Puget Sound Kelp Conservation and Recovery Plan

May 2020

Prepared by the Northwest Straits Commission, NOAA's National Marine Fisheries Service, Puget Sound Restoration Fund, Washington State Department of Natural Resources, and Marine Agronomics.

Our shared vision for thriving kelp forests in Puget Sound

Vibrant kelp forests are vital to the health of Puget Sound and Salish Sea. They provide critical refuge, feeding, and nursery grounds for forage fish, rockfish, and salmon, as well as fueling food webs that support healthy bird and marine mammal populations—including Southern Resident killer whales. Mounting evidence points to significant local declines of kelp forests throughout Puget Sound. In response to these widespread concerns, the Puget Sound Kelp Conservation and Recovery Plan provides a research and management framework for a coordinated and collaborative approach to protecting and restoring kelp forests of Puget Sound. We envision revitalized Puget Sound kelp forests stretching from Olympia to Vancouver, B.C. providing economic, recreational, and ecological benefits to all living things that call these shores and waters home.

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Want to join us in our shared vision for kelp? Sign on to the vision statement by adding your organization here: https://nwstraits.org/our-work/kelp/

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Illustration above used with permission of Claudia Makeyev.
Cover Photo: Bull kelp forest. Image courtesy of Eiko Jones Photography.

Acknowledgments

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A diverse group of local and regional experts contributed valuable perspectives to this Puget Sound Kelp Conservation and Recovery Plan. We would like to thank the many participants who took part in the kelp workshops in 2016, 2018, and 2019. Appendix C includes a full participant list and notes from the workshops. Workshop participants represented the following organizations:

Clallam Marine Resources Committee
Friends of the San Juan's
Island Marine Resources Committee
Jamestown S'Klallam Tribe
Jefferson Marine Resources Committee
King County Department of Natural Resources
Marine Agronomics LLC
Natural Resources Consultants
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Puget Sound Restoration Fund
Puyallup Tribe
Samish Indian Nation
San Juan Marine Resources Committee
San Juan Salmon Recovery Lead Entity
Simon Fraser University
Skagit Marine Resources Committee
Snohomish Marine Resources Committee
Stillaguamish Tribe
Suquamish Tribe
Surfrider Foundation
Swinomish Indian Tribal Community
Tulalip Tribes
University of British Columbia
University of California, Davis
University of Chicago
University of Victoria
University of Washington
University of Wisconsin, Milwaukee
United States Army Corps of Engineers
United States Geological Survey
Washington Department of Ecology
Washington Department of Fish and Wildlife
Washington State Department of Natural Resources
Western Washington University
Whatcom Marine Resources Committee

The discussions in the workshops formed the framework for this Kelp Plan. Without the time and energy contributed by representatives from these organizations, this effort would have failed. We hope this plan provides our community with a framework for continued focus and momentum toward kelp conservation and recovery.

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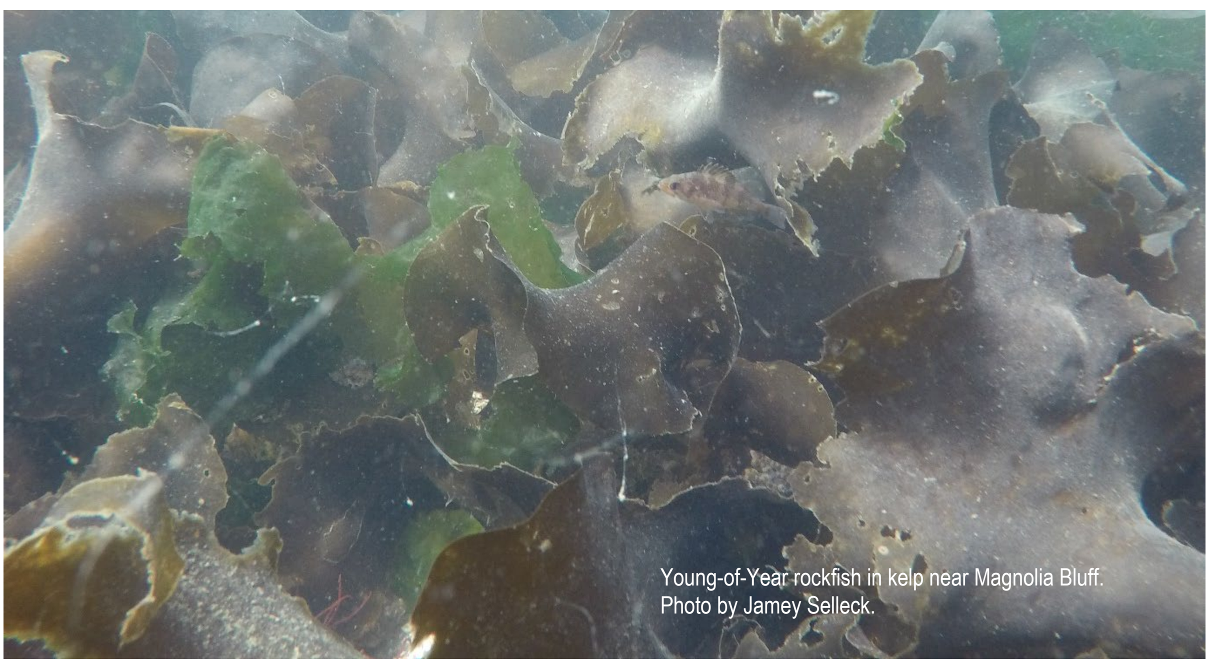

Young-of-Year rockfish in kelp near Magnolia Bluff.
Photo by Jamey Selleck.

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Setchell's kelp (Laminaria setchellii), Ebey's Landing, Whidbey Island.

List of Acronyms

CWA	Clean Water Act
DNR	Washington State Department of Natural Resources
DOE	Washington State Department of Ecology
EPA	United States Environmental Protection Agency
EFH	Essential Fish Habitat
ESA	Endangered Species Act
GMA	Growth Management Act
HPA	Hydraulic Project Approval
MRC	Marine Resources Committee
NGO	Non-Governmental Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWS	Northwest Straits
PSP	Puget Sound Partnership
PSRF	Puget Sound Restoration Fund
RCW	Revised Code of Washington
SMA	Shoreline Management Act
SMP	Shoreline Master Program
TMDL	Total Maximum Daily Load
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish and Wildlife
WWTP	Wastewater Treatment Plant

Glossary

Biogenic habitat: Habitat provided by living organisms (i.e., kelp, eelgrass, or terrestrial plants).

Blade or Lamina: The flattened and elongated portion of a kelp individual where most photosynthesis occurs.

Floating kelp: Species that are held aloft either in the water column or at the water surface by pneumatocysts (buoyant bulbs).

Gametophyte: The sexually differentiated, microscopic, haploid, reproductive kelp life stage that produces egg and sperm (gametes).

Grazer: Herbivorous species (usually invertebrates) that feed directly on fresh or detrital kelp material.

Holdfast: Structure at the terminal end of a kelp stipe used to anchor the individual onto substrate.

Kelp: Species of brown seaweed in the order Laminariales.

Kelp forest: The community and services provided by intact ecosystems dominated by kelp species composed of multiple species and strata (stories) that rise above the benthos (seafloor) and can extend up to 10 to 25 meters to the surface

Pneumatocyst: Bouyant, gas-filled float on some species of brown algae that lifts a portion of the individual off the benthos (bottom).

Sorus (pl. sori): Reproductive patches on kelp blades that undergo meiosis and produce zoospores.

Sporophyte: The conspicuous phase of the kelp life cycle. The macroscopic diploid life stage that produces reproductive zoospores.

Stipe: The stem of a kelp individual that connects the holdfast to the blades/lamina. Kelp stipes vary between species.

Stressor: Any of several physical or biological parameters known to affect long-term kelp health and persistence.

Turf algae: small filamentous and foliose green and red algae that provide fewer ecosystem services and lower biodiversity

Understory / non-floating kelp: Species lacking pneumatocysts. These species either lay along the seafloor or held aloft in the midstory by a rigid stipe.

Zoospore: A microscopic phase of the kelp life cycle. Single-celled structures produced through meiosis, usually motile. Once settled on substrate, they quickly germinate into male and female gametophytes.

I. Executive Summary

Kelp—some of the largest of all seaweeds—form extensive living structures that provide an array of valuable ecosystem goods and services to deep water and nearshore environments in Puget Sound. These underwater forests act as foundations for diverse and productive nearshore ecosystems, supporting food webs and providing critical habitat for a wide array of marine life.

Anecdotal observations and research suggest that Puget Sound is losing its kelp forests. Extensive losses of bull kelp have been documented in South and Central Puget Sound, and localized declines have been observed throughout Puget Sound. Concerns also exist about potential losses to other kelp species, yet trends are unknown due to data gaps. Although kelp distribution and drivers of declines in Puget Sound are not well understood, data from kelp ecosystems in other temperate coastal regions indicate that widespread loss of kelp habitats would be devastating to the Puget Sound ecosystem. There is a consensus in the scientific community that coordinated action is needed to reverse downward trends in kelp populations by addressing both longstanding and emerging stressors. Cumulative impacts from human stressors threaten kelp. These impacts include degraded water quality from pollution, nutrient loading, increased turbidity, and sediment deposition; introduction of invasive species; and alterations to food-web dynamics from commercial and recreational fishing. Additionally, warming ocean waters and other impacts from climate change pose new and intensifying threats to kelp resilience that often exacerbate the negative effects of other stressors.

This Puget Sound Kelp Conservation and Recovery Plan (Kelp Plan) provides a framework for coordinated research and management actions to protect these fundamental and iconic kelp species from a suite of global and local stressors. Successfully achieving kelp conservation and recovery will require a collaborative effort between our community of Tribes, managing entities, and stakeholders in Puget Sound. Additional collaboration with Canadian federal, provincial, and First Nation entities will support conservation and recovery efforts in the Puget Sound/Georgia Basin region.

Actions identified in this Kelp Plan address six strategic goals:

1. Understand and reduce kelp stressors;
2. Deepen understanding of the value of kelp to Puget Sound ecosystems and integrate into management;
3. Describe kelp distribution and trends;
4. Designate kelp protected areas;
5. Restore kelp forests; and
6. Promote awareness, engagement, and action from user groups, Tribes, the public, and decision-makers.

We propose the following research, communication, and conservation actions to achieve these strategic goals.

1. **Understand and reduce kelp stressors.** Water quality degradation, urbanization/development, invasive species, and warming ocean temperatures are cumulatively affecting kelp and likely driving regional declines in bull kelp populations. These stressors are likely to increase in magnitude with continuing population growth and climate change.

   Reduce human impacts on water quality and kelp habitats:

   - Inform future management actions through continued research into the impacts of current and historical human activities on kelp forests.
   - Identify priority stressors negatively affecting Puget Sound kelp on a sub-regional scale to target management actions.
   - Fully implement and enforce available protections for kelp through existing regulations, programs, and policies.
   - Increase protection for kelp populations by addressing key gaps in existing regulations and implementation programs.
   - Form interagency workgroups to increase collaboration and information sharing across management organizations to improve implementation and to address policy gaps.
   - Reduce human-caused nutrient and sediment loading.
   - Support sustainable kelp harvest by informing recreational harvesters about regulations and sustainable kelp harvest methods.

   Reduce impacts from biological stressors:

   - Strive to incorporate kelp and other trophic considerations into fisheries management planning.
   - Explore invasive macroalgae (*Sargassum muticum* and *Undaria pinnatifida*) control alternatives, ecological roles, and long-term management considerations with respect to climate change.

   Reduce impacts from climate change:

   - Investigate climate change impacts to improve management decisions, such as prioritizing locations for kelp protected areas, restoration sites, and mitigation activities.
   - Investigate the climate-related benefits of kelp, and develop management opportunities for these benefits.

- Investigate the development of temperature-tolerant strains of native kelp species for potential use in restoration and mitigation outplanting in regions where local stressors are reduced.

2. **Deepen understanding of the value of kelp to Puget Sound ecosystems and integrate into management.** Kelp provides critical habitat as well as food and foraging opportunities for associated nearshore species in Puget Sound. Quantifying services provided by kelp will support management actions, especially for pinto abalone, threatened and endangered species of rockfish, salmon, and Southern Resident killer whales.

