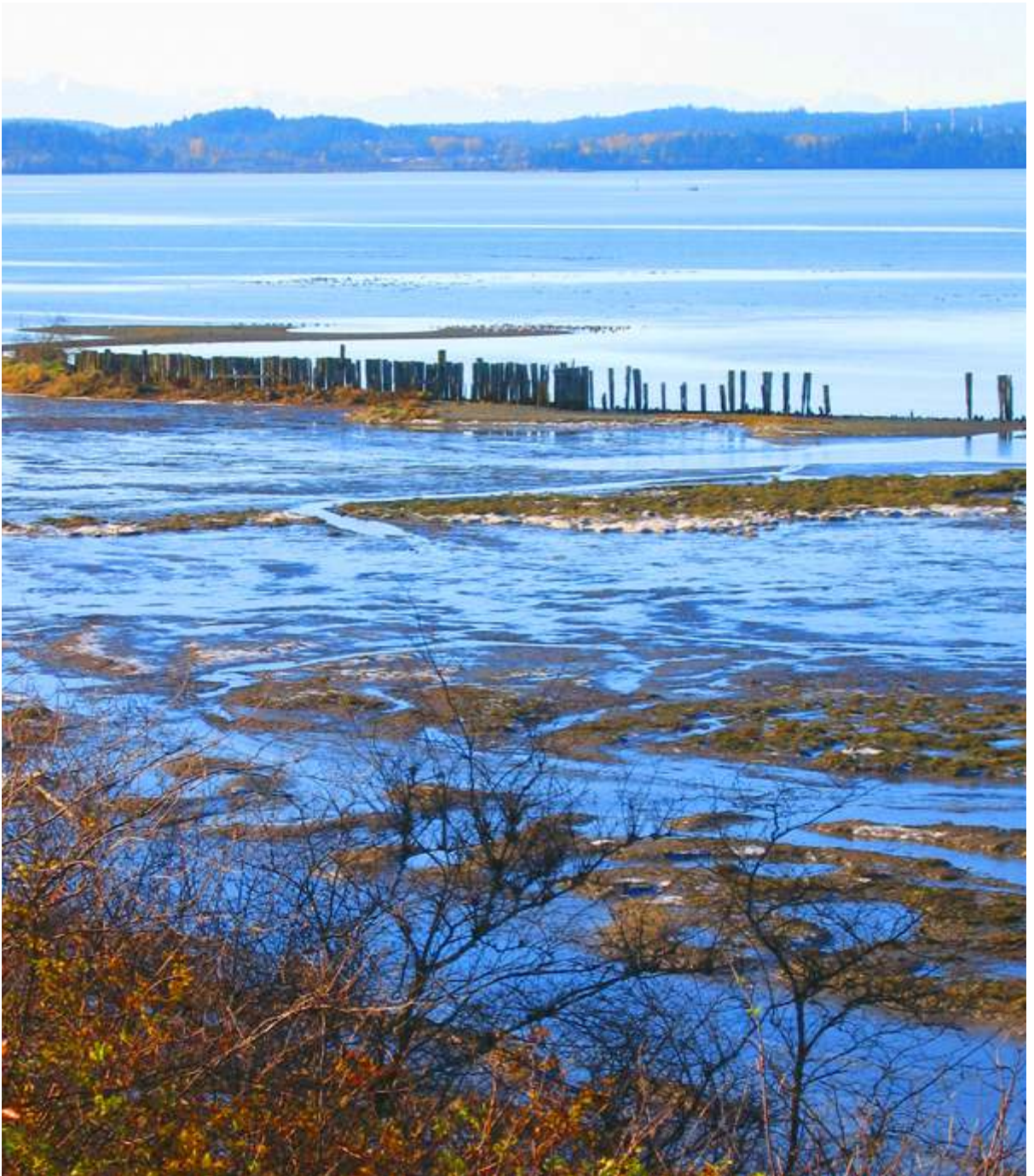


**Padilla Bay National Estuarine Research Reserve**

# **Management Plan**

**2016-2020**

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## Acronyms

ACLIPSE:	Advancing Climate Literacy through In-Service and Pre-Service Educators
ACOE:	United States Army Corps of Engineers
ADA:	Americans with Disabilities Act
AED:	Automatic External Defibrillator
BNSF:	Burlington Northern Santa Fe (Railway)
B-WET:	Bay-Watershed Education and Training
C-CAP:	Coastal Change Analysis Program
CDMO:	Central Data Management Office
CELCP:	Coastal and Estuarine Land Conservation Program
CERCC:	Coastal Ecosystem Response to Climate Change
CERF:	Coastal and Estuarine Research Federation
CFR:	Code of Federal Regulations
CMO:	Coastal Management Office
CPR:	Cardio Pulmonary Resuscitation
CSC:	Coastal Services Center
CTP:	Coastal Training Program
CTPC:	Coastal Training Program Coordinator
CVP:	Coastal Volunteer Program
CZM:	Coastal Zone Management
CZMA:	Coastal Zone Management Act
DES:	Washington State Department of Enterprise Services
DRP:	Disaster Response Plan
DSP:	Diarrhetic Shellfish Poisoning
ECO:	Education, Communication, Outreach
EIS:	Environmental Impact Statement
ENSO:	El Niño Southern Oscillation
EPA:	United States Environmental Protection Agency
ESRI:	Environmental Systems Research Institute
ESRP:	Estuary and Salmon Recovery Program
FEMA:	Federal Emergency Management Agency
FHL:	Friday Harbor Laboratory
FTE:	Full Time Equivalent
GIS:	Geographic Information Systems
GISP:	Geographic Information Systems Professional
GDP:	Gross Domestic Product
GPS:	Global Positioning System
HVAC:	Heating, Ventilation, Air Conditioning
KEEP:	Kindergarten – 12th Estuary Education Program
LED:	Light Emitting Diode
LEPC:	Local Emergency Planning Committee
LIDAR:	Light Detection and Ranging
MARINe:	Multi-Agency Rocky Intertidal Network

## Acronyms

MEM:	Marsh Equilibration Model
MHHW:	Mean Higher High Water
MLLW:	Mean Lower Low Water
MRC:	Marine Resources Committee
NCI:	North Cascades Institute
NANOOS:	Northwest Association of Networked Ocean Observing Systems
NERR:	National Estuarine Research Reserve
NERRA:	National Estuarine Research Reserve Association
NERRS:	National Estuarine Research Reserve System
NNOCCI:	National Network for Ocean and Climate Change Interpretation
NOAA:	National Oceanic and Atmospheric Administration
NRCA:	Natural Resource Conservation Area
NRCS:	Natural Resources Conservation Service
NSRS:	National Spatial Reference System
NWAC:	Northwest Area Committee
NWESD:	Northwest Educational Service District
OA:	Ocean Acidification
OCM:	Office for Coastal Management
OCRM:	Office of Coastal Resource Management
PADI:	Professional Association of Diving Instructors
PBF:	Padilla Bay Foundation
PBNERR:	Padilla Bay National Estuarine Research Reserve
PCBs:	Polychlorinated Biphenyls
PDF:	Portable Document Format
PDO:	Pacific Decadal Oscillation
PERS:	Pacific Estuarine Research Society
PIC:	Pollution Identification and Correction
PNNL:	Pacific Northwest National Laboratory
PSEMP:	Puget Sound Environmental Monitoring Program
PSNRP:	Puget Sound Nearshore Restoration Program
PSP:	Paralytic Shellfish Poisoning
PSP:	Puget Sound Partnership
QA/QC:	Quality Assurance/Quality Control
RTK:	Real-Time Kinematic
SCEA:	Skagit Conservation Education Alliance
SCD:	Skagit Conservation District
SCUBA:	Self-Contained Underwater Breathing Apparatus
SEA:	Shorelands and Environmental Assistance
SEAP:	Shorelands and Environmental Assistance Program
SET:	Surface Elevation Table
SSAM1:	Sentinel Site Application Module 1
STEM:	Science, Technology, Engineering, Mathematics
SWMP:	System-Wide Monitoring Program

## **Acronyms**

SWSS:	Sea Star Wasting Syndrome
TOTE:	Teachers On The Estuary
USFWS:	United States Fish and Wildlife Service
USGS:	United States Geological Service
UW:	University of Washington
WAURISA:	Washington Urban and Regional Information Systems Association
WCC:	Washington Conservation Corps
WDFW:	Washington State Department of Fish and Wildlife
WDNR:	Washington State Department of Natural Resources
WERC:	Western Ecological Research Center
WSU:	Washington State University
WWU:	Western Washington University
YSI:	Yellow Springs Instruments, Inc.

# Executive Summary

This management plan was developed to guide the Padilla Bay NERR's activities and direction over the next five years (2016-2020). Reserve priorities were determined by reviewing relevant documents such as the NERRS Strategic Plan (2011-2016) and NERRS Research and Monitoring Plan (2012-2017), along with agency and stakeholder input. The Reserve has developed meaningful and informed goals with these priorities in mind.

Padilla Bay NERR was designated as the nation's eighth National Estuarine Research Reserve in August 1980. Within the NERRS, it represents the Columbian biogeographic region and the Puget Sound sub-region. The 11,966-acre Reserve is located in western Skagit County in western Washington State, north of Seattle and south of Bellingham. The Washington State Department of Ecology (Ecology) is the Reserve's managing agency with a strategic focus on preventing and reducing toxic threats, delivering integrated water solutions, reducing and preparing for climate impacts, and protecting and restoring Puget Sound. Padilla Bay NERR plays a key role for the agency in the latter two objectives.

Padilla Bay is an estuarine system within the larger Skagit River delta and located along the fertile Puget Sound lowlands adjacent to the San Juan Archipelago. The Reserve contains upland and aquatic habitats that support a wide variety of plant and animal species, many of high commercial and recreational value. It is representative of the greater Puget Sound biogeographic region and is currently the only NERRS designated in Washington State. Habitats in the Reserve range from forested uplands to deep water benthic environments. The majority of the Bay is intertidal with extensive meadows of eelgrass that provide homes and nursery areas for species such as Dungeness crab, juvenile salmon, and hundreds of thousands of waterfowl and marine birds. The Reserve is located in an area that is rural and agricultural with nearby industrial development and offers recreational and educational opportunities for citizens and visitors to the area.

Padilla Bay NERR operates in partnership with many other agencies, organizations, tribes, and volunteers, and relies on advisory committees and a non-profit foundation (Padilla Bay Foundation) to carry out its mission. Many local and regional (Puget Sound) management issues are part of the Reserve's work plan. Responsibilities for addressing these issues reside with the managing agency (Ecology), the Puget Sound Partnership (PSP), and a host of other federal, state, local and tribal governments.

The Reserve's priority coastal management issues currently are:

- Climate change impacts: The Reserve is educating planners and local residents about the impacts they can expect and how to adapt and adjust.
- Water quality in estuaries and watersheds: The Reserve's SWMP program monitors water quality in the estuary and the Skagit Conservation District's Citizen Science programs (Stream Team and Storm Team) help monitor water quality in the streams and sloughs emptying into major

water bodies (Samish Bay, Padilla Bay) in this area. Our education program manages the volunteers for this effort.

- Invasive species impacts: The Reserve implements and models invasive species best management practices (invasive species decontamination protocols, survey and control methods).
- Loss of shoreline processes: The Coastal Training Program offer classes such as “Nearshore Geological Processes” for coastal planners.
- Habitat loss: Habitat loss is important and can range from changes in natural resources use or health (such as seagrasses) to increased storm frequency or strength leading to erosion.

Padilla Bay NERR is unique in this area because its primary focus is on estuaries, why they are important, and the coastal zone management issues associated with them. The Reserve’s staff are skilled at making scientific information understandable for stakeholders, partners and other Reserves.

The Education Program provides programs for school children from pre-school to college. They implement a K-12 Estuary Education Program (KEEP) and offer Teachers on the Estuary (TOTE) workshops for teachers. They also offer a wide range of programs for the public and classes about climate change.

The Coastal Training Program (CTP) targets planners in Washington State. The CTP develops classes (such as a Climate Change Workshop) using needs assessments and guidance from the CTP Advisory Committee. This kind of education leads to better decisions by planners and lessens impacts on natural resources.

The Research and Monitoring Program coordinates and implements the NERR System Wide Monitoring Program (SWMP), promotes research in Padilla Bay and provides information to researchers about NERRS Science Collaborative funding. The System-Wide Monitoring Program collects data on water quality, weather, and eelgrasses and is available to the public via a website managed by the Central Data Management Office (CDMO).

The Natural Resources Stewardship Program develops relationships with stakeholders to better understand how the Reserve’s resources are managed by other agencies and used by the public. Natural resources staff implement programs to monitor invasive species, manage noxious weeds, and get baseline data on resources.

The Reserve is committed to remaining a vital resource for the community, region, state, and nation. Always evolving, PBNERR is dedicated to engaging the public and volunteers, staying abreast of the latest issues and opportunities, and encouraging science-based exploration and learning.

The Strategic Plan in Chapter 2 addresses the Reserve’s goals, objectives and actions for 2016-2020. Specific objectives and actions are found at the end of each chapter.



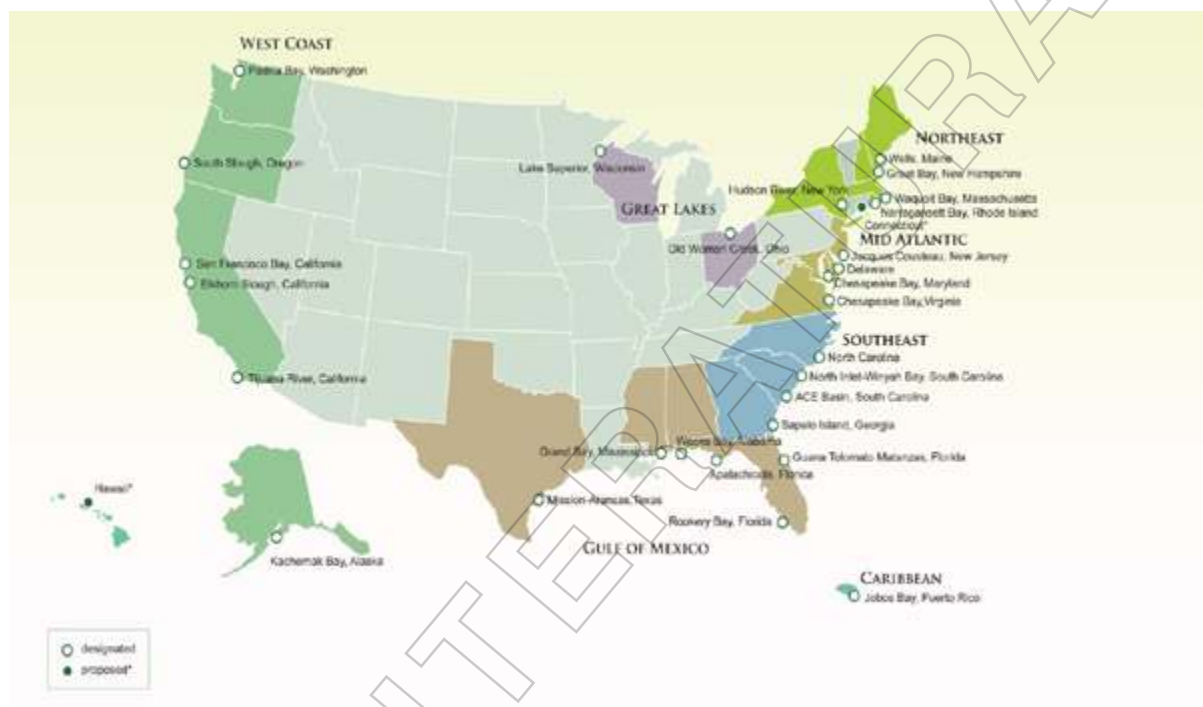
# Chapter 1 – Introduction

## Introduction to the National Estuarine Research Reserve System

The National Estuarine Research Reserve System (NERRS) was created by the Coastal Zone Management Act of 1972, as amended, to augment the National Coastal Zone Management Program which is dedicated to comprehensive, sustainable management of the nation's coasts.

The Reserve System is a network of protected areas representative of the various biogeographic regions and estuarine types in the United States. Reserves are established for long-term research, education and interpretation to promote informed management of the Nation's estuaries and coastal habitats (15 C.F.R. § 921.1(a)). The Reserve System currently consists of 28 reserves in 23 states and territories, protecting over one million acres of estuarine lands and waters (Fig. 1.1).

The Reserve System is a partnership program between the National Oceanic and Atmospheric Administration (NOAA) and the coastal states. NOAA provides funding, national guidance and technical assistance. The state partner manages reserve resources on a daily basis working collaboratively with local and regional partners.



**Figure 1.1 National Estuarine Research Reserve System Map**

## National Estuarine Research Reserve System Strategic Goals

Estuaries are biologically rich, economically valuable, and highly vulnerable ecosystems. The vision and mission of the Reserve System reflect the importance of these systems within our communities.

Vision: Resilient estuaries and coastal watersheds where human and natural communities thrive.

Mission: To practice and promote stewardship of coasts and estuaries through innovative research, education, and training using a place-based system of protected areas.

The program goals, per Federal regulations 15 C.F.R. § 921.1(b), outline five specific goals for the Reserve System:

1. Ensure a stable environment for research through long-term protection of National Estuarine Research Reserve resources;
2. Address coastal management issues identified as significant through coordinated estuarine research within the system;
3. Enhance public awareness and understanding of estuarine areas and provide suitable opportunities for public education and interpretation;
4. Promote Federal, state, public and private use of one or more Reserves within the System when such entities conduct estuarine research; and
5. Conduct and coordinate estuarine research within the system, gathering and making available information necessary for improved understanding and management of estuarine areas.

These foundational goals are complemented by those that are systematically set by the program every five years. Strategic planning has been an integral part of the National Estuarine Research Reserve System for nearly twenty years. The planning process is designed to bridge national program direction with local coastal management needs through a representative and participatory process that supports NOAA's mission of science, service, and stewardship. The 2011-2016 Reserve System Strategic Plan focuses reserves' core strengths of research, education, and training on three core issues: climate change, habitat protection, and water quality. The Reserve System Strategic Plan Goals are:

1. Protected Places: Estuaries and coastal watersheds are better protected and managed by implementing place-based approaches at reserves.
2. Science: National Estuarine Research Reserve System scientific investigations improve understanding and inform decisions affecting estuaries and coastal watersheds.
3. People: National Estuarine Research Reserve System education and train-

ing increase participants' environmental literacy and ability to make science-based decisions related to estuaries and coastal watersheds.

## **Biogeographic Regions and Boundaries of the National Estuarine Research Reserve System**

NOAA has identified eleven distinct biogeographic regions and 29 sub-regions in the United States, each of which contains several types of estuarine ecosystems (15 C.F.R. § 921.1(a)), Appendix A). When complete, the Reserve System will contain examples of estuarine hydrologic and biological types characteristic of each biogeographic region. As of 2014, the Reserve System includes 28 reserves and two states in the process of designating a reserve.

Reserve boundary size will vary greatly depending on the nature of the ecosystem. Boundaries must include an adequate portion of the key land and water areas of the natural system to approximate an ecological unit and to ensure effective conservation. Reserve boundaries encompass areas for which adequate state control has or will be established by the managing entity over human activities occurring within the reserve. Reserve boundaries include a "core" area which is comprised of key lands and waters encompassing resources representative of the total ecosystem, which if compromised could endanger the research objectives of the reserve. Reserve boundaries also include a "buffer" area designed to protect the core area and provide additional protection for estuarine-dependent species, including those that are rare or endangered. Buffer areas may also include areas necessary for research and interpretation facilities. Additionally, buffer areas are identified to accommodate a shift of the core area as a result of biological, ecological or geo-morphological change, which reasonably could be expected to occur. (15 C.F.R. § 921.11(c)(3))

## **National Estuarine Research Reserve Administrative Framework**

The process for federal designation of a National Estuarine Research Reserve has many steps and involves many individuals and organizations. While each reserve is a partnership program between NOAA and a coastal state, there are many entities that collaborate to support designation of a reserve. Other partners include federal and state agencies, non-profit groups, universities and members of the local community. For more information on the designation process see [nerrs.noaa.gov/about/designation-process.html](http://nerrs.noaa.gov/about/designation-process.html).

