APPENDIX E: Inventory of Recommended Studies

Rec. No.	Action Agenda Area	PSA No.	Recommendation title	Recommendation Description	General Commentary
R1	Habitats	1	Areas of special significance to tribal people	Develop a mechanism to define areas of special significance to the tribal people from this area. This information is critical in determining what areas should receive special attention for restoration and what areas will receive increased resistance to development.	
R2			Changing species composition in freshwater ecosystems	How will freshwater ecosystems be affected by the changes in species composition that are likely to result from climate change, land use alteration and species invasions?	
R3		1	Status of lowland lakes	What is the current status of lake health in the Puget Sound Lowlands, and what challenges and opportunities exist to protect these ecosystems in the future?	
R4		3	Detecting change in freshwater ecosystems	What are reliable scientific metrics for detecting chronic, long-term changes in the freshwater ecosystems of the Puget Sound Lowlands?	
R5	Floodplains		Floodplains: the combined effects of sea level rise and changing flow regimes	Estimate the combined effect of sea level rise and increased river flows on inundation in tributaries to Puget Sound. Floodplains are frequently host to conflicting priorities associated with environmental restoration, economic development, and recreation. In these areas, decisions regarding restoration and land use priorities require information on the likely changes in flood risk with climate change. In spite of this need, little has been done to evaluate the combined effect of these on inundation associated with flood events. The science of climate change impacts on sea level and river flows have both matured to the point where robust projections can be made: what is lacking is the integration of the two.	
R6			Floodplains: effects of climate change on flood risk	Develop analytical tools to evaluate the effect of restoration and changes to floodplain infrastructure on future flood risk with climate change. Conservation groups are increasingly working with private land owners and other stakeholders to collaboratively identify solutions that benefit all parties. Proposed land use actions often lack quantitative information on the likely impact of changes on flood risk, in particular with climate change. Models are needed that can integrate new land use change scenarios with sea level rise and increased river flooding and identify changes in flood risk across the floodplain.	
R7	Species and food webs	8	Salmon habitat improvements	What are accumulative effects of small barriers and road culverts on salmon population health, and what is the optimal strategy for removing these barriers to maximum ecological returns on economic investments?	
R8		8	Interactive effects of multiple stressors on salmon	How do Pacific salmon populations respond to the independent and interactive effects of multiple stressors that include anticipated changes in regional climate and human land-use, and the continued invasion of non-native species?	
R9		8	ESA and Salmon/steelhead	What habitats or habitat characteristics for salmon and steelhead species are likely to be irrevocably lost and what and where are realistic restoration and recovery goals for existing species and habitats? To what extent might an improved understanding of the historic losses and variability help set the context for the future and what are future potential(s) for recovery? Particularly for salmon, what assurances are there that productivity gains through habitat restoration will not be undone by management that reduces population diversity and fitness?	
R10		9	Stormwater and salmon	Understand the impact of copper in stormwater on salmonoids. (Supports PSA9)	
R11		10	Freshwater invasive species	What is the vulnerability of freshwater ecosystems to the introduction, establishment and impact of non-native species and what changes in management and policy are needed to minimize current and future invasion risk?	
R12		10	Climate change effects on vulnerability to invasive species	How will changes in land use and climate affect factors that facilitate species invasions and how will invasive species influence the Puget Sound Partnership's recovery strategy?	
R13		10	Public's role in control of invasive species	How can the public be better engaged to help prevent and control invasive species?	
R14	Freshwater	11	Development of a habitat values and functions assessment tool for Puget Sound lowland streams.	Rationale: Values and functions assessments are necessary for establishing the value of mitigation and would be particularly useful for establishing mitigation bank debit and credit tools. We have a system for wetlands, but not streams.	
R15		12	How will climate change affect other Puget Sound protection and recovery actions, especially with respect to river and stream flow and temperature?	Climate change (including natural variability) is, and will be, a strong driver of Puget Sound environmental responses. Hydrologic modeling tools that are able to provide estimates of historical, current and future flow and temperature conditions (perhaps other water quality conditions in the future) should be supported well enough so that they are maintained and refined and the results can be made to the Puget Sound research community. Models of Puget Sound hydrology and river and stream temperature have been developed that indicate that future changes in flow regimes and temperature will result in changes in aquatic habitat that may not be as favorable for coldwater organisms, including salmon. These tools should be supported, maintained and refined and the information used to establish benchmarks (see above) and provide context for other monitoring and assessment activities.	
R16		13	Nearshore sediment budgets	Develop detailed sediment budgets for selected littoral cells. Investigate erosion rates, sediment sources, and patterns of long-term shoreline change in order to improve understanding of beach behavior and sensitivity to changes (natural and anthropogenic) in sediment supply, sediment transport, and long term sea level changes.	Several years ago, a small workgroup coordinated a state of the science workshop on the issue of shoreline armoring on Puget Sound (http://pubs.usgs.gov/sir/2010/5254/). Several papers within this document included lists of research and information needs. The following are a few I've liberally selected and adapted, but that I believe should be included in priorities.

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R17		13	Nearshore database	Undertake a program to complete major regional nearshore datasets. This includes high resolution coastal topography/bathymetry from laser and acoustic surveys, the development of a sound-wide shallow water wave model, and a comprehensive model of sound-wide water level information. This information is an essential basis for many additional types of technical analyses.	
R18		13	Nearshore sediment supply	Investigate the response of Puget Sound beaches to changes in coastal sediment supply and the resulting implications for beach ecosystems. Consider natural variability in sediment supply, changes due to shoreline armoring and watershed development, and the potential influence of accelerated sea level rise. Link physical changes to beach morphology and substrate to the condition of shoreline ecosystems, such as submerged aquatic vegetation, forage fish spawning substrate, and back-barrier habitats. Results will help guide protection and restoration strategies at both local and regional scales.	
R19		13	Nearshore modeling	Initiate a long-term, multidisciplinary investigation of Puget Sound beach systems at multiple spatial scales. The objective is to improve understanding of ecological responses to physical conditions and sediment dynamics at site, drift cell, and regional scales, with a specific focus on improving protection and restoration practices. Use a collaborative approach and seek complementary funding sources to serve research, educational, and management needs. Consider modeling after concept of "intensively monitored watersheds."	
