APPENDIX F: SCIENCE NEEDS IDENTIFIED BY SCIENTIFIC, PRACTITIONER, AND STAKEHOLDER COMMUNITIES

Appendix F – Science Needs Identified by Scientific, Practitioner, and Stakeholder Communities

The Puget Sound Partnership contacted approximately 200 interested scientists from academia, state, federal, local agencies, tribes, and environmental organizations and other stakeholders to request input on science needs for this Biennial Science Work Plan. Respondents were asked to provide responses to the following two questions:

1. Within your area of focus, where is scientific uncertainty the greatest? What are the key questions that are important for Puget Sound recovery about mechanisms, interactions, and responses remain unanswered? Please describe qualitatively how good the information is you have to support your assessment of uncertainty (e.g., high – lots of scientific papers; moderate – some papers or local studies, or theoretical support; needs a lot of improvement – no data, or anecdotal evidence, etc.).
2. Where based on your understanding is the lack of social, natural, or physical scientific work (e.g., measurement, analysis, prediction, and communication) most impeding our ability to recover the Puget Sound?

The Partnership received approximately 45 responses with a total of 150 suggestions. Suggestions have been condensed and summarized are presented below in categories matching the key priority areas of the Action Agenda Update. Responses were categorized by ecosystem components and/or pressures to align the topics with the priority areas of the Action Agenda Update (Table 2). A list of contributors is provided at the end of this appendix.

Table 1. Responses by Category

Ecosystem Component or Pressure		# of Responses
Upland, Terrestrial & Freshwater	Habitats	12
	Species & Food Webs	7
	Mitigation	4
Marine & Nearshore	Habitats	10
	Species & Food Webs	36
	Mitigation	8
Pollution	Toxics	15
	Runoff from the Environment	10
	Wastewater	3
	Shellfish	1
	Oil Spills	0
	Other	1
Climate Change		7
Human Dimensions		8
Sustaining, Coordinating, & Using Science to Adapt Actions	Building Capacity	4
	Foundational Questions	9
	Scientific Tools for Informing Policy	5
	Integrated, sustained monitoring	9
	Education, training, & outreach	3
Total		**152**

Upland, Terrestrial & Freshwater Ecosystems

Habitats

Habitat and Fish Production. How does habitat over time relate to fish production, assuming enough adults to fully seed the habitat? Standard models carry calculations to flow and habitat, but do not carry these results to numbers of fish. Related to this is the previous question, but this question can be restated as: how much quality x quantity of habitat is needed for each fish? This question is probably influenced by water quality and primary and secondary productivity. Dr. Henriette Jager (Oak Ridge National Laboratory) and Dr. Steve Railsback (Humboldt State University) are two of a number of people who could be consulted as both have done considerable individual-based modeling (which is much more intensive than the instream flow modeling).

Corridor Ecology. We need better understanding of corridor ecology in light of urbanization and climate change especially as it relates to movements by local endemic, non vagile species (e.g., gastropods).

Isolation. What is the degree of isolation of organisms between basins in Puget Sound? When is it important to manage by basin? How do natural processes and productivity differ between the basins?

Empirical Evidence. The science community has largely taken a coarse filter approach to conservation of terrestrial biodiversity with little empirical evidence that ecological systems are the right unit to plan around. We need more empirical evidence relating species occurrence, density and viability with coarse filter typology.

Landscape-Level Planning. If WDFW wants to encourage landscape-level land use planning that effectively conserves wildlife then we need more field research to estimate landscape-level parameters, such as housing density and percent forest cover, that relate the degree of urbanization to the density of various native species.

Flow-Dependent Habitat. What is the best way to quantify flow-dependent fish habitat? The standard option in most instream flow modeling weights suitabilities of depth, velocity, and substrate or cover equally (i.e., they are multiplied together to generate an index of quality x quantity of habitat). There are a number of questions related to this and WDFW staff have been working on this question for many years, particularly development and testing of suitability for depth, velocity, substrate, and cover.

High Flows. How do different magnitudes of high flows change low flow channels? Under what circumstances do they make channels wider? Under what circumstances do they make channels more incised? Dr. Derek Booth (University of Washington) should be consulted in refining the questions and research.

Hydraulic Continuity. A critical question for softening the conflict around instream flows is quantification of hydraulic continuity. Site-specific geology will influence the relationship, but to what extent do distance and depth of wells modify their impact on stream flow? Can management rules be developed to address and modify the standards in the Postema decision (www.ecy.wa.gov/programs/wr/caselaw/images/pdf/postema.pdf) from the State Supreme Court? The existing standard implies a 100% instantaneous effect of well water withdrawal on stream flow, putting any new well in conflict with instream flows without allowing for diminution of impact with distance. Hydrogeological models exist or can be developed to model the degree of impact over distance, but such models are expensive and data intensive. No policy considers diminution of impact.

Land Use and Flows. How does land use influence peak flows and high flows that modify channels? Research should be addressed to different parts of watersheds: headwaters, lower tributary headwaters, foothills, lowlands, floodplains. Dr. Derek Booth (University of Washington) should be consulted in refining the questions and research.

Stream Flow Pressures. The Puget Sound Partnership Leadership Council has adopted Puget Sound Ecosystem Recovery Targets for Summer Stream Flows. These targets are based on trends in 13 Puget Sound tributary rivers and streams. But, the Pressures that specifically affect flows in these streams have not be analyzed and identified. A key next step for linking the targets to implementation is to conduct the analysis to determine which Pressures affect stream flow, what particular Pressures are critical in creating the observed trends in stream flow, and prioritizing the Pressures for which implementing management activities are most likely to improve stream flows. This research would not only link targets to specific implementation in these 13 rivers and streams, but could also inform broader policy and program initiatives for maintaining and improving stream flows basinwide.

Precipitation and Ground Water. Where is precipitation focused on a very local scale? What areas absorb most of the groundwater and the least of it, and how does the ever increasing presence of non-permeable surfaces affect that? There may be some areas where we want to completely avoid installing non-permeable surfaces. We know very little about the residence time of ground water in Kitsap County, for example. We don't know the total amount, how connected the underground system is and what the absorption rates are as a function of geographic location. Models have been and are being developed, but it's important to the health of the Sound and, in Kitsap County, to our understanding of how we can use our ground water. Do we measure run-off properly?

Species & Food Webs

Effects of land use change versus fish management on salmon. Considerable time and money are being spent to manage land use effects and restore habitat for salmon. However, there is also considerable confusion about what is driving salmon productivity at the local scale. Recently (Hoekstra et al 2006, Stanford http://afs.confex.com/afs/2011/webprogram/Paper5318.html) have concluded that harvest and hatchery effects may be more a factor than freshwater impacts yet there is much clamor that land use is by far the major if not sole factor limiting salmon production. A big concern is whether the legacy and ongoing effects of fish management are contributing to reduced productivity over and above habitat impacts. For example, hatchery fish have been shown to reduce fitness in several ways and hatchery fish are pervasive in many streams. Although not as well assessed, harvests are selective and not consistent with natural selection. Therefore, it is likely that harvest is also reducing fitness. The combination of harvest and hatcheries is almost certainly causing loss of fitness, and therefore lowered productivity, of natural spawning stocks. So, the question arises whether harvest and hatchery actions are undermining the effectiveness of habitat actions.

Restoration needed to meet B-IBI target. What mix of land use, stormwater and stream restoration programs and projects is needed to meet the 2020 recovery target of insects in streams? Specifically the restoration component of this target: By 2020, 30 stream drainages with "fair" B-IBI scores are restored so they now have "good" B-IBI scores.

Juvenile Salmonid Downstream Migrants. What are the annual abundance, timing and life histories of juvenile salmonid downstream migrants in all of our river systems? The information would allow us to better manage our fisheries and protect fish habitat through the hydraulic code which in turn should help maintain or improve populations of fish.

Non-Game Fish and Mussels. Almost nothing is known regarding the distribution, abundance and status of non-game stream fish and freshwater mussels in Washington. Management or conservation of species is not possible if we do not know where they occur and we cannot respond to changes in geographic distributions due to climate change or human activities to avoid imperilment if we do not know where species occur and do not understand their habitat requirements. This information is invaluable for directing conservation, monitoring and restoration.

