A Risk Analysis Framework for the Puget Sound Ecosystem
PUBLIC DISCUSSION DRAFT
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The Puget Sound Partnership has been given the task of protecting and restoring the Puget Sound ecosystem by 2020. The initial Partnership adopted an ecosystem-based management approach, and recommended that an ecosystem assessment be used to organize the scientific and policy analyses needed to support their ambitious objectives. In order to chart a path towards a 'healthy' Puget Sound by 2020, the new Partnership will need to (1) adopt clearly defined and measurable outcomes for each of their 6 ecosystem goals, and (2) implement strategies and actions necessary to achieve the desired outcomes. An ecosystem assessment is a synthesis and analysis of information of relevant physical, chemical, ecological and human processes in relation to specified ecosystem objectives. Ecosystem assessments result in a forecast of ecosystem status under different management strategies; and thus are instrumental in informing decisions about how to achieve ecosystem goals (NOAA 2007, Levin et al 2008). Such ecosystem assessments have been used successfully in Australia and Europe (refs); and the United Nations, NOAA, and a growing number of regional governments are beginning to incorporate them into their ecosystem-scale management approaches.

The first two steps of an ecosystem assessment are to (1) define objectives and how progress towards ecosystem health will be measured, and (2) conduct a risk analysis that summarizes information about the current status of ecosystem components (i.e., water quality and quantity, species and food webs, habitats and their processes, human health, and human socio-economic and cultural well-being) and the relative magnitude of threats or drivers that are affecting the ecosystem components (refs, NOAA 2007). For the first step, the initial Partnership outlined broad ecosystem goals, and a separate science-policy process currently is underway to identify provisional indicators of ecosystem health (see scope of work for indicators project.)

Results from the second step of the ecosystem assessment, the risk analysis, allow attributes of each ecosystem goal (e.g., particular species for the species/food web goal; dissolved oxygen, temperature and nitrogen for the water quality goal) to be classified relative to their current status and their susceptibility to natural drivers or human threats. There are two parallel stages of a risk analysis: (1) estimating the current status of ecosystem components, and (2) conducting a vulnerability assessment to ascertain the degree of threats facing each component and its resiliency to natural and human-mediated perturbations (refs). Policy decisions about which attributes of ecosystem health are highest priority for action (e.g., possibly those which are most vulnerable) and what

actions are most likely to improve an attribute's status (e.g., those actions addressing the biggest threats) can be informed by a risk analysis. Over the longer term as a full ecosystem model and assessment are developed, the effects of alternative actions on the status of ecosystem attributes relative to their desired condition can be quantitatively assessed.

In this document, we outline the methods and initial, illustrative results of the Puget Sound-wide risk assessment. The purpose of the Sound-wide risk assessment is to provide spatially explicit summaries of existing information on status of ecosystem components, threats and drivers in watershed, estuarine, and marine portions of the ecosystem. The work we describe is ongoing, and future iterations of this document will include additional information on status of ecosystem components and the threats and drivers affecting them. Additional information on status, threats, and drivers are available at smaller scales for some ecosystem components within the Puget Sound basin. Such information will be incorporated into the Puget Sound Action Agenda, but are not part of the broad-scale analysis reported here.

METHODS

The first phase of the risk analysis entails a summary of existing status and threats assessments that are available across the Puget Sound basin. Some additional spatial analyses also are included here to provide more location-specific results. Our general approach is to include spatially explicit information on status, threats, or drivers as we proceed; and thus we are building a more complete picture of current status of ecosystem goals and threats/drivers over time. Information on status of and threats to the human well-being goal largely has not been summarized in existing assessments; thus an illustrative and very preliminary risk analysis for this goal is available in this first phase. This first iteration of the risk analysis is a mix of qualitative and quantitative information; as more data are amassed in the latter half of 2008 and into the future, increasingly quantitative analyses will be included in the risk analysis so that better estimates of the potential ecosystem response to threat mitigation are available to help inform decisions on priority actions.

Status assessment

The status assessment summarizes what is known about the current condition of the 6 main *ecosystem components* in Puget Sound: water quantity, water quality, species/food webs, habitats/processes, human health, and human well-being (PSP 2006). Each ecosystem component is further described by a set of *attributes*, or more specific traits that can be measured and reported. In this analysis, *status* of a component or attribute is a multi-factor state that can be estimated by such metrics as its abundance, trend, productivity, spatial distribution or extent, diversity, some measure of its quality, or an estimate of the likelihood of its persistence or condition into the future (i.e., viability). We summarize status for several attributes of each ecosystem component, depending on the availability of information. Gaps in our understanding of status are noted for those attributes lacking information.

