of information about how relevant natural and socio-economic factors relate to ecosystem-management goals. This synthesis will provide the scientific underpinnings for an ecosystem-based management approach for the Puget Sound basin.¹²²

A recent paper¹²³ 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.¹⁰⁵
- 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.¹²⁴
- 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.¹²³

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.¹²⁵

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.¹²⁶

Other Management Approaches

Two approaches to managing the uncertainty associated with species, biodiversity, and the food webs that are championed by many in the conservation community are the precautionary principle¹²⁷ and adaptive management.¹²⁸

The **precautionary principle** encourages policies that protect human health and the environment in the face of uncertainty.¹²⁹ 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.^{130,131} Kriebel et al. (2001) describe the precautionary principle to have four central components: "taking preventative action in the 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."¹²⁹ The State of California has adopted the precautionary approach as a starting point for addressing 19 fish species.¹³²

Adaptive management, designed to deal with uncertainty, is considered by some as a method to implement the precautionary principle.¹³³ 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.¹²⁸

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.¹³⁴

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.¹³⁵

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 specific strategies.¹³⁶

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.⁹¹ 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.¹³⁷ Baseline data were collected in 2004-2005; other results have not yet been published.¹³⁸

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.¹²⁵ 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 that appear to more effectively protect and promote species, biodiversity, and food webs 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.¹⁰²
- Harvest management can effectively maintain or enhance the status of the target species.⁹⁶ Revised harvest quotas that reflect the needs of other species in the ecosystem are expected to have more widespread benefits.
- If implemented, single-species recovery approaches, such as those under the ESA, can effectively restore the target species.⁸⁶ ⁸⁷ 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.

- Derelict gear removal has been shown to be cost-effective in Puget Sound.118
- Comprehensive management approaches addressing ecosystem and harvest needs are more certain to benefit the ecosystem than current single-species harvest management approaches.88
- There is strong scientific consensus that ecosystem-based management will more effectively ensure healthy, intact, and resilient ecosystems with diverse and abundant species.124

While these management approaches have been shown to be effective, we do not have a sense of the relative magnitude of the threats they address.

References

- ⁸⁴ Washington Biodiversity Council, 2007. *Washington's Biodiversity: Status and Threats*.
- ⁸⁵ Hillman and Giorgi, 2002. *Monitoring Protocols: Effectiveness Monitoring of Physical/Environmental Indicators in Tributary Habitats*. Prepared for the Bonneville Power Administration, Portland, Oregon. http://www.krisweb.com/biblio/gen_bpa_hillmanetal_2002.pdf.
- ⁸⁶ US Department of the Interior press release, available at http://www.doi.gov/news/07_News_Releases/070628.html.
- ⁸⁷ Federal Register: February 20, 2008. Proposed Rule. 73(34)9408-9433.
- ⁸⁸ Taylor, M. F. J., K. F. Suckling, and J. J. Rachlinksi, 2005. *The Effectiveness of the Endangered Species Act: A Quantitative Analysis*. *BioScience* 55(4):360-367.
- ⁸⁹ Washington Department of Natural Resources – Aquatic Resources Division, 2001. *The State of Washington Commercial Geoduck Fishery Management Plan*. Also see <http://www1.dnr.wa.gov/htdocs/aqr/shellfish/tribal.html>
- ⁹⁰ Palsson, W. A., J. Thomas, T. J. Northup, and M. W. Barker, 1998. *Puget Sound Groundfish Management Plan*; Bargmann, G. and the Washington Department of Fish and Wildlife, 1998. *Forage Fish Management Plan*.
- ⁹¹ Puget Sound Action Team, 2007. *2007 Puget Sound Update: Ninth Report of the Puget Sound Ambient Monitoring Program*.
- ⁹² Christensen, R., 2005. *An evaluation of the Puget Sound Groundfish Management Plan for the Conservation of Rockfishes (Sebastes spp.) in Puget Sound, Washington*. Master's Thesis: University of Washington School of Marine Affairs. Abstract available at http://www.sma.washington.edu/students/thesis/thesis_abstract.php?id=408.
- ⁹³ See: http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHCP/Pages/aqr_esa_aquatic_land_hcp.aspx and http://wdfw.wa.gov/hcp/wla_hcp.html
- ⁹⁴ <http://www.nwr.noaa.gov/Salmon-Habitat/Habitat-Conservation-Plans/Index.cfm>.
- ⁹⁵ Puget Sound Indian Tribes (PSIT) and Washington Department of Fish and Wildlife (WDFW), 2006. *Comprehensive Management Plan for Puget Sound Chinook: Harvest Management Component*.
- ⁹⁶ Good, T.P., R.S. Waples, and P. Adams, 2005. *Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead*. NOAA Technical Memorandum NMFS-NWFSC-66.
- ⁹⁷ <http://wdfw.wa.gov/fish/creel/halibut/2007halibut.htm>
- ⁹⁸ Bradbury, A., B. Sizemore, D. Rothaus, and M. Ulrich, 2000. *Stock Assessment of Subtidal Geoduck Clams (Panopea abrupta) in Washington*. Washington Department of Fish and Wildlife. <http://apps.leg.wa.gov/WAC/default.aspx?cite=220-20-010>, <http://apps.leg.wa.gov/RCW/default.aspx?cite=79.135.410>
- ⁹⁹ Larson et al., 2005. Sixgill Shark (*Hexanchus Griseus*) Conservation Ecology Project Update. In Proceedings of the 2005 Puget Sound Georgia Basin Research Conference. Available at http://www.engr.washington.edu/epp/psgb/2005psgb/2005proceedings/papers/E5_LARSO.pdf.
- ¹⁰¹ Bilby, R. E., B. R. Fransen, J. K. Walter, C. J. Cederholm, and W. J. Scarlett, 2001. *Preliminary evaluation of the use of nitrogen stable isotope ratios to establish escapement levels for Pacific salmon*. *Fisheries* 26:6–14; Knudsen, E. E., E. W. Symmes, and F. J. Margraf, 2003. *Searching for a life history approach to salmon escapement management*. *Nutrients in Salmonid Ecosystems: Sustaining Production and Biodiversity*. *American Fisheries Society Symposium* 34:261–276.
- ¹⁰² Shared Strategy for Puget Sound, 2007. *Puget Sound Salmon Recovery Plan*.
- ¹⁰³ Gustafson, R. G., W. H. Lenarz, B. B. McCain, C. C. Schmitt, W. S. Grant, T. L. Builder, and R. D. Methot, 2000. *Status review of Pacific hake, Pacific cod, and walleye pollock from Puget Sound, Washington*. NOAA Technical Memorandum NMFS-NWFSC-44.