R20		13	Nearshore responses to sea level rise	Investigate the impact of accelerated sea level rise on Puget Sound beaches. Combine empirical studies with numerical methods to examine changes to erosion rates, sediment budgets, and beach characteristics, with an emphasis on understanding how this may impact beach ecology and the efficacy of various protection and restoration strategies.	
R21		13	Nearshore recovery and adaptive management	Develop adaptive management program based on existing and planned restoration projects on Puget Sound beaches. Beach projects, such as removing seawalls, beach nourishment, and restoring stream mouths and barrier estuaries, are opportunities to learn in a controlled fashion about beach processes and responses to human actions.	
R22		13	Nearshore responses to armoring	Undertake detailed studies of armored and unarmored shorelines. Employ well-designed empirical analyses of paired sites or other reference comparisons. Include environmental data (waves and water levels), coordinated physical and biological measurements, and a variety of spatial and temporal sampling strategies.	
R23		13	Role of orgainic material on food webs	Investigate the role of large wood, detritus, and beach wrack in beach ecosystems and in sustaining nearshore food webs. Consider the role of these features in forming and maintaining habitat and in influencing physical processes such as sediment erosion and deposition. Recent work both locally and in other regions suggests that beach ecosystems are strongly subsidized by inputs of organic material from elsewhere.	
R24		13	Nearshore responses to disturbance	Evaluate nearshore biological and physical attributes that respond to pressures from human disturbance, such as riparian vegetation, wood, and sediments on beaches.	
R25		13	Effects of armoring	Research the effects of shoreline armoring on the nearshore, focusing on ecological functions and physical processes at drift cells with differing levels of percent armored to try to identify any "thresholds" of armoring	
R26		13	Develop sediment budgets for Puget Sound net shore-drift cells to increase our understanding of restoration and conservation needs for maintaining habitats and recovering dependent species.	The Puget Sound nearshore has been identified as critical habitat for juvenile and adult salmon, and a host of other important species. We have mapped many of these species and are on track to understand the interactions of a wide variety of micro habitats and interactions between species and habitats. Yet we have not advanced the understanding of the habitat-forming processes of sediment erosion, transport, and deposition beyond a basic level. We have not devoted the resources of the amount of time needed to define sediment budgets and changes to them over time. This will take more effort than on more rapidly eroding and higher sediment transport coasts common in the US, as our coast is much more crenelated and has slower rates of change.	

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R27	Habitats	13	Develop sediment budgets for Puget Sound net shore-drift cells to increase our understanding of restoration and conservation needs for maintaining habitats and recovering dependent species.	This is supported in the Recommended Future Analysis section of the recent key PSNERP document: Strategies for nearshore protection and restoration in Puget Sound. Puget Sound Nearshore Report No. 2012-01. Two of these are quoted here: Table 67 – Recommendations for future planning analysis of nearshore ecosystems (from page 91): 6. SEDIMENT BUDGETS Data resources and modeling strategies for cost effective planning of protection and restoration of sediment supply in diverse and complex sediment systems. The ultimate challenge is to define targets for protection or restoration of sediment supply based on the sensitivity of systems to sediment starvation. This will require much higher quality data than proposed under beach classification and proposed feeder bluff mapping, and development of strong field data from representative sites in Puget Sound. BEACH CLASSIFICATION Develop and apply a model to estimate the ability of beach systems to provide ecosystem services. Such a model should incorporate additional physical attributes including slope, sediment source, watershed condition, and stream mouth structure, as well as the biological structure provided by eelgrass, kelp, or coastal forest, while resolving the extreme variation of beach system length, using more precise estimates of sediment source, and with a more sophisticated framework for integrating barrier embayments, and the interactions between beach systems in creating and sustaining barriers and barrier-type embayments. The use of sediment budgets and sediment management plans is common in other areas of the US and in the world. The Puget Sound region has not advanced to this stage yet, and needs the scientific understanding of our more complex, finer scale, and more slowly evolving coastal systems of our sheltered coasts to advance. This lack of understating is hampering both protection and recovery efforts. Questions we know are important and have general understanding of but lack	What is lacking most is not the lack of understanding of stressors and impacts to our nearshore and terrestrial environments, we have a very good understanding of individual stressors and problems. We do not have a thorough understanding of how all of these work together--but we do not need that to increase the habitat restoration, stormwater management and other water quality improvements, and developing effective means to bring the public along for action. In other words, what we need is the political will and funding to put restoration, retrofit, and treatment projects in place at a much faster rate. We also need less studies of studies (constantly re-compiling the same incomplete data sets and studies), which in the Puget Sound area more than anywhere else I have observed, wastes an immense amount of time, energy, and money--all of which are in short supply.
R28		13	Are Puget Sound beaches sediment-limited?	Has armoring of Puget Sound shorelines left beaches "sediment starved", or are other sediment sources sufficient to keep beaches in an equilibrium? This effort will require a detailed sediment budget and probably historic-current comparisons. [This was described as a real research priority, "of the type that are desperately needed to have the ammunition for effecting change (eg in regulations)".]	