Upon designation, the reserve implements the approved management plan and is eligible for NOAA financial assistance on a cost-share basis with the state. A reserve may apply to NOAA for funds to help support implementation of the management plan largely funding operations, research, monitoring, education/interpretation, training, stewardship, development projects, facility construction, and land acquisition. Management plans provide a vision and framework to guide reserve activities during a five-year

period and enable the reserves and NOAA to track progress and realize opportunities for growth. Each management plan contains the reserve goals, objectives, and strategies supported by programs focused on research and monitoring, education and outreach, training, and stewardship. They also outline administration, public access, land acquisition and facility plans and needs, as well as restoration and resource manipulation plans, if applicable. Reserves are increasingly confronted with complex questions regarding new uses in or near reserves that may or may not be compatible with the Reserve System's mission. A thoughtful and comprehensive management plan provides a foundation for addressing these challenges to protect and manage reserve resources wisely and ensure the public and coastal decision makers value and protect coastal resources.

NOAA administers the Reserve System and establishes standards for designating and operating reserves, provides support for reserve operations and system-wide programming, undertakes projects that benefit the Reserve System, and integrates information from individual reserves and programs to support decision-making at the national level. Additionally, NOAA periodically evaluates reserves for compliance with federal requirements and with the individual reserve's federally approved management plan, as mandated under Section 312 of the Coastal Zone Management Act (15 C.F.R. § 921.40).

NOAA currently provides leadership and support for three system-wide programs including the System-Wide Monitoring Program (SWMP), the K-12 Estuarine Education Program (KEEP), and the Coastal Training Program (CTP), as well as the NERRS Science Collaborative. They also provide support for initiatives focused on the Reserve System's priorities: climate change, water quality and habitat protection.

## **Introduction to the Padilla Bay NERR**

### **Local History**

Evidence shows Native American habitation in the general Padilla Bay-Skagit River area for at least 5,000 years. Several prehistoric sites are found near Padilla Bay but none actually on the bay or its margin. This is probably due to extensive diking which occurred in the late 19th and early 20th centuries. Habitation by Native Americans elsewhere in Washington can be traced back some 12,000 to 15,000 years. The Noo-Wha-Ah, the Samish, and the Swinomish all used the resources of Padilla Bay.

Spanish explorers traveled through Skagit and Padilla Bay in the 1790s and Padilla Bay was "discovered" by Jose Narvaez and named after the Viceroy of Mexico, Juan Vicente de Guemes Pacheco de Padilla. Many of the islands and landforms in northern Puget Sound were named by the original Spanish explorers.

In the early 1800s, many Native American tribes were decimated by diseases brought by white trappers, traders, and settlers. The Swinomish tribe has hunted and fished at Padilla Bay for hundreds of years. The current boundary of the Swinomish Reservation is adjacent and across the channel from the southwest boundary of the Reserve.

The earliest settlers built log cabins on Fidalgo Island in 1858 (just west of Padilla Bay). In 1867 a trading post was erected about five miles south of Padilla Bay on the Swino-mish flats in La Conner. Shortly thereafter the agricultural and timber potential of the area was recognized. In 1867, a logging camp was established on Samish Island at the north end of Padilla Bay. The wetlands that separated Samish Island from the diked mainland were eventually diked and filled, making it an island no longer. By 1888 eleven camps were situated between Edison (to the east of Padilla Bay), and Bay View, near the southern end of the bay. In 1874 much of the area was served by steamboats as there were few roads. Land access was limited to horse trails and short, local wooden plank roads, called puncheon roads.

By 1882 the community of Bay View had a butcher shop, hotel/saloon and other stores. One of the state's biggest logging companies was headquartered there. By 1890 most of the area had been logged off except portions of Bay View Ridge, and this area was soon to be cut. Huge fires consumed large areas of the ridge and the thriving community of Bay View in 1910. Bay View was never rebuilt to its previous size. This logging and clearing, along with the diking of the southern end of the bay, brought a pronounced agricultural movement to the region that thrives to this day. The original marsh areas, when diked and flushed with freshwater, provided much valuable acreage for farms and brought even more settlers to the area.

Fishing was an important part of the Padilla Bay history and still is today. Clam beds and native oysters were abundant early in the bay's history, although few remain today. Many early attempts to stock the bay with non-native seed oysters and clams were initially successful. However, increased sedimentation and predators made commercial use of the bay infeasible. Crabbing and salmon harvesting occur on the fringe of the bay but are not as productive as they were at the turn of the 20th century.

## **Historic Uses**

The area around Bay View ridge was once a tidally influenced river delta and marsh (Fig. 1.2). Since the arrival of settlers in the late 1800s and the initiation of logging, diking, and agriculture, there have been significant changes to the margins of the bay and surrounding lands. Thousands of acres of marsh and mudflat were converted to farmland with the construction of drainage systems. The incorporation of many farms into diking and drainage districts provided comprehensive protection of farmland. The districts collect taxes for construction and maintenance of dikes and drainage ditches. The dikes that exist around the perimeter of Padilla Bay's eastern and southern shores have been in existence since about 1918.

# SKAGIT VALLEY RIVER DELTAS

circa 10,000 yrs. ago

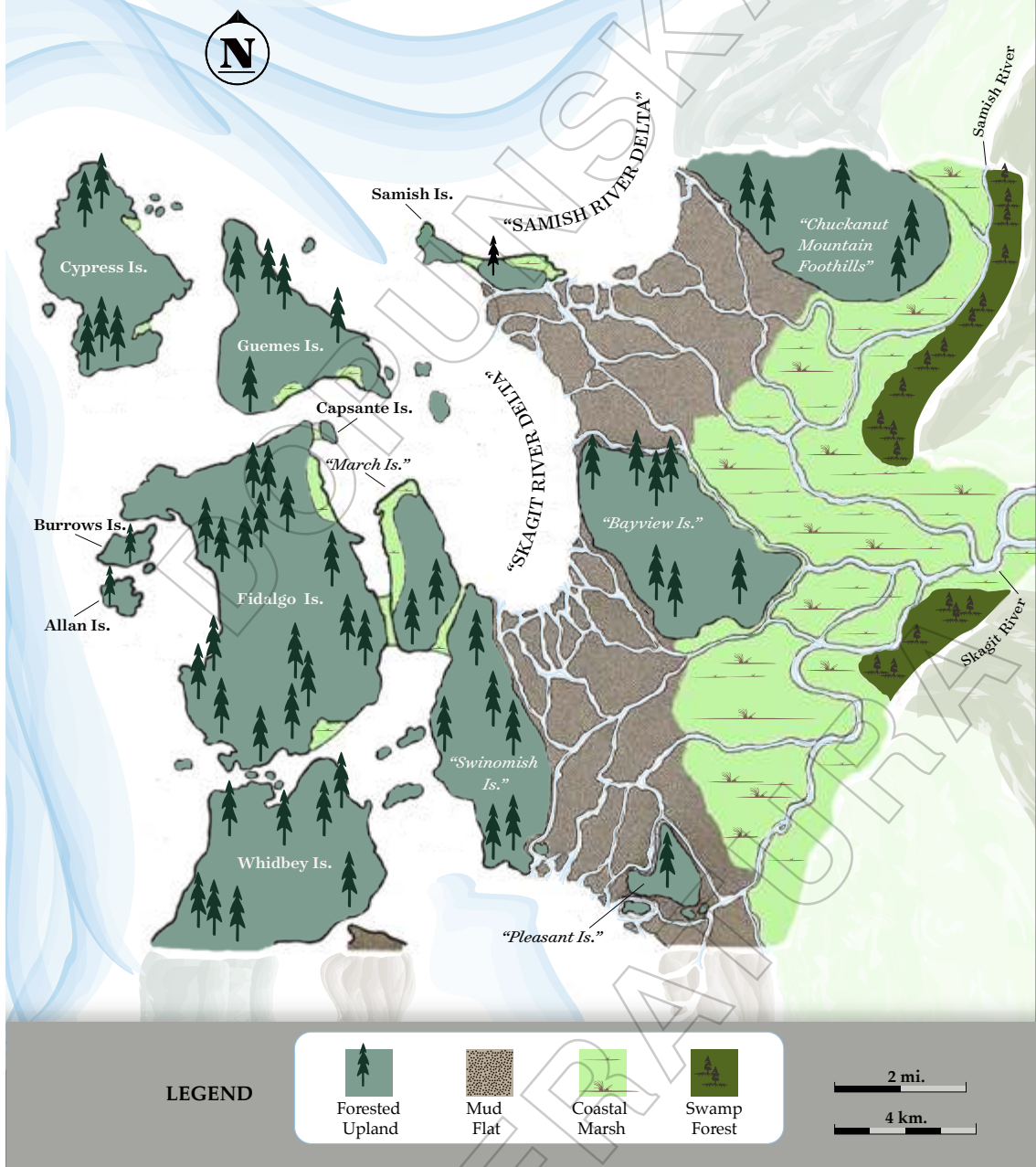


Figure 1.2 Post-glacial Skagit-Samish delta.

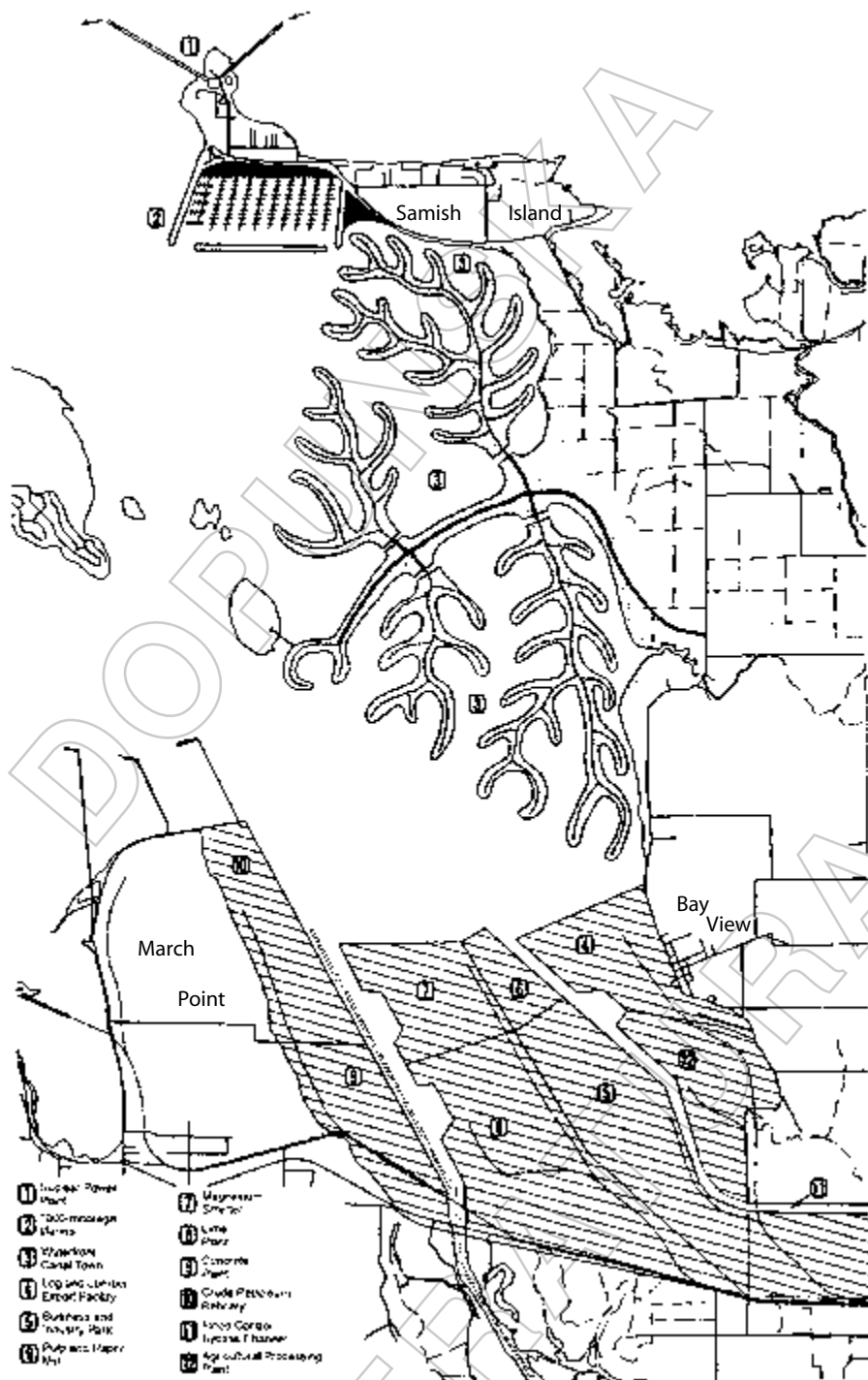


Figure 1.3 Composite of past development proposals.

## **Proposals for Development**

During the last 70 years various other projects and developments have been proposed for the bay. Many of these proposals are located on Figure 1.3. In-text references to these proposals are keyed to the map legend by numbers in brackets (e.g. [1]). Most prominent was a massive dredge-and-fill residential development proposed by the Orion Corporation [3]. With the State's 1993 acquisition of their 8,004 acres of Orion's tidelands this proposal is no longer under consideration. Public meetings and hearings in the 1960s identified a proposal for a massive industrial park development for the entire south end of the bay [4, 5, 6, 7, 8, 9, 10, and 12]. Diking proposals were considered, such as the one to dike the entire bay (this was actually started in the early 1920s), but were abandoned due to financial or physical problems.

With the passage of the State Shoreline Management Act in 1971 and the designation of Padilla Bay as a Shoreline of Statewide Significance under the act, the majority of such proposals are no longer feasible. This act and designation help to protect habitats and species in the Reserve.

## **Designation of the Reserve**

The potential benefits of having Padilla Bay become a National Estuarine Research Reserve were significant but not without potential conflict. As early as 1974, state and federal working groups were trying to find areas in Washington that would be eligible for estuarine reserve status under the provisions of the Coastal Zone Management Act. Approximately 40 areas were listed as potential sites by a committee working with the Washington State Department of Ecology. A final list of 10 sites was reached after applying criteria from the federal guidelines. Padilla Bay, with its unique eelgrass resource, was selected for consideration by NOAA's Office for Ocean and Coastal Resource Management (OCRM). Upon formal application to NOAA in 1979, the Governor established steering and technical committees to study boundaries, research, education, and administrative alternatives for the newly proposed Reserve. A draft environmental impact statement was published in April, 1980, and the final in July of that year. Formal designation of the Padilla Bay NERR took place in August 1980.

## **Ecological Attributes**

### ***Geomorphology***

Puget Sound was carved out by continental glaciers containing up to 2,500 cubic miles of ice. This crushing weight descended on the Puget Sound area probably four times in the last 100,000 years. The massive sheets of ice created valleys, basins, and the north-south aligned bays commonly found here. The retreat and melting of the last glacier some 12,000 to 13,000 years ago left most of the topographic features we recognize today (see Figure 1.2). Saddlebag, Dot, and Hat Islands are the oldest geological features in the Reserve, consisting of serpentine rocks over 200 million years old.



The majority of sediments in the bay originated as historic delta deposits from the Skagit River complex. For thousands of years the Skagit River carried water and sediment from the watershed into the estuary. It has only been since the mid-1850s that extensive areas of coastal marsh and mudflat have been diked and drained to create agricultural lands.

### ***Hydrology***

With diking of the river and bay completed during the last century, normal river flow (and sediment load) no longer enters Padilla Bay but is carried directly into Skagit Bay through the diked channels of the north and south forks of the Skagit River.

Adjacent water bodies provide Padilla Bay with waters of varying salinity. From the south via the Swinomish Channel, Skagit Bay waters diluted by the Skagit River provides lower salinity (10-20 parts per thousand), while open exposures to the west (Guemes Channel to Rosario Straits) provide waters in the range of 25-35 parts per thousand. The average salinity of the bay is 26-29 parts per thousand. Much of the regional fresh-water influence is from the Fraser River in Canada to the north.

Padilla Bay is a vast natural resource, covering more than 14,000 acres in its total geographic boundary. It is a broad, flat intertidal embayment that fills and empties fairly rapidly with the two daily tides. The tides are mixed semi-diurnal with two low tides and two high tides a day that vary in height daily. It is an “orphaned estuary,” abandoned by normal flows of the Skagit River due to diking, but truly estuarine in the sense of the characteristics of the entire Puget Sound estuary.

Waters in Padilla Bay are well-mixed, with little entrapment. Water temperatures approach a mean of 52°F although very hot summers can elevate temperatures in the shallow bay significantly. The normal range of temperatures is 40°F to 65°F. Water depths average around 2.74 m (9 feet) with channel depths approaching 4.5 - 6 m (15 to 20 feet) below Mean Lower Low Water (MLLW). At a usual summer low tide approximately 60 to 70 percent of the bay is exposed, including substantial portions of the eelgrass meadow, which covers approximately 7,500 acres (Bulthuis 1991a). This extensive eelgrass area, one of the largest on the western coastline of North America, is an important nursery habitat for fish and crab and a wintering ground for many migratory waterfowl.

### ***Climate and Weather***

The Pacific Northwest climate results from the weather and close proximity to mountain ranges, such as the Cascades. Precipitation falls largely between October and March, while high pressure systems keep the region fairly dry from May – October. Temperatures are mild all year with an average annual precipitation of greater than 30 inches (Climate Impacts Group 2014). Annual rainfall at Padilla Bay is approximately

**Table 1.1 Upland and estuarine habitat types and acreages.**

	Habitat Type	Acreage
<b>Upland</b>	Forested**	23
	Grassland/meadow**	19
	Thicket/hedgerow**	12
	Freshwater wetland#	13
<b>Estuarine</b>	<i>Zostera marina</i> *	7,734
	<i>Zostera japonica</i> *	1,652
	Macroalgae*	867
	Salt marsh*	143
	Intertidal bare*	2,855
	Subtidal bare*	2,065

\*\*Shull (2015). Habitats delineated on aerial photo.

# Graham-Bunting Associates (2004). Wetland delineation.

\* Bulthuis and Shull (2006). 2004 data.

27 inches, increasing as one moves east toward the Cascade Range (e.g., Mount Vernon's average is 34 inches).

The El Niño/Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) phenomena affect climate in this region. In warm phases, they increase the odds of a warmer-than-average Pacific Northwest winter and spring and decrease the odds for a wetter-than-average winter. The opposite is true for the cool phases of these phenomena (Climate Impacts Group 2014).

Both temperature and precipitation have increased over the 20th century. The region has warmed about 1.5°F and warming was greatest west of the Cascades during winter/spring. There is a predicted warming rate of about 0.5°F per decade in the future with climate change (Climate Impacts Group 2014). For more information, see "Climate Sensitivity and Impacts" later in this chapter.

## Key Habitats and Species

### *Habitat types*

Habitats in the Reserve are represented in Table 1.1 and Figs. 1.4 and 1.5. Key habitats and species descriptions follow. The upland habitats on the 64-acre site near the Breazeale Interpretive Center were delineated on an aerial photo (Fig. 1.4) by our GIS Analyst and approximate acreages are provided (Table 1.1). About five of the 64 acres

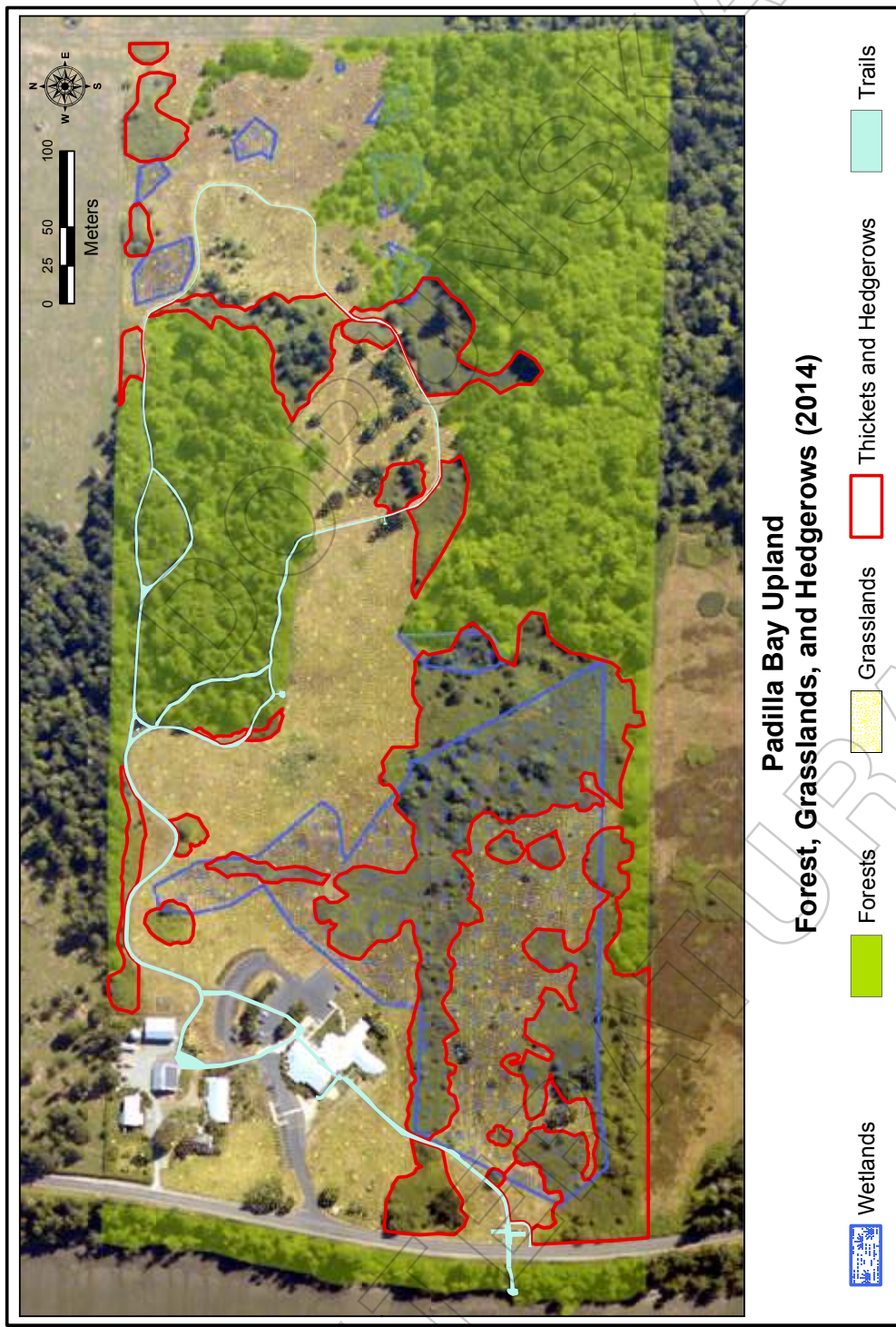


Figure 1.4 Upland habitats on the 64-acre upland site where the Breazeale Interpretive Center is located.