Near-term vs. longer-term approach to assessing status of the Puget Sound ecosystem

The logical sequence of conducting an integrated ecosystem assessment (IEA) is to identify indicators of ecosystem condition and function first, and then to focus the risk assessment on those indicators. Because of tight timelines for production of an ecosystem "Action Agenda" by the PSP, groups of scientists have proceeded simultaneously with identifying ecosystem indicators and the risk analyses. Once more work is completed on identifying ecosystem indicators, the next iteration of the status assessment will be conducted on specific indicators that are known to be effective measures of ecosystem status for each component. Ultimately, results from a status assessment will be a report on the condition of indicators (and collectively, ecosystem components) relative to narrative outcomes, quantitative targets, or other reference conditions describing desired states of a 'healthy' ecosystem.

Approach to status summaries in this report

Information on status within the Puget Sound ecosystem comes from a variety of reports, ranging from general assessments such as *The Puget Sound Update* (PSAT 2007) and ecoregional assessments conducted by The Nature Conservancy (TNC citations), to more specific databases from state and federal agencies and non-governmental organizations (e.g., NOAA Fisheries 2007, REEF 2008, WA DOE 2008, USGS 2008). The ways that status information is reported in these sources is as varied as the characteristics of the species, habitats, and water they describe. Thus a primary task for this risk assessment was to develop a common language for summarizing status information from marine, estuarine, and watershed environments. This common language includes attributes that are used to describe each ecosystem component and also categories of status that accurately reflect each attribute's relative condition or amount.

<u>Defining attributes for each ecosystem component</u>. Until status indicators for each ecosystem component are formally identified, we instead report status information for attributes of each component. Such attributes are descriptors of the ecosystem component that tell us something about its condition, and for which we have some information in at least some parts of the Puget Sound region. Ultimately, indicators of ecosystem status will likely include many of these attributes—but at this early stage of the IEA, it is not possible to tell which ones will be most useful or informative in assessing ecosystem condition. Examples of attributes we can use to describe status and potential or already used sources of the information are listed in Table 1 for each ecosystem component. For many attributes, information either is not available throughout the region or it has not been compiled and summarized. Such gaps in our understanding of ecosystem status are noted in subsequent tables to accurately reflect this source of uncertainty.

Summarizing and categorizing status information. We amassed available spatially explicit data on status for attributes within each ecosystem component. We used the following criteria for data availability:

1. Spatially explicit data summaries published in existing reports or peer-reviewed papers
2. Publicly available data that exist for all Action Areas but have not yet been published or summarized spatially
3. Publicly available data with limited spatial distribution that illustrate or capture an under-represented ecosystem attribute.

Examples that satisfied any one of these criteria (listed in order of preference) were then reviewed by the steering committee and selected based on their relative importance and/or the anticipated level of confidence in the assessment. Where possible, the summarizing and ranking of the selected examples for each of the Puget Sound Action Areas were conducted by those steering committee members with expertise with the particular data type or field of study. In most cases, the data needed to be binned by Action Area, which was done using geo-processing tools in ArcGIS (ESRI 2007). For those data that did not fit cleanly into Action Areas (e.g., county-based data may overlap with 2 or more Action Areas), some data manipulation was required, and this is noted in the corresponding summary tables. Areal and linear geometries for the various status and threats/drivers examples were calculated as part of the GIS processing. Summaries for total area, marine area, land area, and shoreline length were calculated for each of the Action Areas to allow for data normalization. The raw and normalized metrics for each example were then reviewed by the steering committee, and were assigned relative status ranks (described below). Figure 1 lays out the general workflow we used for this assessment.

We employ two different methods for summarizing status of ecosystem components for each Action Area defined by the PSP. Where information in assessments exists, status information for each ecosystem component is summarized on a 'poor to good' scale of ecosystem condition. In these rare instances, judgments have been made about how much of an attribute it 'enough' for a particular level of ecosystem function, and the current amount can be related to such targets or thresholds. For example, thresholds exist for some water quality attributes that describe the levels of toxics, toxins, nutrients, or pathogens above or below which some ecosystem response is likely. These thresholds can then be used to categorize water quality in particular locations as 'good' or 'poor', depending on the value of local samples relative to standards previously established. The definitions of 'poor' to 'good' condition vary among assessments and attributes; thus methods by which status is categorized are reported in the status tables for each metric we include.

In the more common cases where information on status (i.e., abundance, productivity, spatial distribution, diversity, or overall viability) of an attribute is available, but the metrics are not related to overall 'good' to 'poor' status, we summarize available data as 'high-moderate-low' (i.e., "H-M-L") amount or condition. In these instances, the status categories do not translate readily to 'good' or 'poor' condition; but rather indicate a

relative or absolute amount or extent. We report the method by which 'high' to 'low' status is assigned for each metric we include.