- ¹⁰⁴ Stout, H. A., B. B. McCain, R. D. Vetter, T. L. Builder, W. H. Lenarz, L. L. Johnson, and R. D. Methot. 2001. *Status review of copper rockfish (Sebastes caurinus), quillback rockfish (S. maliger), and brown rockfish (S. auriculatus) in Puget Sound, Washington*. NOAA Technical Memorandum NMFS-NWFSC-46.
- ¹⁰⁵ West, J. E., 1997, 2004. *Protection and Restoration of Marine Life in the Inland Waters of Washington State*. Puget Sound/Georgia Basin Environmental Report Series No. 6
- ¹⁰⁶ Cornwall, W., 2007. *Maples falling victim to backwoods thieves*. Seattle Times, May 17, 2007; Greimel, H., 1999. *Bark bandits stripping Oregon's Cascara trees*. Seattle Times, September 5, 1999.
- ¹⁰⁷ Welch, C., 2006. *A war in the woods*. Seattle Times, June 6, 2006.
- ¹⁰⁸ Hooker, S.K. and L. R. Gerber, 2004. *Ecosystem-based management: The potential importance of megafauna*. *BioScience* 54(1).
- ¹⁰⁹ Apostolaki, P., E. J. Milner-Gulland, M. K. McAllister, and G. P. Kirkwood, 2002. *Modelling the effects of establishing a marine reserve for mobile fish species*. *Canadian Journal of Fisheries and Aquatic Sciences*, 59.
- ¹¹⁰ Palsson, W.A., R.E. Pacunski, and T.R. Parra, 2004. *Time will tell: Long-term observations of the response of rocky habitat fishes to marine reserves in Puget Sound*. 2003 Georgia Basin/Puget Sound Research Conference Proceedings, T.W. Droscher and D.A. Fraser, eds. Puget Sound Action Team, Olympia.; Palsson, W.A., 1998. *Monitoring the response of rockfishes to protected areas*. Pages 64-73. In: *Marine Harvest Refugia for West Coast Rockfish: A Workshop*, M. Yoklavich ed., NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-255;
- Palsson, W.A. and R.E. Pacunski, 1995. *The response of rocky reef fishes to harvest refugia in Puget Sound*. Pages 224-234, In: *Puget Sound Research '95, Volume 1*, Puget Sound Water Quality Authority, Olympia, WA.
- ¹¹¹ Hatchery Scientific Review Group (HSRG) – Lars Mobrand (chair), John Barr, Lee Blankenship, Don Campton, Trevor Evelyn, Tom Flagg, Conrad Mahnken, Robert Piper, Paul Siedel, Lisa Seeb and Bill Smoker. April 2004. *Hatchery Reform: Principles and Recommendations of the HSRG*. Long Live the Kings, 1305 Fourth Avenue, Suite 810, Seattle, WA, 98101 (available from www.hatcheryreform.org).
- ¹¹² National Research Council, 1996. *Upstream: salmon and society in the Pacific Northwest*. National Academy Press.
- ¹¹³ Pew Oceans Commission, 2003. *America's Living Oceans: Charting a Course for Sea Change*. Pew Oceans Commission, Arlington, VA.
- ¹¹⁴ U.S. Commission on Ocean Policy, 2004. *An Ocean Blueprint for the 21st Century*. Final Report of the U.S. Commission on Ocean Policy to the President and Congress, Washington, D.C.
- ¹¹⁵ International Union for Conservation of Nature, *Global Invasive Species Database*, <http://www.issg.org/database/welcome/>.
- ¹¹⁶ Boersma, P. D., S. H. Reichard, and A. N. Van Buren (eds), 2006. *Invasive species in the Pacific Northwest*. University of Washington Press, Seattle, WA; Britton-Simmons, K. H., 2004. *Direct and indirect effects of the introduced alga, Sargassum muticum (Yendo), in subtidal kelp communities of Washington State, USA*. *Marine Ecology Progress Series* 277:61-78; Lim, P. 2003. *Pathways and Regulation of Aquatic Nuisance Species into British Columbia's Waterways*. Proceedings of the 2003 Georgia Basin Puget Sound Research Conference.
- ¹¹⁷ Puget Sound Partnership, 2006. *Sound Health, Sound Future: Protecting and Restoring Puget Sound*.
- ¹¹⁸ Natural Resources Consultants, Inc., 2007. *A Cost-Benefit Analysis of Derelict Fishing Gear Removal in Puget Sound, Washington*. Prepared for the Northwest Straits Foundation.
- ¹¹⁹ Natural Resources Consultants, Inc., 2008. *Rates of Marine Species Mortality Caused by Derelict Fishing Nets in Puget Sound, Washington*. Report prepared for: Northwest Straits Initiative.
- ¹²⁰ Brown, N. A. and J. K. Gaydos, 2005. *Species of Concern within the Puget Sound Georgia Basin Marine Ecosystem: changes from 2002 to 2004*.
- ¹²¹ Christensen, N.L., A. M. Bartuska, J. H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J. F. Franklin, J. A. MacMahon, R. F. Noss, D. J. Parsons, C. H. Peterson, M. G. Turner, and R. G. Woodmansee, 1996. *The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management*. *Ecological Applications* 6: 665-691.
- ¹²² National Oceanic and Atmospheric Administration, 2008. DRAFT White Paper: Integrated Ecosystem Assessments.
- ¹²³ Ruckelshaus et al., 2008. *Marine Ecosystem-based Management in Practice: Scientific and Governance Challenges*. *BioScience*: January 2008, Vol. 58, No. 1.
- ¹²⁴ McLeod, K. L., J. Lubchenco, S. R. Palumbi and A. A. Rosenberg, 2005. *Scientific Consensus Statement on Marine Ecosystem-Based Management*. Signed by 221 academic scientists and policy experts with relevant expertise and published by the Communication Partnership for Science and the Sea at <http://compassonline.org/?q=EBM>
- ¹²⁵ Government Accounting Office, 2005. *Chesapeake Bay Program: Improved Strategies are Needed to Better Assess, Report, and Manage Restoration Progress*. GAO-06-96.