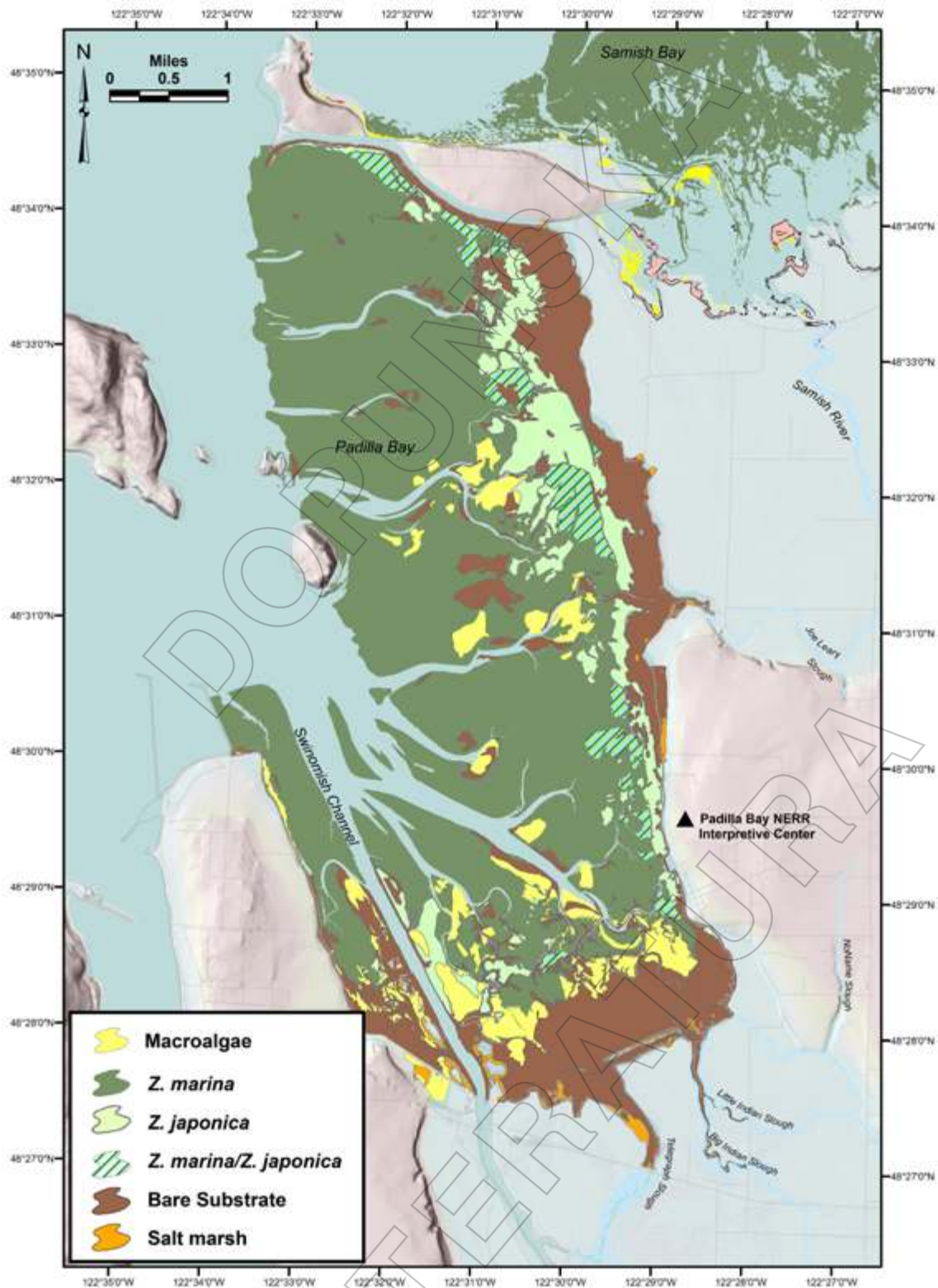


Figure 1.5. Estuarine habitats in Padilla Bay in Skagit County, Washington. [2004 map created by Suzanne Shull].



are developed (buildings, parking lots, trails). The freshwater wetlands in the uplands were delineated in 2004 (Graham-Bunting Associates 2004) and overlap with mapped grassland and forested habitats (Fig 1.4). The estuarine habitats delineated in 2004 were reported in Bulthuis and Shull (2006) and are shown in Fig. 1.5. Some of the area shown in the 2004 delineation lies outside the Reserve boundary (west of the Swinomish Channel). Therefore the habitat acreage totals are greater than the ownership acreages within the boundary.

## **Upland Habitats**

### **Forests**

There are two types of forest on the 64-acre upland site: conifer dominated and deciduous dominated. There are also trees on the bluff between Bay View-Edison Road and the shoreline that we will call the coastal edge.

The coniferous forest harbors second-growth Douglas-fir (*Pseudotsuga menziesii*), western red-cedar (*Thuja plicata*), red alder (*Alnus rubra*), and big-leaf maple (*Acer macrophyllum*) (Fig. 1.4, north). Shrubs and understory include Oregon grape (*Berberis nervosa*), salal (*Gaultheria shallon*), ocean spray (*Holodiscus discolor*), Indian plum (*Oemleria cerasiformis*), red elderberry (*Sambucus racemosa*), salmonberry (*Rubus spectabilis*), red-flowering currant (*Ribes sanguineum*) and sword fern (*Polystichum munitum*). Stinging nettle is also present (*Urtica dioica*).

The deciduous forest habitat is dominated by red alder (*Alnus rubra*), with some scattered Douglas-fir (*Pseudotsuga menziesii*) (Fig. 1.4, south). The understory includes Nootka rose (*Rosa nutkana*), salmonberry (*Rubus spectabilis*), red elderberry (*Sambucus racemosa*), ocean spray (*Holodiscus discolor*) and sword fern (*Polystichum munitum*).

The coastal edge forest is similar to the upland forests, but some additional trees are present, such as Pacific madrone (*Arbutus menziesii*) and bitter cherry (*Prunus emarginata*) (Fig. 1.4, west). The understory is similar to the coniferous dominated forest (above).

Small mammals in the forested areas include Douglas squirrel (*Tamiasciurus douglasii*), northern flying squirrel (*Glaucomys sabrinus*), and Eastern cottontail (*Sylvilagus floridanus*). Coyote (*Canis latrans*) and long-tailed weasel (*Mustela frenata*) prey on small mammals, while raccoon (*Procyon lotor*) feed on a wide range of food items. Owls such as the great horned owl (*Bubo virginianus*) and barred owl (*Strix varia*) also prey on small mammals. Black-tailed deer (*Odocoileus hemionus columbianus*) browse on low-hanging branches and shrubs. Accipiters include the bald eagle (*Haliaeetus leucocephalus*), red-tailed hawk (*Buteo jamaicensis*), sharp-shinned (*Accipiter striatus*) and Cooper's hawk (*Accipiter cooperii*) with the occasional falcon, such as merlin (*Falco columbarius*). Woodpeckers such as the downy (*Picoides pubescens*), hairy (*Picoides villosus*) or pileated (*Dryocopus pileatus*) search for insects and ants in dead trees and

stumps. The wooded habitats also provide feeding, roosting and nesting areas for migratory songbirds and ephemeral ponds for Pacific tree frogs (*Pseudacris regilla*) and Northwestern salamanders (*Ambystoma gracile*).

The coastal edge trees and shrubs provide perching and nesting sites for bald eagles (*Haliaeetus leucocephalus*) and perching sites for merlin (*Falco columbarius*), peregrine falcon (*Falco peregrinus*) and hawks. Bald eagles feed on small mammals in the surrounding agricultural land but also prey on fish and ducks in the bay. In addition to a large wintering population, a few pairs of bald eagles reside in the area year-round, using nest sites around Padilla Bay. Other birds on this edge include Steller's jays (*Cyanocitta stelleri*), crows (*Corvus* spp.) and ravens (*Corvus corax*).

Padilla Bay and Samish Bay support one of the largest known wintering populations of peregrine falcons (*Falco peregrinus*) in North America. All five species of North American falcons have, on occasion, been seen here in a single day. Ten species of raptors winter in this area including peregrine falcon, merlin (*Falco columbarius*) and snowy owl (*Nyctea scandiaca*).

### **Upland Grasslands, Hedgerows and Thickets**

The upland grasslands are open areas dominated by grasses and adjacent to forests and wetlands (Fig. 1.4). The grasslands are important as habitat for rodents such as moles, voles and mice that are prey items for red-tailed hawks and northern harriers (*Circus cyaneus*), great blue heron (*Ardea herodias*), long-tailed weasels (*Mustela frenata*) and coyotes (*Canis latrans*). Striped skunks (*Mephitis mephitis*) are largely nocturnal and eat rodents, but also eat insects, fruits, and nuts.

The hedgerows occur along fencelines and are dominated by dwarf rose (*Rosa gymnocarpa*) and Nootka rose (*Rosa nutkana*), intermixed with snowberry (*Symphoricarpos alba*) (Fig. 1.4). Thickets are shrubby "islands" of vegetation in the grasslands and near wetlands and are dominated by snowberry, trailing blackberry (*Rubus ursinus*), and non-native Himalayan (*Rubus armeniacus*) and Evergreen (*Rubus laciniatus*) blackberries (Fig. 1.4). Black hawthorn (*Crataegus douglasii*) can also form impenetrable thickets.

### **Upland Freshwater Wetlands**

There are ten delineated freshwater wetlands in the uplands totaling 13.08 acres (Graham-Bunting Associates, 2004)(Fig. 1.4). The dominant vegetation, depending on the wetland, is either the common rush (*Juncus effusus*) or slough sedge (*Carex obnupta*). Other wetland plant species are present as well.

These seasonally wet areas are habitat for Pacific tree frogs (*Pseudacris regilla*), Northern red-legged frogs (*Rana aurora*), salamanders such as *Ensatina* spp., and Common

snipe (*Gallinago gallinago*). They are also feeding areas for Great blue heron (*Ardea herodias*).

## **Estuarine Habitats**

### **Salt marsh**

Tidal salt marsh was once the dominant habitat in the lowlands around Bay View ridge. It now exists in a few small areas around the bay (143 acres) (Fig. 1.5). The dominant salt marsh species are salt grass (*Distichlis spicata*), pickleweed (*Salicornia pacifica*), and salt bush (*Atriplex patula*). Other species present include seaside arrowgrass (*Triglochin maritima*), Lyngby's sedge (*Carex lyngbyei*), American bulrush (*Schoenoplectus americanus*), and Canadian sandspurry (*Spergularia marina*). In a couple of areas, such as at the mouth of Joe Leary Slough and marsh at the south end of the bay, Sea milk-wort (*Glaux maritima*) and Silverweed (*Potentilla anserina*) are present. Voles and other small mammals are present and provide a food resource for northern harriers (*Circus cyaneus*), and red-tailed hawks (*Bubo jamaicensis*), and coyotes (*Canis latrans*).

One major salt marsh area (the former Sullivan-Minor property) located on the central eastern shore of the bay is a result of an early dike breaching and washing away. This area is characterized by seven plant communities listed in Granger and Burg (1986) as: 1) log dump (low elevation), 2) Lyngby's sedge (*Carex lyngbyei*; eastern border/northern third), 3) Cattail (*Typha latifolia*) - reed canarygrass (*Phalaris arundinaceae*; south-east corner), 4) saltgrass (*Distichlis spicata*; transitional between low and high marsh), 5) pickleweed (*Salicornia virginica*; low elevation and around salt pans), 6) saltgrass (*Distichlis spicata*) - pickleweed (*S. virginica*); low to moderate elevations in marsh), and 7) bentgrass (*Agrostis alba*) - Aster sp.; (high elevation, southern portion).

### **Unvegetated Mudflat**

The mudflat is home to a wide variety of worms, clams, shrimp, amphipods, and crabs, as well as a feeding area for birds such as Great blue heron (*Ardea herodias*) (bare substrate, Fig. 1.5). Two Great blue heron (*Ardea herodias*) rookeries are located north and southwest of the bay, both outside of Reserve property. The larger heron rookery (around 200 pair) is located on private property on Samish Island. The smaller rookery is located just north of Highway 20 on March Point. At times over 100 herons have been counted in the bay stalking fish and crabs in the shallow water.

Common algae found in the intertidal zone are sea lettuce (*Ulva* sp.) and *Enteromorpha* spp., thin translucent green algae. Other common genera include *Laminaria*, *Ceramium*, *Gracilaria*, and *Fucus*. Colonial diatoms coat the surface of the mud exuding silver bubbles of oxygen. A larger red alga (*Tiffaniella snyderae*) is sometimes found.

Marine invertebrates are abundant in the bay's mud and sand. Examples are polychaete worms such as the lugworm (*Abarenicola* sp.) and *Capitella*. Clams include the bent-

nosed clam (*Macoma nasuta*), the mud clam (*Mya* sp.) and *Transenella* sp. Many other organisms live on the surface probing the sediment for food or discarded material. Shrimp and crab, particularly the Dungeness crab (*Metacarcinus magister*), are the most common.

One of the most prolific visitors to the mudflats is the dunlin (*Calidris alpina*). These shore birds probe the mud with their long beaks on receding tides for amphipods, insects, worms, and small molluscs.

### **Vegetated Mudflat (Eelgrass)**

The estuarine flora of Padilla Bay consists primarily of the eelgrasses *Zostera marina* and *Zostera japonica* (Fig. 1.5). These are vascular marine grasses that spread vegetatively through underground stems or rhizomes and also by seed. They flower and pollinate underwater. This seagrass meadow covers approximately 7,500 acres of the bay (Bulthuis 1991a). Nowhere else in coastal Washington state is there such a large, contiguous meadow of seagrasses. A number of factors contribute to the success of eelgrass in Padilla Bay: the salinity, sediments, shallow depth and water clarity. The eelgrass is used by a myriad of creatures from small marine snails to the small sea goose or Black brant (*Branta bernicla*), which eats eelgrass as a major part of its diet. Many smaller organisms live around and on the seagrass blades such as brooding anemones (*Epiactis prolifera*), skeleton shrimp (*Caprella* spp.), isopods (*Idotea* sp.), stalked jellyfish (*Hali-clystus* sp.) and others. Small fish find food such as amphipods and isopods. Worms burrow in the mud and digest bacteria off of eelgrass detritus. Common algae found in the intertidal zone are sea lettuce (*Ulva* sp.) and *Enteromorpha* spp., both of which are thin translucent green algae. Other common genera include *Laminaria*, *Ceramium*, *Gracilaria*, and *Fucus*.

### **Slough and Channel**

Sloughs include Telegraph, Indian, No Name and Joe Leary (Fig. 1.5). The largest channel within the Reserve is the Bayview Channel (Fig. 1.5). Freshwater sloughs around Padilla Bay generally have lower salinities than the open bay. The edges of sloughs support plants like Lyngby's sedge (*Carex lyngbyei*), American bulrush (*Schoenoplectus americana*), tufted hairgrass (*Deschampsia caespitosa*), and seaside arrowgrass (*Triglochin maritima*). Small fish such as sculpins, sticklebacks, and juvenile salmon live in and move around via sloughs. Dabbling ducks, such as mallard or teal may be found in the sloughs feeding on vegetation, while harbor seal (*Phoca vitulina*) may be looking for fish or crustaceans to feed on. Harbor seal haul out on the edges of channels at low tide and Padilla Bay is a pupping area for them. River otter (*Lutra canadensis*) also use slough habitats as areas to raise young and find food.

### **Open Water**

When the bay is flooded by high tides, all the habitat area in Fig. 1.5 is covered except



for beaches and high marsh. Marine mammals found in Padilla Bay include the harbor seal (*Phoca vitulina*) and river otter (*Lutra canadensis*). Harbor seals use the bay's isolated sand and mudflats along tidal channels as haul-out sites for resting, grooming, and sunning. Large numbers of seals have been observed in the bay near Indian and Joe Leary sloughs. Outside of Padilla Bay in deeper water, pods of killer whales (*Orcinus orca*) are not uncommon. The harbor porpoise (*Phocoena phocoena*) and Dall's porpoise (*Phocoenoides dalli*) are occasionally found in the deeper waters near the bay as are California (*Zalophus californianus californianus*) and Steller's (*Eumetopias jubata*) sea lions.

Padilla Bay is an important migration route for juvenile chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), pink (*O. gorbuscha*) and chum salmon (*O. keta*). To pink and chum salmon, Padilla Bay is especially important as a rearing area. They use the nearshore and shallow areas to obtain food before they venture into deeper water. Common flat fish include English sole (*Parophrys vetulus*), Dover sole (*Microstomus pacificus*), rock sole (*Lepidopsetta bilineata*) and starry flounder (*Platichthys stellatus*). Pacific herring (*Clupea harengus pallasii*) use Padilla Bay, but do not spawn in Padilla Bay.

During the winter the bay contains on average 50,000 ducks of 26 species. Counts as high as 120,000 have been made in some years. The Black brant (*Branta bernicla nigricans*) winters at Padilla Bay. Peak numbers of 20,000 dwindled to 2,000 to 3,000 in 1980-1981 causing a temporary ban on hunting from 1983-1987. A limited brant season was opened again in 1987.

### **Dredged Spoil Islands (sandy)**

Dredged spoil materials were historically pumped along the perimeters of the Swinomish Channel when maintenance dredging operations were carried out. The islands on the east side of the channel created by this activity are referred to as the Swinomish Spit and are quite sandy and dune-like with little elevation (Fig. 1.5). The lowest edges of the islands are salt marsh habitat dominated by pickleweed (*Salicornia virginica*) and salt grass (*Distichlis spicata*) with some American bulrush (*Schoenoplectus americana*) at the northern end and some Gerard's rush (*Juncus gerardii*) on the eastern side of the spit. The next higher elevation harbors big-headed sedge (*Carex macrocephala*), seaside plantain (*Plantago maritima* spp. *juncoides*), and dune wildrye (*Elymus mollis*), among others. A biological soil crust of lichens and mosses has formed on the upper surface of the interior of the islands. Other grasses present in this location include red fescue (*Festuca rubra*), and cheat grass (*Bromus tectorum*).

Common animals include shore crabs (*Hemigrapsus* spp.) and rodents such as voles and mice. The few trees provide perches for eagles and hawks and this area is a gravelling site for Black brant (*Branta bernicla*). It would not be unheard of to see a river otter or coyote in this location. Terns and gulls fly over or rest along the shorelines.