   Improve understanding of kelp value:

   - Quantify functional roles of kelp habitats for associated species and provide guidance to managers on regulatory implementation, such as endangered species habitat conservation.
   - Calculate the value of kelp ecosystem services for use in developing mitigation guidance.

3. **Describe kelp distribution and trends.** Successful implementation of existing regulations relies on accurate information regarding the distribution and trends. Consistent and coordinated multi-year monitoring is essential for establishing accurate inventories and understanding natural variation.

   Gain accurate information on kelp distribution and trends:

   - Update and expand information on the current extent of canopy-forming and understory kelp.
   - Make distribution and trends data available to agencies and the public for use in spatial planning, project planning, and regulatory implementation.
   - Coordinate the strategic monitoring of canopy-forming and understory kelp throughout Puget Sound through expanding efforts and building collaborations between organizations.
   - Expand the understanding of historical distributions and trends by compiling historical information sources and exploring traditional ecological knowledge.
   - Identify the genetic structure of kelp populations, including connectivity, dispersal, and population dynamics.
   - Form a research and monitoring workgroup to increase collaboration and information sharing across organizations.

4. **Designate kelp protected areas.** Puget Sound kelp recovery begins with the conservation and protection of kelp forests.

   Protect kelp habitat:

- Protect kelp habitat in existing and new reserves, refuges, and protected areas.
- Assess the extent of recreational kelp harvest and its potential impacts. Develop spatial management plans and strategies for kelp harvest activities.

5. **Restore kelp forests.** Restoring historical kelp forests requires indirect habitat improvement through stressor reduction and direct kelp population enhancement in areas where natural recruitment is limited. In addition to reducing stressors responsible for declines, developing best practices will be critical for successful kelp restoration and mitigation projects.

   Restore kelp forests:

   - Develop a spatial plan identifying regions and sites for priority restoration actions and mitigation.
   - Continue the development of kelp restoration techniques for use in enhancement and mitigation projects.
   - Fund and implement restoration activities at priority sites.

6. **Promote awareness, engagement, and action from user groups, Tribes, the public, and decision-makers.** The success of the Kelp Plan and the conservation and recovery of kelp in Puget Sound depends on increased awareness, engagement, and support of actions to sustain kelp.

   Promote awareness, engagement, and support:

   - Share information on (1) the value and role of kelp ecosystems as critical nearshore habitat and food web support (for forage fish, rockfish, salmon, and killer whales) in Puget Sound; and (2) the growing concern regarding significant losses to bull kelp canopies.
   - Build research capacity through coordinated knowledge sharing of ongoing kelp recovery projects and research gaps.

At the heart of these strategic goals is the need for continued interagency coordination; communication between researchers and managers; and funding to support research, monitoring, education, outreach, implementation, and enforcement. The actions outlined in this Kelp Plan require a unified collaborative effort from federal and state management agencies, Washington State Tribes, Non-governmental organizations (NGOs), and local stakeholders. Raising awareness of the need to support kelp conservation and recovery will help further strengthen budding collaborative partnerships. This Kelp Plan is a call to action. It advocates that kelp be recognized as a necessary element of ecosystem-wide recovery planning, including the prioritization of funding to support the actions outlined in this Kelp Plan.

Black rockfish swimming in bull kelp forest near Keystone Jetty.
Photo by Adam Obaza- Paua Marine Research.

Sugar kelp (Saccharina latissima), Squaxin Island.
Photo by Helen Berry.

II. Introduction

Kelp—groups of brown algae that include some of the largest of all seaweeds—provide valuable ecosystem goods and services to deep water, terrestrial, and nearshore environments. Underwater kelp forests act as foundations for diverse and productive nearshore ecosystems, supporting food webs and providing critical habitat for a wide array of marine life (Steneck et al. 2002; Christie et al. 2009; von Biela et al. 2016).

Most available information on kelp in Puget Sound pertains to the floating canopy-forming bull kelp (*Nereocystis luetkeana)*. Despite a lack of systematic surveys, available data from multiple sources document long-term declines in canopy cover of bull kelp within several areas of Puget Sound (Berry et al. 2019, *in review*). While bull kelp forests are not declining everywhere, many historical Puget Sound bull kelp forests, especially in Central and South Puget Sound, have been entirely lost or reduced to vestiges of historical abundances. The consequences of these declines are not limited to the direct effects on kelp populations, but also influence, both directly and indirectly, the many species and ecosystem services that depend on the presence of kelp forests. Though the distribution and drivers of declines in Puget Sound are not well understood, data from kelp ecosystems in other temperate coastal regions indicate that a large-scale loss of kelp habitats would be devastating to the Puget Sound ecosystem (Steneck et al. 2002; Graham 2004; Rogers-Bennett and Catton 2019).

2.1 Purpose of the Conservation and Recovery Plan

The Puget Sound Kelp Conservation and Recovery Plan (herein referred to as "the Kelp Plan") provides a framework for research, conservation, recovery, and communication actions aimed at protecting and restoring Puget Sound kelp species and the goods and services provided by them. This document provides a synthesis of the most current information regarding kelp in Puget Sound and should be considered best available science by local governments and other state agencies.

This Kelp Plan is a call to action! Kelp is a critical element of ecosystem-wide recovery.

The overarching intent of the Kelp Plan is to strengthen the implementation and enforcement of existing regulatory and management policies, and to develop additional tools to conserve and restore Puget Sound kelp habitats. Successfully achieving kelp conservation and recovery will require collaboration between the community of scientists, Tribes, managing entities, and stakeholders in Puget Sound.

The Kelp Plan aims to address the following strategic goals:

1. Understand and reduce kelp stressors;

2. Deepen understanding of the value of kelp to Puget Sound ecosystems and integrate into management;
3. Describe kelp distribution and trends;
4. Designate kelp protected areas;
5. Restore kelp forests; and
6. Promote awareness, engagement, and action from user groups, Tribes, the public, and decision-makers.

Recommended management actions, particularly those focused on reducing stressors, support recovery plans for other species and issues of concern, including eelgrass (*Zostera marina*) (DNR 2015), salmon (*Oncorhynchus* spp.) (NMFS 2007), Southern Resident killer whales (*Orcinus orca*) (NMFS 2008), rockfish (*Sebastes* spp.) (NMFS 2017), and ocean acidification (Washington State Blue Ribbon Panel on Ocean Acidification 2012; Washington Marine Resources Advisory Council 2017). Actions identified in these plans, and other actions that protect and improve Puget Sound ecosystem health, benefit kelp, but kelp is often left out of local discussions pertaining to critical species that warrant protection and recovery measures. This Kelp Plan is a call to action. It advocates for recognizing that kelp is an integral element of ecosystem-wide recovery planning, including the prioritization of funding to support the actions outlined in the Kelp Plan.

2.2 Plan Development and Coordination

Efforts to develop a conservation and recovery plan for Puget Sound kelp began in 2016 after the need to conserve kelp habitats in Puget Sound arose as a priority during the development of the Rockfish Recovery Plan for Puget Sound and the Georgia Basin (NMFS 2017). Participants in the rockfish recovery planning process stressed the importance of kelp forests as critical habitat for many juvenile rockfish species, and as support for long-term rockfish recovery. Consequently, the rockfish recovery plan outlined the need for synthesizing available research on kelp, improving understanding of kelp distribution, and developing conservation and restoration approaches for kelp habitats (NMFS 2017 Appendix V). Following the completion of the rockfish recovery plan, NOAA’s National Marine Fisheries Service (NMFS) allocated funds for the development of the Kelp Plan.

Development of the Kelp Plan began in September 2017. It proceeded during a two-year process led by the Northwest Straits Commission (NWS Commission) with invaluable guidance and support from the Puget Sound Restoration Fund (PSRF), Marine Agronomics LLC, Washington State Department of Natural Resources (DNR), NMFS, and Washington Department of Fish and Wildlife (WDFW). Activities included forming the Kelp Core Team to oversee plan development; synthesizing literature and current research on kelp in Puget Sound; holding workshops with researchers, agencies, tribes, and stakeholders; and facilitating peer review and public comment of the Kelp Plan.

Kelp Core Team

The Kelp Core Team provided technical expertise during Kelp Plan development and workshop planning and reviewed deliverables. The Kelp Core Team includes the following organizations:

Puget Sound Restoration Fund,

Washington State Department of Natural Resources,

Marine Agronomics LLC,

National Marine Fisheries Service, and

Northwest Straits Commission.

Knowledge Review and Data Gaps

Efforts in Year 1 of the Kelp Plan development focused on synthesizing and communicating available data and current research on kelp in Puget Sound through a literature review and two workshops. Year 2 efforts included surveying technical experts on needs for kelp recovery and using the results to create a prioritized list of the knowledge gaps. This list informed decisions for kelp conservation and recovery strategies. The survey results are provided in Appendix C.

Workshops

Four workshops were held during the Kelp Plan development process. These workshops brought together technical experts to share current research, review data gaps, prioritize actions to address data gaps, and discuss management opportunities and needs. Workshop participants and notes are available for review in Appendix C.

Workshops in 2018 focused on discussing kelp status and trends, stressors, and ecosystem linkages, and then identifying data gaps and associated research and monitoring needs. Workshops held in 2019 focused on outlining actions to address high-priority knowledge gaps and identifying management and policy tools, gaps, and opportunities for kelp conservation. Results from votes tallied at workshops revealed a consensus among workshop participants on research and monitoring needs that support specific management actions.

Puget Sound Conservation and Recovery Plan Area

Recommended conservation and recovery actions in the Kelp Plan are specific to Puget Sound[1] and adopt the area boundaries used in the Rockfish Recovery Plan (NMFS 2017). Figure 1 shows the Puget Sound Kelp Conservation and Recovery Plan area. Puget Sound—the southern arm of an inland sea located on the Pacific Coast of North America—can be subdivided into basins including South, South Central, and North Central Puget Sound, Whidbey basin, Hood Canal, the San Juan Islands and Georgia Strait, and the Strait of Juan de Fuca. The western boundary for the

[1] The Washington State Legislature defines Puget Sound as Water Resource Inventory Areas (WRIA) 1-19.

Kelp Plan is the Victoria Sill, a significant oceanographic feature in the Strait of Juan de Fuca. Patterns of circulation created by the Victoria Sill create discontinuities in temperature, salinity (Masson and Cummins 2000), nitrogen (Mackas and Harrison 1997), primary production (Foreman et al. 2008), and water column organic carbon (Johannessen et al. 2008). Together, these factors create habitat conditions within the basins of Puget Sound that are distinct from the exposed outer coast.

Stalked kelp (Pterygophora californica), Ebey's Landing, Whidbey Island.
Photo by Tom Mumford, Marine Agronomics LLC.