-
- ¹²⁶ Northwest Straits Evaluation Panel, 2004. *Northwest Straits Marine Conservation Initiative: Five Year Evaluation Report*. Submitted by the Northwest Straits Evaluation Panel with support from the Policy Consensus Center of the University of Washington and Washington State University.
- ¹²⁷ United Nations, 1992. *Rio Declaration on Environment and Development (Annex I)*. Report of the United Nations Conference on Environment and Development, Rio de Janeiro 1992. United Nations, New York.
- ¹²⁸ Duncan, S., 2001. *To Early to Tell, or Too Late to Rescue? Adaptive Management Under Scrutiny*. PNW Science Findings, Pacific Northwest Research Station, Portland, OR.
- ¹²⁹ Kriebel, D., J. Tickner, P. Epstein, J. Lemons, R. Levins, E. L. Loechler, M. Quinn, R. Rudel, T. Schettler and M. Stoto, 2001. *The precautionary principle in environmental science*. *Environmental Health Perspectives* 109:871-876.
- ¹³⁰ Raffensperger, C., and J. Tickner (eds), 1999. *Protecting Public Health and the Environment: Implementing the Precautionary Principle*. Island Press, Washington, D.C.
- ¹³¹ Raffensperger, C., and J. Tickner (eds), 1999. *Protecting Public Health and the Environment: Implementing the Precautionary Principle*. Island Press, Washington, D.C.
- ¹³² Kaufman et al., 2004. Transition from low to high data richness: an experiment in ecosystem-based fishery management from California. *Bulletin of Marine Science*, Volume 74, Issue 3 (May 2004), pp. 693-708. Abstract available at [http://apt.allenpress.com/perlserv/?request=get-abstract&doi=10.1043%2F0007-4977\(2004\)074%5B0693%3ATFLTHD%5D2.0.CO%3B2&ct=1&SESSID=1a87faad517b6744e0134b7d689bf181](http://apt.allenpress.com/perlserv/?request=get-abstract&doi=10.1043%2F0007-4977(2004)074%5B0693%3ATFLTHD%5D2.0.CO%3B2&ct=1&SESSID=1a87faad517b6744e0134b7d689bf181).
- ¹³³ IUCN - The World Conservation Union, TRAFFIC International, Fauna & Flora International and Resource Africa. 2003. *The Precautionary Principle and Environmental Governance: sustainable development, natural resource management and biodiversity conservation*. <http://www.pprinciple.net/publications/ppsummary.pdf>
- ¹³⁴ National Research Council, 2001. *Compensating for Wetland Losses Under the Clean Water Act*. National Academy Press, Washington, D.C.; National Research Council, 1992. *Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy*. National Academy Press, Washington D.C.
- ¹³⁵ Rice, C.A., 2007. *Evaluating the Biological Condition of Puget Sound*. PhD thesis, University of Washington, Seattle, WA.
- ¹³⁶ Puget Sound Assessment and Monitoring Program (PSAMP) Steering Committee and Management Committee, 2008. *Keys to a Successful Monitoring Program: Lessons Learned by the Puget Sound Assessment and Monitoring Program*.
- ¹³⁷ Intensively Monitored Watersheds. <http://www.ecy.wa.gov/programs/eap/imw/index.html>; Currens, K. P., H. W. Li, J. D. McIntyre, W. F. Megahan, and D. W. Reiser, 2006. *Review of study plan for the intensively monitored watershed program*. *Washington Independent Science Panel Report 2006-1*. Governors' Salmon Recovery Office, Olympia, WA (<http://www.governor.wa.gov/gspro/science/isp.asp>).
- ¹³⁸ <http://www.rco.wa.gov/srfb/docs.htm#validation>

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

This section of the discussion paper describes the regulatory, voluntary, educational, and other approaches that a wide variety of organizations are undertaking to protect and restore species, biodiversity, and the food webs in the Puget Sound basin.

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.^{139,140}

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 webs. 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 Washington Invasive Species Council 2008 Strategic Plan, 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 webs 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.

Habitat Alteration

- 1 **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 that 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.¹⁴¹ The National Environmental Policy Act (NEPA) 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.¹⁴²
- 2 **Tribes** around Puget Sound work to restore and enhance habitat in their treaty areas to reverse the decline of species and other natural resources.^{143, 144}
- 3 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 lands¹⁴⁵ and WDFW is developing multi-species HCPs for wildlife management areas and for Hydraulic Project Approvals.¹⁴⁶ (Please see the Land Use/Habitat Protection and Restoration paper for more information about the HPA program.) Since 1997, DNR has managed its timber lands under an HCP.¹⁴⁷ While HCPs primarily focus on actions that may "take" threatened or endangered species, they can allow for some flexibility

in management. 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.¹⁴⁸

- 4 **Cities and counties** implement Comprehensive Plans, Shoreline Master Programs, Critical Areas Ordinances, zoning laws, and other regulations that 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.¹⁴⁹ 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.¹⁵⁰ 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.¹⁵¹
- 5 **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 Salmon Watchers program, and many others.