## **Rocky Islands**

The rocky islands within our boundary include Hat Island (owned by Washington Department of Natural Resources), Dot and Saddlebag (both owned and managed by Washington's Parks and Recreation Commission) (Fig. 1.5). Brown marine algae such as bull kelp (*Nereocystis luetkeana*) grows subtidally off of Saddlebag and rockweed (*Fucus distichus*) grows in the rocky intertidal. Also in the rocky intertidal, there are green algae (*Ulva* spp., *Enteromorpha* spp.) and red algae (*Caulacanthus ustulatus*, *Endocladia muricata*, *Gelidium* spp., *Mastocarpus papillatus*, *Mazzaella* spp., and *Porphyra* spp.).

Barnacles (*Chthamalus dalli/fissus*, *Balanus glandula*, *Semibalanus cariosus*), chitons (*Katharina tunicata*, *Lepidochitona dentiens*, *Lepidozonia* spp., *Mopalia* spp.), snails (*Bittium* spp., *Calliostoma* spp., *Nucella* spp.), crabs (*Hemigrapsus* spp., *Pagurus* spp., *Petrolisthes* spp., *Pugettia* spp.), seastars (*Pisaster* spp., *Leptasterias* spp.), isopods (*Idotea* spp.), and mussels (*Mytilus trossulus*) are found in the rocky intertidal habitat on Saddlebag and Hat Islands.

Harbor seals (*Phoca vitulina*) regularly haul out on the rocky shores of Hat Island to rest at high tide. Birds such as Bald eagle (*Haliaeetus leucocephalus*), Great blue heron (*Ardea herodias*), and Peregrine falcon (*Falco peregrinus*) frequent these offshore islands to look for food or to roost.

## **Beaches**

Beaches are in the high intertidal and range from cobble to gravel to muddy sand. They can host shore crabs (*Hemigrapsus nudus*), littleneck clams (*Leukoma staminea*), worms, and amphipods, among other invertebrates. The beaches are fed by bluffs composed of glacial till on Samish Island and Bay View Ridge. Normal shoreline function is disrupted in various locations by dikes and seawalls. Old wooden pilings from the early diking efforts in the mid-1800s to early 1900s can still be seen, but are slowly decaying and breaking off. There is at least one forage fish spawning beach for smelt (*Hypomesus pretiosus*) on the shorelines of Padilla Bay.

## **Social Attributes**

### ***Population demographics***

Population demographics can help the Reserve understand the community it serves and who the target audiences may be, including underserved audiences (U.S. Census Bureau 2014).

- The population in Skagit County grew by 1.7% between 2010 and 2013 (116,901 to 118,837) and was 50.4% female in 2013. In 2013, people under 18 years of age made up 22.7% of the population and 18.1% were people 65 years and older.

- The county was mostly white in 2013 (75.8%) while the rest of the population was Hispanic or Latino (17.6%), two or more races (2.9%), American Indian and Alaska Native (2.7%), Asian (2.1%), black or African American (0.9%), and Native Hawaiian or other Pacific Islander (0.3%).

The data below is for Skagit County from 2009-2013:

- People born in a foreign country (9.3%).
- People (5+ years old) speaking a language other than English at home (14.2%).
- High school graduates (or higher) age 25+ years old (88.2%).
- Bachelor's degree or higher and 25+ years old (23.6%).
- 45,293 households
- 2.56 people/household
- Median household income: \$55,925
- Median value of owner-occupied housing units: \$261,400
- Persons below poverty level (13.5%)
- 67.5 people/square mile

### ***Jobs and employment trends***

In 2012 the U.S. Bureau of Economic Analysis estimated that manufacturing was the largest contributor to Skagit County real gross domestic product (GDP). In 2011, contributors to total GDP were: manufacturing (36%); agriculture, forestry, fishing and hunting (3%); private goods and service-providing industries (86%) with more than half of that coming from private goods-producing industries; and government (14%) (Vance-Sherman 2014).

Skagit County's annual peak nonfarm employment level was reached in 2007, just before the recession. During the recession, Skagit County lost 3,500 jobs or just over 7%. Relative to Washington State, Skagit County entered the recession early, experienced a greater decline and took longer to recover. Recovery began slowly in 2012 and picked up in 2013. From 2012 to 2013, Skagit County recovered 1,300 jobs, with growth in most sectors (Vance-Sherman 2014).

Skagit County's civilian labor force averaged 55,880 in 2013. Of that, 51,260 people were employed and 4,620 were estimated to be unemployed and actively seeking work. The peak unemployment rate in Skagit County in February 2010 was 12.7% while the average unemployment rate that year was 10.7%. The unemployment rate fell slowly but consistently throughout 2012 and 2013. The unemployment rate in July 2014 was down to 5.8 percent (Vance-Sherman 2014).

The resident labor force in Skagit County is seasonal in nature, largely due to the agricultural sector. Every summer, the labor force swells and then contracts during off peak

seasons. From 2002 to 2008, the Skagit County labor force averaged 1.9% growth per year. Since reaching peak levels in 2008, the labor force in Skagit County has been falling (Vance-Sherman 2014).

### ***Climate sensitivity and impacts***

One recent study (Robinson, et al. 2013) compared the sensitivity of Reserve sites in the NERRS to climate change. Padilla Bay, when compared to other Reserve sites, was generally predicted to be less affected by climate change than many of the other sites. However, the reality is that we are already affected by climate change in the Pacific Northwest.

- Ocean acidification has been documented. Low pH (or acidity) in seawater can kill oyster larvae outright and also reduces the availability of aragonite in the water so oyster larvae cannot form shells. This affects other shell-forming animals as well.
- Air temperature has increased over time. Pacific Northwest air temperatures have increased 1.5°F since 1920.
- Sea surface water temperature is increasing. A large mass of warm water has formed in the Pacific Ocean off the coast of North America. It was detected in late 2013 and was expected to continue throughout 2015. It is roughly 2.5°C (4.5°F) higher than normal in the upper 100 m of ocean. The waters are nutrient poor and have adversely affected marine life. Whether this is directly related to climate change or not is not yet known. It could be due, in part, to the Pacific Decadal Oscillation and El Niño events.
- Snowpack is decreasing. The Olympic Mountains had only 7% of average snow water content in winter 2015, while the Cascade Mountains in Washington ranged from 18% of average in the south to 56% of average snow water content in the north.
- Fire frequency and intensity have increased. As of September 2015, wildfires in Washington State had burned 900,000 acres and were declared a federal emergency. Even though most fires in the summer of 2015 were in eastern Washington State, the Reserve saw reduced air quality as smoke from these fires.

Based on National Research Council (2012), sea level rise for the Washington, Oregon and California coasts north of Cape Mendocino is:

- -4 cm to +23 cm by 2030 (1.6" – 9.0")
- -3 cm to +48 cm by 2050 (1.2" – 18.9")
- 10 cm to 143 cm by 2100 (0.9" – 56.3")

The sources of uncertainty in these estimates are assumptions about future ice losses and a constant rate of vertical land motion over the projection period (National Research Council 2012). The threat of future sea level rise is reduced by land uplift and gravitational and deformational effects in this area, but the land is likely rising because

of the strain that is building in the Cascadia subduction zone. The threat of a major earthquake is real and land along the coast could subside instantly and be flooded.

### ***Social sensitivity to climate change***

The relative social sensitivity of the Reserves with regards to climate change was compared in a 2013 study by Robinson et al. In that study, Padilla Bay Reserve was ranked in the upper third of Reserves in its socially sensitivity to climate change. In part, that is due to the fact that local communities rely on many natural resources to support their economic, social and cultural integrity. Two of the groups that are predicted to face immediate impacts from climate change are local shellfish growers and Native American Tribal communities.

There are two shellfish farms in close proximity to Padilla Bay (i.e., Taylor Shellfish Farms and Blau Oyster) located in Samish Bay and more than 300 shellfish farms throughout Washington state. Both Taylor Shellfish Farms and Blau Oyster are located in nearby Samish Bay. As with shellfish operations throughout the state, these growers contribute to state and local economies, with Taylor Shellfish being one of the largest producer of farmed shellfish in the United States. Washington leads the country in production of farmed clams, oysters, and mussels with an annual value of over \$107 million. Collectively the shellfish industry in Washington state provides about 25% of the domestic production of shellfish by weight in the United States.

The effect of climate change on the shellfish industry has already been observed in waters of the Pacific Northwest as ocean acidification interferes with the ability of shellfish such as clams and oysters to make shell. By providing real-time local water quality data collected under SWMP, Padilla Bay provides instantaneous updates and long-term trends in pH of local waters that are used by the shellfish growers. Further, the Reserve plays an important role in understanding drivers of ocean acidification, identifying seasonal variability, and predicting patterns so shellfish growers can adapt.

The effect of climate change on Tribal communities will also include effects of ocean acidification on resources that rely on calcifying marine organisms (e.g., oysters, geoduck and salmon), as well as effects of sea-level rise and tidal inundation on Tribal lands. Most of the local tribes have treaty rights to harvest shellfish, which they use for subsistence, ceremonial purposes, or as a source of income. As with other shellfish growers in the region, ocean acidification will impact Tribal shellfish harvests and livelihood, as well as threaten cultural practices and ceremony related to harvest of natural resources. In an effort to quantify the effects of local climate change, the Swinomish Tribal Community has produced a "Climate Change Adaptation Plan" that outlines the economic, cultural and natural resources that will be threatened by climate change. The Swinomish Tribal Lands are south of Padilla Bay and adjacent to the southern boundary of the Reserve. At the top of the list of effects reported in the Swinomish document are inundation from sea level rise and storm surge (and habitat and natural resources within those areas) and decreased habitat viability due to changing water quality pa-

rameters. In this regard, through sentinel site build-out Padilla Bay offers resources to assess a local rate of sea-level rise that can be used by local county and Tribal planners, as well as access to the SWMP real-time data to help understand short-term variability and long-term trends in water quality. PBNERR will be engaging Swinomish, Samish and Lummi Tribal communities to identify common research and management priorities and to help guide the work at PBNERR so as to best meet the needs of local natural resource stakeholders.

The ability to adapt to climate change – and thus reduce sociocultural vulnerability – relies in part on fostering a generation of young adults that are aware of climate change, facile in the nuances of climate science, and understand ocean-atmosphere connectivity on a global scale. It is this community that can make choices and behavioral changes related to sustainability on a local scale that can have global consequences. To this end, PBNERR through a NOAA Environmental Literacy Grant titled “Advancing Climate Literacy through Investment in PreService Educators (ACLIPSE)” is helping foster the next generation of climate-literate science students by integrating real-time SWMP and ocean observing data into well-established middle-school ocean and climate science curricula. This three-year project will develop an undergraduate course for pre-service science teachers, implement the course in several teacher education programs at universities around the U.S., and ultimately bring climate and ocean literacy into middle school classrooms across the country.

### ***Ecosystem services***

A 2010 study in the Puget Sound Basin identified 23 natural goods and services that benefit people, businesses and government agencies, the value of which is between \$305 billion and \$2.6 trillion. This study listed land cover types and associated ecosystem services. Based on this study, the land cover types within the Padilla Bay NERR include forest, wetland, shrub, grassland, beach, estuary, salt marsh, eelgrass beds and marine water. These provide services such as gas and climate regulation, water flow regulation, waste treatment, water supply, habitat (refuge), pollination, soil erosion control, soil formation, biological control, nutrient cycling, disturbance regulation, and opportunities for aesthetic and recreational pursuits (Batker et al. 2010).

The Reserve’s freshwater wetlands help to store and filter water and produce oxygen. Its salt marshes and seagrass meadows help to store carbon and produce oxygen. Upland forests store water, cool the air, store carbon, and produce oxygen. The Reserve’s terrestrial and estuary habitats help support nutrient cycling and primary production (the basis of food chains and the foods we eat).

Ecosystem valuation plays a role in estuary restoration and may be a factor in ranking funding proposals. Organizations in Puget Sound that have identified and utilized ecosystem valuation and services are the Puget Sound Nearshore Ecosystem Restoration Program (PSNERP) and the Estuary Salmon Restoration Program (ESRP).

Ecosystem services can be broken into categories of: provisioning (e.g., providing food, water, raw materials and medicinal resources), regulating (e.g., control of climate, carbon sequestration, water and air purification, protection from storms/flooding, drought recovery, soil erosion control, etc.), supporting (e.g., nutrient cycling, primary production, biodiversity and habitat, and pollination), and cultural (e.g., spiritual and recreational benefits, scientific and educational benefits, and aesthetic benefits) (Millenium Ecosystem Assessment 2005).

Although the ecosystem services attributed to eelgrass meadows are many, there are two that will be the focus of upcoming research at PBNERR: carbon sequestration and effects on CO<sub>2</sub>/O<sub>2</sub> cycling. Eelgrass habitats are widely accepted as having tremendous carbon storage potential (Luisetti et al. 2013; Duarte et al. 2013), but this potential is based on a limited number of empirical studies where temperate eelgrass communities are poorly represented. Further, carbon sequestration may be greatly overrated in erosional systems such as Padilla Bay. Coupled with the sentinel site build-out and SWMP biomonitoring at PBNERR and there will be a more in-depth evaluation of the carbon sequestration potential of this ecosystem. This will be helpful as managers and planners prioritize coastal restoration and development activities, as it will help accurately attribute value to eelgrass carbon storage potential. Evaluating carbon capture potential of eelgrass beds will also provide information regarding the magnitude of CO<sub>2</sub> drawdown in these systems. When coupled with SWMP water quality data this will help predict the extent to which Padilla Bay may locally mitigate fluctuations in pH and serve as a refuge from acidic conditions for sensitive biota.

## **Threats and Stressors**

### ***Natural and anthropogenic stressors***

Natural stressors include invasive species, climate change, weather patterns, earthquakes and proximity to earthquake zones, and disease-causing organisms (such as those that cause sea star wasting disease and eelgrass wasting disease).

Invasive species crowd out native species and compete for space, food, nutrients, and habitats. The most publicized invasive species in the Padilla Bay estuary has been *Spartina*, but others were introduced for commercial or recreational purposes (e.g., Pacific oysters and Manila clams) or came as a result of the commercial introductions (e.g., oyster drills, east coast clams, and *Zostera japonica*). Whether or not these species are targeted for control can be an economic or even political issue, rather than a purely ecological one.

Periodic long-term climatic events such as El Niño have promoted the movement of European green crab (*Carcinus maenas*) up the Pacific Coast from San Francisco to the west coast of Vancouver Island. An increase in winter storms or storm severity can speed up erosion, leading to loss of salt marsh habitat, or increase turbidity in the water column, leading to stress on eelgrasses due to reduced light.

Earthquakes can cause uplift or subsidence, landslides and tsunamis, all of which can impact habitats and species. Harmful algal blooms have been shown to impact fish or marine mammals in some instances. Organisms that cause illness or fatalities due to weakening the immune system of animals or interfering with a plant's ability to photosynthesize or function normally are present in Padilla Bay and can impact individuals or populations.

Anthropogenic stressors include pollution (such as excess nutrients, high bacterial counts in water due to failing septic systems, heavy metals, PCBs, hydrocarbons, etc.), increasing population (which can lead to increased development), and increased development (which can lead to habitat loss). These stressors can be alleviated by: using best management practices in residential, agricultural and industrial areas, practicing appropriate personal behaviors (e.g., proper use of pesticides and fertilizers, and recycling), waste management (e.g., composting), and using approaches like low-impact development.

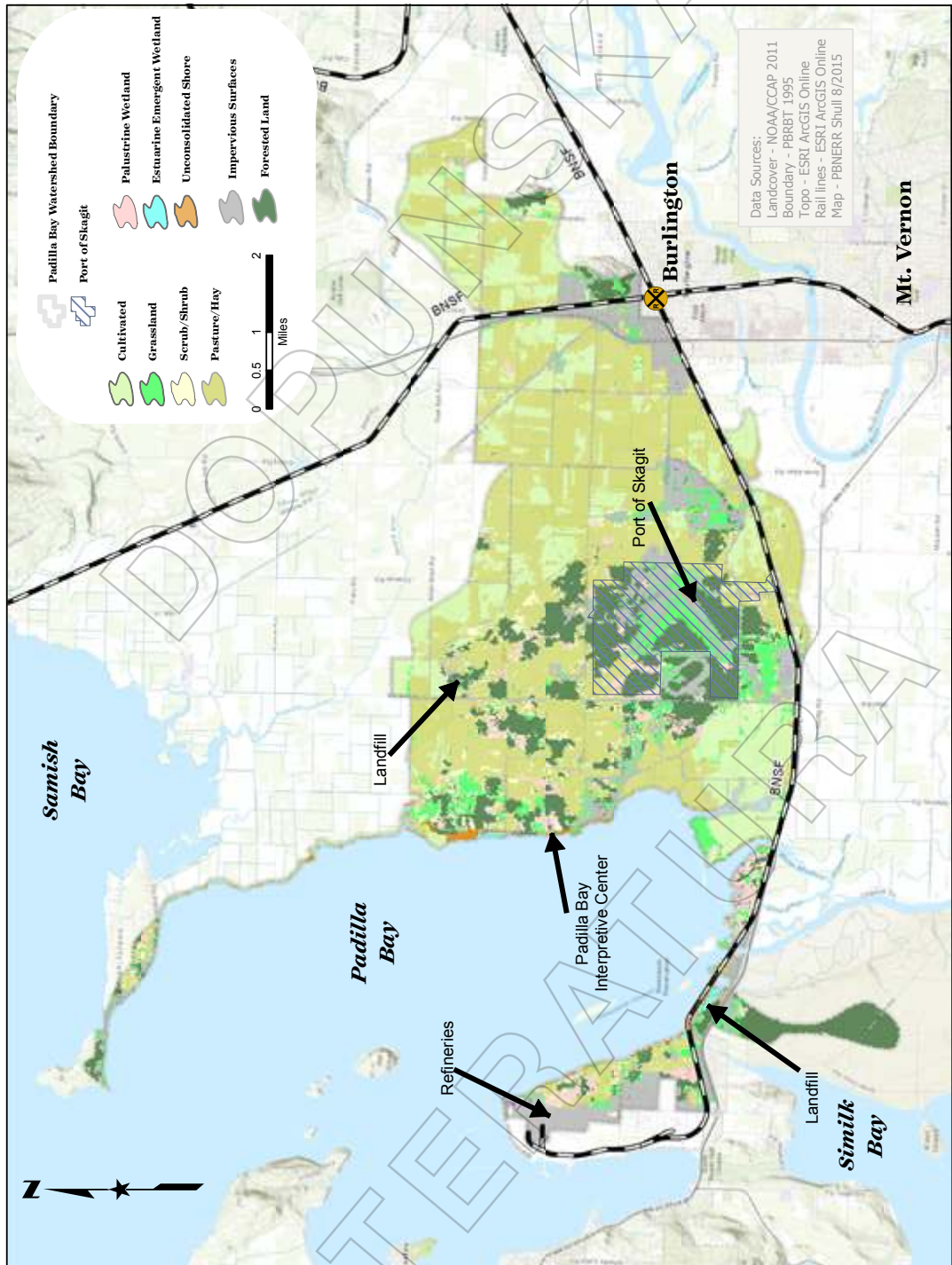
The Reserve is in close proximity to oil refineries, industry, and agriculture. With refineries, there is the potential for spills (either in loading or offloading from oil tankers, lightering from barges, or with transport of oil by train and possible accidents) (Fig. 1.6). The Reserve participates in local planning for oil spills and in oil spill drills, along with industry, state agencies, tribes and local emergency management. The Reserve also participates in the Local Emergency Planning Committee, which includes planning for all types of local disasters.

There is a wide range of businesses at the Port of Skagit County, some of which use or store chemicals (Fig. 1.6). Part of the runoff from the Port drains toward Padilla Bay via ditches and Big Indian Slough, so there is a potential for spills at the Port to impact the bay. However, those companies have to follow regulations and there is permitting for releases into water. Many companies have containment in the case of a spill, so any spills that do reach the bay would be a worst-case scenario and might result from a major earthquake or accident.

Commercial agriculture plays a major role in the Skagit Valley and land adjacent to Padilla Bay is farmed. Runoff flows to ditches around the fields, then into sloughs and ultimately into Padilla Bay, or neighboring bays or waterways. Agricultural best management practices can greatly reduce sediment. Application of fertilizers, herbicides and pesticides according to labels can reduce the impact of chemicals on the bay and its resources (e.g., the eelgrass community). Application of herbicides near water bodies takes additional training, approved products and monitoring of water quality after application. Application of best management practices for water quality by hobby farmers can reduce impact on the estuary the same as for commercial farmers.