Non-Vagile Animal Communities. We need a better understanding of mechanisms for how particular non vagile animal communities (amphibians, small mammals and invertebrates) change across an urbanizing gradient.

Predators. Develop a better understanding of predator impacts on critical/suppressed fish stocks/runs.

Salmon. Population abundance estimates of adult and juvenile salmon used to evaluate population limiting factors are based on outdated methods. Although current methods (developed in the 1970s) have some value re: consistency, their accuracy and precision are questionable. Validation studies are needed to compare newer methods, with the old ones, with the aim to (1) implement more accurate and precise (unbiased) abundance estimation methods and (2) develop bias-correction factors to compare old results with new. Validation studies would run for 2-3 years, conducting old and new methods in parallel.

Mitigation

Effectiveness of stormwater management measures and riparian habitat restoration in recovery of native stream biodiversity. There is great scientific (and management) uncertainty as to whether measures to mitigate the negative effects of urbanization on stream biota through storm water management measures and instream and riparian habitat restoration will result in recovery of native stream biodiversity. More directed research, including monitoring and basin-scale experimentation, is needed to determine how much biological improvement can be expected in response to the most aggressive restoration measures.

Effectiveness (and cost-effectiveness) of stormwater management measures. These issues have been identified by the stormwater work group, so are not described in detail here. The range of information needs are on several scales, ranging from the effectiveness of individual treatment structures, to the effectiveness Puget Sound wide actions such as public education campaigns.

Estuaries and Wetlands. We know very little about the use of estuary and wetland habitat by salmon or the effectiveness of restoration actions in these habitats. An estuary research project, similar to the Intensively Managed Watersheds (IMW) Project, would provide valuable guidance for restoration actions.

Habitat Repopulation. How long does it take fish to repopulate habitat that is made available through the removal of manmade fish blockages or restoration projects? This is a measurement of success that frequently comes up and we lack good information. This is part of the story of salmon recovery that we should be using to increase support for salmon recovery on a broad scale

Marine & Nearshore Ecosystems

Habitats

Habitat Use Patterns. Knowledge about the small- and large-scale movement patterns and resultant seasonal distribution of herring, sandlance, and all species of smelt in Puget Sound are largely unknown, except with respect to spawning. Without knowing the geographic and temporal scope of habitat use patterns during all times of the year it is impossible to evaluate the effects of habitat recovery actions or fishery management decisions on these species.

Reproductive Habitat. There is uncertainty about the value of shorelines as reproductive habitat. Not enough known about surf smelt and others that may be obligate users.

Nearshore Habitats as Nurseries. Uncertainty about value of nearshore habitats as nurseries for key species including rockfish and lingcod.

Connectivity. There is a major gap in knowledge about the connectivity between Puget Sound populations and their conspecifics in the Salish Sea and the Washington coast. Puget Sound is often treated as a self-contained ecosystem, and although this may be valid for its physical characteristics, it is problematic when it comes to conserving and managing marine fish and invertebrates within Puget Sound. Any anthropogenic and natural effects on Puget Sound populations, be it freshwater run-off, pollution, fishing or habitat modification, may be moderated by immigration from populations on the Washington coast, leading to a potential underestimation of local population effects of such disturbances. Although a number of other studies have also shown isolation between Puget Sound and Washington coast populations, these studies are concentrated towards a small and somewhat biased subsection of Puget Sound's biodiversity. More importantly, there is no meta-analysis that synthesizes this information in a format that is useful for managers and stakeholders. I believe that a better understanding of connectivity and local adaptation will be crucial in efforts to recover the biodiversity of Puget Sound.

Eelgrass. The greatest uncertainties on eelgrass habitat exists in the: a) historical abundance and distribution of eelgrass in Puget Sound; and b) magnitude and spatial extent of stressors in Puget Sound.

Eelgrass Site Selection. Development of an eelgrass restoration site selection model and protocols to maximize transplant success. Recovery efforts will need to focus on the science of eelgrass restoration and develop effective tools that will increase eelgrass transplant success and persistence (ability to withstand future stressors).

Kelp. Kelp is recognized as a critical resource world-wide due to its role as biogenic habitat and primary producer. For these reasons, it is identified in the Action Agenda (2009) and related work as an important indicator of ecosystem health. Despite its recognized importance, very little is known about the status and trends in kelp in Puget Sound (Mumford 2007). The greatest uncertainties include: the historical and current abundance and distribution in Puget Sound of canopy-forming, prostrate and stipitate species (historical and current knowledge is limited and focused primarily on canopy-forming kelp); use of kelp by key species in Puget Sound; and key stressors to kelp in Puget Sound. The scientific work that is most needed to strengthen our ability to recover Puget Sound would provide the following: information on current kelp abundance and areas of loss. This information is needed to prioritize areas for restoration and protection; and understanding of the impact of key stressors. This information is needed to prioritize actions to minimize stressors.

Puget Sound Beaches. Improving our knowledge of the physical processes and rates of change of Puget Sound beaches would provide valuable information for better conditioning HPA permits.

Beach Armoring and Sediment. The "off site" effects of beach armoring (i.e., bulkheading) with respect to the sediment supply to down-drift beaches are incompletely understood, especially when bulkhead

are placed in transport zones. While some level of reduction in sediment is typical, the degree to which a given change in sediment quantity affects ecology is poorly studied. Evidence suggests that the quality (i.e., particle size) of the sediment also matters and that beach coarsening has measurable effects on habitat use by forage fishes.

Elwha Nearshore Biology and Habitat. Actions to promote full ecosystem restoration of the Elwha Nearshore include: 1.Continue long term monitoring of fish use of Elwha nearshore by CWI and PC/WWU, NOAA,LEKT, and others, including genetic composition of ESA stocks of salmon and forage fish-at a cross regional scale. 2. Macroinvertbrate assemblage of Elwha and comparative. 3. Post process eelgrass data for macroalgae and fish presence. 4. Conduct additional field surveys to define fish composition and extent in and of understory macro algae beds of Elwha and comparative nearshore. 5. LWD, riparian mapping, Elwha and comparative nearshore. 6. Bird surveys of Elwha nearshore for baseline info (both live and stranded birds) and linkages to other monitoring elements. 7. Marine mammal tracking (harbor seals).

Species & Foodwebs

Food webs. A greater mechanistic understanding of food web interactions and relationships is necessary for increasing our ability to recover Puget Sound. This requires natural scientific measurement, analysis, and prediction to test current food web model relationships.
Food Web Interactions. There are two major sources of uncertainty. First, the populations, distributions and ecology of many important marine organisms (for example, crustacean and gelatinous zooplankton, bottom-dwelling fishes, and most forage fishes) are poorly understood, due to a general lack of long-term monitoring. Second, the Puget Sound ecosystem is connected to many other systems through transboundary processes—migrations, oceanographic fluxes, runoff, and human activities, to name a few. How these transboundary processes affect the internal dynamics of the marine ecosystem has, to my knowledge, not been fully addressed. Needs include: 1. Spatiotemporal monitoring of abundance, distributions and diets of zooplankton, demersal fishes and pelagic (forage) fishes; 2. Prioritization and modeling of processes that regulate marine ecosystem dynamics, including processes that operate across ecosystem boundaries; and 3. Assessment of current ecosystem modeling capacity.

Trophic Levels. There is uncertainty about lower trophic levels in Puget Sound's pelagic habitats. Lacking knowledge re: primary producers (e.g., phytoplankton) and primary consumers (e.g., copepods and krill). How does productivity affect abundance of higher trophic levels (e.g., herring and salmon) on a basin-specific level. What is the carrying capacity of these systems re: hatchery releases of salmon and other species?

Marine Ecology of Salmon Juveniles. There is insufficient research on the early marine ecology of salmon juveniles, which may be a critical component of total marine production for many salmonids. Predation and competition in the Salish Sea might control their populations.

Juvenile Estuarine Use. What is the extent of estuarine and associated tidal and seasonal wetland use by sub-yearling coho and other juvenile salmonids in coastal estuaries? This information would allow us to better utilize the Hydraulic Code to protect these fish from construction impacts.