We briefly summarize methods and data sources for each ecosystem attribute below. More details on sources of data, their interpretation and methods for categorizing them into 'high, moderate, and low' status groups can be found in the status summary tables in the Appendix. More complete documentation of these methods will be available in the next draft of this report.

Human well-being. Methods to describe status of this goal are particularly immature at this point—the indicators work group is beginning to develop attributes for human well-being and they can be incorporated into this analysis over time. Three attributes of human well-being are included in this draft: use of nearshore habitats by recreational SCUBA divers, the number of selected recreation sites per region, and the total recreational and commercial fisheries landings for selected marine species. The SCUBA diving uses are estimated from a voluntary 'citizen-science' database called REEF (ref). These counts available for each Action Area are underestimates of all SCUBA divers, and only include those who voluntarily recorded their activities on the REEF web site. The count of recreation sites are from NOAA's ESI dataset, and include such locations as public access points, beaches, boat ramps, dive sites, ferry docks, marinas, and parks (NOAA ref.) Total harvest of marine species is summarized from PacFIN data (ref), and includes pounds landed of crab, groundfish, salmon, and shellfish from 2000-2006. There are no existing 'good-fair-poor' status classifications for any of these attributes, so all of them are categorized along a scale of 'high- moderate- low' amount (see summary status table for details.)

Human Health. Methods to describe status of this goal are particularly immature at this point—the example we have included in this draft is for the marine environment, and the indicators group is considering others that capture overall human health in the Basin (see Table 1 for a few of the pending data sets that could be included in this component). We report on a single attribute of human health in this draft: fecal coliform risk in shellfish beds. We summarize the proportion of total shellfish bed sites sampled that have a 'poor' or 'fair' suitability according to data from the Washington Department of Health and reported in the Puget Sound Update (PS Update 2007). The proportion of sampled sites with impaired status is grouped along a 'high-low' scale (see summary status table for details.)

Water Quantity. Two attributes of freshwater quantity are summarized in this draft: maximum surface flows, and minimum annual mean low flows for streams within the Action Area. Both of these are long-term cubic-feet-per second statistics from WA DOE's baseflow dataset (WA DOE). There are no existing 'good-fair-poor' status classifications for either of these attributes, so they are categorized along a scale of 'high-moderate- low' amount (see summary status table for details.)

Water quality. Ten attributes of water quality are included in this report, and all but two describe the condition of marine-water quality. Seven of these (i.e. concentrations of

dissolved oxygen, fecal coliform bacteria, dissolved inorganic nitrogen, and ammonium; classifications of stratification and sensitivity to eutrophication,) are a group of metrics from the Puget Sound Update that are grouped into an overall 'index of water quality concern' (PS Update 2007). The other water quality attributes included in this draft are the number of locations within marine and freshwater 303d sampling sites that do not meet water quality criteria or that did not meet criteria in the past and may be undergoing restoration (WA DOE 2007). The final attribute we include is a modeled estimate of groundwater vulnerability to nitrates (Tesoriero and Voss 1997). Interpretation of the results from this final attribute is ongoing, so its' significance for action is relatively uncertain at this stage. All of these water quality attributes are classified according to a 'high-moderate-low' scale (see summary status table for details.)

Habitat. Describing the status of habitat within the entire Puget Sound ecosystem is a daunting task. We defined a manageable set of habitat types in freshwater and upland systems by taking advantage of extensive work already completed by The Nature Conservancy (TNC) of Washington in their ecoregional assessments. TNC summarized from their ecoregional assessments viability or landscape condition ranks for two broad freshwater habitat types (small tributary rivers and medium rivers—Skidmore 2006) and 16 upland habitat types (including 8 major vegetation types: riparian, herbaceous wetlands, oak prairie and grasslands, dry Douglas Fir, wet Douglas Fir, Montane mixed conifer forest, sub-alpine grasslands, shrublands and woodlands). Details on the methodology can be found in the TNC ecoregional assessments and in Tuffly and Comer (2005). Eelgrass is the marine and nearshore habitat type we include in this draft. Information on both abundance (total area and proportion of shoreline) and trend of flat- and fringe-type eelgrass beds are provided from WA DNR data. A detailed analysis of current and historical potential nearshore habitat types is being conducted by PSNERP, and those results will be included in this risk assessment in June. All of the habitat attributes we include to date are classified according to a 'high-moderate-low' scale (see summary status table for details.)