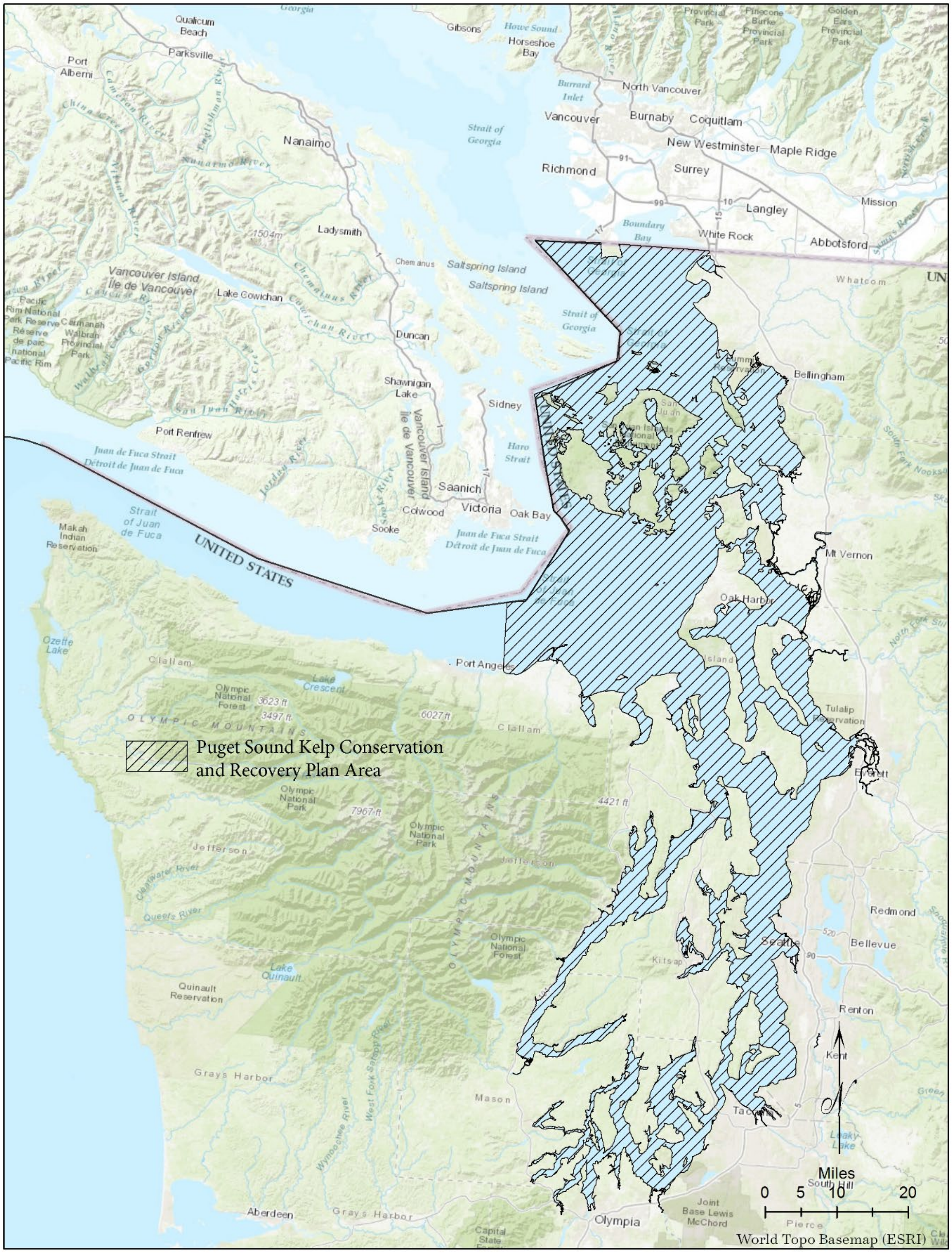

Figure 1. Map of Puget Sound Kelp Conservation and Recovery Plan Area. The area is indicated by the cross-hatched area.

2.3 Precautionary Principle and Adaptive Management

A precautionary principle frames our approach to kelp conservation and recovery in Puget Sound. The precautionary principle stresses the implementation of conservation measures for critical habitats, even in the absence of scientific certainty (Harremoes et al. 2002; Brisman 2011). Available data document significant losses of bull kelp in several basins. The fact that other kelp species share similar environmental requirements with bull kelp raises concerns about losses to understory species as well (Dayton 1985; Bartsch et al. 2008). Additionally, research in British Columbia documents declines in multiple species of kelp, both floating and understory (Starko et al. 2019). In light of this evidence, and given the importance of these habitats to threatened and endangered species, a precautionary approach that includes monitoring, conservation, and restoration actions is critical.

The Precautionary Principle stresses the implementation of conservation measures for critical habitats even in the absence of scientific certainty.

Adaptive management is also central to our plan. Kelp conservation and recovery planning will need to be reviewed and updated as research and action implementation improve our understanding of kelp distribution, key stressors, and priority management actions. Scientific uncertainties in Puget Sound kelp distribution and trends, and the impact of global and local stressors, warrant adaptive management (Goetz et al., n.d.). Both the precautionary principle and adaptive management approaches are meant to be iterative processes, dynamically responding to the best available science as research improves our understanding of Puget Sound kelp ecosystems.

There is a rising concern across the research and management communities that without coordinated research and conservation actions, continued kelp declines may lead to significant impacts to broader Puget Sound ecosystem function. Adaptive management approaches, including restoration activities, could lead to improved habitat function for kelp ecosystems.

Bull kelp forest. Image courtesy of Florian Graner.

III. Puget Sound Kelp Overview

The term "kelp" broadly refers to large (10 cm to 30 m) brown macroalgae (phylum Phaeophyta, class Phaeophyceae) in the order Laminariales. Washington State is home to a diverse community of canopy and understory kelp, with 22 kelp species found along the outer coast and within Puget Sound (Appendix A provides a full list of these species). Puget Sound, as defined by the Kelp Plan in Section 2.2, is home to 17 species of kelp (Appendix A). Giant kelp *(Macrocystis pyrifera*) is excluded from the Kelp Plan because its range is restricted to the western Strait of Juan de Fuca, which is outside the planning area.

Puget Sound is home to 17 species of kelp.

Communities of kelp species form extensive biogenic (living) structures that serve as critical habitat for many taxa, including several fish species listed as species of concern by Washington State and endangered or threatened under the federal Endangered Species Act (ESA). This Kelp Plan employs the term "kelp" to refer to multiple species in the order Laminariales, and common names to refer to individual species, such as bull kelp.

3.1 Kelp Biology

In the macroscopic phase, kelp can be annual or perennial, depending on the species (Dayton 1985; Bartsch et al. 2008). Kelp species in Puget Sound are adapted to cold temperate waters and grow optimally at 5 to 15 °C (Tera Corp. 1982; Maxell and Miller 1996; Bartsch et al. 2008). Many common kelp species, such as bull kelp and sugar kelp (*Saccharina latissima*), die back in the late fall and winter before appearing again as early as February (Druehl and Hsiao 1977; Allen 2018).

Kelp Life History

All kelp species have two distinct life phases, each with different environmental requirements and stress thresholds (Geange et al. 2014). In the macroscopic form, kelp sporophytes produce reproductive patches (sori) along their blades that release microscopic zoospores that germinate into male and female microscopic gametophytes (Schiel and Foster 2006; Hurd et al. 2014). The male and female gametophytes produce sperm and eggs, respectively, and eggs that are fertilized by sperm produce microscopic sporophytes that typically grow to adult size within one season. Figure 2 illustrates the kelp life stages for bull kelp. In Puget Sound, where kelp forests are mostly annual, the microscopic life stages overwinter until the spring (Carney and Edwards 2006). However, the ecology of the microscopic life stage(s) that overwinters is not well understood at this time.

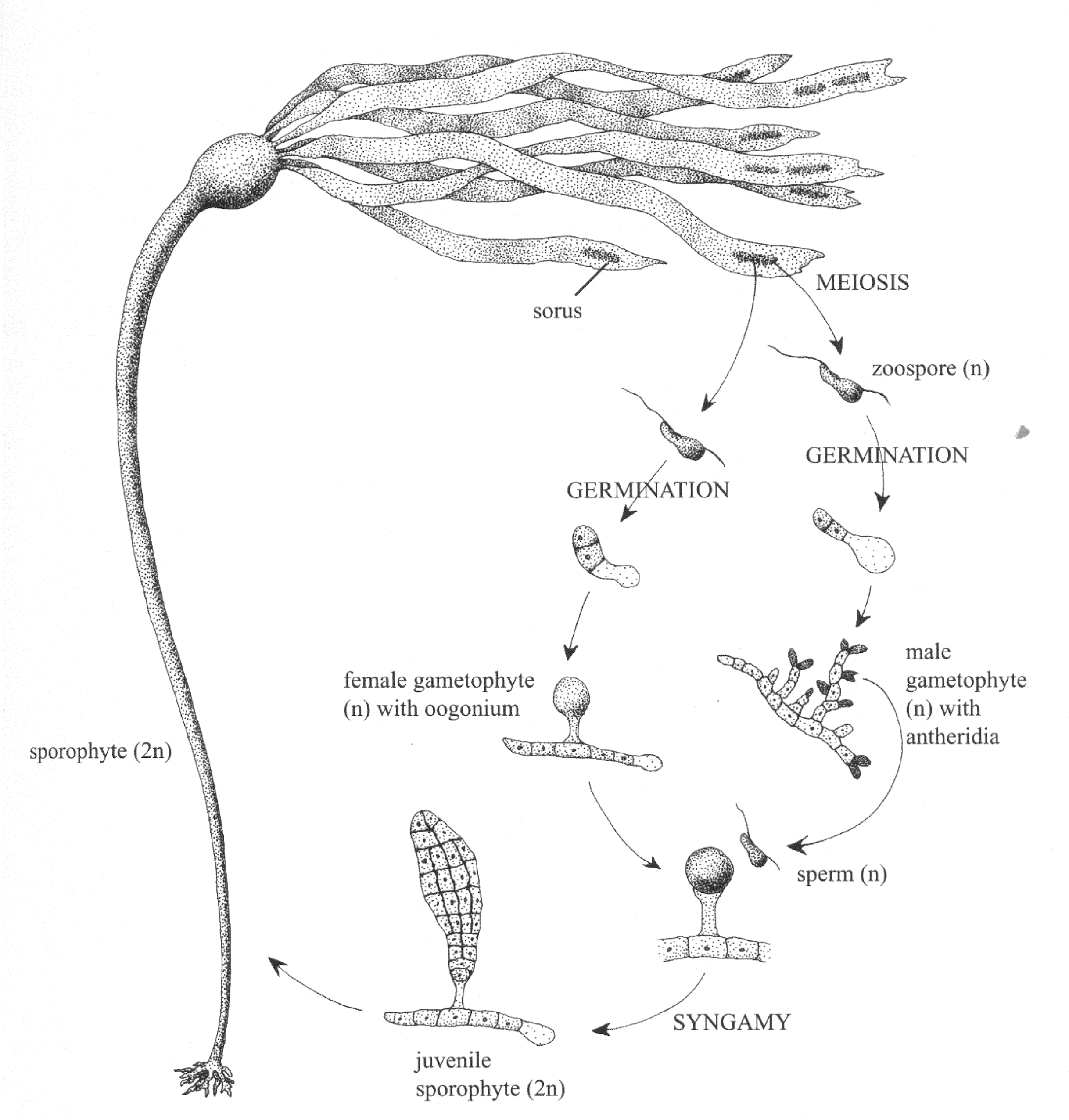

Figure 2. Diagram of kelp life stages. Illustration by Lisa (Scharf) Spitler. In: Mondragon J, and J. Mondragon (2003). Seaweeds of the Pacific Coast: Common Marine Algae from Alaska to Baja California. Sea Challengers, Monterey California, 97 pages.

Kelp Forest Structure

The term "kelp forest" encompasses the community and services provided by intact ecosystems dominated by kelp species. Kelp habitats are composed of multiple species and strata (stories) that rise above the benthos (seafloor) and can extend up to 10 to 25 meters to the surface (Steneck et al. 2002; Figure 3). Kelp sporophytes are organized into three types, shown in Figure 3, based on morphology:

- **Prostrate kelp** lack a rigid stipe or gas-filled buoy (pneumatocyst) and remain close to the seafloor, forming thick understories. For example, *Saccharina latissima, Costaria costata,* and *Agarum clathratum.*
- **Stipitate kelp** stand erect with the help of rigid stipes (stems), thus forming a midstory. For example, *Pterygophora californica.*
- **Floating kelp** rely on pneumatocysts to hold the plant up in the water column and can create large, floating surface canopies. For example, bull kelp (*Nereocystis luetkeana)* and giant kelp (*Macrocystis pyrifera*).

Kelp communities with all three morphological types form the most structurally complex forests, but assemblages of kelp species, regardless of morphology, provide large volumes of living habitat that provides critical foundations for nearshore ecosystems and food webs (Steneck et al. 2002; Teagle et al. 2017). In Puget Sound, prostrate kelp species are the most common (ShoreZone 2001) and provide crucial primary production, refuge, and habitat. Kelp species also host diverse microbial biofilms whose functional roles are not yet known and may play a role in future recovery efforts (Weigel and Pfister 2019).