R29		13	Intertidal bluff and spit restoration response to large scale river restoration: restoration gaps, ecosystem services, and management opportunities.	The Elwha River is undergoing a world scale restoration event with the removal of two large in river dams. The nearshore links the Elwha watershed to the coastal and Salish Seas. Located along the southern shore of the central Strait of Juan de Fuca, the Elwha nearshore extends total approximately 11 mile or 1331 acres. The Elwha nearshore is a high energy shoreline that is ecologically impaired due to sediment starvation primarily from shoreline alterations including diking and bulk heading along the majority of shoreline (Parks et al 2013; Shaffer et al 2012; Shaffer et al 2008). Unlike the Elwha watershed, which is largely (83%) in Olympic National Park, the approximately 11 miles of Elwha nearshore are within a complex matrix of city, county, state, Tribal jurisdictions, and private landowner management. This project is identified as a top priority in the NOPLE three year strategies, Shared Strategy (2007), the Olympic Peninsula Chapter of the Puget Sound Chinook recovery plan, and the Puget Sound Partnership Strait Ecosystem Recovery Action Plan. It acts directly on top priorities identified in the 2012 Elwha Nearshore Consortium (ENC). NOPLE watershed ranking: Elwha: 5, WRIA 18 nearshore 4.27 (the top rankings). This project is time sensitive. The dam removal project is almost complete. Approximately 2.7 mcm (around 30 % of the total 18,000,000 cubic meters) of sediment from dam removal phase that is expected to be delivered to the nearshore within five years of dam removal is estimated to have reached the river mouth. Dam removal sediment should begin reaching the bluff and spit shorelines within three years. While some research is underway to define fine sediment fate offshore there is no work modeling intertidal sediment delivery. Timing is therefore critical to define restoration actions now and implement highest priority actions asap.	Our priorities focus on defining-for the first time- key functions of coastal nearshore systems, with an emphasis on the north Olympic Peninsula/Strait of Juan de Fuca, and the intended goal of nearshore restoration of the Elwha , and protection of the Dungeness drift cell-key Pacific Northwest watersheds. We've looked over the PSP priority actions for 2011-2013 and offer it is a top priority to define specific mechanisms to more effectively implement research findings into Puget Sound nearshore management, including feeder bluff management, ecosystem function for fish, and services of the nearshore.
R30		13	Bluff physical and biological ecosystem function.	Bluffs make up a majority of Salish Sea shorelines yet our understanding of the ecological function and management of these systems are woefully inadequate. Defining additional more effective tools for monitoring and continuing long term bluff ecosystem studies are a priority for recovery and protection of Salish Sea ecosystem function..	
R31		13	Beach monitoring strategy	Develop a Puget Sound-wide beach monitoring strategy. Characterize physical beach changes (sediment, morphology) at a variety of spatial and temporal scales. Employ a nested sampling design that combines regional geographic scope with site-level observations, and that allows analysis of both event-driven variability (storms, landslides) and long term trends. Investigate the role of different environmental factors in influencing patterns of regional shoreline change, including climate, sediment supply, and anthropogenic modifications. Perhaps model after, and integrate with, the DNR Eelgrass Programs.	

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R32		13	Nearshore functional response to a world scale watershed restoration event: fish use of the Elwha nearshore ecosystem.	Located on the north Olympic Peninsula, the Elwha River nearshore is a critical component of the Salish Sea. It is depended on by no fewer than six federally listed salmon species, and numerous forage fish. The Elwha nearshore is impaired ecologically due to extensive shoreline armoring and in-river channelization and dams. The Elwha nearshore is undergoing an unprecedented restoration event with the removal of two large in river dams, which began in September 2011. To date approximately 2.7 million cubic meters of sediment has been delivered to the sediment starved Elwha nearshore. The Coastal Watershed Institute and partners lead a long term study of the Elwha nearshore ecological function which began in 2005 utilizing a BACI design to define the functional response to a world scale restoration event now underway, and linkages of the nearshore restoration event for the larger Elwha and Salish Sea ecosystem.	
R33		13	Kelp bed habitat function for forage fish	Kelp beds are seasonally dominant nearshore habitats of the Strait of Juan de Fuca critical for iconic northwest salmon and forage fish species. Deemed a 'Valued Ecosystem Component' (VEC) by Washington state (Leshine and Peterson 2007), over sixty percent of southern Strait shorelines are ringed by overstory kelp beds. Kelp beds form inner and outer vegetated bands along the nearshore that are critical for resident rockfish populations, migrating juvenile salmon and forage fish including iconic culturally important species such as Chinook salmon and smelt, as well as important accumulation zones for sediment, nutrients, and vulnerable to anthropogenic forces including oilspills and hydrologic regime shifts due to climate change. They are also the material source for intertidal beach wrack. Despite habitat prevalence, critical function, and vulnerability, no information is available on basic interrelated ecosystem components of Salish Sea kelp beds and climate change. This project provides a basic understanding of the functional elements including seasonal composition of kelp beds ecological function to salmon and forage fish species. This project will work collaboratively with transboundary natural resource agencies to assess nearshore vulnerabilities associated with hydrodynamic shifts associated with climate change. This information will allow responders and managers to: 1. Identify the ecologically important components of kelp beds, and vulnerability of kelp beds to climate change impact; 2. Anticipate preventative measures to minimize climate change impacts to critical kelp habitat function; 3. Develop standardized methods for quantifying and cataloging ecological elements of kelp beds for climate change planning; and; 5. Dialog with the community on the functional importance of attached kelp beds. As the major traffic and ecological corridor between Salish Sea and coastal waters, the Strait of Juan de Fuca is the logical first priority region for defining kelp ecosystem functions.	
R34		15	Eelgrass: Define Impacts of development on nearshore	Document impacts of watershed and shoreline development on subtidal resources including eelgrass populations. An emerging area of concern is increasing nitrogen in Puget Sound, likely resulting in phytoplankton and macroalgae blooms, which negatively impact eelgrass populations.	Overall comment: The current priority science action list ranges from general to very specific. A more uniform level of specificity may make this list more useful (e.g. "improve understanding of ocean acidification" versus "improve understanding of ocean acidification impacts on eelgrass populations") as might organizing the list by topics (e.g., climate change impacts, ecosystem indicators, or systems, impacts, solutions, etc.).
R35		15	Eelgrass: Implement effectiveness monitoring	Implement long-term monitoring of restoration and mitigation efforts in Puget Sound in order to understand factors leading to increased restoration success (related to PSA44) (special focus on eelgrass).	
R36		15	Eelgrass: study effects of climate variability, ocean acidification, and increased CO2	Investigate projected effects of (1) increased climate variability on eelgrass (e.g., effects of variable sea level associated with more frequent El Nino/La Nina events) (Related to PSA16), (2) ocean acidification on the eelgrass epiphyte community (more specific than PSA38 and PSA39), (3) and increased CO2 on eelgrass growth.	Eelgrass is an acknowledged indicator of ecosystem health, but decreases in abundance and distribution documented in recent years point to a need to understand the underlying causes of these changes that could be related to climate change, anthropogenic pressures, or other ecosystem disturbances.