Please see the Land Use/Habitat paper for more information about how habitat alteration is being addressed in Puget Sound and the effectiveness of these approaches.

Surface / Ground Water Impacts

- 1 **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.¹⁵² Ecology also is charged with implementing the Water Resources Act of 1971.¹⁵³
- 1 **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.
- 1 **Local governments and water purveyors** develop water system plans detailing future water supply and conservation measures.

Please see the Water Quantity paper for more information about how surface and groundwater impacts are being addressed in Puget Sound and the effectiveness of these approaches.

Pollution

- 1 **Tribes** monitor water quality across Puget Sound.¹⁵⁴
- 1 **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.
- 1 **The Washington Department of Ecology** implements the Clean Water Act, including the state's program under the umbrella National Pollutant Discharge Elimination System (NPDES) and is responsible for monitoring and regulating water quality state-wide.
- 1 **Many counties and cities** in Puget Sound, especially those planning under Phases 1 and 2 of the NPDES, have adopted Ecology's 2001/2005 *Stormwater Management Manual for Western Washington* or its equivalent.¹⁵⁵

Please see the Water Quality paper for more information about how pollution is being addressed in Puget Sound and the effectiveness of these approaches.

Harvest

- 1 **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.
- 2 **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 WDFW and WDNR.¹⁵⁶ Recreational and commercial harvest of shellfish is permitted by WDFW.¹⁵⁷ WDNR manages geoducks in partnership with WDFW and treaty Tribes.
- 3 **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.¹⁵⁸ 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.¹⁵⁹ Federal, state, and private forest landowners have worked together to create three major HCPs on private timber lands.¹⁶⁰
- 4 **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.¹⁶¹
- 5 **The Washington Department of Fish and Wildlife** has established a series of marine reserves to protect iconic or reference habitats and species.¹⁶² WDNR has established Aquatic Reserves to protect habitats.

Invasive Species

- 1 **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. All state and federal land-management agencies are actively involved in removing invasive species from their lands.
- 1 A number of **Tribes** in the Puget Sound basin are actively involved in addressing non-native invasive species, including *Spartina* spp. and knotweed.¹⁶³
- 2 **The Washington Invasive Species Council** provides policy level direction, planning, and coordination for combating invasive species and preventing introductions. The Council's strategic plan, released in June 2008, identifies 22 immediate and long-term recommendations with specific action items, including an effort to determine the invasive species pathways that lack defenses and address those gaps. The plan also shows the diversity of groups working on controlling invasive species, including the Washington Noxious Weed Control Board, the Washington Aquatic Nuisance Species Committee, the Washington Biodiversity Council, and the Washington Tunicate Response Advisory Committee, among many others.¹⁶³
- 1 **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.¹⁶⁴ The Washington Ballast Water Workgroup is working with industry representatives to meet requirements in that Act.
- 1 **Citizens** monitor for invasive species such as tunicates and European green crab.¹⁶⁵

Human Disturbance

- The federal **Marine Mammal Protection Act** prohibits disturbing or harassing marine mammals.¹⁶⁶ Similarly, the ESA prohibits harassing, harming, pursuing, collecting, or capturing listed species.¹⁶⁷
- **The Washington State Legislature approved and Governor Gregoire** recently signed a bill requiring all vessels to stay at least 300 feet away from orcas.¹⁶⁸
- **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 31.¹⁶⁹

- **Local programs** such as the Seattle Aquarium's Beach Naturalist program train volunteers to teach beachgoers how to view and appreciate intertidal life without harming it.¹⁷⁰

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 webs, and biodiversity. As the human population of Puget Sound grows by a projected 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:

- 1 Threats to biodiversity and the food webs 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 webs,¹⁷¹ and disease risk in hatcheries is elevated.¹⁷²
- 2 Harvest management rarely considers the impacts of harvest on species linked in the food webs and on the ecosystem as a whole.
- 3 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.
- 1 Harvest of non-timber forest products, such as salal, mushrooms, and cascara bark, is difficult to manage, and illegal harvest is a growing problem.¹⁷³
- 2 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.¹⁷⁴
- 3 Human disturbance, such as trampling along shorelines associated with recreational activities, can have significant effects on species.¹⁷⁵ 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.
- 4 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 webs. 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.¹⁶³ 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.¹⁴⁰ Management of these threats is also complicated by overarching drivers that 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.¹⁷⁶

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.¹⁷⁷ 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.¹⁴⁰ In addition, habitat loss and pollution outside of Puget Sound can affect migratory species that reside part-time in Puget Sound.¹⁷⁸

Local governments are often constrained in enforcing laws protecting nearshore ecosystems, due to lack of resources and fears of legal challenges and political opposition.¹⁷⁹ 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.¹⁸⁰

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:¹⁸¹

- 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.¹⁸²

Other Puget Sound species that 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.¹⁸³ 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 specific Tribes.¹⁸⁴

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.¹⁴⁰

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

There is no institutional structure for managing biodiversity or food webs.¹⁷⁷ The 2007 Washington Biodiversity Conservation Strategy contains a number of recommendations that, if implemented, should help to address biodiversity in Puget Sound. These include:

- 1 Using the Ecoregional Assessment tool to guide prioritization of habitat conservation;

- 1 Using incentive programs and technical assistance to support conservation among private landowners;
- 1 Supporting local governments in managing growth and development, as well as existing laws, plans, and regulations;
- 1 Improving mitigation programs;
- 1 Conducting public outreach; and
- 2 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 common information base, identify additional data needs, and help to build partnerships essential to conservation.¹⁸⁵ Conservation incentive programs have proved to be a successful non-regulatory method to help private landowners steward their land.¹⁷⁷ A pilot citizen biodiversity stewardship project in Pierce County underscored the importance of local government support for biodiversity conservation.¹⁸⁶

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.¹⁸⁷ There is also significant research underway on better understanding of Puget Sound food webs,¹⁸⁸ 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.¹⁸⁹
- 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.¹⁹⁰
- 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.¹⁹¹
- 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.¹⁹²
- The National Strategy for the Conservation of Australia's Biological Diversity aims to protect biological diversity and maintain ecological processes and systems.¹⁹³ 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.¹⁹⁴
- 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.¹⁹⁵ The country also has a comprehensive, nationwide Biodiversity Strategy.¹⁹⁶

References

¹³⁹ Puget Sound Partnership, 2006. *Sound Health, Sound Future: Protecting and Restoring Puget Sound*.
¹⁴⁰ Washington Biodiversity Council, 2007. *Washington's Biodiversity: Status and Threats*.