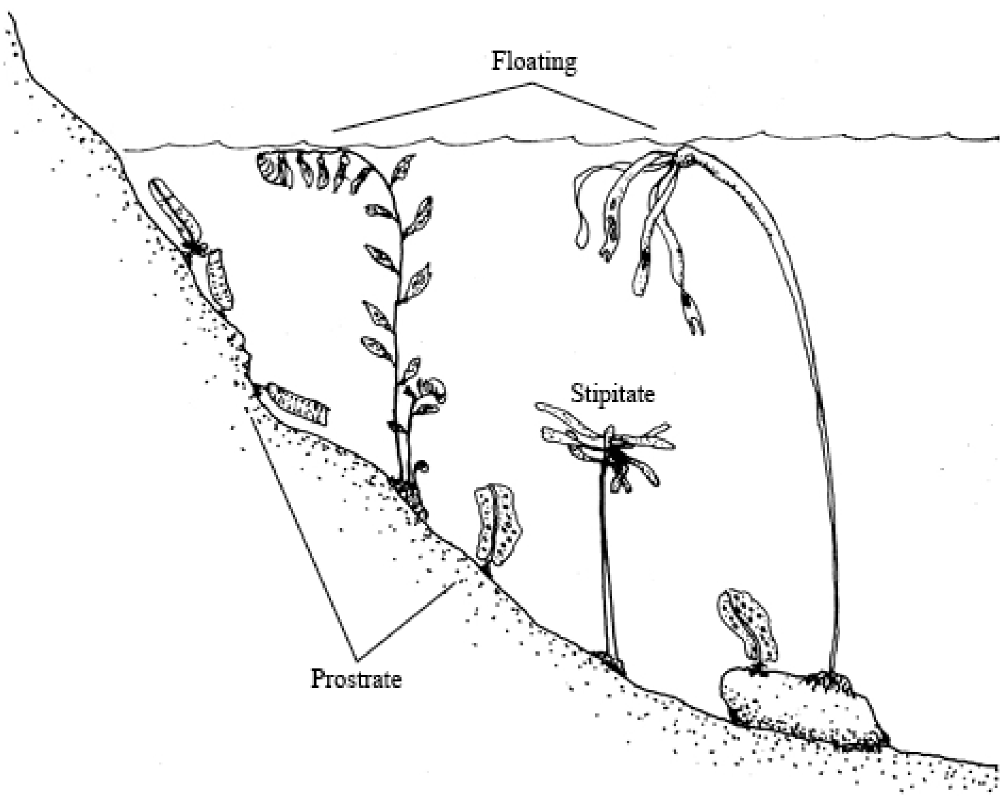

Figure 3. Kelp growth forms showing prostrate, stipitate, and floating kelp species. Illustration by Tom Mumford (2019).

3.2 Kelp Ecosystem Goods and Services

Kelp forests provide a variety of direct and indirect services for nearshore marine habitats and human coastal populations, such as:

- Habitat for ecologically and commercially important species;
- Food web support (primary production, forage habitat);
- Cultural value for Northwest Tribes and local communities;
- Recreation opportunities for harvest, diving, water sports, and fishing;
- Potential local water quality improvements through carbon and nutrient uptake; and
- Natural breakwaters that slow water motion.

In Washington State, kelp forests uptake 27 to 136 metric tons of carbon per day (Pfister et al. 2019). That is equivalent to the emissions of approximately 2,000 to 10,500 vehicles per year (EPA 2018).

Like eelgrass, kelp ecosystems provide critical habitat that increases overall biodiversity (Graham 2004; Altieri and van de Koppel 2014; Unsworth et al. 2018). The habitat is important for many economically valuable species, including threatened salmon and endangered rockfish (NMFS 2017; Shaffer et al. 2020). The large volume of primary production characteristics of kelp ecosystems provides an essential base for Puget Sound food webs, ultimately helping support marine mammals, including killer whale populations (Harvey et al. 2012; Southern Resident Orca Taskforce 2019). In addition to its role as foundation species, kelp is also an influential ecosystem engineer that, at high densities, can improve water quality by assimilating nitrogen (Kim et al. 2015) and slow the movement of water (Gaylord et al. 2007), potentially acting as natural breakwaters. This dampening of water motion increases the residence time of nutrients and particles (Eckman et al. 1989), potentially increasing larval densities of associated species and leading to higher food availability within kelp forests as compared to nearby vegetated and non-vegetated habitats. Finally, kelp forests offer diverse recreation opportunities to local residents, including productive fishing grounds and picturesque kayak and dive sites.

Kelp as Critical Habitat

Kelp forests provide critical habitat through two mechanisms:

1. Creating three-dimensional physical habitat that provides shelter and foraging opportunities, and
2. Acting as a direct food source (primary producer).

Kelp creates large volumes of high-quality habitat in areas with hard and rocky substrates unsuitable for eelgrass or saltmarsh vegetation. Eelgrass and kelp also grow intermixed in shallow areas with mixed substrates (Olsen 2019). Together, kelp forests, eelgrass meadows, and salt marshes can create contiguous marine vegetated habitats critical for associated species.

Primary production in kelp forests exceeds that of tropical rainforests per unit area (Krumhansl et al. 2016), and, in Washington waters, kelp biomass production is up to six times that of phytoplankton per unit volume (Pfister et al. 2019). This high productivity provides an important food source that supports food webs both inside kelp forests and in neighboring deep-water and shoreline habitats (Duggins et al. 2016; Filbee-Dexter and Scheibling 2016; Krause-Jensen and Duarte 2016; Olson et al. 2019; Schooler et al. 2019; Zuercher and Galloway 2019).

Losses in kelp populations result in losses to nearshore biodiversity and negatively impact fisheries, tourism, and coastal health.

The primary production in kelp forests is a foundation of nearshore food webs (Graham 2004; Krumhansl and Sheibling 2012; Koenigs et al. 2015; von Biela et al. 2016). Kelp forests in Norway harbor a greater abundance of marine invertebrates than other marine vegetated areas; in some cases, invertebrate abundances were five times higher than in eelgrass meadows (Christie et al. 2009). Similarly, invertebrate abundances—particularly of species known to be important forage fish, juvenile salmonid, and young-of-year rockfish prey species—are higher within kelp forests than adjacent open water and unvegetated benthic habitats (Siddon et al. 2008; Shaffer et al. 2020). The high volume of habitat provided by kelp, in combination with abundant food resources, makes kelp forests ideal refuges. The refuge and abundant food resource provided by kelp forests allow juvenile and mid-trophic species to feed in relative safety, helping lessen non-consumptive predator effects and leading to higher growth rates (O'Brien et al. 2018; Shaffer 2020). A study of kelp forests in the Strait of Juan de Fuca found that herring, surf smelt, and juvenile salmonids are more abundant inside kelp forests compared to adjacent open water sites (Shaffer et al. 2020). Kelp forests are also important foundations for adult finfish populations (Koenigs et al. 2015). Stable isotope data shows that adult coho salmon, chinook salmon remain reliant on nearshore food webs throughout their lives (see Appendix A for a more detailed discussion; Johnson and Schindler 2009). Healthy populations of finfish, particularly salmon, provide important prey for iconic Puget Sound predators, including killer whales (particularly Southern Resident killer whales), birds, and other marine mammals (Harvey et al. 2012; Southern Resident Orca Taskforce 2019).

The Cultural Importance of Kelp

The first human inhabitants of the Pacific Northwest likely followed a near-continuous band of floating kelp canopies dubbed "the kelp highway" that extended along the Pacific Rim from Asia to South America (Erlandson et al. 2007, 2015). Within the Pacific Northwest, bull kelp played a particularly prominent role in traditional subsistence knowledge and technology and in fishing, hunting, and food preparation and storage (Boas and Hunt 1921; Stewart 1977; Turner and Bell 1971; Turner 1995; Turner 2001) It was also put to more playful uses, as children and adults used the kelp for toys and target practice (Turner 1979, 2001). Finally, kelp played, and continues to play, a vital role in the symbolic and spiritual aspects of traditional Northwest Coast cultures. In some oral histories, kelp represents the interdependence between indigenous people and the sea and the reciprocal ties of kinship between humans and supernatural beings. In other stories, however, murderous kelp beings remind people of the potential dangers of the ocean. Appendix B provides more detail on the cultural importance of kelp for Pacific Northwest Tribes.

For many non-Tribal residents of Puget Sound, kelp forests have been and continue to be an essential food resource, particularly in the San Juan Islands. Bull kelp and other kelp species are harvested and dried for household consumption. Various groundfish species found in kelp forests, including rockfish and greenling, are also harvested for commercial, recreational, and subsistence purposes.

3.3 Kelp Distributions, Trends, and Regional Changes

Kelp forest persistence is highly dynamic over time, but evidence increasingly suggests that climate change stressors will lead to widespread and long-term declines in kelp populations (Connell et al. 2019; Smale 2019; Wernberg et al. 2019; Rogers-Bennet and Catton 2019). Kelp forests in many regions across the globe show decline. Persistent declines to kelp forests have been documented in North-Central California, Nova Scotia, the Gulf of Maine, Ireland, Norway, and South Australia (Wernberg et al. 2019). Recent kelp declines in Northern California (Rogers-Bennett and Catton 2019), Australia (Connell et al. 2019), and other locations (Airoldi and Beck 2007; Filbee-Dexter and Wernberg 2018; Wernberg et al. 2019) have been severe with little to no natural recovery. Causes of kelp loss vary by region, but generally reflect a combination of local and global stressors that interact additively or synergistically (Filbee-Dexter and Wernberg 2018; Rogers-Bennett and Catton 2019). Regardless of the cause, significant declines in kelp populations can result in substantial losses to nearshore biodiversity and negatively impact fisheries, tourism, and coastal health (Graham 2004; Bertocci et al. 2015; Koenigs et al. 2015).

Kelp Distributions and Trends in Puget Sound

Kelp exists in all of the basins of Puget Sound with appropriate habitat conditions, but is most abundant in exposed areas with hard substrate (ShoreZone 2001). While floating kelp canopies are the most conspicuous, they are only present along 11 percent of Washington shorelines while understory kelp is present along 31 percent shorelines. For comparison, eelgrass is present along 37 percent of Washington shorelines (ShoreZone 2001). However, these estimates are based on a compressive, one-time survey conducted in 2000 and may not accurately represent current distributions.

Along the outer coast and Western Strait of Juan de Fuca, floating canopy abundance, while highly variable, has remained stable in recent decades and over the last century (Krumhansl et al. 2016; Pfister et al. 2017). In contrast, traditional and local ecological knowledge from Tribes and residents, citizen-science surveys, and analysis of historical data suggest significant declines in the extent and density of bull kelp forests throughout Puget Sound (as defined in the Kelp Plan). Little information exists regarding changes in distribution or abundance among the 16 understory kelp species in Puget Sound (Mumford 2007).

Bull kelp forests in South Puget Sound have declined by 62 percent since the 1870s, with most losses occurring after 1980 (Berry et al. *in review*). A majority of the losses occurred in the inner reaches of South Puget Sound, with almost complete losses along all shorelines, except the Tacoma Narrows. These decreases include the loss of two bull kelp forests over the past decade and dramatic decreases in canopy area at several remaining forests (Berry et al. 2019, *in review*). In the Central Puget Sound, anecdotal reports document total bull kelp loss around Bainbridge Island and citizen-science data document kelp losses and decreases in canopy area around Edmonds and Mukilteo. Finally, analysis of aerial photography from the San Juan Islands raises concerns over significant losses in the North Puget Sound, especially to the more northern islands exposed to the warmer waters of the Strait of Georgia (Palmer-McGee 2019).

While evidence of kelp losses in Puget Sound is limited to bull kelp, recent research suggests that other kelp species are also vulnerable. Research in British Columbia found that multiple species of kelp declined in wave-sheltered areas compared to kelp in wave-exposed areas. The wave-sheltered environments of Puget Sound may be similarly vulnerable, with numerous species at risk, not just bull kelp (Starko et al. 2019).

3.4 Stressors

Environmental and biological conditions influence the abundance, persistence, and health of kelp populations (Dayton 1985; Steneck et al. 2002; Filbee-Dexter and Wernberg 2018; Pfister et al. 2019). Generally, kelp species in Puget Sound require hard substrates for attachment, and clear, cold water with sufficient nutrients to support growth (Wernberg et al. 2019). Sensitivity to changes in water quality makes kelp a potential sentinel or indicator species for nearshore environments, with losses often following the deterioration of local water quality and increased water temperatures (Reed et al. 2016; Filbee-Dexter and Wernberg 2018; Smale 2019). Biological controls in the form of competition with other seaweed species and grazing from herbivorous invertebrates also exert significant influence over kelp populations (Duggins 1980; Davenport and Anderson 2007; O'Brien and Scheibling 2016). These biological stressors can, and do, interact additively and synergistically with environmental stressors (Crain 2008). While there are areas of concern within Puget Sound, data are limited, and more research is needed to understand embayment-specific effects of local stress regimes (PSEMP Marine Waters Workgroup 2018; Berry et al. 2019; Calloway 2019).