R37		15	Eelgrass: study impacts of harvesting on donor populations	Improve the success of eelgrass restoration efforts by evaluating impacts on eelgrass donor populations of plants harvested for restoration purposes and the effects of small scale adaptations on eelgrass restoration success (e.g., adaptation to depth).	
R38		15	Eelgrass: study its role in the food web	Evaluate functional linkages between eelgrass abundance and other ecosystem components of management interest. e.g., eelgrass in relation to fish and invertebrate populations that utilize eelgrass habitat.	
R39		16	Develop a linked physical oceanography, nutrient, and plankton model of all Puget Sound	In the absence of a full ecosystem model of Puget Sound, a more limited model of the physical oceanography, chemistry, and plankton will allow for more effective predictions of how climate, management, future scenarios will affect the ecosystem.	
R40		16	Develop spatially-explicit food web models for each Puget Sound basin	Food web models can and should be used to support several existing Priority Science Actions. However, the utility of existing food web models is limited by their small spatial scale (i.e., only Central Basin). Developing food web models for Hood Canal, South Sound, and North Sound will allow for the testing the effects of management action and system perturbations on ecosystem components.	
R41		16	Model trade-offs among recovery priorities in a food web context	The PSP recovery targets include increases in the abundance (or maintenance) of several species that are closely linked in the marine food web: salmon, herring, crab, eelgrass, orcas. Yet, no effort has been put into understanding the implications of increases in each of these closely linked species in a food web context. For example, increasing the overall amount of eelgrass in Puget Sound may attract more diving sea ducks, who rely heavily upon eelgrass beds as a food source in winter and spring, feeding heavily on benthic invertebrates, including crabs, and herring spawn. Other such possible trade-offs exist and have yet to be explored.	

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R42	Species and food webs	18	Quantify populations of forage fish and their spatial and temporal variability;	Do the basic research needed to answer the questions: a) what are the limiting factors to FF populations? Are numbers of spawning sites or spawn survival limiting, or predation on adults, or other processes? and b) are numbers of forage fish limiting to any Puget Sound consumers? These issues are critical as the basis for any push to restore spawn sites or regulate certain fisheries. [This was described as a real research priority, "of the type that are desperately needed to have the ammunition for effecting change (eg in regulations)".]	Spend less time, money, and energy on workshops, assessments, compilations, and indicators and more time, money, and energy on actual research; there are very few real research priorities on that old list (some exceptions are 16, 19, and 20, all of which still apply).
R43		18	Develop and implement monitoring program for forage fish species	At present, major gaps in our understanding of the distribution and abundance of forage fish species (aside from herring) exist. Critical to our understanding of the role of Pacific herring, an ecosystem indicator, is their functional overlap (in space, time, as predators, prey) with other forage fish species. Further, our ability to assign mechanism to changes in the status of Pacific herring is limited by the lack of biological samples of herring that provide basic population-level information, such as age structure or diets.	
R44		18	Edits to existing List of 48 Actions: #18: edit to include "and their effects on forage fish"		
R45		18	Analyze the diets of forage fish predators to estimate abundance of unmonitored species and assess vulnerabilities of predators to loss of forage fish	The abundance of forage fish species is notoriously difficult to quantify directly via surveys. Fortunately, these small fish species play a vital role as prey for many other fish, bird, and mammal species that we can readily observe. Therefore these predator species provide the possibility that we can use the predators as indirect samplers of forage fish in Puget Sound. From the predator's perspective we can ask: what are the most important forage species in Puget Sound? We will compile an inventory of current available information about what is known about predator exploitation of forage fishes in Puget Sound. We will include analysis of how predator use varies across years, by season, and among Puget Sound regions. We will also perform a scoring of predator vulnerability based on behavior, life history, and degree of dependence on forage species. We will also explicitly enumerate gaps in available predator information and highlight areas that could benefit from additional study.	
R46		18	Quantify effects of stressors on forage fish in a life-history context	While we may be able to generate a list of potential stressors for forage fish, we have yet to compare those stressors in the appropriate context. We need a unified framework for assessing the effects of stressors on forage fish that takes into account the spatial and temporal variability of those stressors, and the different life stages vulnerable to each stressor.	
R47		18	Determine the food web effects of the "rise of jellyfish" in Puget Sound	Jellyfish are increasing in Puget Sound, there is little doubt of this. Unknown are the effects, but the potentialities include competition with mid-trophic level species, including juvenile salmon, herring, and other forage fish species. Sound-wide sampling coupled with a stable isotope analysis and a simple food web model will determine the extent to which jellyfish pose a real risk to important mid-trophic level species that are of conservation concern.	
R48		42	Quantify links between stressors and ecosystem states (eelgrass, forage fish)	Beyond the Puget Sound-wide threats assessment, certain ecosystem components will require more quantitative approaches, especially so that direct links can be drawn between management actions and ecosystem states (how much shoreline to protect, and where? How much eelgrass is needed, and where? At what threshold level of nutrients do we see eelgrass declines?). In these cases, scientific studies should be conducted to quantify links between stressors and ecosystem states. This would be a follow-on to the Threats Assessment, once the top threats for each ecosystem component have been identified.	
R49		18	Ecosystem services of forage fish: accurate value for our Puget Sound smelt and sand lance.	These are iconic species but since there are no commercial fisheries for these species, their economic value is harder to define (See Earth Economic valuation of Clallam County 2013 that has just been released).We feel further developing these values so they accurately reflect forage fish ecosystem and economic services for the Salish Sea is of very high importance.	
R50	Contaminants	22	Toxics in freshwater	What are the aggregate effects on freshwater ecosystems of current-use and emerging toxicants in the Puget Sound?	