Residential development and an increase in impervious surfaces, septic systems, and use of fertilizers, herbicides and pesticides can have an impact on runoff and runoff water quality. Excess nutrients can create algal blooms that can reduce light to eelgrass-





**Figure 1.6 The Padilla Bay watershed encompasses agricultural, residential, commercial and industrial areas, including oil refineries and the Port of Skagit County.**

es or can use up oxygen in the water column as they decay. Pesticides can impact more than the target species if applied improperly. The Reserve supports community education about products and practices that have the least impact on the environment. Management of floodwater in the Skagit River basin has been an issue for many years. The Army Corps of Engineers (ACOE), working with Skagit County, has spent several million dollars conducting studies and evaluating many flood control scenarios. Working with many state and local committees the Corps released a draft of their plan (and EIS) in 2014 identifying the five highest-ranked projects for bringing 100-year flood protection to key areas of the Skagit Valley. These included four projects that would channelize river flow away from the cities and into Padilla Bay, and one project to increase the height of existing dikes. The Corps has identified the dike-raising project as their preferred alternative, although there are many agencies and tribal interests that believe other options, or combinations of options, still need to be explored. Options that channelize floodwater into Padilla Bay have been proposed over the years and the Reserve and Department of Ecology have identified possible impacts to seagrasses from these types of proposals. Reserve staff will continue to work with federal, state and local government entities as flood planning moves forward.

A railroad line runs east to west along the southern shore of Padilla Bay and crosses the Swinomish Channel. This line carries many tank cars to and from the refineries and other industrial sites on March Point. Preparation for the possibility of derailments and spills in this area, given the type of materials transported, is prudent.

Other threats to Reserve resources include leachate from the county's current and historic landfills within the watershed, development along shorelines and in the watershed and resulting runoff, and other uses that might adversely impact the eelgrass community. In 2008 the old March Point landfill, just west of the Reserve boundary, was added to the Department of Ecology's list for cleanup action. Reserve staff coordinates with Ecology's Toxic Cleanup personnel and can provide historic and scientific data from our library. An analysis of issues within Padilla Bay NERR that may require research can be found in the Research and Monitoring Section of this document (Chapter 3).

With growth occurring throughout Skagit County, increasing residential, commercial and industrial development in the Padilla Bay watershed poses rising water quality and water quantity issues. Water quality monitoring results have forced a recreational shellfish harvest closure adjacent to the community of Bay View and the Skagit County Natural Resources Division (Water Resources Section) will be developing Pollution Indicator Controls for the Bay View watershed. Either too much (winter) or too little (summer) surface water entering the sloughs, combined with excess nutrients from farming and lawn care, have placed some sloughs on the State's Impaired Waters list. The Reserve is participating in studies with agencies and local citizens to remedy these problems while improving habitat function, and increasing upland surface water storage and groundwater recharge.

# **Padilla Bay NERR Boundary**

## **Background**

The state, including Washington State Departments of Ecology, Fish and Wildlife, Natural Resources and the Washington State Parks and Recreation Commission, owns 11,966 acres that comprise the Reserve (see Fig. 1.7 and “Core and Buffer Rationale” below).

There is still private ownership of some of the Padilla Bay Tracts north of Hat Island and in the Associated Oyster Tracts in the southwestern part of the bay and shared ownership of a salt marsh on the eastern shoreline. There is private ownership in the buffer lands in the south as well.

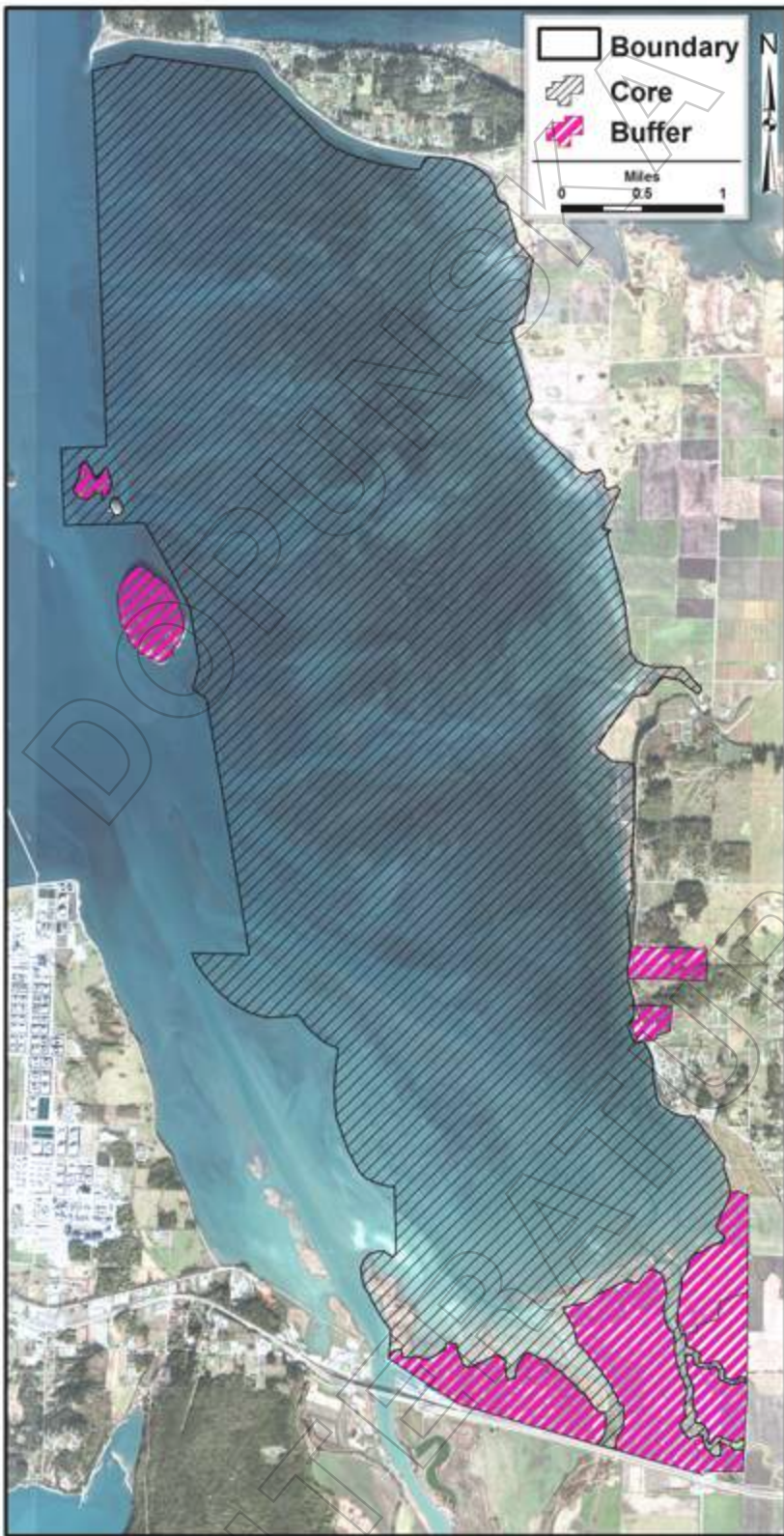
## **Boundary Description**

A general description of the Reserve’s boundary is as follows:

- South: The southern boundary is a diagonal line west to east just north of Dike Island.
- East: The eastern boundary, approximately 8 miles long, follows northward from the diagonal line mentioned above near the mouth of Indian Slough north along the Shore Trail and then the shoreline along Bay View Ridge and then the dikes to Samish Island. It also includes Bay View State Park and the Breazeale property where the Reserve’s facilities are located. There are 2 or 3 parcels along that shoreline that are still in private ownership.
- North: The northern boundary is parallel with, but located 500 feet south of, Samish Island, a high-density residential area.
- West: The western boundary is open water and is east of the Swinomish Channel. The southwestern boundary is located consistent with the claimed Swinomish Indian Tribal Community eastern reservation boundary. The northwestern boundary is the seaward boundary established in 1931 by the State Commissioner of Lands and the western boundaries of Saddlebag Island State Park and Hat Island.

## **Core and Buffer Rationale**

The boundary area encompasses two zones: 1) Core: key tideland and water areas and 2) Buffer: uplands adjacent to Padilla Bay. The core area consists of state-owned salt marsh, intertidal mudflat and sub-tidal habitats (Fig. 1.7). This is the most ecologically productive and sensitive area, and includes the extensive eelgrass meadow and areas important for juvenile salmon and crab. The state owns 11,490 acres in the “core” with 738 acres remaining in private ownership (Appendix B, Tables B.1, B.2). The state owns 476 acres in the “buffer” with 614 acres remaining in private ownership (Appendix B, Tables B.1, B.3). Therefore, the state owns 11,966 acres in the combined core and buffer



**Figure 1.7 Padilla Bay NERR proposed boundary with core (tideland) and buffer (upland) areas.**



while 1,352 acres remain in private ownership. Buffer acreage includes farmland and upland (such as rocky islands and the 64 acres where the Reserve offices are located).

### **Acreage Acquired Between 2008 and 2015**

The Reserve has acquired an additional 110 acres of “core” tidelands inside the boundary since the last management plan in 2008. Eleven Padilla Bay Tracts were acquired (4 tracts in the north: 40 acres, and 7 full tracts in the eastern bay: 70 acres). Acquisition of core tidelands is necessary for geographic continuity for research projects and access. Acquisition of these parcels also helps protect eelgrass beds.

### **Boundary Expansion**

No specific land acquisitions are identified for the five year period of this plan. Reference Chapter 11 - Land Acquisition Plan for the state’s acquisition strategy (willing sellers) and Appendix B for parcels remaining in private ownership.

### **Private Lands Status**

As of 2015, 11,966 acres of tidelands and uplands are under Reserve or other state agency management (Appendix B, Table B.1). Appendix B (Tables B.2 and B.3) contains a list of parcel numbers and tract numbers for the remaining 1,352 acres of private land in the proposed core and buffer areas of the bay and adjacent lands.

### **Land Use Type**

The region surrounding Padilla Bay NERR is part of the Skagit Valley agricultural complex, one of the most fertile regions in the world (Fig. 1.6). Crops in 2013 included 35,000 acres of field crops (alfalfa, barley, corn and grass silage, grass, oats, pea hay, small grain and wheat), 14,000 acres of potatoes, 4,000 acres in miscellaneous crops, nearly 3,500 acres in vegetable seed, 2,000 acres in blueberries and 1,100 acres in bulb crops (such as tulips). Lesser acreages (100-800 acres each) included grass seed, raspberries, strawberries, cucumbers, carrots, blackberries and apples (WSU Skagit County Extension, 2013). It produces 25% of the nation’s frozen peas and 85% of the cabbage and beet seed crop. It is a world leader in daffodil and tulip bulb and flower production. The agricultural richness is a result of thousands of years of sediment deposition by the Skagit River, combined with river and bay-front diking programs over the past 100 years.

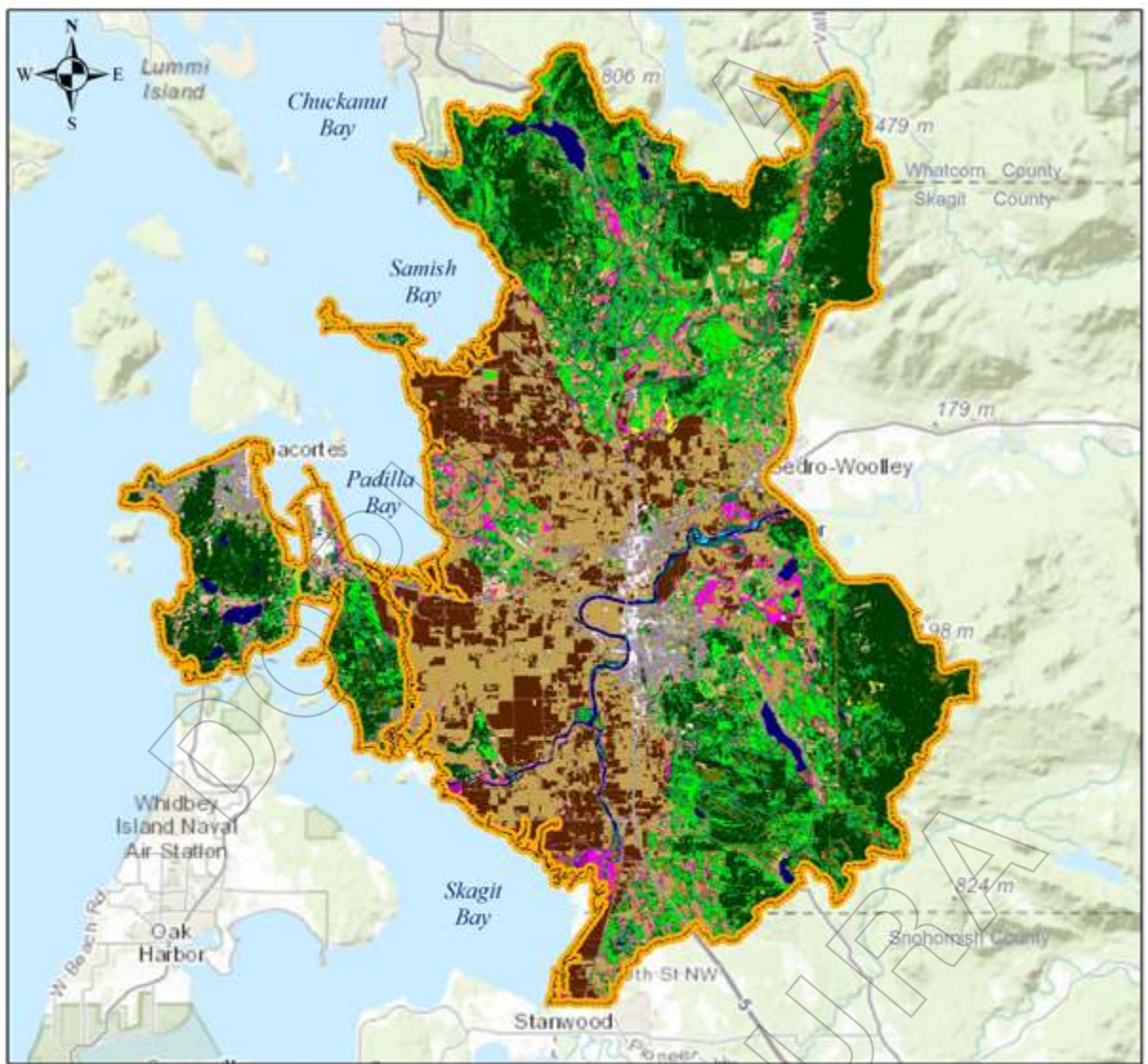
Land use in the watershed was approximately 52% cropland, 20% pasture, 20% forest (mainly on Bay View Ridge), and 8% in urban and miscellaneous uses (which includes industrial, commercial, and residential areas), airport runways, etc. in the 1980s. There have been small shifts to more urban uses, but the vast majority of the lands in the watershed are still used for agricultural or dairy operations. There were approximately 30 dairies producing milk with a value of \$52 million in 2013 (WSU Skagit County Extension).

sion, 2013). Several residential areas are located in the western reaches of the county, with the Port of Skagit County industrial park and airport located on Bay View Ridge near the Breazeale Interpretive Center (Fig. 1.6). The eastern half of March Point, site of refineries and chemical processing industries, also drains directly to Padilla Bay.

Commercial development and light industry are located along major transportation routes adjacent to the Reserve. On the western fringe, near the City of Anacortes, industrial development is intensive (Fig. 1.6). This area (March Point) harbors two large oil refineries (Shell and Tesoro), along with other chemical industries. Both refineries have large unloading wharves extending into Padilla and Fidalgo Bays, which receive oil tankers from around the world. The Burlington Northern Railroad crosses the Swinomish Channel in the southwestern part of the bay, and carries petroleum and products in both directions. Fertilizer, feed, and seed processing facilities are also located adjacent to the southern boundary of the Bay.

### **Targeted Watershed**

The “targeted watershed” map was created to aid with habitat mapping and land use/land change. Coastal Change Analysis Program (C-CAP) data can be “clipped” to this targeted watershed boundary (orange boundary on Fig. 1.8). This large boundary was chosen because Padilla Bay is affected by activities in a much larger area than its own boundaries or watershed (e.g., the Fraser River in Canada dilutes the Salish Sea; activities in the Samish River watershed can affect water quality just to the north of Padilla Bay, etc.). The northern boundary is near Lake Samish in Whatcom County. The eastern boundary stretches to Sedro Woolley, the south boundary to Stanwood and the western boundary to Fidalgo Island.



**Padilla Bay Targeted Watershed and 2001 Land Cover**

**Legend**

Background	Cultivated Land	Scrub/Shrub	Estuarine Emergent Wetland
Unclassified	Pasture/Hay	Palustrine Forested Wetland	Unconsolidated Shore
High Intensity Developed	Grassland	Palustrine Scrub/Shrub Wetland	Bare Land
Medium Intensity Developed	Deciduous Forest	Palustrine Emergent Wetland	Open Water
Low Intensity Developed	Evergreen Forest	Estuarine Forested Wetland	Palustrine Aquatic Bed
Developed Open Space	Mixed Forest	Estuarine Scrub/Shrub Wetland	Estuarine Aquatic Bed

**Figure 1.8. The Padilla Bay “targeted watershed” boundary.**

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## **Chapter 2 - Padilla Bay NERR Strategic Plan**

### **Introduction**

Padilla Bay NERR is housed within a regulatory and environmental state agency that has similar concerns to the Reserve's about climate change and water quality and is aligned with using the best available science to inform decisions. The Reserve is housed within a program in that agency with a focus on healthy watersheds and habitats and passing those on to future generations.

The Reserve has and will continue to “practice and promote stewardship of coasts and estuaries” through research, education and training and using Padilla Bay as an example of what people can achieve locally or regionally. The Reserve commits to engaging citizens and communities, creating strong partnerships, using best management practices and seeking regional collaborations.

### **A Focus on Coastal Management Issues**

For the purposes of revising this Management Plan, Reserve staff met to discuss coastal issues of importance to the Reserve and other agencies and organizations, social and cultural factors that influence decisions, stakeholder involvement and other topics of importance for planning strategically for the next five years.

The coastal management issues of focus for Padilla Bay NERR in the next five years (2016-2020) are:

- 1) Climate change impacts
- 2) Water quality in estuaries and watersheds
- 3) Invasive species impacts
- 4) Loss of shoreline processes
- 5) Habitat loss in estuaries and watersheds

The list of issues was based on a search of local, state agency, and non-profit organization documents and the ranking was by Padilla Bay staff and stakeholders through the use of an on-line tool. These issues were also discussed with stakeholders to better understand their needs and perspectives and how those needs differed from the Reserve's (see Chapter 6-Natural Resources Stewardship, Table 6.5).

## NERRS Guiding Principles

The NERRS is guided by several principles, as stated in the NERRS Strategic Plan (2011-2016):

- Engage local communities and citizens to improve stewardship of coastal resources
- Create strong partnerships to enhance the success of Reserve programs
- Integrate research, education, and stewardship to address complex coastal problems
- Implement best management practices at reserves to lead by example
- Seek regional collaborations to extend the influence of reserve programs and products.

## National Estuarine Research Reserve System Vision and Mission

**NERRS Vision:** Resilient estuaries and coastal watersheds where human and natural communities thrive.

**NERRS Mission:** To practice and promote stewardship of coasts and estuaries through innovative research, education, and training using a place-based system of protected areas.

The NERRS identified three areas of focus over the 2011-2016 period: climate change, habitat protection, and water quality. As we revise our management plan, the NERRS is gearing up for a new strategic plan for the 2017-2022 period and the focus may change for the national system during the term of this management plan.

## Washington State Department of Ecology Vision and Mission

The Reserve is managed by the Washington State Department of Ecology (Ecology) whose focus is currently on: facing climate change, managing water, reducing toxic threats, caring for shorelines and using the best science and research to improve the health of Puget Sound.

**Ecology's Vision:** Innovative partnerships sustain healthy land, air and water in harmony with a strong economy.

**Ecology's Mission:** Protect, preserve and enhance Washington's environment for current and future generations.

Ecology's goals are to: protect and restore land, air, and water; prevent pollution; promote healthy communities and natural resources; and deliver efficient and effective services.

There are ten programs within Ecology: Air Quality, Environmental Assessment, Hazardous Waste and Toxics Reduction, Nuclear Waste, Shorelands and Environmental Assistance, Spills, Toxics Cleanup, Waste to Resources, Water Quality, and Water Resources. The Reserve, along with the Coastal Zone Management Program, is housed within the Shorelands and Environmental Assistance Program (SEAP). SEAP helps communities manage shorelands and wetlands and the primary focus is on state and local responsibilities for administering Washington State and federally delegated laws. Padilla Bay NERR is a section within that program.