The major stressors known to affect kelp populations are summarized below. Interactions among unidentified stressors not discussed explicitly here (e.g., disease introduction from restoration and commercial aquaculture, the introduction of new non-native species, effects of large oil spills, etc.) may also play an important role in future adaptive management strategies (see Appendix A for more detailed discussion of key kelp stressors).

Nutrient Loading

Kelp requires adequate nutrients for reproduction and growth. These minimum requirements can increase during periods of rapid growth and in the face of additional stressors (Bartsch et al. 2008; Stephens and Hepburn 2016; PSEMP Marine Waters Workgroup 2018). In field studies, nitrogen concentrations of 10 µmol/L resulted in increased giant kelp blade biomass and decreased blade erosion rates (Stephens and Hepburn 2016). Similarly, nitrogen concentrations of 10 µmol/L resulted in higher bull kelp recruitment success as compared to 1 and 5 µmol/L (Muth et al. 2019). Nutrient concentrations vary widely throughout Puget Sound; in some areas, concentrations remain consistently above these thresholds while they dip below these thresholds in others (Pfister et al. 2019; Berry et al. *in review*). Though the direct impacts of excess nutrients on kelp in Puget Sound are understudied, there is evidence that anthropogenic nutrient loading has altered nutrient dynamics and algal biomass in Puget Sound (Khangaonkar et al. 2018). In addition, excess nitrogen loading can indirectly affect kelp populations, promoting phytoplankton blooms that can quickly reduce available light (Burkholder et al. 2007; Mohamedali et al. 2011; Khangaonkar et al. 2018), and lend a competitive advantage to turf species that displace kelp (Russell et al. 2009; Falkenberg et al. 2013; Feehan et al. 2019). Turf algae include small filamentous and foliose green and red algae that provide fewer ecosystem services and lower biodiversity (Connell et al. 2014; Filbee-Dexter and Wernberg 2018; Appendix A). Because of these indirect impacts, anthropogenic nutrient loading from wastewater treatment plants, stormwater runoff, and other point and non-point sources of water pollution can have serious consequences for kelp forests (Benedetti-Cecchi et al. 2001; Falkenberg et al. 2013; Norderhaug et al. 2015).

Climate Change

Kelp forests are generally found in high latitudes and prefer cool water. Consequently, warming ocean temperatures threaten kelp forests across the globe (Smale 2019; Wernberg et al. 2019). The optimal temperature for many Puget Sound kelp species (for example, those in the genus *Laminaria sensu lato*, *Costaria costata,* and bull kelp) falls in the range of 5 to 15 °C (Tera Corp. 1982; Bartsch et al. 2008). Temperature stress makes kelp less tolerant and more vulnerable to other stressors, and marine heat waves have resulted in significant kelp forest losses in Northern California and Australia (Tera Corp. 1982; Rothäusler et al. 2009; Rogers-Bennett and Catton 2019; Wernberg et al. 2019). More discussion on this topic can be found in Appendix A. Due to the geomorphological complexity of Puget Sound, temperature stress will likely affect shallow and sheltered embayments more than deeper, well-mixed areas (e.g., sills separating major basins). Future management actions will benefit from identifying local temperature regimes and resulting impacts to kelp populations. While little can be done at the local level to reduce global stressors, such as rising ocean temperatures, actions taken to reduce local stressors can help decrease overall stress to kelp species in Puget Sound.

Fine Sediment Loading

Human activities in Puget Sound have both increased and blocked upland sediment loading (i.e., logging and dams, respectively) (Rubin et al. 2017) as well as the frequency of sediment resuspension from benthic and subtidal activities. Changes in fine sediment loading from river discharge, stormwater runoff, in-water construction activities, and coastal development can negatively impact kelp recruitment and microscopic life stage survival by burying suitable substrate and increasing turbidity (Airoldi 2003). However, the nature and severity of impacts depend on the timing of sediment deposition and the level of exposure at a given kelp forest (Geange et al. 2014). In the short term, increased sediment loads can increase mortality of dormant microscopic kelp life stages (Arakawa 2005; Deiman et al. 2012; Watanabe et al. 2016), while higher turbidity from sediment loading can significantly delay spring recruitment and reduce the maximum depth of kelp forests (Glover et al. 2019). Finally, sediment dynamics in Puget Sound have been altered by large-scale historical changes to upland and nearshore landscapes (Perkins and Collins 1997; Pearson et al. 2018). The effects of historical and current human-related alterations to nearshore sediment delivery on kelp habitat availability and population dynamics in Puget Sound are unknown and warrant further investigation.

Grazers

The loss of kelp forests due to uncontrolled grazing is well documented in the popular and scientific literature (Estes and Duggins 1995; Steneck et al. 2002; Ling 2008; Rogers-Bennett and Catton 2019). Generally, loss of mid- and high-level predators often results in expansions of grazers that negatively impact kelp populations (Davenport and Anderson 2007; Steneck et al. 2013: Rogers-Bennett and Catton 2019). However, decreases in grazing pressure can also lead to significant changes in kelp forest composition, allowing perennial species to displace annuals such as bull kelp (Duggins 1980; see Appendix A for a more detailed discussion).

Purple urchins have been responsible for recent large and persistent kelp losses in northern California (Rogers-Bennett and Catton 2019), and there is concern that urchin barrens may be expanding north into Oregon (Flaccus and Chea 2019). Puget Sound hosts three urchin species, but WDFW has not documented extensive urchin barrens during urchin population surveys (personal communication with Henry Carson, WDFW, November 14, 2019).

While herbivory from macrograzers, like urchins, is critical in understanding kelp forest dynamics (Steneck et al. 2002), smaller mesograzers—such as amphipods, small crustaceans, and small gastropods—may also negatively affect kelp populations (Davenport and Anderson 2007; O'Brien and Scheibling 2016; Pfister and Betcher 2017). Often, pressures from smaller grazers interact synergistically with environmental stress, resulting in more significant impacts than expected.

Fisheries Impacts

In Puget Sound, historical cod, pollock, hake, salmon, rockfish, urchin, sea cucumber, lingcod, cabazon, and abalone fisheries have significantly altered Puget Sound marine food webs (see Appendix A for more detail). The impacts of these changes on kelp population distributions and dynamics are unknown.

Harvest

Recreational harvest of kelp is allowed for individual use, and jointly managed by DNR and WDFW. Currently, DNR and WDFW only recommend sustainable harvest practices; best practices are codified for Washington State Parks only (WAC 325-32-350). A recent study on Whidbey Island found that unsustainable harvest practices (clipping kelp too close to the stipe) precluded regrowth post-harvest and negatively impacted kelp densities for up to a year after harvest (Kilgo 2019). Statewide regulations restrict harvest to 10 pounds of kelp (regardless of species) per person per day and recommend sustainable cutting (above the plant growth area, or meristem) (RCW 79.135.410). Currently, there is no formal, statewide monitoring of recreational kelp harvest to document harvest locations, species, methods, and quantities to assess the potential impacts of harvest on kelp populations. In Washington State parks, sustainable harvest is permitted in three parks during defined dates; all other parks are closed to recreational kelp harvest. In other areas, local regulations further limit or prohibit harvest.

Washington State does not allow commercial harvest of wild seaweed or kelp (RCW 79.135.410). There is one exception for giant kelp harvest for the traditional herring “spawn-on-kelp” fishery, but giant kelp does not occur within the boundaries of the study area of the Kelp Plan, and this fishery has been closed for decades.

Shoreline Development and Activities

Human activities and shoreline development generate a wide range of potential stressors affecting kelp species. Shoreline development and activities include, but are not limited to, overwater structures, outfalls, shoreline armoring, dredging, marinas, and navigation. The impacts on kelp can be both direct and indirect. Potential impacts include, but are not limited to dredging and construction in or near kelp forests, increased turbidity from increased sediment inputs (Rubin et al. 2017; Glover et al. 2019), shading from overwater structures (Szypulski 2018), anthropogenic nutrient loading (Falkenberg et al. 2013; Khangaonkar et al. 2018; Feehan et al. 2019), exposure to petroleum products from tanker spills (Antrim et al. 1995), and impacts from recreational and commercial boating activities. While existing regulations do consider kelp when permitting human activities and shoreline development, specific guidance for surveys (i.e., WDFW’s interim macrovegetation survey guidelines) and mitigation measures are not clear and have different requirements than for other macrovegetation. Collaborative research, in partnership with regulators and policymakers, will better support the management of kelp impacts from human activities and shoreline development.

Invasive Species: *Sargassum muticum* and *Undaria pinnatifida*

The invasive seaweed *Sargassum muticum* is known to displace native kelp species in Puget Sound (Britton-Simmons 2004). *Sargassum* was estimated to span approximately 20 percent of the shoreline in Puget Sound in the late 1990s (ShoreZone 2001). In Barkley Sound along the outer coast of British Columbia, *Sargassum* distributions have increased in wave-sheltered areas in recent decades (Starko et al. 2019). There is a concern that the *Sargassum* range has also expanded in the wave-sheltered environment of Puget Sound since the late 1990s (personal communication with Brent Hughes, Sonoma State University, November 12, 2019). While little data exists on *Sargassum* distribution and trends in Puget Sound, existing data from previous vegetation surveys may provide better insight. The invasive kelp species *Undaria pinnatifida* (known more commonly as Wakame) has been encountered as far north as San Francisco along the California coast (Zabin et al. 2009), and there is concern regarding its potential presence in Washington State waters and Puget Sound. Currently, there is no evidence that *Undaria* has been introduced to Puget Sound, but in the absence of comprehensive understory kelp surveys, its presence is unknown. While *Undaria,* like *Sargassum*, is a common invasive species throughout the Pacific Coast, there is no consensus on its impacts on native kelp assemblages (Casas et al. 2004; South et al. 2017).

Kelp crabs on bull kelp, Squaxin Island.
Photo by Julia Ledbetter.

IV. Puget Sound Kelp Management Framework

Kelp and kelp-based ecosystems in Washington State are managed within a framework of ownership, regulations, and trust responsibilities. The management is split between Tribes, state and federal management agencies, and county and municipal governments.