R51		22	Toxics in the food chain	There has been increasing attention to toxics contamination in Puget Sound, as evidenced by state regulatory activity around human health water quality standards associated with fish consumption. While this question is highly charged, science could assist in understanding the extent, sources, scale and ramifications of toxics in Puget Sound to help develop effective solutions. Which key toxics (and emerging contaminants) are present and potentially problematic (what are their effects on human health and ecological systems)? What are key sources and pathways of toxic contaminants, and how (and to what level) can they be reduced most cost-effectively?	
R52		24	Public perception of toxics	Based on the survey that was left in our exhibits this summer, the issue of toxics is the greatest concern for our visitors.	
R53		25	Chemicals of emerging concern	Identify and characterize the impacts from emerging chemicals of concern (e.g. flame retardants, pharmaceuticals, nano-particles, other compounds that readily pass through waste water treatment plants due to high water solubility). (Related to PSA25).	

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R54	Runoff from the Environment	26	Can we identify existing stormwater technology and associated implementation costs that are accepted by the people responsible for stormwater management that effectively treat, reduce or eliminate pollutants of concern, including but not limited to trace metals, organic contaminants like PCBs, pathogens and nutrients such as N and P?	Appropriate and cost-effective stormwater management and treatment approaches are needed to reduce contaminant loadings to receiving water and minimize the effect of streamflow alteration. Studies are ongoing (see Action No. 27), but this work needs to be emphasized more. This action should also include prioritization efforts for retrofit and identification of areas for protection. There is a lot of debate in the stormwater committee about the effectiveness and cost of various approaches to minimizing the effect of flow alteration and contaminant delivery from stormwater runoff. Studies are ongoing, but stormwater managers need information sooner or later that provides guidance on what approaches (and how much of each) need to be applied in the next 20-40 years to reduce contaminant loading and mitigate flow alteration effects resulting from stormwater. For example, in a recent PCB loading study panel discussion, there was a concern that the City of Spokane was making a big mistake in embracing infiltration BMPs for treatment of PCB-contaminated runoff. Is this really such a bad idea? We don't seem to know or bring existing research to bear on this question so that local jurisdictions feel confident that the treatment approaches used will be appropriate in the long term.	Some actions seem to be so nebulous as to make it difficult to see what concrete actions would be taken to address them and how the information would be used to further protection and recovery efforts (e.g., #43). Some actions might like this should be rewritten with more realistic goals or common language so they can actually be translated into concrete action.
R55		29	Stormwater hotspots, solutions, and costs.	The PSP has identified stormwater as a major problem facing Puget Sound, and local governments and their residents will face significant costs in implementing stormwater reduction strategies (e.g., through NPDES permits). Where and to what extent is stormwater runoff affecting the hydrology and water quality of receiving waters in detectable and undesirable ways? Given the spatially diverse nature of land use, what are the local and watershed scale effects of stormwater runoff and how are they most effectively prevented or minimized and mitigated? What stormwater reduction strategies are likely to be most cost-effective to reduce contaminant loadings to receiving water and reduce the impacts to streamflow alteration?	
R56	Wastewater	32	What limits or reductions are needed for human inputs of nitrogen to Puget Sound and what sources should be targeted, including when and how much?	Puget Sound research suggests that human inputs of nitrogen are beginning to degrade the oxygen resources of Puget Sound. More research is needed to help policy makers decide what limits/controls are needed over what time frame to ensure the protection of Puget Sound's oxygen resources. Recent modeling work suggests that the current human impact on dissolved oxygen due to human inputs of nitrogen to Puget Sound may have caused an exceedances of the antidegradation standard of 0.2 mg/L. Modeling scenarios looking at future conditions predict that the effects on Puget Sound oxygen levels will increase by as much as 1 mg/L, but it also appears that upwelling variability and climate change effects could cause even larger changes. What science is needed to help policy makers decide on a reasonable course of action to maintain or improve the quality of Puget Sound. Harmful algal blooms may be another consequence of eutrophication and/or climate change that is still poorly understood. More research is needed to understand the causes of harmful algal blooms in Puget Sound. In addition, shallow embayments of Puget Sound, which originally were thought to be the most sensitive to eutrophication have received less attention (with the exception of Budd Inlet) and deserve more attention in the future, especially with respect to sediment-nutrient interactions and harmful algal blooms.	
R57		32	Nitrogen, dissolved oxygen, HABs, and climate change.	Recent modeling work suggests that there could be human inputs of nitrogen that may affect dissolved oxygen in Puget Sound, but it also appears that upwelling variability and climate change effects could be significant factors. Harmful algal blooms may be another consequence of eutrophication and/or climate change that is still poorly understood. At the same time, implementing nitrogen reduction scenarios (e.g., new wastewater treatment plants or treatment plant upgrades) could be extraordinarily expensive to local governments, and more science is needed to ensure actions are likely to be effective. There are a variety of studies (such as phytoplankton – nutrient interactions, and other research) needed to address the following question: what limits or reductions are needed for human inputs of nitrogen to Puget Sound and what sources should be targeted, including when and how much?	
R58		34	Harmful algal bloooms	Understand the specific environmental conditions that produce toxic harmful algal blooms (HABs) and pathogen events (same as PSA34 on the current priority list; should remain on the list). An increase in environmental pathogens (e.g. Vibrio, fecal coliform) and algal blooms have been documented in Puget Sound waters but the environmental triggers for these events, including location, timing, duration, and levels of toxin have not been elucidated to the point where predictive models can be effectively implemented for mitigation, therefore research is needed to better understand the ecology of these species, environmental conditions that promote bloom events, and determine the triggers for toxin production in order to effectively manage the public health concerns.	
R59		34	Harmful algal bloooms and perceptions	Related to item 34, there should be a directed effort to convey the risks associated with HABs to Tribal people. There are a variety of thoughts about HABs in Tribal communities, including the common belief that HABs do not impact Tribal people. This is particularly important given the amount of shellfish Tribal people eat and the role tribes have in managing the resources of the Salish Sea.	
R60		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Review data to determine if there is a causal relationship between local air emissions and local marine water acidity. If the data confirms such a relationship, take actions to reduce local air emissions that contribute to acidification. (Action 4.1.3)	[Action numbers refer to the report by the Blue Ribbon Panel on Ocean Acidification.]