Salmon in the Salish Sea. We need to improve our understanding of the factors affecting the growth, condition and survival of salmon and steelhead while the outmigrate and reside in the Salish Sea as a top priority. The juvenile stages of salmon and steelhead as they outmigrate and reside in the marine and estuarine environment are critical to the overall survival of salmon and steelhead, and they largely function as a "black box" in fisheries management. Questions within this subject area include but are

not limited to: 1) where is mortality occurring in the marine environment? 2) what role does outmigrant condition play in mortality? 3) Is mortality size selective? (Duffy et. al. 2010-11 publications indicate this with hatchery Chinook, but should be expanded to wild Chinook and other species) 4) Has the environment changed so that the life-history characteristics of certain salmon and steelhead populations no longer line up appropriately? Is this exacerbated by limited life-history diversity in existing populations?

Salmon Recovery. Increased long term post-implementation monitoring and effectiveness monitoring would help us see more clearly which activities bring us closer to salmon recovery. Key questions include: Are listed populations abundant and productive? *Are* freshwater and estuarine habitats healthy and productive? Is water clean enough to support wild salmon? Do rivers and streams have flows that support wild salmon? Are hydroelectric facilities operating in a fish friendly manner? Are streams accessible to wild salmon? Do hatchery practices protect wild salmon? Does harvest management protect wild salmon?

Forage Species. We have poor knowledge as to why forage species such as sandlance, hake, and Pollock undergo significant population changes. For many of the key prey species, we don't have enough information to make definitive statements as to the directionality of population change. These species determine the diets, growth, and survival of mammals, birds, and predatory fish.

Surf Smelt. It is not know whether surf smelt in Puget Sound spawn once and die (semelparous) or spawn in consecutive seasons (iteroparous). Additionally, it is not known whether surf smelt return to their natal beaches to spawn. Evaluating these life history attributes is imperative to evaluating population stability, as well as evaluating rebound potential after overexploitation, overpredation, or natural disaster.

Recreational Smelt Harvest. Recreational surf smelt harvest is not currently monitored or estimated in any way. More to the point, as estimate of surf smelt abundance, or an index thereof, is not produced anywhere in Washington. Ecosystem-based management requires balancing fisheries take, consumption by predators, and all other "sinks" of prey items against production and immigration ("sources").

Eulachon Populations. Eulachon spawning populations are known from the outer Washington coast and the Fraser River, and a relict population exists in the Elwha Basin. Fish of all of these stocks likely rear in Puget Sound. No monitoring of eulachon presence or abundance currently occurs, despite the species being ESA-listed.

Sandlance. Though genetic analyses have recently indicated that surf smelt in Puget Sound are a single, panmictic population, no genetic work has been done for sandlance. Recent genetic work in the Bering Sea and southeast Alaska has documented two new species of sandlance and it is possible there is more than one species in Washington. Additionally, it is possible that even a single species of sandlance could exist in Puget Sound in highly distinct and isolated stocks that merit independent management/protection.

Forage Fish. What techniques can we use to evaluate the annual abundance of forage fish (example; spawning ground surveys, ocean index in conjunction with current NOAA salmonid work)? This information would help us determine how to better protect and maintain forage fish populations.

Pacific Herring. Areas of uncertainty include: genetic population structure (needed to better manage stocks and to inform recovery efforts); population abundance for key stocks - need acoustic/ trawl methods for certain stocks, and to augment spawn-deposition method; population age/size structure,

mortality, and recruitment of key stocks; the reasons for the decline in the Cherry Point herring stock; and the migration/movement patterns of Pacific herring.

Groundfish. Uncertainty related to all population metrics for species not susceptible to bottom-trawl surveys including ESA-listed rockfish including. Metrics include population abundance, natural mortality, population age structure, population genetic structure, and geographic distribution.

Dissolved Oxygen and Groundfish. What is the impact of low dissolved oxygen on groundfish populations, especially listed species?

Current Status of Rockfish Populations. NMFS' and WDFW's recent assessments of the status of rockfish populations in Puget Sound relied on incomplete and inadequate (and some might argue inappropriate) data sets. There is a dire need to conduct statistically robust and rigorous rockfish monitoring to determine: 1) Population abundance of adult and juvenile rockfishes; 2) Spatial distribution of adult and juvenile rockfishes; and 3) Patterns of recruitment in rockfishes.

Threats to rockfish (and other bottom fishes). A recent status review of 5 species of Puget Sound rockfish led the ESA listings of canary rockfish, yelloweye rockfish and bocaccio. In their assessment of risks facing these species (and all rockfish), NMFS identified a number of key uncertainties regarding the threats facing depleted rockfish populations. These are: What is the effect of degraded water quality (contaminants, excessive nutrients, low dissolved oxygen, etc.) on rockfish survival, growth, and reproduction? How does predation from high trophic level species such as harbor seals, Stellar sea lions, and lingcod affect rockfish populations? What risks to rockfish face from the artificial propagation of salmon, lingcod or other species? What are rates of rockfish bycatch in recreational fisheries? What is the impact of derelict fishing gear on rockfish populations? What impact do changing biotic and abiotic habitat conditions have on rockfish survival, growth and reproduction? Increasing our understanding of the impacts of these threats on rockfishes will enhance our ability to recover rockfish populations and the ecosystem within which they reside.

Strategies to recover rockfish populations. A number of strategies have been proposed for rockfish recovery. Chief among these are Marine Protected Areas (MPAs). The efficacy of a network of MPAs is dependent on increasing our knowledge of a number of key ecological attributes of rockfish . These include: 1) An understanding of the degree of connectivity of local rockfish sub-populations via larval dispersal or adult movement. 2) An understanding of habitat use of juvenile and adult rockfish. 3) An understanding of home range size (both the mean and variance) of adult rockfishes. 4) An understanding of the relationship between maternal age and size on reproductive success. 5) An understanding of spatial and temporally variability of rockfish recruitment in Puget Sound.

Rockfish Monitoring. Future management approaches would be enhanced with statistically robust and rigorous rockfish and habitat monitoring to determine: current population abundance and spatial distribution of adult and juvenile rockfishes (i.e. with methods such as remotely operated vehicles); current spatial and temporally variability patterns of recruitment in rockfishes; the collection and analysis of historical fisheries data to better define past fishing effort, species catch-rates, composition and spatial distribution of fisheries, which will assist recovery efforts and provide a contrast to present day populations and species assemblages; habitat use of juvenile and adult rockfish. Home range size (both the mean and variance) of adult rockfishes; the relationship between maternal age and size on reproductive success; benthic habitat mapping and characterization with geophysical tools available such as multibeam echosounders, side-scan sonar, and subbottom seismic reflection profile mapping systems (as has been completed within some of the San Juan Archipelago); and the degree of connectivity of local rockfish sub-populations via larval dispersal or adult movement.

Threats to Rockfish. Our recent status assessment (Drake et al. 2010) and WDFW's 2009 assessment (Palsson et al. 2009) collectively identified a number of areas of uncertainty regarding the possible threats facing depleted rockfish populations. They included: what is the effect of degraded water quality (contaminants, excessive nutrients, low dissolved oxygen, etc.) on rockfish survival, growth, and reproduction? How does predation from high trophic level species such as harbor seals, Stellar sea lions, and lingcod affect rockfish populations (particularly ESA-listed rockfish that typically occupy deep waters as adults)? What risks do rockfish face from the artificial propagation of salmon, lingcod or other species? What is the impact of derelict fishing gear, (particularly gear deeper than 100 feet deep) on rockfish populations and habitat? What impact do changing biotic and abiotic habitat conditions have on rockfish survival, growth and reproduction? For instance, kelp provides critical rearing habitats for juvenile canary rockfish and bocaccio, as well as numerous other fish species. Research of kelp habitat in Puget Sound should be designed to assess the resilience of kelp habitat to stressors linked to anthropogenic disturbance. How does climate regime changes and ocean acidification affect juvenile recruitment and food webs?

