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Hardshell clams, oysters, shrimp, crab, and many other shellfish species hold a special place in the traditions, stories, and beliefs of the Indigenous communities of the Salish Sea. Shellfish provide many foundational ecosystem services that contribute to clean water, habitat structure, and nutrient cycling. In addition to their contributions to a healthy environment, shellfish also supply a year-round source of protein to coastal communities and lay the foundation for health and wellbeing for Indigenous people. Unfortunately, changes in the environment have begun to threaten this foundation. Climate change, particularly the resulting acidification and warming of oceans, is one of the main issues facing shellfish populations today. As greenhouse gas emissions continue to rise, the likelihood of significant losses to shellfish populations does as well. As a result, Native communities rooted in coastal areas are disproportionately at risk of suffering from the effects of climate change in marine systems. Intertwined relationships between cultural practices, livelihoods, and marine resources put emotional, spiritual, and financial security on the line for many tribal members. In recognition of the value of shellfish, many Indigenous communities are actively addressing the impacts of climate change while also determining ways to adapt to a changing environment in order to maintain their way of life.

Recognizing the significant threat of climate change to their people, the Swinomish Indian Tribal Community (SITC) launched a climate change initiative to assess potential climate change impacts on the Reservation and determine appropriate actions to protect community residents and resources. This work resulted in two separate reports that created a vulnerability assessment, a risk analysis, and an adaptation action plan for SITC. Risks to shellfish populations were ranked as high to medium-high, and broad adaptation goals and recommendations were produced, such as the need to seek off-Reservation harvest locations, and the desire to restore habitat and shellfish populations. In the 13 years that have passed since the publication of these documents, our understanding of climate change impacts on shellfish has expanded, while shellfish resource availability for many species is in decline. Concerns over the negative impact of reduced shellfish availability to community health and wellbeing prompted the SITC Fisheries Department to develop a more in-depth and updated adaptation action plan. Additionally, we wanted to expand the spatial scope beyond the Reservation boundaries. The technical report, **Swinomish Climate Change Adaptation Strategies for Shellfish (CCASS)** is the result of that effort, whereas this overview document provides readers with a shorter, more straightforward, description of the technical report.

CCASS Purpose: *To guide research and adaptation efforts of the Swinomish Indian Tribal Community in order to safeguard the availability of shellfish resources for future generations.*

While the primary action needed to slow the impacts of climate change is a reduction of greenhouse gas emissions, global-scale action is not occurring at the rate needed to stop significant changes to our climate. Thus, the adaptation strategies outlined here provide recommendations that aim to reduce shellfish vulnerability to current and expected climate change effects and strengthen the resilience of human and nonhuman systems within the Tribe's usual and accustomed fishing areas. In order to create a shellfish-specific adaptation plan, we reviewed published scientific literature that focused on (1) climate change and ocean acidification impacts on shellfish, and (2) ways to reduce these impacts along with strategies for adaptation. Adaptation actions often work by reducing the stressors on the ecosystem that are not related to climate change (e.g., pollution, coastal development, etc.) and are more within our ability to locally address.

Recognizing that Indigenous knowledge can increase the effectiveness and success of adaptation efforts, we also identified priority actions using culturally-appropriate, community-based strategies whenever possible. In this summary, we report four broad and well-supported strategies that reduce the impacts of climate change on shellfish: (1) preserve intact ecosystems, especially those that support critical habitat or ecosystem services; (2) reduce non-climate stressors; (3) restore physical, ecosystem-forming processes to promote landscape biodiversity and functioning; and (4) enhance native species and ecosystem biodiversity. Each strategy has associated goals to aim for, with specific actions designed to help achieve the goal in our regional environment. Finally, we recommend the following systematic approach before SITC or any other agency implements a suggested management action: conduct or review findings of a vulnerability assessment and risk analysis, involve all affected parties in the decision-making process, and evaluate all feasible options to determine the optimal action.

SHELLFISH ADAPTATION STRATEGIES

Swinomish Shellfish Adaptation Strategy 1: Preserve intact ecosystems, especially those that support critical habitat or ecosystem services

Healthy environments are often better able to withstand stressors than environments that are degraded (via pollution, coastal development, introduced non-native species, etc.). These areas can also serve as important areas of refugia for marine life when environmental conditions become stressful for shellfish. Importantly, protecting intact ecosystems is easier, more successful, and more cost-effective than active restoration, which cannot guarantee the return of the original ecosystem. When considering protection options (such as land purchases or reserve development), it is essential all relevant parties, especially tribes, are involved in the decision-making process.