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Rec. No.	Action Agenda Area	PSA No.	Recommendation title	Recommendation Description	General Commentary
R61	Emerging Issues Ocean Acidification	38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Develop vegetation-based systems of remediation for use in upland habitats and in shellfish areas. (Action 6.1.1) [KEA]	[KEA = Key Early Action designation by Blue Ribbon Panel]
R62		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Ensure continued water quality monitoring at the six existing shellfish hatcheries and rearing areas to enable real-time management of hatcheries under changing pH conditions. (Action 6.2.1) [KEA]	
R63		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Expand the deployment of instruments and chemical monitoring to post-hatchery shellfish facilities and farms. (Action 6.2.2)	
R64		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Investigate and develop commercial-scale water treatment methods or hatchery designs to protect larvae from corrosive seawater. (Action 6.2.3) [KEA]	
R65		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Develop and incorporate acidification indicators and thresholds to guide adaptive action for species and places. (Action 6.2.4)	
R66		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Investigate genetic mechanisms and selective breeding approaches for acidification tolerance in shellfish and other vulnerable marine species. (Action 6.3.5)	
R67		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Establish an expanded and sustained ocean acidification monitoring network to measure trends in local acidification conditions and related biological responses. (Action 7.1.1) [KEA]	
R68		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Develop predictive relationships for indicators of ocean acidification (pH and aragonite saturation state). (Action 7.1.2)	
R69		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Support development of new technologies for monitoring ocean acidification. (Action 7.1.3)	
R70		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Quantify key natural and human-influenced processes that contribute to acidification based on estimates of sources, sinks, and transfer rates for carbon and nitrogen. (Action 7.2.1) [KEA]	
R71		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Develop new models or refine existing models to include biogeochemical processes of importance to ocean acidification. (Action 7.2.2)	
R72		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Determine the association between water and sediment chemistry and shellfish production in hatcheries and in the natural environment. (Action 7.3.1) [KEA]	
R73		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Conduct laboratory studies to assess the direct effects of ocean acidification, alone and in combination with other stressors, on local species and ecosystems. (Action 7.3.2) [KEA]	
R74		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Conduct field studies to characterize the effects of ocean acidification, alone and in combination with other stressors, on local species. (Action 7.3.3)	
R75		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Establish the ability to make short-term forecasts of corrosive conditions for application to shellfish hatcheries, growing areas, and other areas of concern. (Action 7.4.1) [KEA]	
R76		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Enhance the ability to predict the long-term future status of carbon chemistry and pH in Washington's waters and create models to project ecological responses to predicted ocean acidification conditions. (Action 7.4.2)	
R77		38	Recommendation from Blue Ribbon Panel on Ocean Acidification	Enhance the ability to model the response of organisms and populations to ocean acidification to improve our understanding of biological responses. (Action 7.4.3)	
R78			Recommendation from Blue Ribbon Panel on Ocean Acidification	Create an ocean acidification science coordination team to promote scientific collaboration across agencies and organizations and connect ocean acidification science to adaptation and policy needs. (Action 9.1.2)	
R79		39	Ocean acidification and dissolved oxygen	Understand the nature, extent and impact of low dissolved oxygen and ocean acidification on the marine environment. (Supports PSA33, 39)	
R80		39	Survey of the public at Port Townsend Marine Sciences Center	Another issue that ranked high in this survey was climate change including ocean acidification.	
R81	Emerging issues Climate Change	new relating to climate change	Manifold effects of Climate Change	Local governments and other entities that manage programs to restore Puget Sound will have to contend with impacts of climate change, and more research is needed on such questions as: what are the projected effects of climate change throughout the Puget Sound basin (e.g. marine, Puget Lowland, and Cascade Ecoregions)? What problems may emerge or be magnified because of these changes (such as ocean acidification, decreases in biological diversity, proliferation of invasive species)? Given forecast changes and uncertainty, what are the best strategies for minimizing (hedging) risks and creating greatest resilience in face of change? How will climate change affect the type and sequence of Puget Sound protection and recovery actions?	We recognize that many of these reflect items on your list, but they may assist in your effort to revise, organize, or prioritize them. While we are reluctant to make recommendations regarding individual items on the list, we do have a few minor questions on individual items: PSA # 9 - With what confidence do we know that there is a decline in marine survival? PSA # 10 – Should these risks be evaluated in terms of immediate ecosystem responses, and also in light of ecosystem responses as the initial "shock" of the invasion gets assimilated over time? PSA # 12 - For each species - or just for those listed under ESA? PSA # 25 – In addition to synthesizing information on "emerging contaminants of concern" (a broad topic), isn't there a need to understand and communicate the relative risk of these substances? PSA # 29 – As indicated above, doesn't developing stormwater strategies require more research than merely examining environmental benefits of retrofits, but also the evaluation of their costs vs. benefits, and the costs vs. benefits of other approaches. PSA # 31 - Should this be changed to reflect other nutrients? Why limited to nitrogen? PSA # 33 – Given our modern detailed knowledge of contamination pathways and mechanisms, is "non-point pollution" an accurate term anymore? Many fixes will occur at discrete locations. PSA # 43 – This is unclear. Is "…evolutionary learning and adaptation" about people and adaptive management?

APPENDIX E: Inventory of Recommended Studies

Rec. No.	Action Agenda Area	PSA No.	Recommendation title	Recommendation Description	General Commentary
R82	Scientific Tools for Informing Policy	41	Science/Policy Communication	The Action would be to have a broad discussion in the Puget Sound science community that includes any policy makers/deciders that can be identified regarding how science ought to be used to make decisions regarding the recovery of Puget Sound. I just want to make a general recommendation that communication between scientist and policy makers is weak or lacking. I believe part of this stems from a trend toward consolidation in which agencies and staff act as both scientist and policy maker, which I also believe is a big mistake. I'm not sure how this happened. Belt tightening? Lack of ability/will of managers to identify and hold policy makers accountable for decisions? Desire to use science as a cover for policy decisions (i.e., the decision was science-based – scientists told us what the answer is)? A great example of that internally here is that I hear over and over again that science says that river/stream buffers must be 150 ft. I cannot believe that the scientific community has such a precise number. Science would say that if the buffer on this size/type of stream was 50 ft, you might see this, at 100 ft this, and if it was a larger river in this context….	