Genetic Connectivity. What is the genetic connectivity of populations of key species in Puget Sound, especially relative to populations seeding other areas? This is key for understanding the efficacy of Marine Protected Areas. It is key knowledge for protecting population genetic characteristics.

Migratory Species in the Salish Sea. A source of uncertainty is the relative importance of the Salish Sea versus other places as sources of population change among migratory species. There is little point trying to recover a species in the Salish Sea if the issues are occurring elsewhere. Mathematical models using data across a species range can assist in assessing what factors are likely important and where to look. There are several papers on this subject using birds in the Salish Sea (e.g. western sandpipers, snow geese, and great blue herons). Some careful selection of a few species that will provide insight in and outside the Salish Sea might be worth pursuing.

Bird Declines. Long-term bird declines were one of the primary indicators used to suggest that the Salish Sea was in poor ecological condition. What we don't understand is why those birds are declining. I recommend research focused on understanding the mechanism(s) responsible for these declines so that we can inform conservation actions.

Marine birds. The relationship between emerging toxicants (pollutants of anthropogenic origin such as metals, polychlorinated biphenyls, other petroleum hydrocarbons, pharmaceuticals, and other toxicants) and the survival and reproduction of resident and migratory marine birds in Puget Sound is an area of moderate to high uncertainty/recommended research. Few studies have focused on the mechanisms involved in the incidence of contaminants in fish prey of resident marine birds and the potential bioaccumulative effects of contaminant exposure via the food web. Current monitoring is very limited, and little follow-up work on past studies has been done.

Bird Abundance. A major uncertainty in the conservation of birds is whether trend data reflect real changes in abundance. The conventional approach to monitor birds trends is from counts often spanning many years. At the end, we rarely know how to respond to changes detected in the data. For this reason, monitoring programs need to be designed upfront around hypotheses for change. Hypotheses that are supported by the results will help guide future work to respond to the causes for change and recovery. This approach has been adopted by the US Forest Service and its partners in a hemisphere wide project to track shorebirds.

Western Grebe. The population decline of the Western Grebe requires additional attention. Questions include: are declines due to demographic constraints on birds that consistently winter in Puget Sound,

OR are they do to continental-scale redistributions? In either case, why has habitat quality in the Salish Sea changed relative to other wintering areas? Is it related to changes in prey (forage fish) abundance? Changes in predator communities? Answers to these questions would likely be relevant to other marine birds as well.

Marbled Murrelet. An important line of work would be to better understand the stressors and drivers of the distribution and trend of the Marbled Murrelet, a Threatened seabird that uses Puget Sound waters. Washington's marine and terrestrial ecosystems are linked by the Marbled Murrelet's unique life-history, which requires foraging in coastal waters as well as nesting platforms in large diameter mature coniferous trees. This critical dependence on both marine and terrestrial habitat makes the Marbled Murrelet a key umbrella species and indicator of Washington's coastal ecosystem health. Future change in climate and forestry management is likely to alter the extent and configuration of murrelet habitat.

Bivalves. Value of bivalves as sentinels for ecosystem condition and effectiveness monitoring re: recovery efforts.

Native Oyster. Critical research needs include: Native Olympia oyster restoration and Japonica marina interactions; Native Olympia oyster genetics; Native Olympia oyster restoration and resulting salmonid recovery benefits; Native Olympia oyster restoration and groundfish/rockfish recovery benefits; Native Olympia oyster historical distribution and abundance; Native Olympia oyster's effect on water quality, mineralization of sediments, water clarity, localized ecosystem services, etc.; and Native Olympia oyster habitat values - species richness, trophic interactions, etc.

Dungeness Crab. Dungeness crab is a major fishery resource in Washington State. Little is known about the wild year to year fluctuations in catch and hence the recruitment of crab megalopae 4 years prior. WDFW has embarked on a citizen-based sampling of megalopae in traps on private and public docks throughout the region. These traps are effective samplers and maybe able to tell us about the physical oceanogrpahic parameters that accompany good and bad crab recruitment years. This is an important area for research for sampling, fishery data and genetics.

Ecology of Zooplankton. Key questions that are important for Puget Sound recovery are: What are the zooplankton species that are important to key food web components such as juvenile rockfish, juvenile salmon, and baitfish? How have zooplankton communities changed over time and how will they change in the future (there are several repositories of historical samples that can be utilized)? To what extent are toxicants and pollutants concentrated in and passed through zooplankton? How have key zooplankton players responded to environmental stressors in other regions, and are there lessons that can be applied to Puget Sound? How do zooplankton communities respond to hypoxia, eutrophication, temperature increases, and other environmental changes?

Lack of marine phytoplankton expertise. There is a lack of marine phytoplankton taxonomists with the expertise to identify phytoplankton to the genus or species level. There is also a lack of taxonomists with benthic infauna expertise, which leads to only a few taxonomists analyzing most of Puget Sound samples.

Abundant Species. Why are certain species such as pink salmon and Dungeness crab (recent examples) doing so well? What are the environmental or other conditions that promote the abundance of key species?

Critical Stages. What are the "critical stages" of development (if any) for key species? How do humans affect critical stages? How do environmental conditions affect critical stages?

Sentinel Species. Are we missing key sentinel species that could be used to track ecosystem conditions and recovery goals? Need comprehensive evaluation/comparison of marine and anadromous species. Possibly use a grouping or guild of "juvenile salmonids" as sentinels for estuarine condition. Long-lived species as recorders of changes in environmental conditions.

Non-indigenous species. Key questions that are important for Puget Sound's future health are: What is the extent of invasions of aquatic habitats by non-indigenous (NIS) species? What impact do they have on species that provide important ecosystem services? Can we predict where and when new invasive species may arrive, and can we model their impacts? Are there any practical control or eradication measures that can be used to control NIS? There is a moderate amount of scientific data about some aspects of NIS in Puget Sound. How can we manage important resources that are already impacted by NIS? How do we keep new NIS out of Puget Sound? Some information is known about how ballast water introduces NIS into Puget Sound, but little or nothing is known about the role of fouling organisms on boat and ship hulls. What are the NIS of most concern with regard to the damage they could do and the likelihood that they may be introduced to Puget Sound? What is the quantitative spatial extent of NIS that have already invaded Puget Sound? This would identify the magnitude of the problem and also provide a benchmark for future measurements of the problem.

Mitigation

Beach Nourishment. Does beach nourishment adequately mitigate fish habitat impacts for bulkhead projects that prevent sediments from reaching the beach? A greater understanding of sediment delivery and beach nourishment would allow us to adapt mitigation requirements to fully mitigate impacts to fish habitat.

Fisheries Management. Are we managing our fisheries to take advantage of fish habitat that is being opened up or restored through the various salmon recovery efforts? This research would assist us in managing our fisheries to adequately seed habitat with returning adults to maximize natural production and increase benefit to user groups.

Marine Protected Areas. What is the optimal design for and use of Marine Protected Areas for species conservation and recovery?

Seasonal Work Windows. Nearshore construction and development is currently limited to seasonal work windows that are, in large part, based on the known spawn timing of herring, sandlance, and surf smelt. In many Tidal Reference Areas spawn timing assessment has not occurred across the entire year, making these timing windows inadequate tools for use in resource protection.

Elwha Nearshore Modeling and Monitoring. A number of activities are needed to promote full ecosystem restoration of the Elwha nearshore, including: 1) Model linkages between current habitat extent (for example west estuary extent , use (for example fish abundance) and sediment processes in lower river and shoreline to predict post dam removal sediment fate and anticipated near and long term habitat function response. 2) Develop adaptive management actions to respond to nearterm restoration process. 3) Prioritize additional nearshore long term restoration actions prior to dam removal, specifically augmenting of Elwha bluffs shoreline to optimize sediment delivery and identifying additional restoration actions. 4) Monitoring (lower river, estuary, and shoreline of Elwha and comparative drift cells).