Goal 1.1*: Protect intact critical transition zones and allow for shifting of natural shorelines.*

Critical transition zones are areas where the marine environment meets the upland environment, such as marshes, wetlands, bluffs, and beaches. Many life history stages (e.g., larval, juvenile, adult) of shellfish species utilize habitat in these transition zones, demonstrating their importance to the continued longevity of shellfish populations. But these regions also provide humans with many ecosystem services (benefits that plants, animals, and their habitat provide to humans) such as moderating floods, sequestering carbon, and cycling nutrients. As no environmental system works in isolation, the functioning of these transition zones is also dependent on the conditions of nearby ecosystems. Therefore, protecting these transition zones and their surrounding ecosystems should be a high priority as communities decide how to manage coastal populations, protect shellfish resources, and address impacts from climate change. Conservation efforts will also be more resilient to sea level rise if protected areas allow for landward migration.

Suggested adaptation actions for Goal 1.1 include:

- Prioritize protecting multiple large stretches of connected coastline and a broad variety of habitat types.
- Protect juvenile and subadult Dungeness crab habitat by conserving intact tidal flats and adjacent tidal channels.
- Include climate change projections when developing protection plans for critical transition zones.
- Collect shellfish abundance and habitat use data at various life stages to identify and prioritize critical habitat.

Goal 1.2*: Protect seagrass beds and kelp forests.*

Seagrass and kelp beds are found from the area above water level at low tide and underwater at high tide (intertidal zone) to nearshore areas that are always submerged (subtidal zone). Seagrass, which includes eelgrass and kelp, are collectively known as macrophytes and make up among the most productive habitats on the planet. They also support a diverse array of nearshore species and provide many ecosystem services and functions. Specifically, macrophytes are a critical food source for many species, they may locally moderate ocean acidification, and certain species may lessen storm surge and protect shorelines from sea level rise. Due to their importance in the region, we must ensure currently functioning macrophyte beds are allowed to adapt to environmental changes without additional stressors.

Suggested adaptation actions for Goal 1.2 include:

- Protect and restore existing eelgrass and kelp beds.
- Monitor macrophyte beds to identify areas for conservation.
- Better understand local effects of kelp beds on seawater chemistry.
- Gather information on how environmental and ecological factors may influence macrophyte beds.

Goal 1.3*: Protect climate and ocean acidification sanctuaries.*

As climate change continues to alter global climate patterns, discovering and protecting local coastal microclimates (areas with unique environmental conditions that differ from the surrounding region) will become increasingly important. Physical factors such as wind and wave exposure, depth, prevailing currents, substrate type, large woody debris, and the presence of macrophyte beds can influence local ocean conditions and can lead to the formation of microclimates. Historically, these unique areas (i.e., "sanctuaries" or "refugia") have provided shelter for species during extreme climate events, allowing species to survive locally while extreme conditions occurred regionally or even globally. Thus, an emerging conservation goal is to identify and protect microclimates, especially for species that are culturally, ecologically, or economically important, such as shellfish. These sanctuaries, however, are not long-term solutions, but protection could provide species time to adapt to changing ocean conditions while other solutions are sought.

Suggested adaptation actions for Goal 1.3 include:

- Encourage seaweed farming near tribally-important clam beaches.
- Learn what type of refugia is beneficial for various target species.

Swinomish Shellfish Adaptation Strategy 2: Reduce non-climate stressors

A rapidly changing climate is not the only challenge facing shellfish and their habitat; changes in land and sea use, exploitative harvest practices, and pollution bring additional stressors to shellfish populations. These topics encompass a wide range of stressors from coastal development and bottom trawling to road and agricultural runoff. The overall effect results in habitat destruction, loss of biodiversity, and impaired ecosystem function. Therefore, to enhance species, ecosystem, and community resilience to climate change, we must identify and reduce non-climate stressors. Not only is this strategy accommodating for large-scale adaptation, but solutions are technologically ready and provide many benefits at the local scale for both human and nonhuman communities.