R83		41	Enhance coordination between science and management	Enhance collaboration between scientific entities and resource agencies in Puget Sound to more efficiently and strategically address the environmental problems facing the Sound	
R84		42	Identify tipping points in land-based activities for important ecosystem components	We lack quantitative information linking stressors to ecosystem states. Even with such quantitative information, we need to understand the functional relationships between those components, so that we know how much land use/impervious surface/stormwater/pollutants/shoreline development is too much. At what threshold level in a stressor do we see change in the ecosystem indicator, and is there hysteresis in the recovery? Developing these functional relationships requires combination of field work and modeling along gradients of stressors to determine where these thresholds lie.	
R85		44	Establish baselines to detect ecosystem change	Some environmental changes in Puget Sound will be inevitable, despite best recovery efforts. The potential of existing species and ecosystems to adapt to those changes and the level of inevitable transitions, would be important to establish. Also, it would be important to establish baseline information so the Sound's recovery goals can be established.	
R86		44	Can we develop benchmarks for key environmental indicators?	Monitoring and Indicators are key to measuring protection and recovery. More effort is needed to ensure that current monitoring and indicators are robust with respect to natural variability and can be compared to appropriate benchmarks to evaluate progress. Evaluate the hypotheses and statistical designs of existing monitoring programs and indicators and develop benchmarks. Many environmental indicators lack a benchmark with which to measure progress. Some of this difficulty is due to lack of historical pre-disturbance data and due to the natural spatial and temporal variability of the environment. Stream hydrology/geomorphology is highly dependent on local context. Hydrologic models of pre-development conditions across Puget Sound might serve as a template for developing benchmarks. Pre-disturbance hydrology could be compared to modeled current conditions and observations where available to assess what type of changes have occurred and where change is greatest. A tool like this could be refined and maintained and used to explore alternative management scenarios similar to work done on the Snoqualmie with respect to salmon recovery.	With respect to redundancy, Action numbers 3, 11 and 26 seem to all fall under the broad category of indicator development and monitoring, although 11 is specific to stream flow and 26 is specific to benthic invertebrates and stormwater. A number of other actions fall under the "eutrophication" umbrella while others fall under a contaminant ("toxics") category. I suspect that monitoring, indicator development, assessment activities and approaches would be different for each of these broad categories so might best be broken out and articulated for each broad category where appropriate.
R87		44	Apply evidence-based assessments of cumulative effects of restoration actions in PS for improved evaluation of effectiveness, decision-making, and accountability.		
R88		44	Are existing monitoring activities and environmental indicators appropriate and robust indicators of degradation or improvement in response to management actions?	There does not appear to be a systematic/scientific assessment of the design and statistical power of existing monitoring programs to detect change. There also does not appear to be a systematic assessment of the ratio of signal to noise of environmental indicators nor an assessment of the natural variability and measurement error inherent in environmental data. These are key steps to developing a transparent, hypothesis driven monitoring and assessment program with a documented estimate of its ability to detect environmentally relevant change.	With respect to the current list, there seems to be some redundancy/duplication and the list overall might benefit from some consolidation and clarification of each Priority Science Action's associated problem and objective. Although a list is convenient for several reasons, perhaps actions could be listed under categories related to problems needing to be studied/solved, such as "eutrophication", "indicators/assessment", "stormwater", etc.
R89		44	Making monitoring more effective	The PSP (and PSEMP) has invested significant effort in developing environmental indicators, yet much work remains to ensure monitoring information is effective, coordinated, and communicated well. What monitoring information would be most easily comprehended to the public (including diverse and disadvantaged populations) in understanding the extent of problems facing Puget Sound and motivate them to take action? What level of information is needed to develop cost-effective solutions and track their effectiveness? How can we structure monitoring designs to better account for the role of natural perturbations?	

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R90	Coordinated Ecosystem Monitoring	44	Better understanding of long-term changes	Many of the actions on the 2011 - 2013 list while worthy of future work - are going to be of very limited value without the underlying context/understandings of the Puget Sound Marine ecosystem. There is a huge danger of waste, by funding research just because it is on a list and not because it is coordinated and prioritized. Often before moving forward, we need to better understand the past to see changes and measure their impacts, which have led to the present. In the early to mid 1900's much of the Puget Sound waters, around the populated areas, were already heavily polluted and the shorelines already dramatically altered. Any yet there were healthy populations of barnacles, mussels, and thriving ecosystems around most of the docks and beaches. There were healthy populations of herring and other beach spawning forage fish and healthy populations of broadcast spawning populations such as Pacific Cod and Sole. Notably, there was an absence of Dungeness Crab South of Seattle and very few yellow or red jelly-fish. Then things started to change. The populations of Pile Perch and Pogies disappeared along with much of the biomass of Mussels and barnacles and Pile worms attached to the pilings, while at the same time the populations of Yellow and Red jelly-fish exploded. Broadcast spawning populations started to crash. Researchers looked at Micro-layer pollution and were alarmed at the devastation being caused to floating egg survival, but the funds dried up and further work was minimized. I am guessing that there was already some form of "Ocean Acidification" going on in Puget Sound, but nobody was looking at those parameters back then. Science needs to go back into the data from the early 1900's and begin comparing some of the values to create an understanding of the changes that took place. Those comparisons should lead to a better understanding of the chemical changes that have occurred and how those have affected the Puget Sound Marine Ecosystem, which should lead to a better understanding of the parameters that need to be monitored and studied into the future. That will lead to a better understanding	
R91		44	Effects of long-term changes	Items 9, 15, 18, 19 & 20 on your 2011 - 2013 list are all a subset of the work that should be done to better understand the affect of these changes.	
R92		44	Indicator development	Multiple items which focus on Research and modeling on individual components and developing indicators and overall monitoring programs should flow out of the evaluation of existing data and information so that it is targeted on the parameters that are most affecting the Puget Sound marine environment.	