Species/food webs. Status information for a select set of 18 species or species groups is presented in this draft. Seabird and shorebird status is included in three ways: (1) as grouped into seabirds and shorebirds and ranked as 'high-low' concern by TNC (TNC 2004); (2) as individual abundance and trend information from WDFW on pigeon guillemots, scoters, and Western grebes; and (3) as an individual status assessment for the marbeled murrelet (TNC 2004). Fish species reported include: Chinook salmon (NMFS 2007), coastal cutthroat trout (TNC 2006), copper rockfish status (PSAMP 2007), herring stock condition (PS Update 2007), CPUE for ling cod (PS Update 2007 and WDFW data), summary of overall groundfish and rockfish stock status (PSAMP 2007, draft rockfish assessment). Sea otter status is reported from TNC. A broad metric of intertidal species richness represents the marine invertebrate attributes. Upland species status is reported for bald eagle, Cascades frog, and the Golden paintbrush where those species occur (TNC 2004-2006). Several species or species groups have had status assessments conducted and thus their information is summarized as 'good-fair-poor' status (i.e., groundfish stocks, copper rockfish, coastal cutthroat trout, Golden paintbrush, sea otter, marbeled murrelet, Cascades frog, and bald eagle). The status information for the

remainder of the species or species groups is categorized along a 'high-low' scale (see summary status table for details.)

Sources of uncertainty in status assessment

We aim to document several sources of uncertainty that should be kept in mind when interpreting the results of this risk assessment: (1) information is insufficient or lacking to describe the status of an attribute (e.g., in many cases, trends in condition or a reference condition for the attribute is not known, thus it is difficult to relate the current abundance to status; in other cases, the status of an attribute is completely unknown, such as for zooplankton), (2) the ecosystem consequence of a particular amount or condition of an attribute is not known (e.g., what are expected outcomes if eelgrass area, groundwater flows, or concentrations of pharmaceuticals in fresh and marine waters are reduced or increased by a specific amount?), (3) status information on individual attributes that is lost in 'rolling up' or summarizing across attributes within an ecosystem component to generate an overall status level, (4) the cumulative effects of changes in status of ecosystem components on one another's status are not well understood, and (5) The spatial coverage of monitoring is limited and cannot easily reflect the status of an Action Area.

Threat/driver assessment

A vulnerability assessment helps identify which threats or drivers have the biggest potential impact on ecosystem components. In this report, we define *threats* as human activities that perturb ecosystems; and *drivers* as natural phenomena that perturb ecosystems. The mechanisms through which ecosystem components could be affected by threats, and the way in which impacts are manifest in changes to the ecosystem components are numerous. For example, dredging can pose a threat to ecosystem attributes through disruption of benthic sediment stability, changes in water quality, and by directly killing invertebrates or fish, to name a few mechanisms. The ultimate impacts of dredging on ecosystem components could be a reduction in fish growth rates due to a reduced prey base and poor water quality, declines in invertebrate numbers due to direct mortality, or a reduction in human health due to increased exposure to toxic compounds from dredged sediments. The impact of threats or drivers depends on their relative magnitudes, and the differences in response of ecosystem components to threats due to the inherent susceptibility and resilience of ecosystem attributes. Policy leaders can use the results of these assessments to help make decisions about which threats to focus on first, depending on their likely impacts on ecosystem attributes.

Near-term vs. longer-term approach to assessing threats and drivers in the Puget Sound ecosystem

A formal threat/driver assessment includes information on the relative impact of threats to and drivers of ecosystem components, and an estimate of the vulnerability of ecosystem components to human activities and natural drivers (refs). Vulnerability of ecosystem components typically are defined based on:

- Spatial scale, frequency, magnitude and functional impact (single species to whole ecosystem) of threat
- Susceptibility (combined probability of experiencing a threat and the response of the ecosystem element to the threat—e.g., taking into account resistance to the threat.)
- Resilience or recovery time following disturbance

In combination with a current status assessment, those attributes with high susceptibility and vulnerability can become the focus of more detailed quantitative risk analyses, which produce a synthetic picture of the likely consequences of the conditions of threats/drivers on ecosystems. The Puget Sound IEA being conducted by NOAA Fisheries is developing quantitative approaches to assessing many of these vulnerabilities, including those inherent to species, habitats, or water bodies that make them more or less resilient to changes in the natural functioning of the ecosystem. Because of tight timelines for production of an ecosystem "Action Agenda" by the PSP, we are focusing in this threat/driver assessment on spatially explicit summaries of their magnitudes. Additional work on conceptual models that qualitatively describe what is known about the linkages among ecosystem components and between threats or drivers and the attributes will complement this work.

Approach to threat/diver summaries in this report

The primary question we address in this report is: What are the relative magnitudes of threats to (or drivers of) ecosystem elements within sub-regions and throughout the Puget Sound? (i.e., which threats or drivers could have the greatest potential impact on ecosystem components?) This information is not widely summarized for the Puget Sound ecosystem, so the work we present here is a first step at summarizing attributes that are indicative of the primary threat and driver categories for the ecosystem.