Elwha Nearshore Sediment and Physical Processes. Actions to promote full ecosystem restoration of the Elwha Nearshore include: 1) More detailed and comprehensive sediment mapping and study of

lower river and estuary; specifically extending current sediment mapping in the lower river north to include river mouth. 2) Definition of relative contribution of bluff erosion to sediment budget of Elwha, Dungeness drift cells. Ground based shoreline LiDaR. 3) Expansion of 2009 Lidar study to include estuary, boat and land based Lidar for bluffs along lower river and shoreline, to and including Dungeness Spit; 4)Wave buoys (CDIP). 5) Continue and expand nearshore habitat report and sediment mapping (USGS) update to include: a. Further east and comparative areas; b. Offshore and inshore to include eelgrass area (MLLW-25-30'). 6) Comprehensive assessment of water quality in impounded, east, and west estuary including turbidity and nutriends (both CTD's and hand held YSI readings). 7) Mapping of the historic Elwha nearshore (Brad Collins style study); 8) Monitor of discharge of river from suspended sediments prior to dam removal.

Elwha Nearshore Management. Actions to promote full ecosystem restoration of the Elwha Nearshore include: 1. Develop and implement an Elwha nearshore restoration action plan. Priorities of plan include preservation of Freshwater Bay and lower river nearshore thru property CE/acquisition, ecosystem restoration of the Elwha estuary, and restoration of Elwha feeder bluffs and Ediz Hook. Incorporate feed rate into bluff management. 2. Analysis of sedment projections to estuary and development of adaptive management actions that might be anticipated; 3. Preserve feeder bluffs of Dungeness drift cell, which are comparative sites and of extremely high ecological importance. 4. Identify ELJ sites if any in Elwha nearshore 5. Cost benefit analysis of changing pipeline alignment so not on beach along feeder bluffs 6. Adaptive management priority actions (contingency actions) for sediment processes in river 7. Data clearing house for data managers, data integration, shoreline atlas 8. Continue working with citizens, local colleges and education groups.

Pollution

Toxics

Impact of toxic stressors on freshwater ecosystems. There is significant uncertainty in the ability to track toxic contaminants in freshwater ecosystems; monitoring data are limited in many water bodies. Since most of the contaminants deposited in Puget Sound originate in upland areas and are transported to the Sound via freshwater streams and rivers it makes sense that we have a better understanding of the impact of these stressors on freshwater ecosystems. While the existing Ecosystem Recovery Targets focused on freshwater evaluate "water quality" they provide limited insight on the impacts of contaminants to freshwater ecosystems. For example, neither of the two freshwater based targets would be able to track the high levels of contaminants in Lake Washington fish, or the incidence of coho pre-spawn mortality in streams. While the B-IBI can measure general conditions of stream health and conventional water quality parameters (DO, temperature, nutrients etc, this measure is not currently designed to be sensitive to the effects of contaminants that can be common in many streams. As such, there is significant uncertainty associated with the ability to understand the impact of contaminant stressors on freshwater ecosystems.

PBDE Flame Retardants. A focus on points of entry of polybrominated diphenylether (PBDE) flame retardants should be established so that pollution can be prevented. These compounds have contaminated wildlife, especially top aquatic carnivores (e.g. Orcas) in the Pacific Northwest. With people discarding foam rubber, treated fabrics, computers, and other contaminated materials, there is a very time-sensitive need for containment. Manufacturers may also be important sources.

Toxics Monitoring. Develop an integrated toxics monitoring program that includes marine mammals, fish, and other appropriate models to gain a better understanding of the movement (or lack of) through the food web and a better understanding of those chemicals that are likely having ecosystem impacts.

Health of Biota. What are acceptable levels of toxic contaminants in biota, relative to their own health and the health of their consumers (including humans). Need effects thresholds.

Biota at Population Level. What is the effect of toxic contaminants on marine and anadromous biota at the population and community level?

Bioaccumulative Contaminants. How/where do bioaccumulative contaminants enter the food web? Directly via water-to-pelagic organisms or indirectly via water-to-sediments-to organisms?

Point Sources. We're getting much better at identifying point sources of pollution in the Sound and Hood Canal – this is extremely important and should be a major research focus.

Range of Pollutants. What are we measuring? We only see what we look for and many chemicals are being overlooked, in terms of what's dumped (primary chemicals) and how they react with their environment (secondary chemicals). We need be able to identify a greater range of potential pollutants.

Pollutant Mapping. We should have a map of pollutants in the Sound. It would be a good communication tool and it could be improved as our understanding does. It would be nice to see a Google Earth map where you could focus in and get very local water quality info. Point source introduction of pollutants is a huge contribution, so small scale mapping is very important.

Septic Systems. Sample and monitor the quality of sewage effluent (nitrogen & bacteria, primarily) down-gradient of septic system drainfields that have been designed, located, and installed in conformance with modern septic system rules (1996 – present). The purpose of this monitoring/sampling would be primarily twofold: 1. To gain more certainty on the fate and transport of nitrogen from septic systems (that are <u>not</u> located with 100 feet of a shoreline, which is the super-majority of all existing septic systems); and 2. To better identify the types of septic systems, soils, and/or setbacks that achieve the highest levels of nitrogen reduction (influent vs. post-drainfield "effluent"). There is still a large degree of uncertainty for this area, and many models, decisions, and planning are being made with assumptions that may or may not be accurate.

Source of bacteria in nearshore following participation events. There is uncertainty regarding fecal coliform and enteroccoci bacteria in the marine nearshore following precipitation events and the source of bacteria (e.g., human, domestic animals, waterfowl, etc). Understanding this will help enable better targeting of recovery actions.

Marine sediment toxicity tests as indicator. There is uncertainty regarding the validity of using marine sediment toxicity tests as an indicator of sediment quality. Concerns with these tests have been raised multiple times in the scientific literature and by multiple scientists. A workshop or other gathering of scientists to specifically address this issue has not occurred to date and should be addressed.

Toxics in Marine Food Webs. Through our work with the beached transient orca, CA-189, which showed some of the highest levels of organic pollutants ever found in a marine mammal, we have also become concerned by persistent and emerging toxic compounds in the Salish Sea. Emerging pollutants, such as endocrine mimicking compounds, flame retardants, plasticizers, and pharmaceuticals introduced into marine waters are poorly studied. There is relatively little information available about effects of these compounds on human and wildlife health, ways to reduce human exposure or ways to reduce the loading rate of these compounds into the Salish Sea.

Toxic Chemicals. Additional targeted science on specific sources, transport, and fate of toxic chemicals in the Puget Sound ecosystem would focus management activities on key processes. For example, we found high levels of many chemicals of concern in streams draining commercial lands and agricultural areas under the Toxic Chemical Loading Assessment. Further isolating the sources of these chemicals within these landscapes and identifying effective treatment technologies would inform programs targeting these specific sectors. As another example, refining contributions from roofing materials will improve future management and protect the cleanup sites we have already invested in. For nutrients, pathogens, and other conventional contaminants, we generally lack direct measurements of rate parameters. Most programs focus on assessing levels of contaminants in the environment, and relatively little information is available on the transfer or attenuation of these contaminant sources.

Relative Impacts. We have few assessments that compare relative impacts of multiple sources. For example, a Puget Sound model of flame retardants (PBDEs) or metals such as copper would link contaminant loads to food web components. This could be used to evaluate reductions necessary to meet specific environmental endpoints and to identify the most influential sources. We have moderate information from similar assessments of PCBs but no compilations for these specific parameters.

Runoff from the Built Environment

Lack of marine bacteria on an appropriate temporal and special scale. There is a lack of bacteria data on a sufficiently high temporal and spatial scale for marine nearshore beaches. While a long-term monitoring effort may not be required to address all the uncertainties regarding marine bacteria, a multi-year sampling effort would assist in meeting the marine swimming beach recovery target.

Lack of sufficient data in regard to marine phytoplankton and high resolution nutrient and dissolved oxygen. There is an insufficient amount of marine phytoplankton data available (chlorophyll measurements as well as community structure) in addition to an insufficient amount of high temporal resolution nutrient and dissolved oxygen data to assess nutrient and dissolved oxygen dynamics. There is good communication between the entities collecting the majority of water quality data (i.e., King County, Ecology, and UW) and the newly formed marine water quality working group will facilitate communication between these groups as well as others and should continue to be supported.