- 141 NOAA National Marine Fisheries Service, Northwest Regional Office, 2008. *ESA Critical Habitat*. <http://www.nwr.noaa.gov/Salmon-Habitat/Critical-Habitat/>.
- 142 United States Environmental Protection Agency, 2007. *National Environmental Policy Act (NEPA)*. <http://epa.gov/oecaerth/nepa/index.html>.
- 143 Jamestown S'Klallam Tribe, undated. *Mission Statement of the Natural Resources Department*. http://www.jamestowntribe.org/jstweb_2007/programs/nrs/nrs_main.htm.
- 144 Skokomish Tribal Nation, undated. Skokomish Department of Natural Resources. <http://www.skokomish.org/fisheries.htm>.
- 145 See: http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHCP/Pages/aqr_esa_aquatic_lands_hcp.aspx
- 146 See: http://wdfw.wa.gov/hcp/hpa_hcp.html
- 147 Washington Department of Natural Resources, 2004. *Habitat Conservation Plan 5-Year Comprehensive Review – Report to Services: NOAA Fisheries and U.S. Fish and Wildlife Services for the period January 1, 1999 – December 31, 2003*. <http://www1.dnr.wa.gov/htdocs/lm/hcp5yrplan/section1.pdf>.
- 148 Washington State Department of Ecology, undated. *State Environmental Policy Act: What is SEPA?* <http://www.ecy.wa.gov/programs/sea/sepa/e-review.html>.
- 149 Websites of the City of Bainbridge Island and Whatcom County.
- 150 Aken, J., J. Eckert, N. Fox, and S. Swenson, 2008. *Transfer of Development Rights (TDR) in Washington State: Overview, Benefits, and Challenges*. <http://www.cascadeland.org/files/cascade-agenda-files/TDR%20in%20WA%20State.pdf/view>.
- 151 City of Seattle, undated. *Habitat Conservation Plan Overview*. http://www.seattle.gov/util/About_SPU/Water_System/Habitat_Conservation_Plan--HCP/COS_001620.asp.
- 152 Washington Department of Ecology, 2008. *Existing and Future In-Stream Flow Rules, January 2008* (map). http://www.ecy.wa.gov/programs/wr/instream-flows/Images/irpp_wrp/wsisf0108-usgs.pdf.
- 153 Washington State Department of Ecology, undated. *State Water Use Laws: Compliance and Enforcement*. http://www.ecy.wa.gov/programs/wr/comp_enforce/comp_enfor.html.
- 154 E.g., see Clallam County OSS Management Plan
- 155 E.g. see Jefferson County, <http://www.co.jefferson.wa.us/>
- 156 Mackey, M., 2006. *Protecting Oregon's Bull Kelp*. Pacific Marine Conservation Council.
- 157 Washington Department of Health, 2007. *Harvest Checklist for Recreational Shellfish Harvesting*. <http://www.doh.wa.gov/ehp/sf/sflinks.htm>
- 158 Regional Ecosystem Office, 2006. *Northwest Forest Plan (NWFP) Overview*. <http://www.reo.gov/general/aboutNWFP.htm>.
- 159 Washington Forest Protection Association, undated. *The Forests & Fish Law* <http://www.wfpa.org/pages/forestsandfishlaw.html>.
- 160 U.S. Fish and Wildlife Service, 2008. Conservation Plans and Agreements Database. Available at http://ecos.fws.gov/conserv_plans/public.jsp.
- 161 Cowlitz County Sheriff's Office, undated. <http://www.co.cowlitz.wa.us/SHERIFF/civil/forest.htm>
- 162 Puget Sound Action Team, 2007. *2007 Puget Sound Update: Ninth Report of the Puget Sound Ambient Monitoring Program*.
- 163 Washington Invasive Species Council, 2008. *Invaders at the gate: Washington State 2008 Invasive Species Council Strategic Plan*. Available at http://www.rco.wa.gov/invasive_species/default.htm.
- 164 State Ballast Water Work Group, 2007. *Ballast Water Management in Washington State*. A report to the 2007 regular session of the Washington State Legislature.
- 165 Washington Department of Fish and Wildlife news release, March 5, 2002. *Volunteers sought in green crab monitoring effort*.
- 166 See Section 3, Definitions, of the Marine Mammal Protection Act. Accessible at <http://www.nmfs.noaa.gov/pr/pdfs/laws/mmpa3.pdf>.
- 167 See Section 3, Definitions, of the Endangered Species Act. Accessible at http://www.nmfs.noaa.gov/pr/pdfs/laws/esa_section3.pdf.
- 168 Washington State Legislature, 2008. Bill Information, HB 2514 – 2007-2008. <http://apps.leg.wa.gov/billinfo/summary.aspx?bill=2514&year=2007>. Accessed March 21, 2008.
- 169 Washington Department of Fish and Wildlife, 2005. Single-Page Management Recommendations for Washington's Priority Species: Birds. <http://wdfw.wa.gov/hab/phs/vol4/birdabbrevs.htm>.