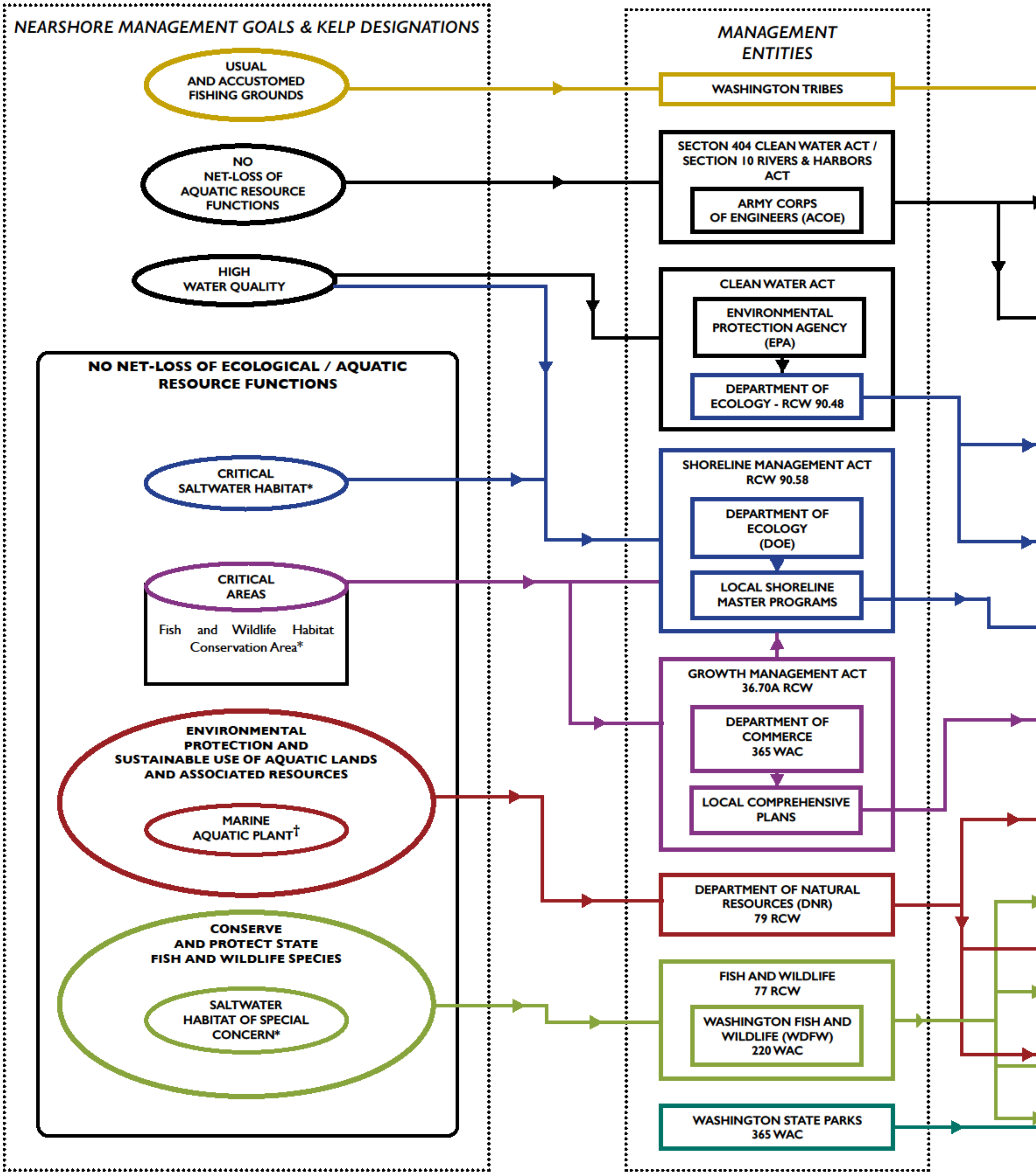

Figure 4 shows the management framework for kelp in Washington State.

Rockfish in understory kelp.
Photo by Adam Obaza- Paua Marine Research.

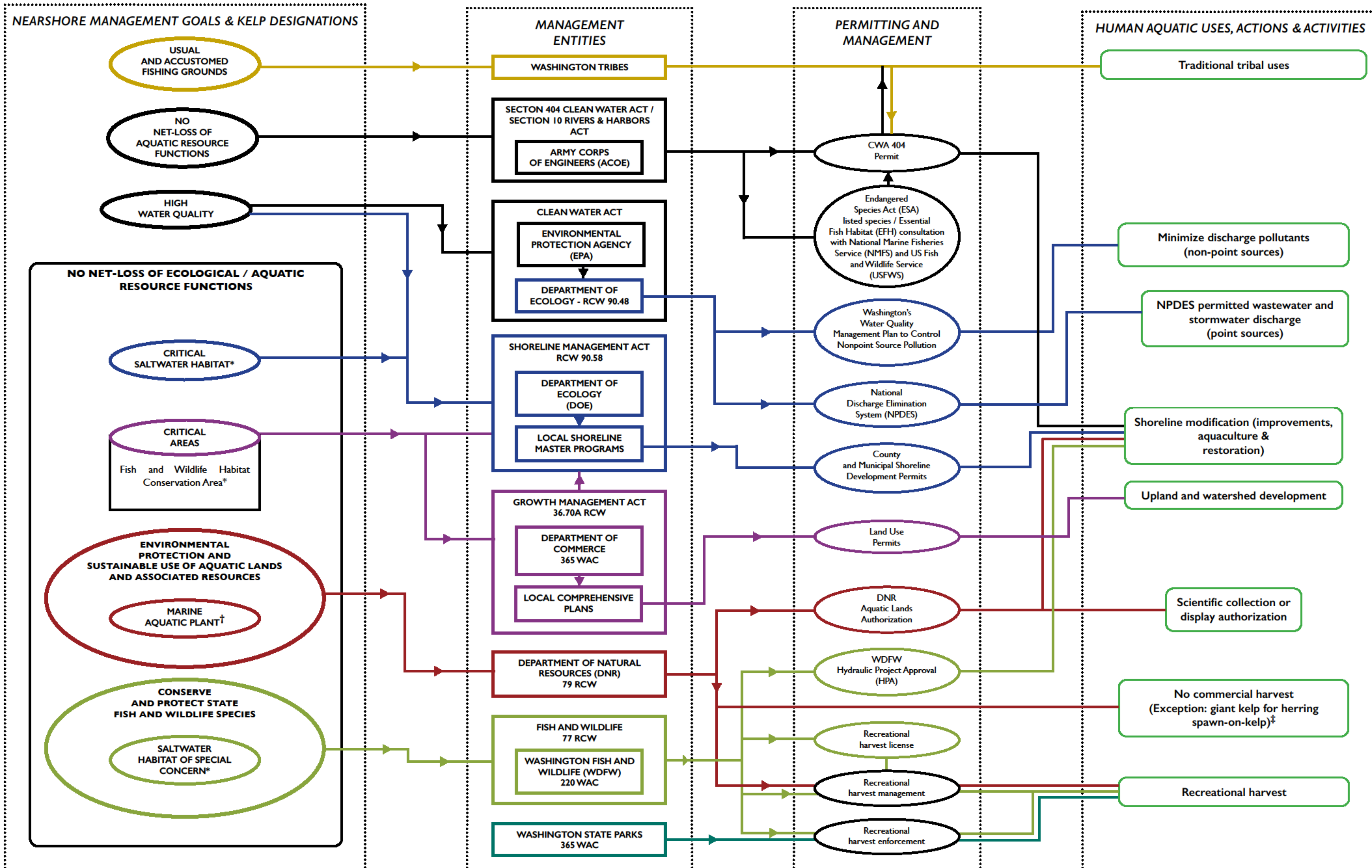

Figure 4. Diagram of the management framework for kelp in Washington State; * Designations that refer to "kelp" specifically and explicitly; † Designations that refer to macroalgae and/or species in the class Phaeophyta generally; ‡ Giant kelp does not occur within the geographic boundaries of this plan.

4.1 Kelp Management Responsibilities

Multiple Tribal and governmental agencies share responsibilities for managing Puget Sound kelp and their habitats.

Washington State Tribes

Washington Tribes have a reserved right to conserve and protect Puget Sound kelp habitats as critical habitat for several culturally and economically important species covered by treaty rights. Conserving and protecting critical fish habitat from environmental degradation was reaffirmed as a fundamental treaty right for all Washington Tribes under Phase II of the "Boldt Decision" (*U.S. v. Washington, 506 F. Supp. 187, 191*), and kelp restoration activities are now considered "fish habitat enhancement projects" by the WDFW (RCW 77.55.181). Kelp, in and of itself, also has significant historical and cultural value for Washington Tribes (Appendix B).

Washington State Department of Natural Resources

The Washington State Department of Natural Resources (DNR) manages and stewards 2.6 million acres of state-owned aquatic lands. The DNR manages aquatic lands in pursuit of five goals:

- Encourage direct public use and access;
- Foster water-dependent uses;
- Ensure environmental protection;
- Provide opportunities for utilization of renewable resources; and
- Generate income from the use of aquatic lands, when consistent with the previous goals.

State-owned aquatic lands include most subtidal areas (bedlands), nearly 30 percent of intertidal areas (tidelands), and unsold shorelands of rivers and lakes (shorelands). In general, bedlands below the extreme lower low water and within the three-mile state boundary are considered State-owned aquatic lands. Because kelp is generally found in subtidal waters and considered an attached resource, DNR manages the majority of Puget Sound kelp resources. Kelp harvest is also regulated under Washington State guidelines and regulations (RCW 79.135.410). State regulations prohibit the commercial collection of natural set kelp. Shellfish and seaweed aquaculture on State-owned aquatic lands requires a DNR use authorization, and DNR includes habitat stewardship measures to ensure the protection of kelp during construction and operations. DNR also has the authority to withdraw sites from leasing by Commissioner's order to promote native species conservation.

DNR established the Aquatic Reserve Program in 2002 to protect areas of "special educational or scientific interest, or of special environmental importance" (WAC 332-30-151). Eight Aquatic Reserves are currently managed by DNR (seven saltwater, one freshwater), and new aquatic reserves can be proposed according to DNR aquatic reserve implementation and designation guidelines. Kelp ecosystems are designated as priority marine habitats under DNR guidelines due to the critical functions and services they provide to associated marine species. Current aquatic reserves contain important areas of extensive and diverse kelp forests in the Strait of Juan de Fuca.

Shoreline Management Act: Department of Ecology and Local Shoreline Master Programs

The Shoreline Management Act of 1971 requires 41 coastal counties and municipalities in Washington State to draft and implement local shoreline management plans (SMPs) according to Department of Ecology (DOE) guidelines and regulations (WAC 173-26). SMPs, besides meeting other requirements, must delineate and afford protections to "critical areas," (RCW 36.70A)—which include kelp and eelgrass beds as "fish and wildlife habitat conservation areas"—using best available science (WAC 365-190-130).

DOE guidelines also require the protection of priority habitat areas, which include kelp as both a component of the Puget Sound Nearshore (WDFW 2008) and a "saltwater habitat of special concern," as defined by the WDFW (WAC 220-660-320). As a result, SMPs must "include policies and regulations to protect critical saltwater habitats and should implement planning policies and programs to restore such habitats" (WAC 173-26-221(2)(C). While these existing regulations provide significant protections for kelp habitats, effective conservation depends on local implementation and enforcement.

Clean Water Act: Washington Department of Ecology

The DOE implements water quality standards in fulfillment of the federal Clean Water Act (CWA), and the standards submitted by DOE must pass review from the EPA before being accepted. Water quality standards drafted by DOE are used in permitting both non-point sources of pollution from stormwater runoff, and point source pollution and waste discharge through the National Pollutant Discharge Elimination System (NPDES). The CWA requires states to develop a Total Maximum Daily Load (TMDL) plan for water bodies that exceed standards and are listed on the CWA Section 303(d) list. Current regulations do not include specific thresholds or pollution protections for kelp, but planned human-source nutrient load reductions aim to improve conditions for Puget Sound as a whole (RCW 90.40.010). It is unknown how effective such regulations are at protecting kelp specifically.

Hydraulic Project Approval: Washington Department of Fish and Wildlife

The WDFW Hydraulic Project Approval (HPA) program is intended to ensure "no net loss" of ecological functions within "saltwater habitats of special concern," specifically as they pertain to fish productivity (WAC 220-660-050). The objective is to minimize impacts of projects that "use, divert, obstruct, or change the natural flow or bed" of state waters. WDFW's HPA guidelines outline specific survey and mitigation requirements (avoid, minimize, compensate impacts) for all project applications, and reserve the right to deny any applications. Current WDFW HPA regulations provide exemptions for SMP development permits for fish habitat enhancement projects, which include kelp restoration activities (RCW 77.55.181).

Recreational Harvest and Scientific Collection Permits

DNR and WDFW share the management of recreational seaweed harvest statewide (RCW 79.135.410). No commercial harvest of naturally growing seaweed is permitted in Washington

State. WDFW issues recreational shellfish/seaweed collection licenses that allow for the harvest of up to 10 pounds (wet weight) of seaweed per day. This license does not require a catch record card, thus tracking seaweed harvests is left to on-the-ground enforcement and management officials from WDFW.

Kelp harvest for non-recreational uses is not well coordinated or tracked. DNR permits collection of kelp for scientific and display uses as a part of its "Aquatic Use Authorization" process on state-owned aquatic lands. The University of Washington's Friday Harbor Laboratories tracks the scientific collection of organisms in San Juan County, including seaweeds (RCW 28B.20.320). Responsibility for scientific and display collection on other lands resides with the local land manager.

Army Corps of Engineers: Clean Water Act, Rivers and Harbors Act Section 10, and Endangered Species Act

The United States Army Corps of Engineers (USACE) is responsible for permitting construction activities within U.S. waters. Section 404 of the CWA regulates dredged and fill material discharged into U.S. waters to "restore and maintain … the integrity of waters of the U.S." Section 10 of the Rivers and Harbors Act requires that construction activities do not interfere with navigable waters. In 1990, a memorandum added the goal of "no net loss" for aquatic resources to the USACE's responsibilities, requiring that any activities impacting aquatic resources include mitigation actions for "special aquatic sites," which include "vegetated shallows." However, "vegetated shallows" are defined as waters that support rooted vegetation, and interpretation differs on whether this category includes kelp and other seaweeds that do not form roots. As a result, kelp is often excluded from federal mitigation guidelines. CWA Section 404 does provide protections against impacts to critical habitat for ESA-listed species, however, and kelp is considered an endangered Puget Sound rockfish habitat.