Lack of models that discern anthropogenic and natural sources of dissolved oxygen. We know the regions that are the likely places for low DO issues/highest concern, particularly constrained basins with long residence times, such as southern Hood Canal, and various southern end-bays and inlets, however, we are still parsing apart the anthropogenic signature from natural/ocean-derived nutrients in these areas. We need better primary production modules which are ecologically self-organizing to improve the quantification of the uncertainties and help refine research needs (better data to capture the diversity of the pelagic ecology, for example, may be needed to adequately capture DO dynamics). In addition, although loading estimates have been generated, the lack of gages for quantifying the total streamflow/load for various streams (downstream of stations/ungaged flows) in the PS watershed still compromises the quality of these estimates, which should be refined (as models are improved and more data become available).

Sampling and Testing. Further sampling and testing, such as molecular typing by smaller organizations might be indicated to elucidate pathogen source(s) and help mitigate their deposition into Puget Sound in coordination with local stakeholders and OH scientists. Such findings can help encourage coordination amongst regional stakeholders, such as wildlife, environmental and human health agencies, and OH scientists to improve upon prevention of outbreaks of waterborne pathogens and to coordinate

response should pathogens be detected. The OH approach will consider multiple aspects of pathogen detection and distribution, including pathogen surveillance and determining if they are of animal or human source. These aspects will involve local, state and federal regulatory responsibilities and constituent water use, and are best addressed at the community level where local stakeholder priorities and possible solutions can be evaluated together for the most optimal outcomes.

Source of Pathogens. The greatest scientific uncertainty is the source of pathogenic bacteria, fungi, protozoa viral diseases that have been identified, and the need to compile this data to: 1) compile a baseline, and 2), start to investigate sources of pollution and the degree of risk to the public and natural resource to reduce sources of water pollution and drive management of those sources that can be related to population growth.

Monitoring Gaps. We lack monitoring data that lead to uncertainty in our understanding and modeling of dissolved oxygen dynamics. We have extremely limited information on vertical particle flux, yet the oxygen drawdown is directly related to this rate. In addition, we have some recent monitoring programs focused on Admiralty Inlet and the Tacoma Narrows, but additional information is needed to characterize the movement of oceanic and other water masses. We have extremely limited information on pH and ocean acidification.

Nutrient dynamics. One key question to address for Puget Sound recovery is nutrient dynamics and the biological response to nutrients and subsequent effect on dissolved oxygen concentrations. While monthly nutrient data are available throughout most of Puget Sound, there is some uncertainty about nutrient pathways from incoming oceanic water, particularly on a finer temporal and spatial scale. In situ monitoring systems will assist with this temporal aspect of uncertainty, but these systems are only in limited locations. The amount of information available on nutrient pathways is moderate at best. There also is a large amount of uncertainty regarding the biological response to nutrients as monthly chlorophyll data are inadequate for assessing phytoplankton response to nutrient availability given the timescales on which phytoplankton can respond. In addition, little data are available for phytoplankton community structure (even at the broader taxa level) and their response to nutrient inputs. This is an area that needs improvement in order to address nutrient-phytoplankton-oxygen dynamics Puget Sound-wide and provide information for the dissolved oxygen recovery target. We urge continued diligence on this topic as ongoing studies by the Department of Ecology relating to dissolved oxygen in Puget Sound, given the importance of developing effective targeted solutions to address these problems. (Note: there are also data needs associated with understanding the extent and cause of harmful algal blooms, although it appears that these are being addressed by others, e.g. NOAA's ECOHAB and PS-AHAB projects).

Fate and transport, and source identification, of anthropogenic nitrogen. Although much work has been done in the region to quantify and evaluate the fate and transport of nitrogen into sensitive areas of the Puget Sound (e.g., Hood Canal, Quartermaster Harbor, South Sound) there remains a large amount of uncertainty regarding fate and transport. This affects the ability to formulate management responses and effective strategies. Innovative measures, such as utilizing emerging contaminants as tracers or pathway indicators, is needed.

Dissolved Oxygen in Hood Canal. Low dissolved oxygen is an issue in Hood Canal. The most significant uncertainty is the amount of human related nitrogen from the near shore on-site septic systems that results in drawdown of dissolved oxygen during the critical summer months. Reducing the uncertainty is essential to developing corrective action to improve the dissolved oxygen in Hood Canal and reduce the stress on the marine life.

Hood Canal Monitoring. There is a need for a sustained marine monitoring program for Hood Canal within the Puget Sound Partnership (PSP) Biennial Science Work Plan. There is a need to continue certain aspects of marine monitoring in support of corrective action recommendations and evaluation of implemented actions. Monitoring the marine system is useful as a gauge which reflects the terrestrial input, the marine dynamics and the scale of natural variability. In the long run there will be monitoring needs focused on specific regions of Puget Sound which will be integrated regionally. The Hood Canal marine monitoring program should serve as component to the larger Puget Sound marine monitoring program as yet to be detailed.

Wastewater

Chemicals of emerging concern. A significant area of scientific uncertainty lies in the lack of understanding, on many levels, regarding chemicals of emerging concern (endocrine disputers, pharmaceuticals and personal care products, PFOS, Bisphenol A, etc.). While some monitoring programs and special studies have evaluated a handful of these chemicals, most are not routinely monitored. While little is known about the presence of most of these chemicals, even less is known about their potential to cause adverse effects to both aquatic life and humans in the Puget Sound region. Limited data collected by NOAA and WDFW suggests that chemicals capable of disrupting the endocrine system are present in Puget Sound at levels sufficient to cause reproductive impairment. However, the specific chemical(s), responsible, and the degree and spatial distribution of this impairment throughout the Sound has not been specifically identified. A better understanding of the specific causal agent(s) is necessary before any action to address the issue can be identified.

Emerging Contaminants. By definition, emerging contaminants warrant additional information to determine sources, transport, and fate in the environment. Early work also could focus on the degree to which current source control or treatment technologies are successful. Also by definition, we have anecdotal evidence sufficient to raise the question for specific emerging contaminants.

Loading of emerging contaminants. Emerging Contaminants can be thought of as chemical species that are being produced in significant quantities anthropogenically and have the potential to be toxic to both human health and the environment, but are currently unregulated and for which well-developed analytical methods do not yet exist. These compounds are typically small organic molecules such as caffeine, ibuprofen, triclosan (an antimicrobial agent), etc. Emerging contaminants may be valuable as chemical markers of anthropogenic inputs (i.e., wastewater effluent, agricultural runoff, stormwater) to the Puget Sound. Method development is needed to allow accurate quantification.

Shellfish

Shellfish and DSP. The greatest area of uncertainty for Department of Health is estimating impacts to humans through shellfish consumption related to DSP. This relates to the absence of monitoring data for this biotoxin. For mechanisms related to distribution of and triggers for DSP, key questions are basic information on presence and distribution in Puget Sound shellfish. For interactions, the key question relates to interactions of temperature, climate, nutrients, and timing of DSP blooms. For responses, the key question relates to whether shellfish will continue to have DSP after remediation actions such as decreased nutrient outputs from septic systems. Qualitatively, the information we have to support our assessment of uncertainty is low – the presence of DSP is new to Washington. However, there are some papers from nearby waters in British Columbia. We are missing information on when and where DSP occurs in Puget Sound and on what triggers toxicity. For human health, DOH has interest in understanding and reducing pressures via septic systems, agricultural practices, industrial waste,

pollution (runoff from roofs, pilings, etc.), pharmaceuticals in wastewater treatment and other non-point sources. The DOH laboratory must have new equipment to be able to test for this toxin. Public health cannot be adequately protected if this capability is not developed.

Other

Plastics in the Marine Environment. PTMSC has been involved in evaluating plastics in the marine environment and plastics ingestion by marine fauna. We sampled beaches in all twelve US Salish Sea counties and documented the ubiquitous presence of large and small plastic debris in beach sediments. We also documented the ingestion of plastics by seagulls. Based on our analysis of research done regionally, more research could be done on ingestion of plastic by other species in the marine ecosystem. The degree to which plastics act as vehicles and attractants for lipophilic toxic compounds needs further study, as does the impact of plasticizers such as phthalates leaching from degrading plastics. The fate and transport of plasticizers, their movement in the food web, and their impacts on human and wildlife health need more study.