- 170 King County Water and Land Resources Division, 2005. *Beach Naturalist season kicks off with low tides revealing some of King County's most precious communities*. Press release, June 2, 2005.
<http://dnr.metrokc.gov/dnrp/press/2005/0602Beachkickoff.htm>
- 171 West, J. E., 1997, 2004. *Protection and Restoration of Marine Life in the Inland Waters of Washington State*. Puget Sound/Georgia Basin Environmental Report Series No. 6
- 172 Shared Strategy Development Committee, 2007. Puget Sound Salmon Recovery Plan. Chapter 3.
- 173 Welch, C., 2006. "A war in the woods." *Seattle Times*, June 6, 2006; Chavey, J. and D. Hereford, 1999. "Brush pickers, brush shed owners charged with theft: Multi-agency sweep brings results in Quinault area." Washington Department of Natural Resources press release No. 99-036.
http://www.stage.dnr.wa.gov/htdocs/adm/comm/1999_news_releases/nr99036.htm.
- 174 Williams, S. L., and E.D. Grosholz, 2008. *Invasive Species in Estuaries and Coastal Environments: Marrying Management and Science*. Estuaries and Coasts.
- 175 Griffiths, J., M. N. Dethier, A. Newsom, J. E. Byers, J. J. Meyer, F. Oyarzun and H. Lenihan, 2006. *Invertebrate community responses to recreational clam digging*. *Marine Biology* 149:1489-1497; Jenkins, C., A. Olson, J. L. Ruesink, and M. E. Haas, 2001. *Watch Your Step: Impacts of Trampling on a Rocky Shoreline of San Juan Island, Washington*. In Proceedings of the 2001 Puget Sound Research Conference; Carney, K.M. and W.J. Sydeman, 1999. *A Review of Human Disturbance Effects on Nesting Colonial Waterbirds*. *Waterbirds: The International Journal of Waterbird Biology* 22(1):68-79.
- 176 Lackey, R. T., 2004. *A salmon-centric view of the twenty-first century in the western United States*. pp. 131-137. In: P. Gallagher and L. Wood (eds), *Proceedings of the World Summit on Salmon*, Simon Fraser University, Burnaby, BC, Canada; Lackey, R. T., 2005. Economic growth and salmon recovery: an irreconcilable conflict? *Fisheries*. 30(3): 30-32
- 177 Washington Biodiversity Council, 2007. *Washington Biodiversity Conservation Strategy*.
- 178 Stutchbury, B., 2008. *Did your shopping list kill a songbird?* *The New York Times*, March 30, 2008.
- 179 Cascadia Consulting Group, Inc., 2006. *Biodiversity Conservation Strategy – Institutional Assessment Report*.
- 180 Rice, C.A., 2007. *Evaluating the Biological Condition of Puget Sound*. PhD thesis, University of Washington, Seattle, WA.
- 181 Puget Sound Action Team, 2007. *State of the Sound 2007*; Washington Department of Fish and Wildlife news release, February 21, 2008, *Commission schedules action on steelhead plan*; Washington Department of Fish and Wildlife, 2005. *Washington's Comprehensive Wildlife Conservation Strategy*.
- 182 Note: As of 2005, according to WDFW, only Status Reports were available for the Mardon Skipper (1999) and Oregon Spotted Frog (1997).
- 183 Palsson, W. A., J. Thomas, T. J. Northup, and M. W. Barker, 1998. *Puget Sound Groundfish Management Plan*; Bargmann, G. and the Washington Department of Fish and Wildlife, 1998. *Forage Fish Management Plan*.
- 184 Washington Department of Natural Resources – Aquatic Resources Division, 2001. *The State of Washington Commercial Geoduck Fishery Management Plan*. Also see <http://www1.dnr.wa.gov/htdocs/aqr/shellfish/tribal.html>
- 185 Hale, L.Z., 2003. *Managing through partnerships*. Presentation by The Nature Conservancy.
- 186 Refer to Washington Biodiversity Project website,
http://www.biodiversity.wa.gov/ourbiodiversity/updatewhite_river.html
- 187 NOAA Fisheries, 2007, *Conducting an IEA in Puget Sound – Draft work plan*.
- 188 Reum, J. C. P. 2006. Spatial and temporal variation in the Puget Sound food web. MS thesis, University of Washington, Seattle, WA.
- 189 Washington Biodiversity Conservation Committee, 2003. *Washington Biodiversity Conservation Strategy Report*.
- 190 California Department of Fish and Game, 1999. *Marine Life Management and Protection Act*.
- 191 Environment Canada, 2003. *Georgia Basin Action Plan*.
- 192 National Botanic Gardens (Glasnevin, Ireland), undated. *Ireland's National Biodiversity Plan*.
<http://www.botanicgardens.ie/gspc/nbp.htm>.
- 193 Australian Government, Department of Environment, Water, Heritage and the Arts, 2007. *National Strategy for the Conservation of Australia's Biological Diversity*. <http://www.environment.gov.au/biodiversity/publications/strategy/goal.html>.
- 194 Australian Government, Department of Environment, Water, Heritage and the Arts, 2007. *Biodiversity*.
<http://www.environment.gov.au/biodiversity/index.html>.
- 195 Biodiversity Information Online, 2008. *Marine Protected Areas Policy and Implementation Plan*.
http://www.biodiversity.govt.nz/seas/biodiversity/protected/mpa_policy.html.
- 196 Biodiversity Information Online, undated. *The New Zealand Biodiversity Strategy*.
<http://www.biodiversity.govt.nz/picture/doing/nzbs/index.html>.

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

This section of the discussion paper summarizes the management approaches that seem to be effective at protecting or restoring species, biodiversity, and the food webs in the Puget Sound basin. It also identifies programs that will need to be changed, and new programs that need to begin, to improve the health of the biota in the basin. Lastly, it suggests criteria to use to select among actions, and discusses the need for monitoring.