National Marine Fisheries Service and United States Fish and Wildlife Service: Endangered Species Act

The NMFS and United States Fish and Wildlife Service (USFWS) designate critical habitat for ESA-listed species and require consultation under Section 7(a)(2) of the ESA with federal action agencies that propose actions that may affect listed species and their habitats. NMFS designated critical habitat in the nearshore for bocaccio, noting that "…substrates such as sand, rock and/or cobble compositions that also support kelp (families Chordaceae, Alariaceae, Lessoniacea, Costariaceae, and Laminaricea) are essential for conservation because these features enable forage opportunities and refuge from predators and enable behavioral and physiological changes needed for juveniles to occupy deeper adult habitats" (78 FR 47635).

National Marine Fisheries Service: Essential Fish Habitat

When a federal agency authorizes, funds, or undertakes an action that may adversely affect essential fish habitat (EFH), they must consult with NMFS on that action. An adverse effect on EFH is considered to be any direct or indirect effect that reduces the quality and/or quantity of the habitat and range from large-scale ocean uses to small-scale projects along the coast. NMFS provides advice and recommendations to federal agencies to avoid, reduce, or offset these adverse effects.

Canopy kelp is considered a "Habitat Areas of Particular Concern" (HAPC), which is a discrete subset of EFH. The canopy kelp HAPC includes those waters, substrate, and other biogenic (living) habitat associated with canopy-forming kelp species (e.g., Macrocystis spp. and Nereocystis spp.). The HAPCs are considered high-priority areas for conservation, management, or research because they are important to ecosystem function, sensitive to human activities, stressed by development, or are rare. These areas provide important ecological functions and/or are especially vulnerable to degradation and can be designated based on either specific habitat types or discrete areas. A HAPC designation does not automatically confer additional protections or restrictions upon an area, but it helps to prioritize and focus conservation efforts.

Kelp Aquaculture Regulations

Kelp aquaculture regulations and practices are not addressed in the Kelp Plan, as this document primarily focuses on the conservation and recovery of naturally occurring populations. There are potential future benefits from expanded seaweed aquaculture, but aquaculture should not be considered a replacement for naturally occurring kelp populations and should not negatively impact or displace them. A developed permitting framework for shellfish aquaculture in Puget Sound (RCW 19.135) is coordinated by the Shellfish Interagency Permitting Team, and kelp aquaculture generally falls within this framework. To date, only one site has been permitted in Washington State. Separate efforts spearheaded by NMFS and Washington SeaGrant are working to develop resources for seaweed aquaculture development in Washington State.

Bull kelp.
Photo courtesy of Eiko Jones Photography.

V. Kelp Conservation and Recovery Actions

The Kelp Plan defines six strategic goals and associated actions as a framework for coordinated research and management to support kelp conservation and recovery in Puget Sound. These goals and actions reflect the precautionary principle discussed in Section 2.3 and outline an approach that includes monitoring, conservation, and restoration actions. Adaptive management will play a key role, as our understanding of Puget Sound kelp populations, ecology, and biology grow. Furthermore, successful kelp conservation and recovery will require continued coordination between user groups, and additional funding and resources to support outlined actions. The Kelp Plan includes the formation of workgroups for ongoing coordination among management and science collaborators to continue this critical work.

While our understanding of kelp and its stressors is not yet sufficient to define a prioritized strategy or list, the broad suite of actions that are needed is clear. Strategic goals and related actions for kelp conservation and recovery are identified below, along with partner organizations that have expressed interest in contributing to these goals. If your organization is interested in joining this collaborative effort but is not listed below, please contact kelp@nwstraits.org.

1. Understand and Reduce Kelp Stressors

Regional- and local-scale stressors in Puget Sound affecting kelp likely differ between sub-regions and are not well understood. Reducing stressors will require research into the dynamics of kelp populations relative to both individual stressors and cumulative stressor impacts on a regional and local scale. Managers often look to reduce stressors on an individual basis by targeting priority key stressors to kelp. However, the spatial scale and potential cumulative and synergistic impacts of stressors on kelp may require a more holistic approach. Adaptive management is critical to support management needs to address stressors individually while incorporating the latest scientific understanding of how individual stressors fit into the bigger picture of kelp recovery. Consistent with the precautionary principle, even a partial understanding of the critical thresholds for individual stressors on kelp and the top priority stressors can be used to target management actions. Failure to reduce stressors that have caused kelp losses will impede successful restoration and recovery efforts.

Failure to reduce stressors that have caused kelp losses will impede successful restoration and recovery efforts.

Several existing tools and regulations direct diverse management entities to minimize kelp stressors (outlined in Section IV). Moreover, the scientific and management communities have expressed a need to strengthen enforcement and compliance of existing laws and regulations, close loopholes, increase interagency coordination, and prioritize kelp conservation. Finally, reducing environmental stressors will provide benefits for kelp and the overall health of Puget Sound.

Human Impacts on Water Quality and Kelp Habitats

Globally, kelp forests rely on clean, cool waters for persistence—and many of these waters are being lost to water quality degradation and warming ocean temperatures. Of specific concern are impacts to the nearshore environment from increased development, and growing populations, all of which can lead to excess nutrient loading, sediment delivery, and point and nonpoint sources of common pollutants and contaminants. Implementation of the following actions will help reduce human impacts on water quality and kelp habitats.

1.1. Form interagency workgroups to increase collaboration and information sharing across management organizations to improve implementation and to address policy gaps.

1.2. Inform future management actions through continued research on the impacts of current and historical human activities on kelp forests (e.g., nutrient and sediment loading thresholds and impacts, turbidity effects on kelp recruitment, substrate availability, and impacts from recreational and commercial boating activities).

1.3. Identify priority stressors that negatively affect Puget Sound kelp on a sub-regional scale to target management actions.

1.4. Fully implement and enforce available protections for kelp through existing regulations, programs, and policies (e.g., DOE SMA Guidance, Local SMPs, WDFW HPA, DNR Aquatic Use Authorizations, mitigation programs, NMFS ESA and EFH consultations).

- 1.4.1. Fully consider kelp in programs that respond to and prevent chemical and oil spills (e.g., DOE Geographic Response Planning).
- 1.4.2. Develop tools to support planners' ability to review/access policy regulations that assist in decision-making.
- 1.4.3. Develop and implement long-term research and monitoring actions using rigorous scientific and adaptive management principles to determine the effectiveness of current regulations and protection actions.

1.5. Increase protection by addressing key gaps in existing regulations and implementation programs.

- 1.5.1. Improve kelp-specific mitigation guidance and implementation.
- 1.5.2. Add an explicit reference to kelp in existing regulations that include kelp protection but do not reference kelp specifically. (e.g., CWA Section 404 definition of Vegetated Shallows, DNR's definition of submerged aquatic vegetation, and WDFW's Priority Habitats and Species list).

1.5.3. Update survey guidelines and foster coordination among the organizations that conduct site-level surveys, such as the WDFW Macroalgae Habitat Interim Survey Guidelines and the Coastal Zone Training Program.

1.5.4. Form an interagency workgroup to review the kelp aquaculture permitting process and develop best management practices, such as cultivating native species, avoiding the spread of pathogens, and avoiding the use of harmful pesticides and other chemicals.

1.6. Reduce anthropogenic nutrient and sediment loading (e.g., stormwater and WWTP permitting, and TMDL planning).

1.6.1. Coordinate and share research with the Nutrient Reduction Program planning and implementation program, led by the DOE.

1.7. Support sustainable kelp harvest by informing recreational harvesters about regulations and sustainable kelp harvest methods.

Biological Stressors

Human activity, historical and current, has altered the biological condition of Puget Sound. Fishing pressure has disrupted elements of the Puget Sound food web, impacting populations of cod, hake, pollock, salmon, rockfish, urchin, sea cucumber, abalone, lingcod, cabazon, and others (See Appendix A for more discussion). Fishing-related changes to marine food webs have the potential to impact kelp populations (See Section IV). Still, the connection between fishing pressure and status of kelp populations in Puget Sound is unknown. Additionally, human activities have introduced non-native macroalgal species, such as *Sargassum*, that compete with native kelp for space and light. Implementation of the following actions will help reduce biological stressors.

1.8. Strive to incorporate kelp and other trophic considerations into fisheries management planning.

1.9. Explore invasive macroalgae (including *Sargassum muticum* and *Undaria pinnatifida*) control alternatives, ecological roles, and long-term management considerations related to climate change.

Climate Change

Anthropogenic climate change poses a profound threat to marine environments all over the globe. For kelp in Puget Sound, increasing water temperatures are a major potential concern. Many of the inner basins naturally experience high water temperatures (Burns 1985; Bos et al. 2015) and the water temperatures are expected to rise with climate change. Additional stress associated with climate change-related impacts to water quality (increased turbidity from increased storm severity and frequency, increased flooding, and sea-level rise), increases in human development resulting from climate-related migration, and ocean acidification-related hypoxia also pose serious threats to Puget Sound kelp populations. Many of these climate-related stressors can be addressed by previously outlined actions in this Kelp Plan to better understand and reduce their impacts on Puget Sound kelp populations. While there is no Washington State or local policy action that can "lower the thermostat" on Puget Sound waters, it is important to note that temperature stress likely exacerbates the impacts of other stressors. Implementation of the following actions will help reduce impacts of climate change.

1.10. Investigate climate change impacts to improve management decisions, such as prioritizing locations for kelp protected areas, restoration sites, and mitigation activities.

1.10.1. Include kelp habitat in regional and local climate adaptation strategies and planning.

1.11. Investigate local effects within kelp beds on seawater chemistry (Pfister et al. 2019) and consider potential management opportunities for these benefits.

1.12. Investigate the development of temperature-tolerant strains of native kelp species for potential use in restoration and mitigation outplanting.

2. Deepen Understanding of the Value of Kelp to Puget Sound Ecosystems and Integrate into Management

Available information indicates that kelp forests provide important ecosystem services to Puget Sound. While we have a general understanding of these ecosystem goods and services from other kelp ecosystems from around the world, our understanding of the magnitude of those services in Puget Sound is incomplete. Improving our understanding of the role of kelp in Puget Sound food webs and the essential ecosystem services it provides will support regulatory actions to better protect kelp. Additional research and management guidance are needed to demonstrate the link between kelp forests and populations of species like salmon, rockfish, forage fish, and killer whales (particularly Southern Residents). A deeper understanding will enhance our ability to advocate for kelp conservation as a necessity for improving the health of Puget Sound as a whole. Implementation of the following actions will improve our understanding of kelp habitats and their values.

2.1. Determine and quantify functional roles of kelp habitats for associated species and provide guidance to managers for regulatory implementation, such as endangered species habitat conservation.

2.1.1. Monitor the use of kelp forests as nurseries, migration corridors, refuges, and high-quality forage grounds for salmonids, rockfish populations, forage fish, pinto abalone, and killer whales.

2.1.2. Utilize local ecological knowledge to assess the value of kelp forests as fishing areas.

2.1.3. Use isotopic and biochemical analysis of Puget Sound species and other tools to assess kelp contributions to nearshore, deep water, and terrestrial food webs.

2.2. Calculate the value of kelp ecosystem services for use in developing mitigation guidance.

3. Describe Kelp Distribution and Trends

Successful management relies on having accurate information regarding the distribution and trends of species and populations of management concern. Currently, synoptic data on kelp distribution throughout Washington State is limited to the 1990s-era ShoreZone Inventory (Berry et al. 2001). More detailed and recent information is needed on the distribution of both canopy-forming and understory species. Additionally, due to the dynamic nature of kelp forests, information on short- and long-term trends is needed to tease apart natural variation and response to stressors. Kelp monitoring is limited to surface canopy surveys by the DNR and NWS Commission, surveys by the Marine Resources Committee in some locations, and understory surveys by the United States Geological Survey (USGS).