R93		44	Re-affirmation of existing priorities	Items 20 - 30+ which focus on toxics and Pathogens should all follow from the work above, with the emphasis on what effect each may be having on survival of different components in the ecosystem or on the overall water quality parameters which are having an impact on key ecosystem components.	
R94		44	Develop and implement monitoring program for zooplankton	Zooplankton are critical prey for a suite of pelagic predators, and at present there is a severe shortage of basic information on the distribution and abundance of zooplankton in Puget Sound. Lacking this information, it is impossible to assign mechanism to changes in the abundance of several pelagic indicator species, including salmon and herring.	
R95		44	Synthesize historical data to establish abundance baselines and assess the past effects of stressors on marine fish community composition.	We presently lack information about what an appropriate abundance target is for nearly all marine fishes in Puget Sound, even though several species are either recovery priorities or species of concern. It is critical that we synthesize historical data where possible to assist in management action going forward. A collaborative effort between PSI, NOAA, UW and WDFW is poised to spend 12 months sythesizing and analyzing 12 a variety of historical data sets and provide such guidance.	
R96		44	Develop ecosystem models to test the effects of management actions on indicators	A major step in the IEA is testing the effects of management actions on the ecosystem.	
R97		44	Test the effectiveness and sensitivity of ecosystem indicators	As part of the adaptive management process, we should be continuing to evaluate the selected indicators and their targets.	
R98		45	Link ecosystem structure to function in restoration	Continue to develop and implement restoration methods that more clearly link ecosystem structure to function for improved long-term restoration success (supports PSA45).	
R99		45	Measuring restoration performance	Select more effective performance criteria for environmental restoration by establishing strong analytical relationships between structural ecosystem elements (e.g. plant density) and functional responses (e.g. fish growth) (supports PSA45).	
R100		45	Metrics for ecosystem services	What are reliable and scientifically defensible metrics for quantifying the benefits that humans receive from freshwater ecosystems and trade-offs among those benefits?	
R101		45	Water availability	What quantity and quality of surface and groundwater will be necessary to sustain US human populations and freshwater ecosystem resilience in the Puget Sound Lowlands during the next century?	
R102		46	Public education about recovery	Social research on how the public learns and reacts to scientific findings and the best methods for communicating such information and inspiring collective action, is crucial.	
R103		46	Changing demographics and behavior	How do demographic and cultural shifts in the human population of the Puget Sound shape conservation values, attitudes, and behaviors?	
R104		48	What are the socio-economic barriers to U.S. citizen students of color matriculating in biological sciences programs at the undergraduate and graduate levels?	Rationale: The demographics of the country and the PNW change, we will need leadership in the environmental sciences from a broader base of social experience.	
R105		48	Tribal people as partners in research	Tribes are often consulted for input into research directions, and tribal natural resource agencies may be involved as partners but greater emphases needs to be directed at incorporating Tribal people as partners in the research. This would involve partnering with appropriate educational and research groups to bring trained Tribal citizens in as research partners.	

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R106	Human Dimensions in Ecosystems	48	Socio-economic research	There are a variety of socio-economic studies that could be done to assist in devising and implementing Puget Sound protection and recovery strategies. Local governments are particularly sensitive to costs of restoration and protection, particularly as federal and state budgets become increasingly constrained and local residents are asked to fund a greater share of the cost of environmental strategies and/or modify their behaviors. Understanding the costs of implementing the Action Agenda should remain a priority, to help ensure the Action Agenda is affordable/realistic (and implemented in a rational order). There should be analyses done to ensure that strategies to address known problems (for example, eutrophication) are indeed the most cost-effective (i.e., the least cost way) to achieve the desired biological or ecological outcomes. Likewise, there could be social and cultural research done to ensure that strategies and priorities reflect interests of and are likely to be desired / implementable by diverse demographic groups (and businesses) present in Puget Sound. There could be research done to demonstrate the positive economic impacts (i.e., jobs) of Puget Sound protection to local economies (which may be more useful and compelling to residents and their local governments than trying to quantify the dollar value of ecosystem services).	
R107			**Economics:** *Corporate ownership of natural resources*	The impact of large corporate ownership of natural resources and related opportunities was a major theme for economics research. This includes an overview of the larger economic picture as it affects Puget Sound natural resources, opportunities for improvement and the alternatives to standard corporate processes. Interestingly, corporations and corporate structure came up in every topic but are not being studied in Puget Sound that we are aware of.	
R108			**Economics:** *Ecosystem Service Valuation.*	A valuation of ecosystem services specific to Puget Sound, using local data and analyses, was identified as an important research gap.	
R109			**Governance:** *Decision making tools and frameworks.*	There are two highlighted research gaps in the governance category. The first is research on the science-policy interface, specifically investigating decision making tools and how they integrate natural and social science research and information, and the relationship between scientists, decision makers and funders. The second noted gap is research on decision-making frameworks and stakeholder participation and how to get to successful recovery via change in behavior.	
R110			**Human Behaviors**: *Landowner behavior and incentives and the political context for behavior change.*	Four human behavior research gaps were emphasized: a) an audience segmentation of shoreline landowners; b) private landowner stewardship behavior and/or incentive programs; c) large and/or corporate landowner incentives; and d) the policy context for behavior change.	
R111			**Psychological and Physical Health***: Natural resource use patterns and connections to human health and the relationship between ecosystem recovery and human well-being.*	Three research gaps were specified: a) non-tribal natural resource use by environmental justice communities; b) psychological and physical health related to the informal resource economy; c) understanding of human well-being connections to ecosystem recovery, values and application to indicator selection and strategy development.	
R112			**Social and Cultural Dynamics***: Corporate Culture*	Similar to the discussion in the Economic workgroup, participants in this group highlighted the need to research corporate culture, behavior, and practices related to natural resource ownership and use.	
R113			**Social and Cultural Dynamics***: Social Science meta-analysis*	Considering the current breadth and depth of social science research related to recovery, this workgroup also recommended a meta-analysis of current social science research and surveys.	