***SEAP's Vision:*** Healthy watersheds provide viable habitat for fish, plants and animals, and support economic growth in communities.

***SEAP's Mission:*** To work in partnership with communities to support healthy watersheds and promote statewide environmental interests.

## **Padilla Bay NERR Vision and Mission**

***Padilla Bay NERR's Vision:*** Healthy and resilient estuaries and coastal watersheds that support sustainable natural and human communities.

***Padilla Bay NERR's Mission:*** To protect and restore coastal and estuarine ecosystems in Puget Sound and the Salish Sea through research, education, stewardship and community partnerships.

The Padilla Bay NERR Strategic Framework is shown in Table 2.1. This framework will help guide our actions under this management plan revision for the period from 2016-2020.

## **Padilla Bay NERR Policies**

### **Public Access**

1. Public access to sensitive biological sites or protected areas shall be limited to protect public safety, critical resources, or the integrity of research areas.
2. Major public access points (trails, observation deck, campus pathways) shall be barrier free to the handicapped.

### **Facilities Development**

1. Reserve facilities shall be free of barriers to the handicapped. ADA standards shall be met and reasonable accommodation shall be provided.

### **Education**

1. Education programs will be designed to meet state and federal standards such as Washington State Essential Academics Learning Requirements, National Science Standards and Ocean Literacy.

Table 2.1 Padilla Bay NERR Strategic Framework

Vision	Healthy and resilient estuaries and coastal watersheds that support sustainable natural and human communities.
Mission	To protect and restore coastal and estuarine ecosystems in Puget Sound and the Salish Sea through research, education, stewardship and community partnerships.
Our Commitment	<ul style="list-style-type: none"> <li>➤ Perform our work in a professional and respectful manner.</li> <li>➤ Listen carefully and communicate in a responsive and timely manner.</li> <li>➤ Solve problems through innovative ways.</li> <li>➤ Build and maintain cooperative relationships.</li> <li>➤ Practice continuous improvement.</li> </ul>
Core Goals	<ul style="list-style-type: none"> <li>➤ Improved scientific understanding of coastal (ecological) communities leads to informed management of natural resources and resilient and sustainable ecosystems.</li> <li>➤ Informed citizens, students and decision-makers have the knowledge and understanding to make wise personal and professional choices that benefit the health of Puget Sound and the Salish Sea.</li> <li>➤ Citizens and decision-makers understand the impacts of climate change on human and natural resource communities and can make informed decisions.</li> <li>➤ The Reserve manages coastal resources in a sustainable manner for the benefit of the ecosystem and the public.</li> </ul>
Strategic Priorities	<ul style="list-style-type: none"> <li>➤ Climate change impacts</li> <li>➤ Water quality in estuaries and watersheds</li> <li>➤ Invasive species impacts</li> <li>➤ Loss of shoreline processes</li> <li>➤ Habitat loss in estuaries and watersheds</li> </ul>

2. Efforts will be made to reach underserved audiences.
3. Programs will emphasize field-based and inquiry learning whenever appropriate.
4. All programs will be evaluated and changes made as necessary.

### **Coastal Training Program**

1. A comprehensive needs assessment will be conducted with shoreline planners, private consultants, state regulatory staff, and other coastal managers every three years to ensure that the CTP is staying on track with their training needs.
2. Performance monitoring data will be collected and reported every six months via an established website. Data includes statistics on the number of professionals served, satisfaction with the content, and intention of decision-makers to apply what they have learned.
3. Online class evaluations will continue to be given after every training class. Programs will be evaluated and changes made as necessary.

### **Research**

1. Research projects in Padilla Bay NERR will be conducted with a Research Permit issued by the Research Coordinator for the purposes of coordination, tracking, and protection of resource integrity.
2. All field and laboratory activities, including watercraft operation, will be carried out consistent with applicable safety plans and manuals.
3. Research in Padilla Bay NERR will be carried out in a manner designed to minimize impact to the bay's biological communities and resources.

### **Monitoring**

1. All field and laboratory activities, including watercraft operation, will be carried out consistent with applicable safety plans and manuals.
2. Monitoring in Padilla Bay NERR will be carried out in a manner designed to minimize impact to the bay's biological communities and resources.
3. Monitoring will be carried out in a manner consistent with policies and protocols established by NERRS.
4. All biotic, abiotic, and GIS data sent to the Coastal Data Management Office (CDMO) will include the appropriate metadata.

### **Natural Resources Stewardship**

1. Natural resources issues are solved by multiple sectors meeting to discuss the issue or by the establishment of a qualified focus group.
2. The Society for Ecological Restoration's "Guidelines for Developing and Managing Ecological Restoration Projects" are used when implementing restoration on Padilla Bay NERR property ([www.ser.org](http://www.ser.org), Resources/ Publications/Foundation Documents).
3. Appropriate laws and regulations will be applied to protect threatened and endangered species and migratory birds.

4. The aquatic and upland resource of the Reserve will be protected by all available local, state, and federal regulations consistent with the established uses of the lands.

## Strategic Plan Terms

For the purposes of this strategic plan our terms are defined as:

*A goal* is what is desired; it is what the Reserve is working to achieve in a broad sense. These goals provide a stable, long-term direction for the Padilla Bay National Estuarine Research Reserve.

*Objectives* are statements of expected results that contribute to the goal; they are specific, measurable, and realistic.

*Actions* are specific items or tasks, performed within a given time, to accomplish the goals and objectives, consistent with our policies.

*Policies* are the standards the Reserve follows to achieve its goals and objectives.

*Regulations* are general or specific rules established to protect natural resources and/or the biological integrity of the Reserve. They are implemented through a variety of federal, state and local codes (See Appendix C).

## Padilla Bay NERR Performance Measures

The Education Program, Coastal Training Program, and Research and Monitoring Program submit NERRS performance measures via the NERRS Performance Database every six months during progress reporting to NOAA (or at requested intervals). Volunteer hours are also submitted at those times.

Every five years, the Reserve's performance is evaluated by CZM Section 312. The current performance measures and targets associated with this evaluation are:

- Total number of people participating in education programs from 2012-2017. Target: 50,000 people.
- Percent of CTP participants from 2012-2017 who intend to apply knowledge or skills in their work or in future decisions. Target: 92%.
- Percent of water quality and weather data that meet the established standards for Quality Assurance/Quality Control (QA/QC) submitted to CDMO from 2012-2017. Target: 90%.

## Padilla Bay NERR Goals, Objectives and Actions

There are two supporting goals and four core goals for the Reserve for 2016-2020. Table 2.2a lists the supporting goals and objectives for each sector. These goals are:

SUPPORT GOAL 1: The Washington State Department of Ecology provides support for the Reserve's administrative, operational and capital resources activities.

SUPPORT GOAL 2: The Reserve supports a collaborative work environment that involves stakeholders, staff members, volunteers, and partners.

Table 2.2b lists the core goals and objectives for each sector. Those goals are:

CORE GOAL 1: Improved scientific understanding of coastal (ecological) communities leads to informed management of natural resources and resilient and sustainable ecosystems.

CORE GOAL 2: Informed citizens, students and decision-makers have the knowledge and understanding to make wise personal and professional choices that benefit the health of Puget Sound and the Salish Sea.

CORE GOAL 3: Citizens and decision-makers understand the impacts of climate change on human and natural resource communities and can make informed decisions.

CORE GOAL 4: The Reserve manages coastal resources in a sustainable manner for the benefit of the ecosystem and the public.

Also included in the tables are which sectors will accomplish each objective, which important coastal management issues they address for the Reserve and which NERR Strategic Plan focus areas (2011-2016) are addressed by the objectives. Actions for 2016-2020 are listed at the end of each chapter.

<b>Table 2.2a Padilla Bay NERR Goals and Objectives (2016-2020).</b>	
<b>PBNERR SUPPORT GOALS &amp; OBJECTIVES</b>	<b>SECTOR</b>
<b>SUPPORT GOAL 1: The Washington State Department of Ecology provides support for the Reserve’s administrative, operational and capital resources activities.</b>	
Objective: Ecology provides state agency administrative framework for the Reserve from 2016-2020.	MGR
Objective: Ecology provides adequate operational support for the Reserve from 2016-2020.	MGR
Objective: Ecology provides support for capital resources activities from 2016-2020.	MGR
Objective: The vehicles will be maintained as per Washington State Department of Enterprise Services and Washington State Department of Ecology during 2016-2020.	MGR
Objective: Boats will be maintained in good repair during 2016-2020.	RES
Objective: Ecology-owned public access areas are maintained by Reserve staff during the 2016-2020 period.	MGR
Objective: Padilla Bay NERR infrastructure and facilities will be maintained during the 2016-2020 period.	MGR
Objective: Padilla Bay NERR will continue green improvements to facilities during the 2016-2020 time period, if funding is secured by the Manager.	MGR
<b>SUPPORT GOAL 2: The Reserve supports a collaborative work environment that involves stakeholders, staff members, volunteers and partners.</b>	
Objective: The Manager reviews staffing needs no less than annually from 2016-2020.	MGR
Objective: The Manager and staff will maintain strategic partnerships throughout 2016-2020.	MGR
Objective: The Manager will arrange for volunteer coordination services for the Reserve from 2016-2020.	MGR
Objective: Padilla Bay NERR vessels and vehicles will be maintained in good working condition during 2016-2020.	MGR/RES
Objective: The Manager will meet with staff to communicate news from Ecology, NOAA and others throughout 2016-2020.	MGR
Objective: The Manager will maintain continuity for the Reserve’s volunteer program from 2016-2020.	MGR
Objective: The CVP Coordinator will continue to develop and refine the volunteer program during 2016-2020.	MGR
Objective: The Reserve coordinates with local and regional agencies and environmental organizations that protect and preserve key lands in the watershed from 2016-2020.	MGR
Objective: The Education Coordinator will maintain strategic education partnerships throughout 2016-2020.	ED



<b>Table 2.2a Padilla Bay NERR Goals and Objectives (2016-2020).</b>	
<b>PBNERR SUPPORT GOALS &amp; OBJECTIVES</b>	<b>SECTOR</b>
<b>SUPPORT GOAL 2: The Reserve supports a collaborative work environment that involves stakeholders, staff members, volunteers and partners.</b>	
Objective: The Education Coordinator understands the needs of education stakeholders from 2016-2020.	ED
Objective: The education program will encourage volunteer participation from 2016-2020.	ED
Objective: The education program will work with partners from 2016-2020 to accomplish education goals	ED
Objective: The CTPC will maintain strategic Coastal Training Program partnerships throughout 2016-2020.	ED
Objective: The Stewardship Coordinator will maintain strategic stewardship partnerships throughout 2016-2020.	STEW
Objective: County or state-owned public access areas adjacent to the Reserve are maintained by those respective agencies from 2016-2020.	STEW
Objective: The Reserve coordinates with local and regional agencies and environmental organizations that protect and preserve key lands in the watershed from 2016-2020.	MGR

### Key for Tables 2.2a and 2.2b

#### Sectors

MGR: Management

RES: Research

ED: Education

CTP: Coastal Training Program

STEW: Stewardship

#### PBNERR Coastal Management Issues (In the “PB” columns)

CC: Climate change

WQ: Water quality

IS: Invasive species

SP: Shoreline processes

HL: Habitat loss

#### NERRS Strategic Plan (2011-2016) Areas of Focus [In the “NERRS” columns]

CC: Climate change

WQ: Water quality

HP: Habitat protection



**Table 2.2b Padilla Bay NERR Goals and Objectives (2016-2020).**

PBNER CORE GOALS & OBJECTIVES	SECTOR	PB								NERRS		
		CC	WQ	IS	SP	HL	CC	WQ	HP			
<b>CORE GOAL 2: Informed citizens, students and decision-makers have the knowledge and understanding to make wise personal and professional choices that benefit the health of Puget Sound and the Salish Sea.</b>												
Objective: Scientific data and research findings will be shared with the broader scientific, resource management, and stakeholder communities from 2016-2020.	RES	X	X		X	X						
Objective: Engage citizens, students and other non-scientists in research at PBNERR and other aspects of the process of science and research.	RES	X	X				X	X				
Objective: Research findings will be made available to Re-serve visitors, students, CTP participants and other interested public audiences from 2016-2020.	RES	X	X				X	X				
Objective: The Research Coordinator will communicate regularly with the Education and CTP Coordinators to identify opportunities for integration of research into planned activities, projects and programs during 2016-2020.	RES	X	X		X		X	X				
Objective: The education staff will offer effective education programs that focus on the values of estuary systems and appropriate stewardship behaviors during 2016-2020.	ED		X			X		X			X	X
Objective: The education staff will offer effective teacher training that focuses on the values of estuary systems and appropriate stewardship behaviors from 2016-2020.	ED	X	X			X	X	X			X	X

**Table 2.2b Padilla Bay NERR Goals and Objectives (2016-2020).**

PBNER CORE GOALS & OBJECTIVES	SECTOR	PB CC	PB WQ	PB IS	PB SP	PB HL	NERRS CC	NERRS WQ	NERRS HP
<b>CORE GOAL 2: Informed citizens, students and decision-makers have the knowledge and understanding to make wise personal and professional choices that benefit the health of Puget Sound and the Salish Sea.</b>									
Objective: The education staff will identify and reach out to underserved audiences from 2016-2020.	ED		X			X		X	X
Objective: The education staff will work with partners to offer "Storming the Sound" annually .	ED	X	X	X		X	X	X	X
Objective: The CTP will offer 18-21 classes in western Washington and 1-3 classes in eastern Washington each year from 2016-2020.	CTP	X	X	X	X	X	X	X	X
Objective: The CTP Coordinator will explore partnerships in 2016 in order to create new CTP classes from 2016-2018.	CTP	X	X		X	X	X	X	X
Objective: The CTP Coordinator will work with instructors to update three existing classes in 2016 and 2017.	CTP		X			X		X	X
Objective: The CTP Coordinator will work with instructors to adapt and/or offer existing classes for eastern Washington from 2016-2020.	CTP				X	X			X
Objective: The CTP Coordinator will work with instructors to develop new classes on priority issues from 2016-2020.	CTP		X		X	X		X	

**Table 2.2b Padilla Bay NERR Goals and Objectives (2016-2020).**

				PB	PB	PB	PB	PB	PB	PB	NERRS	NERRS	NERRS
PNERR CORE GOALS & OBJECTIVES		SECTOR	PB	CC	WQ	IS	SP	HL	CC	WQ	HP		
CORE GOAL 3: Citizens and decision-makers understand the impacts of climate change on human and natural resource communities and can make informed decisions.													
Objective: PBNERR will support and actively engage in research during 2016-2020 that addresses the effects of climate change on the Padilla Bay ecosystem and coastal waters of the Salish Sea.		RES		X			X		X				
Objective: Education staff will implement programs that help citizens to reduce carbon emissions and help them adapt to a changing climate from 2016-2020.		ED		X					X				
Objective: The Education Coordinator will seek grant funding over the 2016-2020 time period to develop climate-oriented classes for citizens.		ED		X					X				
Objective: The CTP Coordinator will work with instructors to offer a series of climate-related courses from 2016-2020.		CTP		X					X				

Table 2.2b Padilla Bay NERR Goals and Objectives (2016-2020).												
			PB	PB	PB	PB	PB	PB	PB	PB	NERRS	NERRS
PBNERR CORE GOALS & OBJECTIVES		SECTOR	CC	WQ	IS	SP	HL	CC	WQ	HP		
<b>CORE GOAL 4: The Reserve manages coastal resources in a sustainable manner for the benefit of the ecosystem and the public.</b>												
Objective: Provide scientific information and research findings that support the efforts of local and regional resource managers during the 2016-2020 period.		RES	X	X				X	X			
Objective: The Stewardship Coordinator will lead the effort to survey, map, and control noxious weeds on Reserve properties from 2016-2020.		STEW			X							X
Objective: The Stewardship Coordinator will monitor selected natural resources in Padilla Bay from 2016-2020.		STEW	X	X	X			X				
Objective: The Stewardship Coordinator will attend meetings of local groups from 2016-2020 to better understand their projects and how those projects may affect natural resources in Padilla Bay.		STEW	X	X	X	X	X	X	X			X
Objective: The Stewardship Coordinator will review and update the Padilla Bay NERR Disaster Response Plan in 2020 and participate in disaster training and exercises throughout this period.		STEW	X	X	X	X	X	X	X			X
Objective: The Manager and Stewardship Coordinator will review the guidelines for allowable/non-allowable uses no less than every five years.		MGR/ STEW	X	X				X	X			X
Objective: Maintain good communication with natural resources stakeholders from 2016-2020.		MGR/ STEW	X	X	X	X	X	X	X			X

**Table 2.2b Padilla Bay NERR Goals and Objectives (2016-2020).**

		PB	PB	PB	PB	PB	PB	PB	PB	PB	NERRS	NERRS	NERRS
	SECTOR	CC	WQ	IS	SP	HL	CC	WQ	IS	SP	HL	CC	WQ
<b>PNERR CORE GOALS &amp; OBJECTIVES</b>													
<b>CORE GOAL 4: The Reserve manages coastal resources in a sustainable manner for the benefit of the ecosystem and the public.</b>													
Objective: Review and update resource unit policies no less than every five years.	MGR/ STEW		X	X	X	X	X					X	X
Objective: All Padilla Bay NERR staff will report any prohibited uses of Reserve natural resources to the Manager or Stewardship Coordinator during 2016-2020.	MGR/ STEW		X		X	X						X	X

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## Chapter 3 – Research and Monitoring Plan

### Introduction

Padilla Bay NERR is located in a region of the Salish Sea known as the Northwest Straits, with Canada and the Georgia Basin to the north and the greater Puget Sound and Strait of Juan de Fuca to the south and west. As such, the research program at PBNERR is able to help address science and management issues relevant to not only Puget Sound, but also the greater Salish Sea ecosystem and the Columbian biogeographic region as a whole. Padilla Bay has a wide range of marine and nearshore habitats (e.g., mudflats, rocky intertidal, and deep pelagic zones) and is also home to one of the largest contiguous eelgrass habitats in North America (~8,000 acres) that includes both the native eelgrass *Zostera marina* and non-native *Zostera japonica*.

The region in which Padilla Bay is located remains underrepresented in research and monitoring relative to other parts of the greater Puget Sound. When combined with routine collaboration that occurs with research faculty at nearby universities and other government agencies, Padilla Bay NERR is in an ideal position to engage in, support and/or promote research endeavors in local waters that might not otherwise occur and that address local, regional and national issues. Research and management priorities to which PBNERR monitoring and research contributes includes recovery and expansion of eelgrass habitat in Washington State, investigating effects of climate change, sea-level rise, and ocean acidification, addressing needs of nearby Native American Tribal communities and commercial shellfish operations, engaging volunteers in citizen-based science, and using SWMP data to identify long-term changes in water quality and oceanographic properties of the Salish Sea.

### NERR Research and Monitoring Program

The National Estuarine Research Reserve System's mission provides that reserves are protected and managed to afford opportunities for long-term research. Research at each reserve is designed to fulfill the Reserve System goals as defined in the regulations (15 C.F.R. § 921(b)):

- Address coastal management issues identified as significant through coordinated estuarine research within the system;
- Promote federal, state, public and private use of one or more reserves within the system when such entities conduct estuarine research;
- Conduct and coordinate estuarine research within the system, gather and making available information necessary for improved understanding and management of estuarine areas.

To sustain these system goals, the 2011-2016 Reserve System Strategic Plan outlines research objectives that support the focus areas of climate change, habitat protection, and water quality:

- Expand capacity to monitor changes in water quality and quantity, habitat, and biological indicators in response to land use and climate change drivers.
- Improve understanding of the effects of climate change and coastal pollution on estuarine and coastal ecology, ecosystem processes, and habitat function.
- Characterize coastal watersheds and estuary ecosystems and quantify ecosystem services to support ecosystem-based management of natural and built communities.
- Increase social science research and use of social information to foster coastal stewards that value and protect estuaries.

The Reserve System's research and monitoring programs provide the scientific basis for addressing coastal management challenges. Reserve research and monitoring activities provide valuable information about estuarine resources to increase understanding and awareness of their importance to a variety of audiences including scientists, resource managers, educators, and the general public.

### **NERRS Research Programs**

Currently, there is one focused effort to fund estuarine research in the Reserve System. The National Estuarine Research Reserve System Science Collaborative is a program that focuses on integrating science into the management of coastal natural resources. Through an adaptively managed program, the Science Collaborative funds collaborative research and science transfer programs and projects that develop and apply science-based tools to better understand how to detect, prevent, and reverse the impacts of coastal pollution, habitat degradation and ecosystem processes in a time of climate change. The program is designed to enhance the Reserve System's ability to support decisions related to coastal resources through collaborative approaches that engage the people who produce science and technology with those who need it. In so doing, the Science Collaborative seeks to make the process of linking science to coastal management decisions, practices, and policies more efficient, timely, and effective and share best practices and examples for how this can be done.