<u>Defining attributes for primary threats and drivers</u>. A common list of potential threats and drivers for the whole ecosystem—watershed, estuarine and marine--is reported in Table 2. This list is based on several local (e.g., PSAMP and TNC) and international (e.g., Halpern et al. 2008) assessments, and includes both human activities that can lead to ecosystem changes and the mechanisms through which those changes can occur. We grouped threats and drivers into six general categories of threats and 1 natural driver category for ease in reporting at the whole ecosystem scale. More detailed examples and descriptions of the kinds of threats and drivers included within each general category are provided in Table 2. It is important to note that some of the data available are proxies or surrogate metrics for the attribute, and thus should be considered to be potential, rather than actual threats to ecosystem components. For example, one of the metrics summarized for the toxic pollution attribute is the number of permitted hazardous waste facilities by Washington Department of Ecology. This number is likely to be correlated with the risk of a hazardous chemical spill, but it is not a direct count of how many spills actually have occurred.

Summarizing and categorizing threat/driver information. For each of the 7 general threat/driver categories, we amassed spatial data layers, and selected a more limited set for this initial illustration based on the following criteria for data availability:

1. Spatially explicit data summaries published in existing reports or peer-reviewed papers
2. Publicly available data that exist for all Action Areas but have not yet been published or summarized spatially
3. Publicly available data with limited spatial distribution that illustrate or capture an under-represented threat/driver

Examples that satisfied any one of these criteria (listed in order of preference) were then reviewed by the steering committee and selected based on their relative importance and/or the anticipated level of confidence in the assessment. Where possible, the summarizing and ranking of the selected examples for each of the Action Areas were conducted by those steering committee members with expertise with the particular data type or field of study. In most cases, the data needed to be binned by Action Area, which was done using geo-processing tools in ArcGIS (ESRI 2007). For those data that did not fit cleanly into the Action Areas (e.g., county-based data may overlap with 2 or more Action Areas), some data manipulation was required, and this is noted in the corresponding summary tables. Areal and linear geometries for the various status and threats/drivers examples were calculated as part of the GIS processing. Summaries for total area, marine area, land area, and shoreline length were calculated for each of the Action Areas to allow for data normalization. The raw and normalized metrics for each example were then reviewed by the steering committee, and were assigned relative threat or status ranks (described below). Figure 1 lays out the general workflow we used for this assessment.

Given our current information, it is not possible to categorize spatial information on threat/driver magnitude into some estimate of 'low' to 'high' impact for ecosystem components in each Action Area. Ultimately, as more information from conceptual and quantitative models becomes available, threat or driver information can be summarized in terms of their likely impacts on ecosystem condition. For this report, we summarize the magnitude of a threat or driver from 'high' to 'low', which literally reflects whether there is relatively 'a lot' or 'a little' of the threat or driver. Similar to the status categories, these do not translate readily to impact on ecosystem condition; but rather indicate a relative or absolute amount or extent. We report the method by which 'high-moderate-low' threat or driver magnitude is assigned for each metric we include.

Methods details on sources of data, their interpretation and methods for categorizing them into 'high, moderate, and low' threat/driver groups can be found in the threat summary tables in the Appendix. More complete documentation of these methods will be available in the next draft of this report.

Developing conceptual models linking threats/drivers to status of ecosystem components.

Developing conceptual or qualitative models is a useful approach to organize existing knowledge about ecosystem functioning and structure. A group of scientists is working to describe what we know about the inter-connections among ecosystem components and how drivers and pressures affect the status of the ecosystem. The conceptual models they are developing are based on the 'DPSIR' framework (Driver-Pressure-State-Impact-Response--refs), which is a highly regarded approach to identifying the primary drivers and sources of ecosystem change and likely responses to those drivers. These conceptual models will be used in the short term to help link actions to ecosystem components whose status is imperiled (i.e., they will help answer "which threats should I address in order to improve the water quality in this basin?"). They also will be used to focus quantitative analyses that can provide estimates of the likely magnitude of ecosystem response if certain drivers or threats are addressed (i.e., that will help answer "how much of an improvement in water quality can I expect if I reduce this threat by 10%?"). First drafts of these conceptual models will be available in April 2008.

Sources of uncertainty in threat/driver assessment

(1) Information does not exist or is insufficient for several potentially important threats/drivers, (2) metrics available to summarize spatial information are proxies or surrogates for a potential threat or driver, but are not a direct measure of that threat, and (3) links are uncertain between threat mitigation or changes in drivers to changes in status of desired or undesired ecosystem components (e.g. viruses and bacteria in wastewater discharges from passing cruise ships have not yet been implicated in increased illnesses from eating shellfish beds or bathing beach exposures in temperate waters.)