Addressing the Threats to Species and Biodiversity in Puget Sound

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

Currently, the Puget Sound Basin lacks a comprehensive approach to managing threats to species, biodiversity, and the food webs. However, a number of individual plans and programs 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.^{197,198} 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. The completion of these plans is a first step toward conservation outcomes; their implementation is critical to achieving tangible benefits. To date, implementation of these plans is lagging due to insufficient funding. 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 webs 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,¹⁹⁹ and could be used to prevent over-harvest of many species, such as halibut, salmon, geoduck, sea urchins, sea cucumbers, and other invertebrates.^{200,201} Use of the precautionary principle to eliminate commercial harvest pressure on seaweed and sharks and other fishes has reduced pressure on and slightly improved the health of groundfish stocks.²⁰² Implementation of the recommendations from such efforts as the Puget Sound and Coastal Washington Hatchery Reform Project²⁰³ should also improve hatchery practices so that they contribute to recovery of species in Puget Sound..
- **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 view and appreciate intertidal life without harming it.²⁰⁴
- **Swift action to avoid the introduction of non-native species** is more effective than trying to eradicate established invasive species.²⁰⁵
- **Multi-stakeholder groups** have been shown to be effective at mobilizing local support for conservation and increasing voluntary compliance with conservation goals.²⁰⁶ 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 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 number and volume of oil spills in Puget Sound since 1986.²⁰⁷ The Marine Mammal Protection Act prohibits harassing or killing marine mammals. Since its passage, some populations of marine mammals have increased in Puget Sound.²⁰⁸ Populations of bald eagles and peregrine falcons rebounded after DDT was banned.²⁰⁹

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 making progress toward their goals, Puget Sound lacks an ecosystem-based management framework to protect and restore marine, estuarine, freshwater, and terrestrial species, biodiversity, and the food webs. 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 webs. Because there currently is no system for managing the food webs, this approach would fill a major gap. This approach must also prioritize among actions to protect and restore species, biodiversity, and the food webs, 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 webs in the Puget Sound basin.

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 webs 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. The Partnership should create a suite of recovery and/or management plans for both listed and unlisted species that focuses on managing species for recovery and sustainability.
- 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 webs.
- 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 Assessment and 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 webs and biodiversity in the Puget Sound basin, from the marine waters to alpine regions.

Which actions need the greatest attention?

All of these actions require attention, but the ecosystem-based framework must be created first. However, it is important to note that many actions can and should continue while the ecosystem-based framework is being created.

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 webs 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?
- **Effectiveness:**
 - Does it affect multiple species, biodiversity or the food webs?
 - 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 native food webs 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, and plans to protect biodiversity and prevent non-native species invasions. Create plans for other imperiled species and communities, with the goal of creating a suite of recovery and/or management plans that focuses on managing species for recovery and sustainability.
3. **Protect or conserve habitats** or areas with high biodiversity and high potential value to the food webs.
4. Continue to **build our understanding** of the food webs, threats to the food webs 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 webs.

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.

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. Although there will always be some uncertainty associated with our actions, we still must act where we are reasonably certain the actions will have benefits to the Puget Sound ecosystem.

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. Ensure that terrestrial and freshwater systems are well represented in this approach. Pursue the goal of creating a suite of recovery and/or management plans that focuses on managing species for recovery and sustainability
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. For example, complete the development of and implement the regional and watershed adaptive management programs for the Puget Sound Salmon Recovery Plan.
- Create and implement plans for imperiled species and communities.
- Prioritize and enforce existing regulations and start reviewing their effectiveness.
- Fix existing regulations that have known problems.
- 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.
- Assess whether current protected areas (terrestrial and aquatic) are adequately protected to ensure sustainability of imperiled and common native species. Fill gaps where they are found.
- 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.
- Continue and strengthen efforts to remove pollutants (including debris and derelict gear) from water and sediments, and thus from the food webs.
- Create and implement community-based social marketing programs to encourage behavior changes to protect biodiversity and the food webs.
- 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,²¹⁰ 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 webs as a baseline against which to monitor progress and manage adaptively. Monitor these indicators and publish trend information about them on a regular basis, potentially as a scorecard.
- 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 webs.

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. Continue to pursue the goal of creating a suite of recovery and/or management plans that focuses on managing species for recovery and sustainability.

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. Partner with the Washington Biodiversity Council and Washington Invasive Species Council to implement the Washington Biodiversity Conservation Strategy and the Washington Invasive Species Council's strategic plan. Identify and protect habitats critical to the survival of declining species and to keeping common species common.

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 webs, 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 are the Puget Sound native food webs? This research should be designed to provide information about trends, patterns, and mechanisms of change in the native food webs, 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.
4. Create and disseminate a Species, Biodiversity, and Food Webs scorecard that publicizes the results of the monitoring programs and illustrates the health of species, the food webs, and biodiversity in the Puget Sound basin. Partner with the Washington Biodiversity Council, which is working on such a scorecard.

Rationale: There are very large gaps in our knowledge, particularly of the native food webs 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.

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 webs and its supporting habitats. Keep abreast of ongoing research activities into the effects of harvest and culture, such as the current focus on geoduck aquaculture.
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 webs. Similarly, culture practices ensure the propagation of target species but don't consider their effects on the food webs. 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 webs varies dramatically depending on the species and the ecosystem, as described below. The paragraphs below describe the essential information needed to establish baselines against which to measure our progress.

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. Initial research should focus on key or indicator species that will help advance our knowledge of the health of the ecosystem. Lastly, we need to answer the question “how much is enough” for the abundance, productivity, spatial structure, and diversity of key species so that we can measure progress toward viable species populations.

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 Webs: We know relatively little about Puget Sound's native food webs. Information about predator-prey interactions, the structure of the food web, phytoplankton and zooplankton, spatial and temporal variations, 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 webs, we need to understand what changes in the food webs are natural and which are human-caused.