### **NERRS System-Wide Monitoring Program**

The System-Wide Monitoring Program provides standardized data on national estuarine environmental trends while allowing the flexibility to assess coastal management issues of regional or local concern and is guided by the Reserve System-Wide Monitoring Program Plan. The principal mission of the monitoring program is to develop quantitative measurements of short-term variability and long-term changes in water quality, biolog-

ical systems, and land use/cover characteristics of estuaries and estuarine ecosystems for the purposes of informing effective coastal zone management. The program is designed to enhance the value and vision of the reserves as a system of national references sites and focuses on three ecosystem characteristics:

1. *Abiotic Characteristics*: Abiotic measurements are supported by standard protocols, parameters, and approaches that describe the physical environment including weather, water quality, hydrological, and sediment related parameters. The monitoring program currently provides data on water temperature, specific conductivity, percent saturation of dissolved oxygen, pressure, pH, turbidity, salinity, concentration of dissolved oxygen, and pressure corrected water depth. Meteorological data include air temperature, relative humidity, barometric pressure, wind speed, wind direction, rainfall, and photosynthetically active radiation (PAR). In addition, the program collects monthly nutrient and chlorophyll a samples and monthly diel samples at one SWMP data logger station. Data is Federal Geographical Data Committee compliant and available via the Reserve System Centralized Data Management Office.
2. *Biotic Characteristics*: As funds are available, reserves are focusing on monitoring habitats and biodiversity.
3. *Watershed and Land Use Classifications*: The Reserve System is examining the link between watershed land use and coastal habitat quality by tracking and evaluating changes in coastal habitats and watershed land use/cover. This element is guided by the “NERRS Habitat Mapping and Change Plan.”

Building on these foundational elements, the Reserve System is developing a network of sentinel sites and the capacity to assess the impact of sea level/lake level changes and inundation on the diverse set of coastal vegetative habitats represented in the system. Reserves are implementing a suite of activities, as described in the 2012 Reserve System Sentinel Site Guidance Document, to assess the relationship between vegetative communities (marsh, mangrove and submerged aquatic vegetation) and sea level. Reserves are adding surface elevation tables and monitoring pore water chemistry along vegetation monitoring transects and linking their System-Wide Monitoring Program to a network of specialized spatial infrastructure to allow precise measurement of local sea level and lake level changes and subsequent impacts to key habitats. The Reserve System is working in partnership with NOAA's National Geodetic Survey and the Center for Operational Oceanographic Products and Services to support the development of sentinel sites.

## **Padilla Bay NERR Research Program Context**

This chapter provides strategic direction for the Reserve's Research and Monitoring for the next five years. This plan reflects the research and monitoring efforts necessary to work towards addressing local, regional and national questions regarding the science, management, and assessment of impacts of global change on estuarine ecosystems. Local and regional priorities are identified through regular communications and inter-

actions with research scientists and natural resource managers working in the greater Salish Sea ecosystem and Washington's outer coast. This approach is built on basic principles regarding current needs in estuarine research (e.g., assessing impacts of climate change, sea level rise, eutrophication, ocean acidification, and water quality) while allowing flexibility to strategically pursue research questions as they arise and adapt to changing science, monitoring and research needs over the next five years. This chapter concludes with a list of actions and strategies the Research and Monitoring staff will implement to address goals and objectives related to Reserve priorities.

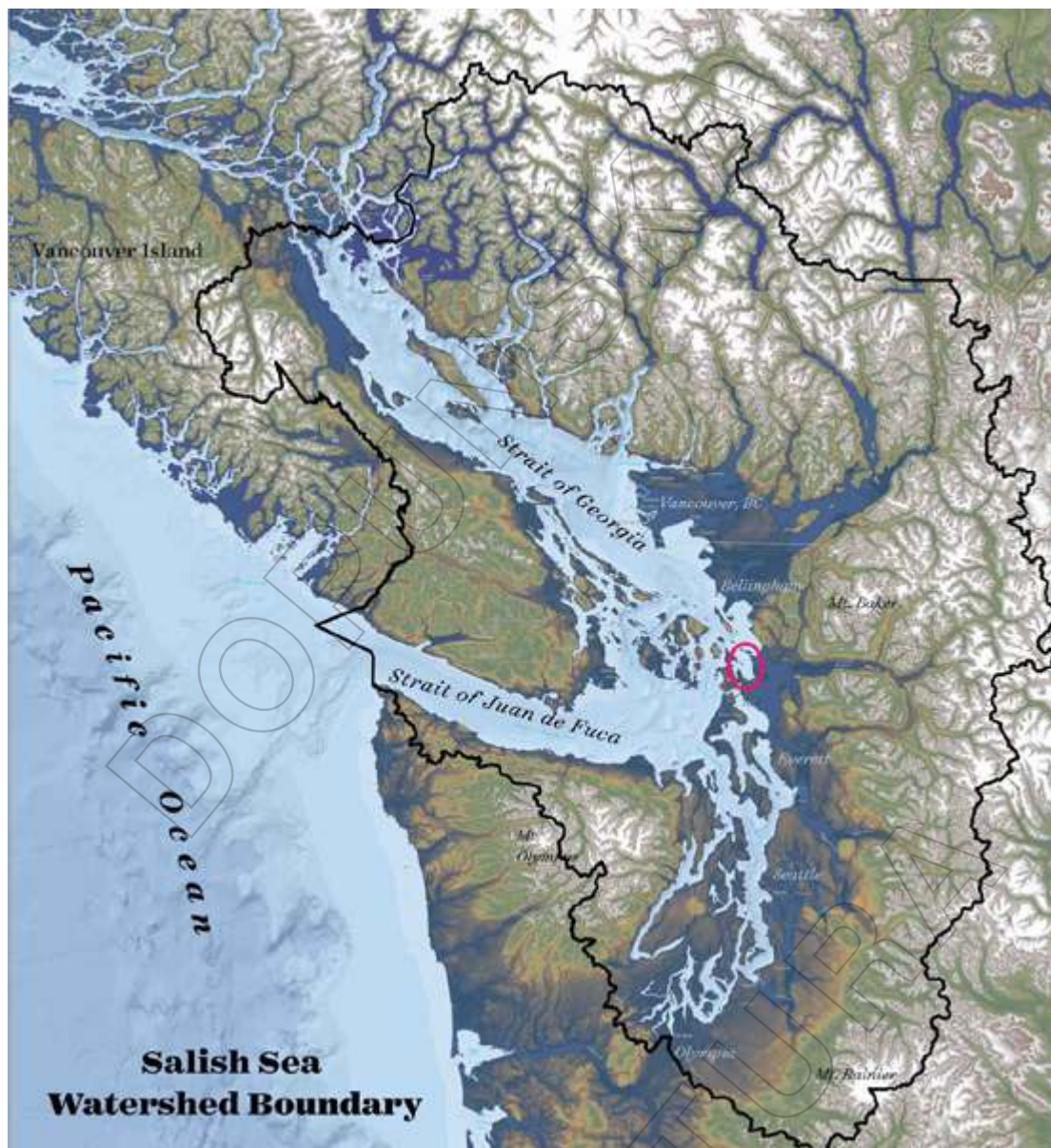
## **Overview**

The National Estuarine Research Reserve System (NERRS) was created in 1972 by the Coastal Zone Management Act (16 U.S.C. § 1461) to increase our ability to responsibly manage estuarine ecosystems (see Chapter 1, The NERR System). The NERR System provides a mechanism for addressing scientific and technical aspects of coastal management problems through a comprehensive, interdisciplinary, and coordinated approach. Research and monitoring programs, including the development of baseline information, form the basis of this approach as stated in the mission of the NERRS in 15 C.F.R. § 921.1(a). NERRS research and monitoring activities are guided by national plans that identify goals, priorities, and implementation strategies for these programs. This approach, when used in combination with the education and outreach programs, will help ensure the availability of scientific information that has long-term, system-wide consistency and utility for managers and members of the public to use in protecting or improving natural processes in their estuaries.

## **Regional and Geographic Context of Research at Padilla Bay**

Padilla Bay is located in a region of the Salish Sea known as the Northwest Straits, with Canada and the Georgia Basin to the north and the greater Puget Sound and Strait of Juan de Fuca to the south and west. Padilla Bay was designated a National Estuarine Research Reserve under the CZMA for the "Columbian Biogeographic Region" and the "Puget Sound Sub-region". Thus, the research program at PBNERR has a responsibility to address science and management issues relevant to not only Puget Sound, but also the greater Salish Sea ecosystem and the Columbian biogeographic region as a whole in which PBNERR is centrally located (Fig. 3.1). Many of these issues have emerged as part of the Puget Sound Partnership (PSP), an organization created by Washington State government to clean up the Sound, making it "fishable, swimmable, and diggable" by the year 2020.

The Washington Department of Ecology (Ecology) Coastal Management Office (CMO) has become increasingly involved in these actions, with additional mandates to address the health of Puget Sound. As part of the Shorelands and Environmental Assistance (SEA) Program in Ecology, PBNERR has a responsibility to support research on priority issues for both Ecology and the SEA Program, including issues related to broader coastal zone management. In addition, conservation and environmental quality in Puget



**Figure 3.1 Salish Sea and associated watershed with Padilla Bay indicated (circle).**

Sound is and has been the concern of federal and state agencies. To this end, over the years research at Padilla Bay has addressed priorities and issues of the EPA Puget Sound Estuary Program, Washington State Puget Sound Water Quality Authority, Puget Sound Action Team, and Puget Sound Partnership. Research conducted at PBNERR will continue to advance scientific knowledge that can address issues of importance in the Salish Sea and for other stakeholder organizations within the region.

Regional and local issues and priorities continue to shape the research conducted at Padilla Bay. Issues of regional importance include protection and restoration of coastal habitat, reduction of toxic inputs, reduction of human and animal waste inputs, protection of ecosystem biodiversity and imperiled species, controlling invasive species, and

understanding the impacts of climate change. Place-based management issues specifically relevant to Padilla Bay include overland flow and nutrient inputs from the predominantly agricultural watershed, evaluating the ecological role and ecosystem functions of eelgrass in Padilla Bay and potential threats to these communities, interactions between native eelgrass *Zostera marina* and the non-native *Zostera japonica*, invasion and spread of non-native *Spartina* on the intertidal flats, the effect of climate change, ocean acidification and sea-level rise on habitats, shorelines, biota, water quality and ecological functions in Padilla Bay, and general improvement of our understanding and awareness of changing environmental conditions, trends, and their drivers.

### **Alignment with NERRS Strategic Plan**

Research and monitoring at Padilla Bay addresses all of the science objectives set forth in the 2011-2016 NERRS Strategic Plan and thus works towards the goal that “scientific investigations improve understanding and inform decisions affecting estuaries and coastal watersheds”. The continued growth of our monitoring program through efforts of PBNERR research staff and through collaboration and support of external researchers has allowed expansion of monitoring (i.e., Science Objective #1) to include additional biotic characteristics such as plankton communities, community metabolism rate measurements, and monitoring of rocky intertidal habitats. Through increased monitoring and analysis of sea-level rise, pH and carbonate chemistry, we are working towards improved understanding of the effects of climate change (Science Objective #2). Work investigating the ecology of native and non-native seagrass communities in Padilla Bay and their role in carbon sequestration will help us evaluate ecosystem services and better inform ecosystem-based management (Science Objective #3). Finally, a new direction of growth is the integration of public stakeholder needs and priorities into research efforts at Padilla Bay by growing our capacity to support volunteer-based science, which will allow the reserve to engage and recruit public audiences in the process of science and foster coastal stewards that value and protect estuaries (Science Objective #4).

Activities and efforts of the Research and Monitoring programs at Padilla Bay will address other goals and objectives of the 2011-2016 NERRS Strategic Plan that fall under the “Protected Places” and “People” goals. Collaboration with local university partners has allowed field testing and deployment of newly-developed pH sensors in the Reserve, which will advance our progress on evaluating water quality and climate change impacts (Protected Places, Objective#2). This objective is also met by the expansion of monitoring measurements to include rates of water-column oxygen consumption and CO<sub>2</sub> production, and experimentation to evaluate the temperature dependence of these processes. With respect to the NERR educational goal, the Research Coordinator is co-PI on a NOAA Environmental Literacy grant that is working to incorporate real-time SWMP data into inquiry-based activities for middle schools classrooms and pre-service teacher training (Objective#1) and through continued work with the Education, CTP and Volunteer coordinators at PBNERR, we assist in the development and delivery of programs addressing climate change and water quality awareness among public audiences (Objective#2).



## Importance of Padilla Bay as a Research Reserve

Padilla Bay and its operation as a National Estuarine Research Reserve allow the research program to contribute to research in the Salish Sea in numerous ways. Specific factors that contribute to the value of PBNERR in advancing estuarine research include:

- The status of Padilla Bay and its habitats as part of the National Estuarine Research Reserve System ensure that is protected both by federal and state agreements.
- The region in which Padilla Bay is located (i.e., central Salish Sea/Northwest Straits) remains underrepresented in research and monitoring relative to other parts of the greater Puget Sound. In this regard, the Padilla Bay Reserve is poised to engage in, support and/or promote research endeavors in local waters that might not otherwise occur.
- Recovery of eelgrass communities and expansion of eelgrass habitat is a priority for Washington State and other management entities focused on marine water quality in the region. With one of the most extensive areas of contiguous eelgrass beds in North America, Padilla Bay provides a living laboratory in which the ecology, management and restoration of eelgrass – and the role of eelgrass in the larger estuarine ecosystem – can be explored.
- Padilla Bay includes a mosaic of other habitats, including native salt marsh, sand flats, mud flats, rocky intertidal communities, and extensive network of tidal channels throughout the bay.
- As a result of colder water temperatures and periodic intrusion of more acidic waters associated with upwelling, pelagic processes and physico-chemical properties of the Salish Sea are particularly vulnerable to the effects of climate change and ocean acidification (OA). There is evidence, however, that eelgrass may be able to locally mitigate the effects of ocean acidification in shallow embayments. Thus, PBNERR is in a position to investigate local effects of climate change and OA, while also exploring how these are related to ecosystem services associated with submerged aquatic vegetation.
- PBNERR is in close proximity to several Native American Tribal communities and commercial shellfish operations, all of which are economically and socially reliant on coastal ecosystems and will likely be negatively impacted by sea-level rise and ocean acidification. Partnering with these stakeholders will help guide research and monitoring priorities to increase the social and economic relevance of work at PBNERR.
- Because the Padilla Bay ecosystem is not directly impacted by extensive anthropogenic activities, perturbations, or other point-sources of contamination, the Reserve can serve as a reference site (i.e. control) for larger-scale studies within the region and beyond.
- Over forty years of research in Padilla Bay has established a collection of historical and baseline data that provide valuable insight, background, and context for initiating additional research projects in Padilla Bay. This



research and other relevant knowledge about Padilla Bay are detailed in a comprehensive site profile that was recently published in 2013.

- Long-term (i.e., >10 years) datasets of weather, marine physicochemical parameters, and other metrics of water quality are well established at Padilla Bay NERR and are available to scientists to supplement their work as they develop research questions, investigate hypotheses, identify trends, and interpret results from their studies.
- The Reserve shares geographic proximity and/or professional affiliations with other National Estuarine Research Reserves, state, local and Tribal governments, other Washington State management agencies, and several universities and colleges within the region. This network provides an opportunity for collaborative studies among diverse stakeholders.
- The Reserve has extensive laboratory space, research vessels, field equipment and other infrastructure to support visiting scientists in a variety of different types of research endeavors. The Reserve also offers lodging facilities for overnight or short-term stays at Padilla Bay.

## Ecological Setting

Padilla Bay contains extensive beds of seagrasses, mainly *Zostera marina* but with a significant proportion that is non-native *Zostera japonica* (Webber et al. 1987; Bulthuis 1991a, 1995; Bulthuis and Shull 2002, 2006). These seagrasses are a critical ecological resource of the bay. They are the major primary producer (Thom 1988, 1989, 1990); they provide direct food supply for the resident and migratory sea birds such as Black Brant (Jeffrey 1976; Reed et al. 1989); they directly and indirectly support a diverse and productive invertebrate infauna and epifauna that, in turn, are the major food organisms for fish (Simenstad et al. 1988, Caine 1991, Thom et al. 1991) and avifauna; they provide habitat and shelter for resident and transitory fish including juvenile salmon (Fresh 1979; Simenstad et al. 1988); and they are the preferred habitat for young Dungeness crab (Dinnel et al. 1990). Intertidal flats that lack macroscopic vegetation are rich in benthic diatoms (Thom 1989) and are important as habitat for crustaceans and other invertebrates that are important prey items for juvenile salmon and wading birds (Simenstad et al. 1988).

Padilla Bay is an important nursery and feeding area for fish such as juvenile chum and Chinook salmon, surf smelt, Pacific sand lance and threespine stickleback (Simenstad et al. 1988). Dungeness crabs appear to use the bay as a nursery area, with high populations of young crabs in the seagrasses and larger crabs in the channels (Dinnel et al. 1986, McMillan et al. 1995).

Padilla Bay contains extensive populations of resident and migratory Black Brant (Reed et al. 1989), other waterfowl and wading birds (Jeffrey 1976). The abundance of waterfowl supports several Peregrine Falcons (endangered), and the Bald Eagle (threatened) uses the bay and surrounding uplands for feeding and nesting.

## Historical Context

The earliest record of research in Padilla Bay is in a paper by Shelford et al. (1935). Later, the lack of success of an oyster industry in Padilla Bay prompted investigations of pollution sources. The construction of oil refineries on March Point in the early 1950s prompted the first extensive attempt to survey the plants and animals in Padilla Bay (Sylvester and Clogston 1958), followed by several reports of environmental effects in the area after an oil spill occurred near Anacortes in 1971. Washington State agencies such as the Department of Fish and Wildlife have conducted various surveys over the years that have included data from Padilla Bay. The possibility of oil pipelines and shipment of oil to and through northern Puget Sound prompted numerous surveys and baseline studies of the area and many of these studies included one or more sampling sites in Padilla Bay (Bulthuis and Stevens 1991).

Since the establishment of Padilla Bay as a National Estuarine Research Reserve, NOAA sponsored research during the 1980s specific to Padilla Bay on seagrasses and tidal flat plants, crabs, and water quality. PBNERR research staff mapped the vegetative communities and habitats of Padilla Bay and studied flood currents into Padilla Bay (Bulthuis 1991a, 1995; Bulthuis and Conrad 1995a, 1995b, Bulthuis and Shull 2002, 2006). The establishment of a Research Assistantship in Estuarine Science and Coastal Zone Management at PBNERR has resulted in numerous Master of Science theses and student reports on the Padilla Bay ecosystem. This body of graduate research has been supplemented by students participating in the NOAA Graduate Research Fellowship program. Bibliographies of reports that include these studies on Padilla Bay have been published as PBNERR Technical reports (Bulthuis 1989; Bulthuis 1993a; Bulthuis and Shull 1998) and a general review of these studies was published as a U.S. Army Corp of Engineers Technical report (Bulthuis 1996a). All of these studies provide an indication that Padilla Bay is a productive and important estuarine ecosystem, and one that is ecologically unique with respect to the extent of eelgrass beds and related ecosystem services.

## Monitoring Program

An Environmental Monitoring Plan for PBNERR was developed in 1996 and revised in 2004. The following section outlines some of the main elements of that plan, with further details available elsewhere (Bulthuis 1996b). The institutional framework that guides monitoring at PBNERR includes (1) its role as a National Estuarine Research Reserve and participation in the System-wide Monitoring Program, (2) management by the Washington State Department of Ecology, and (3) cooperative links and collaborations with many institutions including universities and research groups in government agencies. Monitoring efforts at PBNERR make a valuable contribution to the growing monitoring network in the greater Puget Sound, which includes Department of Ecology Marine Waters Unit and buoys and platforms supported by the Northwest Association of Networked Ocean Observing Systems (NANOOS). Padilla Bay is one of the few locations in the greater Puget Sound where continuous, long-term monitoring of water quality parameters is being implemented – especially considering the high frequency and spatial

resolution of SWMP at PBNERR. The Monitoring Plan addresses long-term monitoring efforts from a scientific, management and stewardship perspective and thereby supports the PBNERR Research Plan and the Natural Resources Stewardship Plan.