Goal 2.1*: Reduce nutrient loading.*

Referred to as "nutrient loading," excess nitrogen and phosphorus from upland sources such as wastewater treatment facilities, animal feedlots, or residential lawns can enter coastal waterways and cause algal blooms. When the algal bloom begins to decline, the process of dead algae breaking down can lower pH and oxygen levels in the water, often creating conditions that cannot sustain marine life. For many shellfish species, who cannot move very quickly or at all, the results of nutrient loading can be fatal. Furthermore, low to zero oxygen events (referred to as "hypoxic events") will likely increase when nutrient loading is coupled with warmer ocean temperatures and changes in water circulation. Increases in water temperature may also be linked to more frequent harmful algal blooms that produce paralytic shellfish toxins and domoic acid, impacting human health and harvest opportunities. Thus, it is important that nutrient sources are identified and reduced or eliminated to benefit human and nonhuman communities.

Suggested adaptation actions for Goal 2.1 include:

- Increase local monitoring of nutrients and harmful algal blooms in Whidbey Basin and northern Puget Sound.
- Enhance shellfish aquaculture projects in areas with low dissolved oxygen and high nitrogen input.
- Encourage sustainable Indigenous and western farming and agricultural practices.

Goal 2.2*: Monitor toxic pollutants.*

Due primarily to industrial discharge and urban/agricultural runoff, coastal waters contain some of the highest levels of metals and pollutants that filter feeders, such as clams or oysters, can readily uptake. Further worsening the problem, ocean acidification changes water chemistry and, in doing so, can make metals more abundant, compounding physical stress on shellfish. Warmer water temperatures can also increase the toxicity of certain contaminants already present within the water and impact the health of humans consuming shellfish. Risk of shellfish exposure to toxic chemicals has also increased recently due to expanded shipping traffic (particularly of tanker vessels carrying crude oil) and transportation of other hazardous chemicals by rail.

Suggested adaptation actions for Goal 2.2 include:

- Increase monitoring of toxic pollutants in Whidbey Basin and northern Puget Sound.
- Ensure oil spill response resources are sufficient to address spill risks, protocols are updated, and execution is efficient.

Goal 2.3*: Promote sustainable harvest management practices.*

Overfishing continues to be one of the primary human impacts on marine ecosystems, harming the way ecosystems work and the ability of species to adjust to climate change. Similar to global trends, there are signs of overexploitation in several marine invertebrate fisheries in Puget Sound. Unfortunately, harvest management options to promote species recovery and prevent future overharvest are limited because we do not know enough about the biology of many target species. New management strategies may be needed to account for environmental threats to species' health and productivity. Indigenous communities have a long history of sustainably managing resources using a variety of technologies. The application of place-based knowledge by Native communities should be encouraged to increase fishery yields in a manner that promotes biodiversity and restores the complex systems that supported human and nonhuman communities for millennia.

Suggested adaptation actions for Goal 2.3 include:

- Restore ancient Indigenous shellfish mariculture practices.
- Utilize best available science and fill research gaps to better inform sustainable harvest management policies.
- Reduce fisheries-related mortality through research and outreach.

Swinomish Shellfish Adaptation Strategy 3: Restore physical, ecosystem-forming processes to promote landscape biodiversity and functioning

Across the Salish Sea, more than 150 years of development have fragmented the shoreline, impaired physical processes (e.g., sediment movement), and increased habitat loss. Shellfish carry out their life cycles in many types of ecosystems and would benefit from the restoration of ecosystem-forming processes that encourage connected habitats and diversity. Coastal wetlands, shellfish beds, subtidal kelp, eelgrass beds, and intertidal clam habitat are among the most vulnerable habitat types to climate change. A more resilient nearshore environment can also provide cobenefits for coastal communities like flood protection and carbon sequestration.

Goal 3.1: *Restore connections in coastal areas to improve natural transportation of materials.*
The degree of connectivity in nearshore environments regulates the frequency and transfer of material, energy, plants, and animals. Well connected shorelines support ecosystem structure and function. Today, however, the Salish Sea shoreline is far more fragmented, freshwater inputs are diverted and concentrated, and hard armoring (e.g., bulkheads) of erosional bluffs prevents the accumulation of beach building material. These stressors often lead to a reduced sediment supply, which in turn affects shellfish habitat. Thus, to promote ecological processes, projects restoring connectivity should be given high priority.