Updated information on distribution and trends is essential to inform point-in-time surveys, link changes in distributions to stressors, and guide planning. Additionally, continued and regular monitoring will help managers detect where the loss of kelp forests is occurring. This information will allow policymakers and managers to effectively target sites with stable kelp forests for conservation and sites with measured losses for recovery efforts. Finally, it will allow for the regional tracking of kelp resources. Implementation of the following actions will provide new information on kelp distribution and trends.

- 3.1. Update and expand information on the current extent of canopy-forming and understory kelp.
- 3.2. Make distribution and trends data available to agencies and the public for use in spatial planning, project planning, and regulatory implementation.
- 3.3. Coordinate and expand efforts to strategically monitor canopy-forming and understory kelp throughout Puget Sound and build collaborations between organizations.
  - 3.3.1. Continue and expand surface monitoring of Puget Sound canopy-forming kelp.
  - 3.3.2. Develop Puget Sound-specific subtidal monitoring protocol, and establish a network of partners conducting subtidal kelp index site monitoring (e.g., REEFCheck, PSRF)
  - 3.3.3. Encourage compatibility among protocols to support data synthesis, linking ecological functions, and relationships to local stressors.
  - 3.3.4. Collaborate with the Puget Sound Partnership to expand the eelgrass Vital Sign to incorporate kelp indicators (such as kelp canopy area and understory kelp distributions).
- 3.4. Expand understanding of historical distributions and trends by compiling historical information sources and exploring traditional ecological knowledge.
- 3.5. Identify the genetic structure of kelp populations, including connectivity, dispersal, and population dynamics.

4. Designate Kelp Protected Areas

Puget Sound kelp recovery begins with the conservation and protection of kelp forests. Besides implementing and strengthening current regulations to conserve kelp, the establishment of priority kelp habitat areas will support local and regional conservation efforts. Given that stressors and available management tools vary by location, we anticipate that enhanced protections will be site-specific. Coordination among multiple management organizations could increase the span of protections at a site (for example, limitation of harvest and land use activities). Implementation of the following actions will increase kelp protection.

4.1. Protect kelp habitat in existing and new reserves, refuges, and protected areas.

4.1.1. Increase the protection of existing kelp forests through organizations like DNR and USFWS.

4.1.2. Use withdrawal letters and set standards for lease agreements to ensure the protection of kelp forests (DNR).

4.2. Assess the extent of recreational kelp harvest and its potential impacts, and develop spatial management plans and strategies to reduce potential impacts from projected kelp harvest activities.

4.2.1. If necessary, identify priority enforcement needs relating to permits and recreational harvest activities to support existing protections.

5. Restore Kelp Forests

Historical kelp forests can be restored through a combination of indirect habitat improvements to reduce stressors and direct kelp population enhancement. Reestablishment of persistent kelp forests relies on first eliminating or minimizing the stressors that contribute to current documented losses. Since restoration methods and best practices are still being developed, it is critical that we monitor restoration and mitigation sites following project completion and assess the success and efficacy of new methods. Restoration success could be increased by identifying places with the greatest potential to support kelp. Finally, we must work to shift current approaches to mitigation away from piecemeal actions and towards a more holistic, total-ecosystem approach that takes into account kelp forest connectivity and large-scale issues of nearshore habitat connectivity. Implementation of the following actions will help restore kelp forests.

5.1. Develop a spatial plan identifying regions and sites for priority restoration actions and mitigation.

5.1.1. Target management actions that reduce stressors at priority restoration sites.

5.1.2. Reintroduce kelp through outplanting at sites that are recruitment limited.

5.1.3. Develop a mitigation bank of priority locations for kelp enhancement and restoration projects, and for when *in-situ* mitigation is not viable.

5.2. Continue development of kelp restoration techniques for use in enhancement projects and mitigation.

5.2.1. Develop best management practices for designing, installing, and maintaining compensatory mitigation sites and restoration projects.

5.2.2. Define measurable project success standards to include ecosystem goods and services and long-term persistence of kelp forest.

5.2.3. Develop monitoring protocols to verify project success/compliance.

5.2.4. Support the development of local kelp seed banks for use in genetically appropriate restoration.

5.3. Fund and implement restoration activities at priority sites.

5.3.1. Target restoration-funding sources for stressor reduction and population enhancement projects.

5.3.2. Reach out to restoration funding sources to include funding for kelp restoration.

5.3.3. Use compensatory mitigation as a tool to restore goods and services provided by kelp forests.

6. Promote Awareness, Engagement, and Action from User Groups, the Public, and Decision-Makers

The success of this Kelp Plan and the conservation and recovery of kelp in Puget Sound depends on increased awareness and engagement in support of actions to sustain kelp. We must improve our understanding of the current status and ecological value of kelp in Puget Sound, implement the research and management needs identified in this Kelp Plan, and educate individuals on how they can help. Implementation of the following actions will help increase awareness and engagement in kelp recovery efforts.

6.1. Share information on (1) the value and role of kelp ecosystems as critical nearshore habitat and food web support (for forage fish, rockfish, salmon, and killer whales) in Puget Sound; and (2) the growing concern regarding significant losses to bull kelp canopies.

6.1.1. Educate decision-makers (federal, state, and local entities) regarding the value of kelp, local declines, and the needs articulated in the Kelp Plan.

6.1.2. Work with Tribal partners to elevate the prominence of traditional ecological knowledge regarding kelp.

6.1.3. Encourage partners (e.g., Tribes, anglers, commercial fishermen, Washington Public Port Association, industry, recreational harvesting groups, and NGOs) to help tell the story of kelp to local communities and decision-makers.

6.1.4. Develop curricula and other educational tools focused on Puget Sound kelp ecosystems for K-12 classrooms and other education forums (e.g., aquariums, science centers, reserves).

6.1.5. Carry out targeted outreach and advocacy to develop support for the implementation of the goals outlined in the Kelp Plan.

6.1.6. Develop public educational materials and maps on how boaters and outdoor recreation groups can minimize their impacts to kelp (e.g., parks, boat launches, marinas).

6.2. Build research capacity and coordinate knowledge sharing of ongoing kelp recovery projects and research gaps.

6.2.1. Create and maintain a regularly scheduled forum for information sharing and knowledge gathering between Tribal, federal, state, and local entities.

6.2.2. Coordinate kelp conservation actions and research activities with the Salish Sea International Kelp Alliance, British Columbia, and states of Oregon and California.

6.2.3. Coordinate knowledge sharing through regular participation in conferences, workshops, publications, social media, etc.

Partners in Kelp Conservation and Recovery

Partners committed to participating in actions at the time of Kelp Plan development include but are not limited to:

DNR
DOE Water Quality Program
Feiro Marine Life Center
Kwiáht
Marine Agronomics LLC
MRCs
NMFS
NWS Commission
NWS Foundation
The Pew Charitable Trusts
Port Gamble S'Klallam Tribe
Puget Sound Partnership
PSRF
REEFCheck
Salish Seaweeds
Samish Indian Nation
SeaDoc Society
Tulalip Tribes
University of Washington
USGS
WDFW
Washington State University
Western Washington University

MRC kayak-based survey of bull kelp forest at Ebey's Landing.
Photo by Rich Yukubousky.

Kayakers and bull kelp in Commencement Bay, Tacoma.
Photo by Washington State Legislative Support Services.

VI. Conclusions

Bull kelp forests have declined and disappeared from some areas of Puget Sound. There is a growing concern within the scientific community that this trend is not limited to bull kelp, and that threats to kelp species are intensifying. The development of this Kelp Plan brought together kelp scientists, ecosystem recovery experts, tribal resource managers, and local, state, and federal representatives. The parties discussed current research and data gaps, and identified key goals and actions that support science-based regulation and management to conserve and restore kelp. The Kelp Plan defines six strategic goals and related critical actions to initiate a regional response.

1. Understand and reduce kelp stressors;
2. Deepen understanding of the value of kelp to Puget Sound ecosystems and integrate into management;
3. Describe kelp distribution and trends;
4. Designate kelp protected areas;
5. Restore kelp forests; and
6. Promote awareness, engagement, and action from user groups, Tribes, the public, and decision-makers.

At the heart of the six strategic goals is a need for ongoing coordination of research and interagency efforts; improved communication between researchers and managers; and additional funding to support research, monitoring, education, outreach, implementation, and enforcement. The actions outlined in the Kelp Plan require a unified effort from many people and organizations to carry out the strategic goals. Raising awareness of the need to support kelp conservation and recovery will help further build this network. The Kelp Plan provides the framework to coordinate research and management actions to support the persistence of kelp in the face of global and local stressors, and ensure that these iconic native species continue to thrive in our local waters.

At the heart of kelp recovery efforts is a need for ongoing interagency coordination of research, better communication between researchers and managers; and additional funding to achieve the strategic goals.

Bull kelp forest at Ebey's Landing. Photo by Rich Yukubousky.

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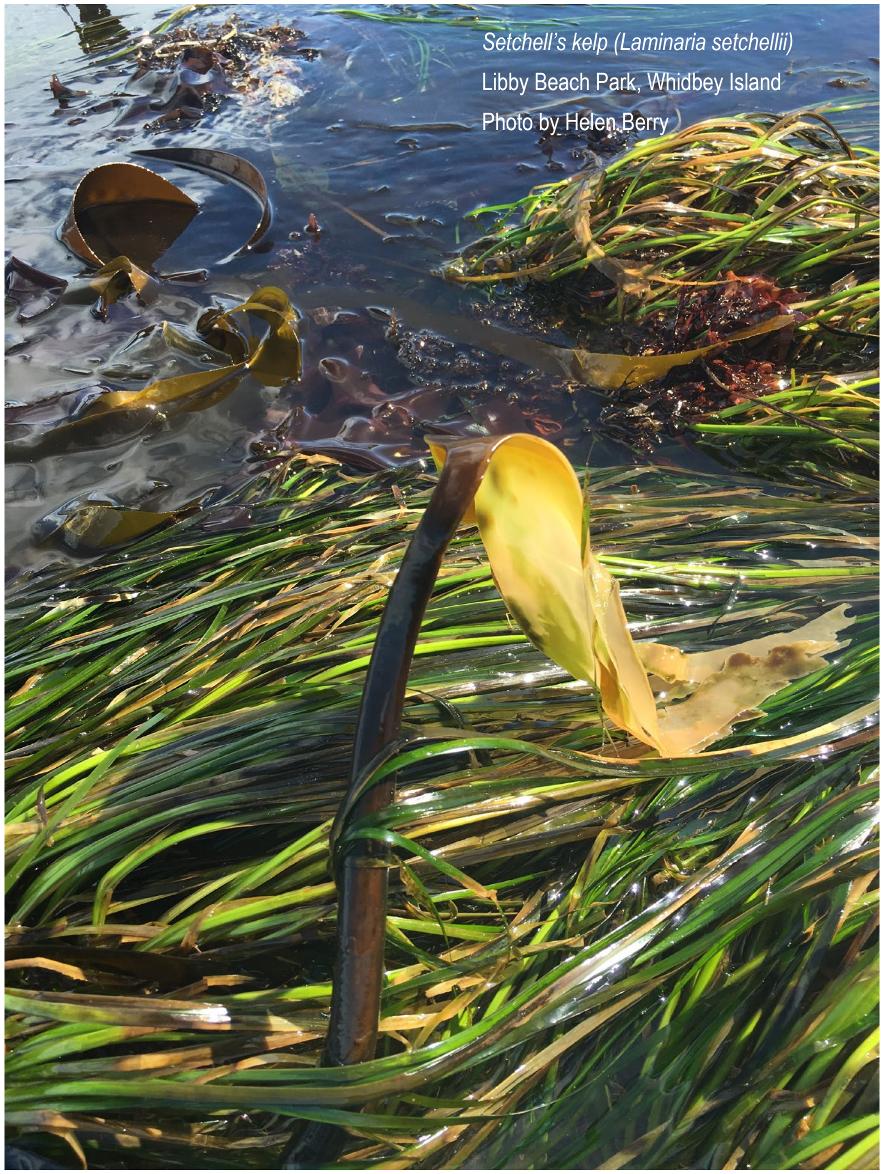
Setchell's kelp (Laminaria setchellii)
Libby Beach Park, Whidbey Island
Photo by Helen Berry