Marine Debris. We need to classify, quantifying identifying the source of, and remove debris from the marine environment. Key unanswered question: Identifying the debris sources. Are our watersheds in fact 'debris sheds.' It would be useful to our understanding of the Salish Sea to understand debris in other areas. There are other collection and identification programs but there appears to be no overall Puget Sound data gathering effort. Debris (components and amounts) varies greatly within the Salish Sea.

Variability. Our monitoring programs indicate a variety of hotspots in the ecosystem and overall ambient conditions but may not capture high spatial or temporal variability. We should identify parameters and media where continuous monitoring and remote sensing investments make the most sense. We have moderate information based on recent advances in ferry-based data platforms, profilers, and remote sensing.

Climate Change

Future impacts from climate change. It presents several key questions affecting Action Agenda, including "How will ocean acidification impact our food web?" How will climate change impact species ranges, including invasive species, and how will those range shifts impact health of our ecosystems? How will climate change impact timing of migrations and movements of species that depend on one another for one or more critical stages in their life histories? The Action Agenda and Biennial Science Plan should recognize and consider these questions.

Ocean Acidification. We need aggressive evaluation of baseline conditions so we can understand degree of ongoing change.

Temperature Monitoring. Monitoring of stream and lake temperature, especially during summer, would provide valuable information for planning for and adapting to climate change. Almost no temperature monitoring is conducted in Washington, but it increasingly simple and inexpensive to monitor.

Benthic Communities. Changes to benthic communities in relation to habitat and climate change require additional attention.

Climate variation. There is a growing body of evidence that climate variation (including cyclic variation like PDO and longer-term anthropogenic change) affects shellfish performance in many ways, with potential influences through trophic interactions (including for scoters, a marine bird of concern).

Genetic Variability and Adaptation. Have populations lost genetic variability to the point where they have diminished abilities to respond to changing environments? What are the molecular connections between genomic variability, adaptive gene complexes, and factors limiting population recovery?

Weather Station Data. We should have all the public and private weather station data stored in a repository so we can track climate change. Such a large data set would be extremely valuable to the people trying to evaluate Sound conditions in 30, 50, 80 years. A changing climate will result in changing vegetation and other biotics. Warmer stream water, for example, acts as a viable host for more types of bacteria. If we know how the climate is changing, we can predict what new biotics we might expect.

Human Dimensions

Social Science. There is a profound need to invest in robust, peer review quality social science of Puget Sound conditions, management effectiveness and opportunities. This includes sociological, anthropological, economic and legal studies. Human dimensions research should be linked to natural and physical science research. Management, as a social construct, must be informed by detailed assessments, not hunches, to identify 'best practices'. Furthermore, while important, further ecological and oceanographic studies will not identify management options or opportunities. Numerous examples (California MLPA, Australia Great Barrier Reef) have clearly demonstrated the need for empirical, applied social sciences. It is surprising that this has not been an emphasis to date.

Baseline Literature Review. A baseline social science literature review is needed to identify current resources and determine where gaps remain. This literature review would include studies directly pertaining to Puget Sound. It would also incorporate studies from other major basin systems in the nation (e.g. Chesapeake Bay, the Everglades) for relevant findings.

Public Engagement Assessment. Recognizing different demographics' role and connection to ecosystem services there is a need to complete a comprehensive characterization (baseline data collection effort) and evaluation of public engagement in support of ecosystem recovery (behaviors, patterns, preferences, etc.) including citizen science, stewardship, and changes in behavior. This knowledge will inform programmatic design and implementation over time. Engaging the arts, religious groups and other non-traditional communities would be a means by which to expand "public" support, involvement, and engagement over time.

Human Dimensions and Open Standards for Conservation. The human dimensions portion of the Open Standards for the Practice of Conservation Framework should be completed. This would involve the development of a conceptual model of contributing factors for our current state of the ecosystem as a means to define objectives/outcomes needed to advance ecosystem recovery goals for the human dimension of the ecosystem. This framework could be refined for unique "place based" analysis such as is being done by the Hood Canal Coordinating Council. Human dimension indicators and targets could then be developed based on individual area's stressors and valued social, economic, and cultural components.

Ecosystem Services Valuation. Ecosystem restoration and enhancement is not just good for the environment, it is good for people too. That is, people derive benefits from services provided by a healthy environment. To achieve recovery goals, the Partnership must measure the process and

effectiveness of recovery not only in terms of ecosystem health, also in terms of the impacts that recovery has on people. Numerous studies have been conducted to estimate the value of marine ecosystems (Pendleton, 2008; coastalvalues.org/work/reseources.html), including studies of the economic values of restoration in other parts of the United States (Austin et al, 2007). But few studies have been conducted that show empirically that restoration and preservation have had an effect on human uses of ecosystem services. This is particularly true for the Puget Sound. It is recommended that the PSP invest in ecosystem service valuation studies that cover a range of provisioning, regulating, and cultural services as outlined in the Millennium Ecosystem Assessment Framework.

Economic Incentives. There is a wide array of economic incentives, including tax reductions, conservation easements, transfer of development rights, and fee simple land purchase. We need research to determine the most cost-efficient combination of regulatory and voluntary programs for controlling the conversion of native habitats to residential development.

Habitat Value. What is the biological/production value of ALL habitats and how does this value vary over time?

Fisheries. There is uncertainty about the economic and social impacts of closing fisheries because of low population abundance, including impacts on commercial and recreational fishers and on related industries (boating, stores, bait suppliers, etc.).

Sustaining, Coordinating, & Using Science to Adapt Actions

Building capacity

Institutional Analysis. There is a need apply institutional analysis to the overall management framework to evaluate where the PSP (Shared Strategy) approach is the most efficient and effective. This research could take the form of institutional/management mapping, network analysis and an evaluation of existing social capital and organizational capacity (within and across institutions) to achieve ecosystem recovery goals. Are there other models that might work better to reach ecosystem recovery goals? It is time to readdress opportunities and constraints to more effectively and efficiently restore the Puget Sound. An outcome from this analysis would be to increase the capacity for institutions, NGOs, and the tribes to work better together, recognizing the need to bridge (in particular) western and tribal values and management approaches.

Interdisciplinary Coordination. Lack of coordination between social, natural, and physical science disciplines is a factor impeding development of realistic recovery strategies. Researches should help each other understand the meaning and relevance of their work. It is also necessary to coordinate with user groups and the public.

Governance. The strengths and weakness of the current Puget Sound governance system is poorly understood. The last overarching study was in the early 70s by Bish. Management seems to be operating on a basis of available opportunities and policy maker understanding of what is feasible/preferable. The global standard is to base management decisions on applied social ecological research.

Ensuring adequate scientific basis of actions. In efforts to update the Action Agenda (and identify near term actions), and haste to implement them, the Partnership should not lose sight of the need that they be supported by best available science (evidence) to demonstrate that they will be both effective and cost-effective. This requires work in the natural, physical, and social sciences. The public will demand that actions be effective and a good expenditure of funds, and failures of actions to produce

demonstrable results (because they were determined in the absence of science, or with poor application of existing science) will undermine public confidence, waste resources, and be detrimental to the overall effort. Uncertainty will always exist, but there should be a scientific basis that each action is truly needed (will be effective, and cost-effective). At the same time, it is important to scientifically test assumptions that certain activities are not problematic (and thus not included) simply because of lack of knowledge (i.e. to challenge, assumptions that no action is needed because it has not been shown to be a problem). Simply put, focused scientific work should help confirm that actions are likely to be effective and nothing big is missing.

Foundational Questions

Need for additional work at appropriate ecosystem scales. The partnership should promote a scaled approach to ecosystem recovery (including salmon protection), considering both the larger (whole species populations and ecosystem processes) in addition to individual projects / basins (implementing concepts described in the attached article). For example, successfully seeing such a vast area truly recovered would necessitate "recovering" even vaster areas (parts of the Pacific Ocean, for example) as well as witnessing changes in other socio-economic and Tribal/First Nations variables such as harvesting – not just in Puget Sound, but everywhere that impacts biology and ecological processes in Puget Sound. There need to be mechanisms that ensure and oversee inter-jurisdictional cooperation to understand how individual projects affect populations affect entire populations and communities of fish.