A. What objectives should we consider to monitor progress?

Some objectives to consider include:

- No more species merit listing, and common native 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 webs contain robust, redundant nodes (such as important primary consumers) and pathways that maintain the ecosystem's resiliency 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 webs
- Trends in and status of biodiversity (see scorecard recommendation above and in the Washington Biodiversity Strategy)

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 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 webs, 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. Since some species migrate beyond the borders of the Puget Sound basin, it will be necessary to coordinate efforts with other states and countries such as Canada.

Any monitoring program should be aligned well with the goals of ecosystem-based management, and its results should be summarized regularly in a scorecard 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. The monitoring program should evolve over time to reflect new findings – and new questions. There is much monitoring work that can begin now, before the comprehensive program is complete.

Finally, the data produced via this monitoring program must be easily accessible and coordinated.

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 comprehensive research program to deepen our understanding of Puget Sound's native food webs 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.

References

- ¹⁹⁷ Taylor, M.F.J., K.F. Suckling, and J.J. Rachlinksi, 2005. *The Effectiveness of the Endangered Species Act: A Quantitative Analysis*. *BioScience* 55(4):360-367.
- ¹⁹⁸ Puget Sound Action Team, 2007. *2007 Puget Sound Update: Ninth Report of the Puget Sound Ambient Monitoring Program*.
- ¹⁹⁹ Good, T.P., R.S. Waples, and P. Adams. 2005. Updated Status of Federally Listed ESUs of West Coast Salmon and Steelhead. NOAA Technical Memorandum NMFS-NWFSC-66.
- ²⁰⁰ <http://wdfw.wa.gov/fish/creel/halibut/2007halibut.htm>
- ²⁰¹ Bradbury, A., Sizemore, B., D. Rothaus, and M. Ulrich. 2000. Stock Assessment of Subtidal Geoduck Clams (*Panopea abrupta*) in Washington. Washington Department of Fish and Wildlife.
- ²⁰² Palsson, W.A., Thomas J. Northup, T.J., and Barker, M.W., 1998. *Puget Sound Groundfish Management Plan*; Bargmann, G. and the Washington Department of Fish and Wildlife, 1998. *Forage Fish Management Plan*.

²⁰³ Hatchery Scientific Review Group (HSRG) – Lars Mobrand (chair), John Barr, Lee Blankenship, Don Campton, Trevor Eveyln, Tom Flagg, Conrad Mahnken, Robert Piper, Paul Seidel, Lisa Seeb and Bill Smoker. April 2004. *Hatchery Reform: Principles and Recommendations of the HSRG*. Long Live the Kings, 1305 Fourth Avenue, Suite 810, Seattle, WA 98101 (available from www.hatcheryreform.org).

²⁰⁴ King County Water and Land Resources Division, 2005. *Beach Naturalist season kicks off with low tides revealing some of King County's most precious communities*. Press release, June 2, 2005. <http://dnr.metrokc.gov/dnrp/press/2005/0602Beachkickoff.htm>

²⁰⁵ Shared Strategy for Puget Sound, 2007. *Puget Sound Salmon Recovery Plan*.

²⁰⁶ Northwest Straits Evaluation Panel, 2004. *Northwest Straits Marine Conservation Initiative: Five Year Evaluation Report*. Submitted by the Northwest Straits Evaluation Panel with support from the Policy Consensus Center of the University of Washington and Washington State University.

²⁰⁷ Washington Department of Ecology, 2007. *Spill Scene: Spill Prevention, Preparedness, and Response Program 2006 Annual Report*. Volume 10, Number 1. WDOE Publication: 07-08-002.

²⁰⁸ Caretta, J. V., K. A. Forney, M. M. Muto, J. Barlow, J. Baker, B. Hanson, M. S. Lowry, 2007. *U.S. Pacific Marine Mammal Stock Assessments: 2006*. NOAA Technical Memorandum NMFS

²⁰⁹ United States Fish and Wildlife Service, 2000. "Eighth Annual International Migratory Bird Day Celebrates Success of Peregrine Falcon Recovery." Press release number 00-79, April 24, 2000. <http://www.fws.gov/cno/news/2000/2000-79.htm>.

²¹⁰ Niemeijer, D. and R.S. de Groot, 2008. "A conceptual framework for selecting environmental indicator sets." *Ecological Indicators* 8: 14-25.

DRAFT

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.²¹¹

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; add reference to run timing – salmon – Wayne references
- **Demographic diversity** populations are represented by a natural frequency of young, middle and older ages and small to large sizes, as well as life history stages. *Use this term when discussing rockfish harvests*
- **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;²¹²
- **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.²¹³

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,²¹¹
- **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.

Cultured Species

Any species raised by humans for human use is considered a “cultured species” in this paper. These include hatchery fish, cultivated shellfish, managed timber, and all agricultural species.

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.”²¹⁴

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 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 trophic level within a food chain.²¹⁴

References

- ²¹¹ Washington Biodiversity Council, 2007. *Washington Biodiversity Conservation Strategy*.
- ²¹² Townsend, C. R., M. Begon, and J. L. Harper, 2008. *Essentials of Ecology*. Blackwell Publishing.
- ²¹³ Incorporates definitions from Townsend, et al., 2008, Forman, R. T. T., and M. Godron, 1986. *Landscape Ecology*. Wiley & Sons, New York, and Farina, A., 2000. *Principles and Methods in Landscape Ecology*. Kluwer Academic Publishers, Dordrecht. Modified around definitions provided by Collin, P. H., 2004. *Dictionary of Environment and Ecology*. 5th Ed., Bloomsbury Publ. and Lincoln, R. J., G. A. Boxshall, and P. F. Clark, 1982. *A Dictionary of Ecology, Evolution and Systematics*. Cambridge University Press, Cambridge, UK.
- ²¹⁴ McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt, 2000. *Viable salmonid populations and the recovery of evolutionarily significant units*. NOAA Tech. Memo. NMFS-NWFSC-42.

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.

DRAFT