RESULTS

Note to reader: there are several ways to 'slice' the presentation of results from this assessment, including (1) discussion of the status of each ecosystem component and the magnitude of each threat/driver category; (2) highlights of status and threat/drivers within and across Action Areas; and (3) regional roll-up of status of 6 ecosystem components and 7 major threat/driver categories. It is likely that each of these will be useful ways to present the results, depending on the intended audiences. For this draft, we illustrate the first 2 of these 3 kinds of results summaries with a few of the ecosystem components and threats/drivers by way of example. In future drafts, each of these summary approaches can be provided more fully, depending on preferences of our intended audiences.

(1) Status of each ecosystem component and magnitude of threats/drivers (example)

STATUS EXAMPLE

The full results for each individual ecosystem component and the attributes we have summarized to date are contained in Table 3 (i.e., the 'status summary tables') in the

Appendix. Figure 2 is an example of how to show the status of several attributes for the species/food web ecosystem goal.

Water quality

The status of water quality attributes in the Puget Sound ecosystem is highly variable, depending on the attribute, metrics for describing its status, and Action Area. Dissolved oxygen samples in marine waters occasionally reach concentrations below threshold concentrations thought to be necessary for species and food web support (PSAMP 2007). Although low dissolved oxygen can occur naturally especially from seasonally upwelling ocean water, dissolved oxygen levels thought to be from anthropogenic causes are lowest in areas of Hood Canal, South Puget Sound and Whidbey Basin, and are at moderate levels in the other Action Areas. High fecal coliform levels indicate a local source of contamination, and occur in Hood Canal, San Juan Islands, and the Whidbey Basin. The remaining Action Areas are scored as having moderate levels of fecal coliform bacteria across sampling sites. Concentrations of nutrients (dissolved inorganic nitrogen—DIN, ammonium—NH4) in marine waters also are spatially variable. Low DIN concentrations over several months during the growing season suggest that phytoplankton growth may be nutrient limited, thus those areas may be susceptible to eutrophication when nutrients from human activities are added (Puget Sound Update, 2007). On average, low DIN conditions occur rarely in all Action Areas except for areas of the North Central Puget Sound and the Whidbey Basin, which area-wide experience moderate levels. High ammonium levels suggest an external nutrient source, and combined with strong and persistent stratification, these areas would be likely to have poor water column mixing and other water quality problems (Puget Sound Update, 2007). Overall average NH4 concentrations are low at sites in all Action Areas except for Eastsound, Quartermaster Harbor, and Budd Inlet, which bring their Action Areas to moderate levels. Hood Canal, South Puget Sound, and Whidbey Basin are scored as especially sensitive to eutrophication in the face of excess nutrients. Department of Ecology defines an overall index of marine water quality concern--based on fecal coliform bacteria levels, concentrations of DIN, NH4, dissolved oxygen, and the strength and persistence of stratification. South and South Central Puget Sound and the Whidbey Basin are ranked as 'high' concern, and the remaining Action Areas are considered to be of moderate concern.

Freshwater quality status is indicated by the number of sampling sites on uplands that do not meet water quality criteria and modeled vulnerability of groundwater to nitrates. Action Areas with low freshwater status (i.e., high numbers of sites not meeting water quality criteria) are San Juan/Whatcom, South Central Puget Sound, and the Whidbey Basin. Hood Canal, North Central Puget Sound, and South Puget Sound have moderate status, and the Strait of Juan de Fuca has relatively high status (i.e., low numbers of sites not meeting freshwater quality criteria).

As for many other ecosystem components, there is little/no information on reference condition or trends in water quality attributes; making interpretation of its status difficult. In addition, different data sources can produce different indications of status (e.g., WA

DOE 303d data and the PS Update), so further work is needed to reconcile the implications of different results from different sampling approaches and sources.

THREAT EXAMPLE

The full results for each individual threat/driver category and the attributes we have summarized to date are contained in Table 4 (i.e., the 'threats summary tables') in the Appendix. Figure 3 is a map depicting those threats/driver categories that are relatively high in magnitude in each Action Area.

Habitat alterations

The magnitude of habitat alterations in marine waters is estimated by the number of overwater structures, amount of modified shoreline, and ownership patterns of marine parcels. South Central Puget Sound has a relatively high number of overwater structures per length of shoreline, South Puget Sound and the Strait have low numbers, and the other Action Areas have moderate levels of overwater structures per length of shoreline. Marine parcel ownership by tribal and private entities is considered to be an indicator of sites that are potentially less certain to implement protection or restoration strategies. Hood Canal, South Puget Sound, and the Whidbey Basin have relatively greater proportions of marine parcel ownership in private and tribal hands. The remaining Action Areas have a relatively smaller fraction of their marine parcels in private and tribal ownership.