Land Use and Marine Environments. In Puget Sound, urban development, shoreline alteration, agriculture, industrial development, logging among other human activities are the major pressures on estuarine and marine species. While the PSP recognizes this, quantitative links between land use / land cover and Puget Sound marine species and food webs is lacking. Filling this research gap requires investigations of when, where and how land-based human activities influence ecosystem function in Puget Sound marine environments.

Conservation. We need more information on how to maximize values of land-use conservation approaches to aquatic and terrestrial systems simultaneously. That is, how do we structure land-use patterns (at whatever level policy decides) that maximize benefits to both aquatic and terrestrial biodiversity at the same time?

Lack of awareness and general confusion about the spatial distribution of biological values and land use effects. Simplistic or "one size-fits all" approaches leads to poor understanding of the problem(s) as well as unclear, unachievable, ineffective and sometime counter-productive goals, objectives and actions and undermines credibility of the science.

Differentiating between natural variability versus human-driven change. In assessing effectiveness, there is insufficient understanding about the role of natural variability in space and time versus real land-use driven change. For example, B-IBI scores are good predictors of very bad conditions (urban and sub-urban development) but there is high variability among scores in rural areas. Similarly, variability of salmonid use is very high outside urban and sub-urban development densities and there is a poor understanding of how site and reach-scale conditions contribute to variability in diversity, abundance and productivity of biota. Understanding natural variability is key to differentiating between natural vs human-caused change, assessing effectiveness of actions and for development of effective strategies to protect and restore critical biota and habitats.

Historical Conditions. What are the key aspects of historical conditions that we need to understand? Changes in nutrient regimes? Long-term cycling in abundant species e.g., herring and pink salmon? Oscillations or changes in climate condition?

Pristine Areas. What are baseline ecosystem conditions of pristine areas?

Historical Studies. There is a need for historical (e.g., paleo) ecology studies to document the post glacial (especially modern human) biological character of the system.

Spatial distribution of biological values. Identifying important and un-important places – Not all places/habitats are equal but they are often treated as such. The question of what areas have very high and very low intrinsic value or that are so heavily constrained by existing development that they are unlikely to provide much biological value beyond current condition is important for prioritizing time, money, level of regulations, etc. King County undertook such an evaluation in 2004 as part of its regulatory update (http://your.kingcounty.gov/ddes/cao/PDFs/mapKC-BasinShorelnCond-15051AttachA.pdf) and has made additional similar efforts. This is particularly important in regard to the Partnership's role in targeting and prioritizing actions.

Scientific Tools for Informing Policy

Marine Spatial Planning. We are zoning the terrestrial environment and considering impacts but are not devoting similar efforts to the marine environment. This requires a better understanding of the distribution of species and habitats and a better integration into a comprehensive GIS product.

Mapping. Location and inventory of physical features and biological resources in Puget Sound – continue efforts to map these characteristics in compatible layers.

Key Stressors. Research to advance our limited understanding of the magnitude and spatial extent of key stressors in Puget Sound. This information is needed to prioritize work to minimize stressors.

Prioritization. How do we prioritize recovery efforts and identify important gaps in these efforts? Use ecosystem models to help with this?

Adaptive Management. We need to have an adaptive management plan and science agenda that can assess the ecological consequences (validity) of watershed characterization for terrestrial, freshwater aquatic and nearshore biodiversity.

Integrated, sustained monitoring

Intensively Monitored Watersheds. There is a need to better understand the effectiveness of stream restoration activities by continuing, and expanding where appropriate, the Intensively Monitored Watersheds (IMW) Project.

Restoration Project Monitoring. Monitor the success and longevity of permitted restoration projects across Washington. Many projects, such as road crossings, large wood placement, etc. likely fail, but we cannot make improvements because we have little information on rates or causes of failure.

Hydraulic Permit Authority. Monitor and measure compliance and effectiveness of the Hydraulic Permit Authority program.

Critical Area Ordinances. Monitor and measure compliance and effectiveness of GMA critical area ordinances.

Integrated Monitoring. Develop a monitoring plan that integrates bird, mammal, salmon, forage fish, and zooplankton monitoring in space and time (perhaps from the same vessel) to come up with an integrated assessment of ecological condition.

Effectiveness Monitoring. A key component missing from many management programs is effectiveness monitoring. Effectiveness monitoring of environmental endpoints must be conducted in conjunction with source control and other management actions to evaluate whether they are reducing contaminant inputs. Effectiveness monitoring information is critical to our adaptive management strategy.

Assessment and Monitoring. There is a need for broad (spatially, temporally, taxonomically) biological assessment and monitoring that incorporates the full range of natural and anthropogenic gradients into sampling designs.

Type and extent of monitoring data for ecosystem recovery targets. Monitoring data are necessary for the success of the recently developed Ecosystem Recovery Targets. However; as budgets for local, regional and state monitoring programs continue to be cut, it reduces the availability of monitoring data to track ecosystem changes defined by the targets. This increases the uncertainty associated with the ability to track ecosystem changes and our ability to meet the targets. To more effectively target limited monitoring funds, a better understanding of the specific data needs necessary to effectively use the targets to track progress and conditions would be desirable. What type(s) of data (and how much) are necessary to determine if we are meeting the targets? What is the spatial distribution/scale of data necessary to make meaningful conclusions on a Sound-wide or regional basis? The Ecosystem Recovery Targets have been showcased as a key tool in the recovery of Puget Sound; however, in some cases data may be insufficient to both establish a baseline from which to measure change and to understand if we are meeting the defined goals. A number of issues related to data needs necessary to track the targets need clarification to better focus limited monitoring funds.

Dashboard Indicators. Develop more scientifically driven dashboard indicators (appropriate sampling design)

Education, training & outreach

Education. Organism (health and condition) "tell us" about problems in the ecosystem. How can we use this to help educate people about key problems? How do we get the message across that Puget Sound is not ok? We should encourage people to act locally by educating residents about PS conditions where they live. How do we make the emotional connection with people are: the problem of "death by 1000 cuts" that seems to be occurring?

Pollution Education. The Town of Friday Harbor Sewage Treatment Plant takes care of pathogens and some chemicals but the manager said that if someone dumps turpentine down the toilet it is about the same thing as pouring off of the dock. A project could be done to engage local communities. Take a baseline sample establishing a panel of 8 to 10 of the most pernicious chemicals contributed by residential use followed by 12 more monthly samples. Implement a well defined duplicatable advertising campaign involving the local paper and the schools. The idea is to use creative advertising that clearly makes the link between what goes down the drain and the food chain. The goal is to change the chemical loads by using preferred products.

Education and Outreach. It is critical that the PSP recommend the use of effective education programs - education and outreach that leads to real change that is appropriate and specific to various populations. There is a need for research that investigates impacts of experiential education and how elements found to be most successful can be translated to others.

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Jeff Gaeckle, Washington State Department of natural Resources
Joseph K. Gaydos, The SeaDoc Society at the UC Davis School of Veterinary Medicine
Tom Good, NOAA Fisheries
Keith Grellner, Kitsap County Health District
Bob Hager, Lower Hood Canal Watershed Coalition
Dan Hannafious, Hood Canal Salmon Enhancement Group
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Tom Hom, NOAA Fisheries
Fred Jarrett, South Central Action Area Caucus Group
Jennifer Johnson, Governor's Salmon Recovery Office
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Mindy Roberts, Washington Department of Ecology
Laura Rogers-Bennett, University of California, Davis
Michael Schmidt, Long Live the Kings
Anne Shaffer, Coastal Watershed Institute
Dan Tonnes, NOAA Fisheries
Kenneth Warheit, Washington Department of Fish and Wildlife
Dave White, King County Department of Natural Resources and Parks
Bruce Wulkan, Puget Sound Partnership
Rochelle Labiosa, Environmental Protection Agency
Andrew James, Center for Urban Waters
Justin Miller-Schulze, Center for Urban Waters