Suggested adaptation actions for Goal 3.1 include:

- Removing hard armoring along bluffs and beaches to restore sediment supply.
- Restore tidal flow and freshwater input in Skagit, Snohomish, and Stillaguamish river deltas.
- Conduct site-specific elevation studies to learn about sediment movement and restoration options.
- Improve regulatory and permitting processes to better connect and protect natural transportation of materials.
- Encourage the use of vegetation and other natural or organic materials to protect shorelines.

Goal 3.2: *Conserve the natural composition and configuration of ecosystems.*
Conserving the diversity of ecosystems found in the Salish Sea can allow for the continued evolution of various types of shorelines and support the persistence of species, especially those that use different habitat types to complete their life cycles. Redundancy is also important, as protecting a single ecosystem in a single place is less likely to maintain that ecosystem than protecting that type of ecosystem in multiple locations. When determining what sites specifically to protect, we suggest considering climate change factors such as sea level rise and how that will impact a particular site. For example, a restored marsh may be able to move naturally landward as sea levels rise if the project is located adjacent to gently sloped shorelines rather than a steep shoreline.

Suggested adaptation actions for Goal 3.2 include:

- Prioritize protecting ecosystems that are rare, vulnerable, or have declined the most in size or quantity.
- Identify key ecosystems that support vulnerable life stages or population sources.

Swinomish Shellfish Adaptation Strategy 4: Protect and enhance native species and ecosystem biodiversity
Ecosystems supporting high levels of biodiversity have been shown to be more resilient to climate events, disease, and invasion from exotic species. Biodiversity is also vital for the stability, productivity, and nutrient cycling of various ecosystems. Conservation efforts should prioritize the preservation and restoration of nearshore biodiversity, which will also provide other benefits such as carbon sequestration or shoreline protection.

Goal 4.1: *Enhance presence and abundance of native ecosystem engineers.*
Ecosystem engineers are species that significantly alter their environment by building, impairing, or modifying habitat. Habitat-forming species, such as kelp and native oysters, are critical to the endurance of coastal ecosystems and serve as local ecosystem engineers by providing physical structure that creates protection for other species. Unfortunately, due to a number of compounding stressors including overharvesting, watershed development, and climate change, total global loss estimates of habitat created by living species is an average of 30%. In our region, kelp and eelgrass beds, salt marshes, and native

Olympia oyster beds are all in decline. To bolster biodiversity, the preservation of ecosystem engineers, ideally in regions of climate refugia (Goal 1.3), should be a priority.
Suggested adaptation actions for Goal 4.1 include:

- Restore native Olympia oyster populations.
- Restore eelgrass and kelp beds by reducing non-climate-related stressors.
- Utilize conservation aquaculture to support population enhancement of native species.
- Encourage the collection of oyster shells for reuse in restoration projects.
- Conduct genetics studies on native shellfish populations to identify appropriate enhancement strategies.

Goal 4.2*: Monitor native and non-native species abundance and distribution.*
The geographic distribution of some marine species has already been changing due to warming seas, with a regional increase in species preferring warm temperatures and a decrease in species preferring cold temperatures. Furthermore, climate-related weather events are expected to increase in frequency (e.g., prolonged heat waves), decreasing the ability of ecosystems to recover before the next event. Monitoring species abundance and distribution allows scientists and managers to better document where these population changes are occurring and can inform conservation, restoration, and management efforts.

Suggested adaptation actions for Goal 4.2 include:

- Collect long-term biological datasets to track changes.
- Collect long-term data on physical properties (e.g., water properties, sediment transport, etc.) to track changes in habitat conditions.
- Monitor invasive species and impacts on local ecosystems.
- Monitor disease in targeted species.

Goal 4.3*: Reduce impacts of extreme weather events on important shellfish beds and nursery habitats.*
Human-caused climate change is already leading to more extreme weather events, such as marine or atmospheric heatwaves, and can cause mass mortalities and disease outbreaks in the nearshore environment. Sea level rise will contribute to increased impacts of storm surge and other large wave events capable of flooding and eroding important intertidal shellfish beds and nursery habitats. Mass mortality events can disrupt interactions with other species and have cascading impacts on ecosystem functioning and productivity. It is imperative that we identify effective temporary techniques that may create localized refugia or shelter for target populations.

Suggested adaptation actions for Goal 4.3 include:

- Research and identify techniques to provide temporary refuge for local shellfish populations during extreme weather events.
- Create a rapid response team to coordinate on-the-ground efforts to implement refuge strategies.

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