Watershed habitat alterations are estimated by recent changes in forest cover and area covered by impervious surfaces. North and South Central Puget Sound have relatively high levels of impervious surfaces, South Puget Sound has moderate amounts, and the remaining Action Areas have relatively low levels of impervious surfaces. The greatest rates of recent loss in forest cover have occurred in South Central Puget Sound and South Puget Sound. Forest cover loss has been the lowest in the Whidbey Basin; and the remaining Action Areas have experienced moderate loss of canopy cover during a recent decade.

Brief discussion of major sources of uncertainty in summarizing habitat alterations here…..

(2) <u>Risk assessment highlights for South Puget Sound Action Area</u>

Status summary

Human well-being metrics in South Puget Sound are moderate-high levels as compared to other regions within the Puget Sound Basin. In particular, the number of SCUBA dives reported is moderate, as they are in most Action Areas within the region. Only Hood Canal and South Central Puget Sound have relatively high numbers of logged

SCUBA dives. Compared to other Action Areas, the South Puget Sound also has a moderate level of recreation sites, including counts of public access points, beaches, boat ramps, dive sites, ferry docks, marinas and parks. The total landed catch of marine fish and shellfish species in South Puget Sound is relatively high.

The single human health indicator we summarize—fecal coliform contamination of shellfish beds—is moderate relative to other regions within the ecosystem.

Maximum stream flows in South Puget Sound are moderate relative to other areas (Whidbey Basin has relatively high flows and North Central Puget Sound has relatively low flows). The low flows are relatively low in South Puget Sound streams, making those rivers susceptible to future climate impacts that are predicted to create increasingly lower flows.

Overall marine water quality in South Puget Sound is of high concern, so the overall status is relatively low. Another metric of low marine water quality is a relatively large number of sites sampled that do not meet water quality criteria. In general, South Puget Sound is relatively sensitive to eutrophication because of its moderate stratification and moderate concentrations of NH4, indicating external sources of nutrients entering the basin. Its overall dissolved oxygen levels are moderate as compared to very low concentrations observed on average in Hood Canal and the Whidbey Basin. Very localized areas of low DO have been observed in South Puget Sound, but on average, it is ranked as moderate.

Freshwater quality in South Puget Sound is scored as moderate, based on the number of sampled sites that do not meet water quality criteria. Groundwater vulnerability to nitrates is rated as relatively moderate, which suggests that groundwater may be a source of excess nutrients into marine waters in some locations.

The amount of upland habitats with conservation value in South Puget Sound is moderate-high as compared to other Action Areas. In particular, the South Sound Basin has a relatively high amount of high quality riparian, oak prairie and grasslands, and dry Douglas Fir habitats. Species and food webs supported in those system types could thus be in relatively good condition, depending on the factors limiting those species' persistence. In contrast, the small and medium-sized freshwater stream systems in South Puget Sound are in fair-poor condition.

The attribute of nearshore habitat condition we report—eelgrass abundance and trends—is relatively low abundance and is declining in South Puget Sound. It is likely that eelgrass was never super-abundant in this Action Area, but because of its low abundance, the recent declines are of concern for eelgrass, the food webs it supports, and the shoreline stabilization and other services it provides.

Species status in South Puget Sound is mixed. Marine-associated species generally are relatively low abundance or are declining. Seabird and shorebird colonies are rated as of 'high concern'. In particular, PSAMP surveys have shown that winter populations of

Western grebes and scoters have had short-term trend declines the past 15 years across Puget Sound. Long-term trend declines have been documented in action acres where comparative data is available from 30 years ago. The status of Chinook salmon populations and marine invertebrate species diversity are both low relative to other Action Areas. Groundfish stocks in South Puget Sound are rated as 'moderate' status, since 9 out of 20 monitored are considered by WDFW to be in good condition with stable trends. Rockfish, which are a large group within groundfish, are not relatively abundant in South Sound because of the natural limitations of rocky habitat within the region. However, their trends are declining and they are thus considered to be in poor status condition. In some cases, the relatively low abundances observed in South Puget Sound may have been the case historically—information on reference conditions typically is not available, so it is difficult to ascribe significance to current low abundances for some species.

Terrestrial and watershed species status is mixed in South Puget Sound. There are relatively few occurrences of bald eagles and marbeled murrelets, and most of those are rated as being in 'fair' condition for marbeled murrelets and about equal numbers of 'good' and 'fair' for bald eagles. Coastal cutthroat trout stocks are rated as poor in South Sound, which is consistent with the poor status ranking of the freshwater stream systems in this Action Area.

Threat/driver summary

Sea level rise estimates—our only natural driver summarized to date—are projected to be moderate in South Puget Sound. Other estimates (not included in this draft) that account for on-going land subsidence in the region suggest that the risk from sea level rise in South Puget Sound is the greatest throughout the region.

Human-mediated threats vary in their magnitude in South Puget Sound relative to other Action Areas. Total water withdrawals (surface and groundwater combined) are relatively low compared to those in North and South Central Puget Sound areas.

Pollution potential from oil spills is relatively low in South Sound, and the chances of a hazardous waste spill are likely moderate, based on the number of permitted hazardous waste facilities within the Action Area. Toxics (PCBs and PAHs) sampled in herring and English sole in South Sound are at concentrations considered 'fair to poor' for the condition of those species.

Artificial propagation threats (due to potential disease transmission, inter-breeding between wild and hatchery fish, or negative impacts on other species due to competition for feeding, rearing and spawning areas or direct predation) are moderate for salmon hatchery releases in South Sound.

Harvest impacts—as indicated by the total landed catch of marine fish and shellfish species in South Puget Sound—could be relatively high. Harvest is also a human well-being asset, and the relative balance between the benefits to humans and the negative

impacts on wild species and food webs depends on the degree to which the harvest is sustainable. We currently lack information on that issue, and will work to include such an assessment in subsequent drafts of this report.

Impacts from habitat alterations in South Puget Sound overall are moderate relative to high impacts likely in South Central Puget Sound and low impacts in the San Juan Islands/Whatcom and Strait of Juan de Fuca Action Areas. Change in % forest cover in the 1990s was relatively high in magnitude in South Sound compared to other Action Areas. Potential threats from impervious surfaces and the proportion of the shoreline that is modified are moderate relative to other sub-regions. Likely consequences of forest canopy loss and impervious surfaces are impaired freshwater flows (which can become more flashy and cause scouring of river channels, erosion, and transport of high concentrations of contaminants, nutrients and pathogens). Stream and land temperatures also can increase when shady overstories are removed. There are relatively fewer overwater structures in South Sound compared to other Action Areas.

(3) roll up examples (in progress)

- Whole ecosystem status summary for each ecosystem component (e.g., Figure 1.)
- Whole ecosystem threat/driver summary (e.g., Figures 2-4)

- Discussion of conceptual models:

Include concrete example of how to use conceptual models to link status and driver/threats (e.g., if eelgrass is declining, which threats/drivers are most likely to impact its decline or recovery?)

QUESTIONS FOR REVIEWERS

<u>Status of ecosystem components</u>

- What do you think about our general approach for summarizing status?
- What is your advice for reporting and categorizing status in the cases where a 'good-fair-poor' assessment has not been done (and we only have information on 'high-moderate-low' amounts of an attribute)?
- Can you recommend other attribute data sets that are available and amenable to summarizing spatially? Which would you recommend that we summarize first, and why?
- What additional uncertainties should we mention for reporting status information in this way?
- What would you recommend as the best ways to visually summarize the status information for those who do not want to look through details in tables?

<u>Magnitude of threats/drivers</u>

- What do you think about our general approach for summarizing the magnitude of threats/drivers?

- What is your advice for reporting and categorizing threats in the cases where we do not have information on 'how much' of a threat driver will cause status of one or more ecosystem component to become imperiled or impaired?
- Can you recommend other threat/driver data sets that are available and amenable to summarizing spatially? Which would you recommend that we summarize first, and why?
- What additional uncertainties should we mention for reporting threat/driver information in this way?
- What would you recommend as the best ways to visually summarize the threat/driver information for those who do not want to look through details in tables?

Next steps

- Given the potentially very long list of attributes we could summarize, and the fact that indicators of ecosystem health will not be identified until later this fall, what minimal level of information do you believe would be important to summarize for representing what we know about the status of ecosystem components and/or the magnitude of threats and drivers in the Puget Sound ecosystem? Please provide a brief rationale.
- What is your advice on how to best use conceptual models to link information on status and threats/drivers that will be summarized in the risk assessment?

Figures and Tables

Table 1. Risk Assessment Table 1. List of attributes that could be used to describe each ecosystem component. This list in the future will be replaced with the list of indicators of ecosystem health after they have been screened and identified.

Table 2. Risk Assessment Table 2. List of attributes describing threats and natural drivers in the Puget Sound ecosystem.

Table 3. Status Summary Tables 4_14_08

Table 4. Threats Summary Tables 4_14_08

Figure 1. Work flow diagram summarizing the methodology for summarizing spatial information on status and threats/drivers

Figure 2. Example of how status information for an ecosystem component (in this case, the species/food webs of Puget Sound) can be represented. Icons represent different species or species groups. The blue-->yellow colors of icons indicate their relative

abundance/trend (as ‘high-moderate-low’), or, in cases where a risk assessment has been conducted, their relative status (as ‘good-fair-poor’).

Figure 3. Example of approach to depicting roll-up of high-magnitude threats/drivers in the Puget Sound ecosystem. Six threat/driver categories are represented by individual icons; icons are included in an Action Area if several of the individual threat/driver attributes are of ‘high’ magnitude. Individual threat/driver levels are reported in Table 4.