Monitoring at PBNERR includes both implementation of the NERRS System-wide Monitoring Program (SWMP) and implementation of monitoring programs specific to Padilla Bay NERR. SWMP includes: 1) continuous monitoring physicochemical water quality parameters at four sites within the Reserve, 2) continuous monitoring of meteorological parameters at a weather station in Padilla Bay, and 3) monthly monitoring of nutrient, total suspended solids and chlorophyll concentrations at the four water quality sites. Other elements of environmental monitoring have been implemented at PBNERR to establish a long-term record of change in multiple habitats of the Reserve. Areal coverage of eelgrasses, salt marsh, and macroalgae began in 1989 and was mapped again in 2004 using a combination of aerial photography, groundtruthing, and GIS mapping. In 2009, Padilla Bay began an annual monitoring program targeting invertebrate and macroalgal species at four rocky intertidal sites as part of the Multi-Agency Rocky Intertidal Network (MARINE) monitoring endeavor. Following regional outbreaks of Sea Star Wasting Syndrome (SSWS) in 2012, we expanded this effort to semi-annual monitoring of the four sites. The MARINE monitoring is being implemented throughout waters of the US Pacific coast and has become a routine part of environmental monitoring at Padilla Bay. The reserve began monitoring vegetative characteristics of eelgrass with the implementation of an annual biomonitoring program in 2011. This effort entails a comprehensive assessment of eelgrass performance at 126 permanent plots along three 4 km transects. A monthly zooplankton monitoring effort began in 2007 and has been conducted by the monitoring specialists with assistance from AmeriCorps and Reserve volunteers. More details on the PBNERR monitoring program are included in Chapter 3, Research Program Delivery – Current Research and Monitoring Efforts.

## **Padilla Bay NERR Research Program Capacity**

This section includes a discussion of the personnel, facilities, equipment and other relevant resources that provide the basis for an active research program at Padilla Bay. We also provide an overview of the ecological setting and history of research at the Reserve.

### **Staff**

The research and monitoring program is supported by a variety of PBNERR staff. The core Reserve Research and Monitoring Team consists of the Research Coordinator, two part-time (i.e., 0.8 FTE) research and monitoring staff, a GIS/geospatial analyst, and an AmeriCorps intern assigned annually to the Reserve. The Research Coordinator provides overall management and oversight for research and monitoring at PBNERR and also assists in research and monitoring efforts. The two part-time research and monitoring staff have been with PBNERR for over eight years, implement the NERRS System-wide Monitoring Program, and are funded primarily through the annual operations award to PBNERR. The research technicians also take the lead in implementing

the MARINE monitoring, eelgrass biomonitoring, and zooplankton surveys. A Geographic Information Systems (GIS) Analyst with 18 years of experience at Padilla Bay is also part of the research team and leads the Habitat Mapping and Change (Tier 1 Biomonitoring efforts), Real Time Kinematic (RTK) control and data acquisition, tidal datum referencing, Sentinel Site planning and data compilation for Sentinel Site Synthesis on Marsh Resilience. The GIS Analyst also contributes to the transect Biomonitoring (Tier 2) project. In addition, one of the three AmeriCorps Members hired each year to work at Padilla Bay are placed with the Research Team and assist with field work, collection of samples, exchange of datasondes, and other research related responsibilities. Unpaid interns, graduate students, and volunteers also help with many aspects of research and monitoring, including eelgrass and rocky intertidal monitoring, establishing new data for and groundtruthing intertidal habitat maps, surveys and enumeration of plankton communities, and laboratory-based research activities (e.g., barnacle settlement, sediment characterization, and eelgrass seed distribution). The Padilla Bay Foundation has recently hired a volunteer coordinator, who is playing an active role in recruiting qualified volunteers to assist with research and monitoring and help expand the volunteer-based science capacity at PBNERR.

At times it is necessary extend beyond the PBNERR staff and coordinate with external parties to implement ongoing monitoring activities, modify activities in response to methodological advancements, or design new approaches altogether. Datasondes and other equipment, such as weather station equipment, can be prone to occasional problems and manufacture representatives and personnel at the CDMO are particularly helpful. Water quality specialists at the Ecology Water Quality and Environmental Assessment offices have years of expertise in monitoring and data management.

### **Facilities, Equipment and Infrastructure**

Research and monitoring at Padilla Bay NERR is made possible by a wide range of facilities, equipment and other resources that support in-house research and monitoring efforts, as well as research conducted by Padilla Bay Research Assistants, graduate students, and scientists at collaborating institutions.

The PBNERR laboratory is certified as an accredited laboratory through the Washington Department of Ecology's Lab Accreditation Program and offers a place where students, interns, visiting scientists and PB research staff are able to sort field samples, conduct preliminary analyses, or prepare samples for analysis elsewhere. General laboratory facilities include extensive bench and lab workspace, wet lab for processing field samples, commercial refrigerators and -20°F ScienTemp chest freezer for sample storage, two total exhaust fume hoods, laminar flow hood, autoclave, Nanopure water purification system, and basic instruments for analysis of water samples. Instrumentation includes various high-precision balances, Olympus SZX7 zoom stereo microscope with video and still imaging capacity, Turner Trilogy and TD-700 fluorometers for chlorophyll analyses, two large capacity drying ovens, Thermolyne benchtop muffle furnace, Presens Fibox 4 Optode for dissolved oxygen measurements and estimates of pelagic respiration, and

Metrohm Titrino for Winkler titrations and other potentiometric assays. In support of SWMP, the lab facility also houses numerous Yellow Springs Instrument (YSI) sondes and supporting instrumentation for calibration and deployment, and a Sigma 900 autosampler.

GIS capabilities have been developed at Padilla Bay in support of the research, monitoring and stewardship programs. GIS has been particularly important in mapping and tracking the distribution of vegetation (emergent marsh and eelgrass), managing location of numerous study sites, helping investigators locate appropriate study sites for their research questions, place their study sites in a wider context, or locate their sites relative to other research sites. GIS capabilities are also critical in the first stages for developing both the Biomonitoring and the Sentinel Site Programs, as well as in continued development of data visualization products at PBNERR.

Padilla Bay has two research vessels (22-foot R/V *Edna B* and 16-foot R/V *Marcellus*) that provide field support to research and monitoring efforts, and are equipped with GPS instruments, safety gear, marine radios, and equipment for water quality and plankton sampling. Access to sites in Padilla Bay for research is often difficult and vessel support is provided on a limited basis. Padilla Bay NERR is not able to provide support for research projects that require substantial vessel support from the reserve.

The PBNERR guesthouse provides overnight accommodation for students and scientists conducting research in Padilla Bay. The guesthouse was opened in 2007 and provides a wide range of accommodations, including kitchen and laundry facilities and lodging for up to 16 people.

### **Scientific Community**

The research staff at PBNERR remain engaged with several relevant scientific networks and communities. The Reserve's Research Coordinator (RC), is currently president of the Pacific Estuarine Research Society (PERS), which is the regional chapter of the Coastal and Estuarine Research Federation (CERF). As part of this role, the RC remains in active communication with regional estuarine scientists, assists in organizing and hosting the annual PERS meeting, and serves on the CERF Governing Board. The RC is also an active member of the Puget Sound Environmental Monitoring Program (PSEMP) Marine Waters Workgroup, which is one of several technical workgroups operating under the PSEMP umbrella that has a specific focus on the inland marine waters of Puget Sound and the greater Salish Sea, including the oceanic, atmospheric, and terrestrial influences and drivers affecting the Sound. Since leaving his appointment at Western Washington University (WWU), the RC has maintained adjunct faculty status with the Biology Department and the Environmental Science Department in Huxley College of the Environment. As such, the RC remains an active and collaborative member of the research community, continues to serve on graduate committees, serves as mentor for graduate students, and promotes the use of PBNERR as a site for WWU faculty research. Through previous and ongoing work in ocean science education, the RC has remained

involved in the Centers for Ocean Sciences Education Excellence (COSEE) network and serves as an advisor for Seattle-based Red Eagle Soaring/SIYAP (Seattle Indian Youth Arts and Performance) group in their efforts to integrate climate and ocean science and traditional knowledge in the education of Native youth.

Both PBNERR Monitoring Specialists are members of PERS and CERF and actively participate in annual and biannual meetings of these organizations. The Monitoring Specialist 2 is actively involved in the Multi-Agency Rocky Intertidal Network (MARINe) and coordinates the participation of PBNERR in the large-scale MARINe monitoring program. MARINe is a partnership of agencies, universities and private groups extending from Alaska to Baja who are committed to determining the health of the rocky intertidal habitat, tracking long-term change, and providing this information to the public.

The PBNERR GIS Analyst, contributes to the Washington State Chapter of the Urban and Regional Information Systems Association (WAURISA), a national GIS community, and has recently served as Board member, Chair of the Membership Committee, and poster session organizer at the annual conference. The GIS Analyst is the co-organizer of the Northwest Washington GIS User Group which provides networking and professional sharing for GIS practitioners in the local and three adjacent counties through quarterly meetings, often hosted at Padilla Bay NERR.

Finally, the research and monitoring team engages others in the local scientific community through the support and involvement of the Board of Directors of the Padilla Bay Foundation. Three members of the Board are scientists, have close research and management connections to Padilla Bay, and have continued to serve in an advisory capacity for research and monitoring efforts in Padilla Bay.

## **Padilla Bay NERR Research Program Delivery**

Padilla Bay is well suited as a research reserve to address local, regional and national-scale issues, as described in the Research Program Context section above. Using the Padilla Bay Strategic Framework, input from PBNERR research staff, regional managers and scientists, current trends in estuarine research and literature, and other stakeholders, the reserve has narrowed the almost infinite aspects of estuarine ecology and management that could be addressed at PBNERR. The following research topics have been identified as both a high priority for the next several years at Padilla Bay and consistent with the NERRS Research and Monitoring Plan (15 C.F.R. § 921.50). Research and monitoring at PBNERR focuses primarily on marine, sub-tidal, intertidal and emergent ecosystems, as Padilla Bay NERR owns only two parcels of upland within the proposed boundaries of the Reserve and terrestrial ecosystems are not presently identified as a high priority. However, it is important to note that the influence of uplands through groundwater, river discharge, and sediment, nutrient and fecal loading is an important component of water quality in Padilla Bay and part of the watershed-scale approach to research at the Reserve.

The Padilla Bay Strategic Framework identifies five Strategic Priorities to broadly guide research efforts. These include:

- Climate change (including sea-level rise, ocean acidification, and temperature variability)
- Water quality in estuaries and watersheds
- Invasive species impacts
- Loss of shoreline processes
- Habitat loss in estuaries and watersheds

Specific focus areas and research questions within these broad priorities are described below:

- 1) Investigating ecology of eelgrass, including seasonal and interannual variability, and factors controlling growth, productivity and survival,
- 2) Identifying interactions between native eelgrass *Zostera marina* and non-native *Zostera japonica*, including inter-specific comparisons such as ecological services and function, habitat suitability, carbon sequestration, and contribution to sedimentation/shoreline stabilization,
- 3) Quantifying the contribution of eelgrass in Padilla Bay to carbon sequestration, net ecosystem metabolism, and potential mitigation of changes in pH related to ocean acidification,
- 4) Geospatial analyses that include distribution mapping of *Z. marina*, *Z. japonica*, and the interface between the two species; habitat suitability and usage indices; and other physical properties including substrate type, temperature, light, and water depth/bathymetry,
- 5) Use of SWMP data to evaluate changes in Padilla Bay as a result of regional and watershed-scale effects of climate change, including reduced summer freshwater flow, episodic high-flow events in winter and spring, and changes in basin-scale circulation patterns and stratification that influence water temperature and salinity,
- 6) Investigating plankton community dynamics and metabolism, including factors that regulate seasonal patterns in zooplankton abundance and diversity and the biological contribution of respiration to changes in ocean pH and ocean acidification,
- 7) Monitoring local sea-level rise (e.g., Sentinel Site protocols) and evaluating the effect of sea-level rise on intertidal organisms and communities, such as changes in distribution of native and non-native eelgrass in Padilla Bay,
- 8) Investigating ecological effects of non-native and/or invasive species (e.g., Japanese eelgrass (*Zostera japonica*), Asian mud snail (*Batillaria attramentaria*), and European green crab (*Carcinus maenas*)) in the Padilla Bay estuary,
- 9) Research into species of special interest in the region (e.g., Puget Sound Chinook, Dungeness crab, Pacific herring, and various species of birds) and other faunal communities associated with eelgrasses, including the many

- juvenile and early life stages that use the eelgrass community as habitat, and
- 10) Continued evaluation of sources of fecal coliform, nutrient and other water-borne contaminants in Padilla Bay.

### Current Research and Monitoring Efforts

Current research efforts include: investigation of community composition and long-term change of rocky intertidal ecosystems as part of the Multi-Agency Rocky Intertidal Network (MARiNe), biomonitoring of native (*Zostera marina*) and non-native (*Zostera japonica*) eelgrass, and investigation of growth rates of the resident seastar (*Pisaster ochraceus*) which is being conducted by AmeriCorps/WCC interns in conjunction with a larger collaboration to investigate seastar wasting disease in the region (Fig. 3.2). The Reserve is also evaluating rates of pelagic oxygen consumption and CO<sub>2</sub> production in Padilla Bay and other regional waters, conducting water column profiles to identify inputs of low pH waters of marine origin, and tracking spatial and temporal variability in zooplankton community dynamics. These research and monitoring projects at PBNERR have improved our knowledge of the functioning and characteristics of Padilla Bay, as well as provide insight into regional-scale climatic process and ecological perturbations. An overview of these research projects and recent findings are described below.

### Biomonitoring Efforts at Padilla Bay

**Rocky Intertidal Habitat Monitoring:** In 2009, the Reserve began monitoring rocky intertidal habitats in Padilla Bay as part of the Multi-Agency Rocky Intertidal Network (MARiNe) (Fig. 3.3). Semi-annual monitoring of sea stars and other rocky intertidal populations (e.g., barnacles, macroalgae, and motile invertebrates) has been conducted at four permanent sample sites on two islands located on the western edge of Padilla Bay (Saddlebag Island and Hat Island). Long-term data from this effort provide a mechanism to track changes in populations, community structure, and responses to natural or human-induced disturbances. One such change evident in our data is the dramatic mortality of the Ochre Star (*Pisaster ochraceus*) that occurred between June and September of 2014 (see Fig. 3.4) and has been attributed to the recent regional outbreak of Sea Star Wasting Syndrome (SSWS). The Ochre Star (*Pisaster ochraceus*) was the dominant species of sea star at the Padilla Bay monitoring sites. However, populations of *P. ochraceus* decreased by over 90% throughout our study areas, with the most recent data collected in 2015 providing no evidence of recovery of this keystone population. PBNERR will continue its involvement in the MARiNe monitoring program and continue monitoring populations at these sites in an effort to document other changes in community structure and/or recovery of seastar populations in subsequent years.

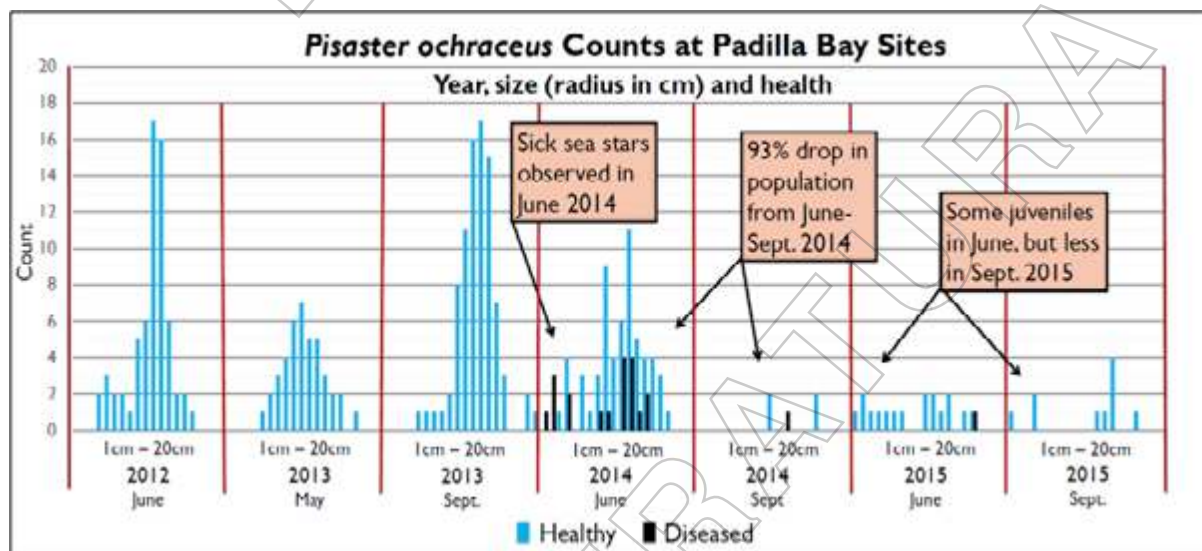
**Eelgrass Habitats:** The interaction between the native eelgrass, *Zostera marina*, and the non-native Japanese eelgrass, *Zostera japonica*, has important implications for native estuarine fauna and flora throughout Puget Sound and Washington State. There is increasing concern that *Z. japonica* may have a deleterious effect on *Z. marina* and many





**Figure 3.2** The growth rates of the Ochre sea star (*Pisaster ochraceus*) are one study currently conducted by the Washington Conservation Corps/AmeriCorps assistants.

**Fig. 3.3** Research staff documenting abundance of sea stars and other invertebrates at one of the PBNERR Saddlebag Island sites.

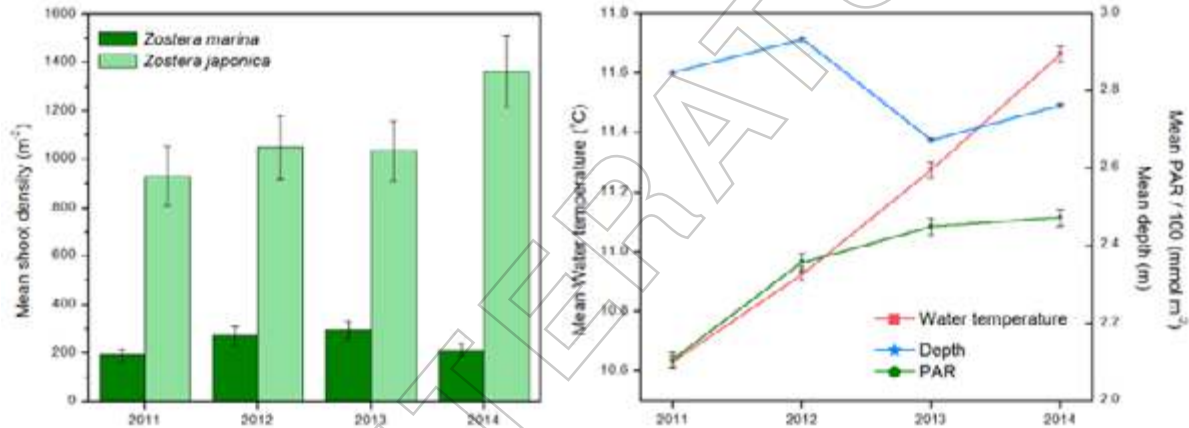


**Figure 3.4** Data from PBNERR rocky intertidal MARINE monitoring efforts revealing the dramatic decline in abundance of the resident sea star *Pisaster ochraceus* during the study period.

questions remain regarding the ecosystem services associated with these organisms, interactions between the two species, and the habitats they provide. Furthermore, commercial shellfish growers are seeking approval to control and possibly remove *Z. japonica* in select intertidal habitats of Washington through the application of herbicides. In 2011, an annual monitoring program was established in PBNERR to document changes in resident eelgrass (i.e., *marina* vs. *japonica*) to address the questions surrounding these issues and to advance our understanding of basic eelgrass ecology. This biomonitoring effort includes surveys of eelgrass density, percent cover, height, elevation, relative abundance of *Z. marina* and *Z. japonica*, and species specific biomass at over 126 permanent plots along three 4 km transects that span the upper intertidal to subtidal range of these two eelgrass species (Fig. 3.5). Data derived from this monitoring effort reveal a substantial increase in density of *Z. japonica* relative to *Z. marina*, with an overall increase in both species of plant height and percent cover (Fig. 3.6). Use of SWMP



**Figure 3.5** The eelgrass biomonitoring project is a labor intensive data collection effort. Above are two Washington Conservation Corps/AmeriCorps assistants participating in biomonitoring fieldwork.



**Figure 3.6** Data from PBNERR eelgrass biomonitoring revealing an increase in density of native eelgrass *Zostera marina* relative to non-native eelgrass *Zostera japonica*.

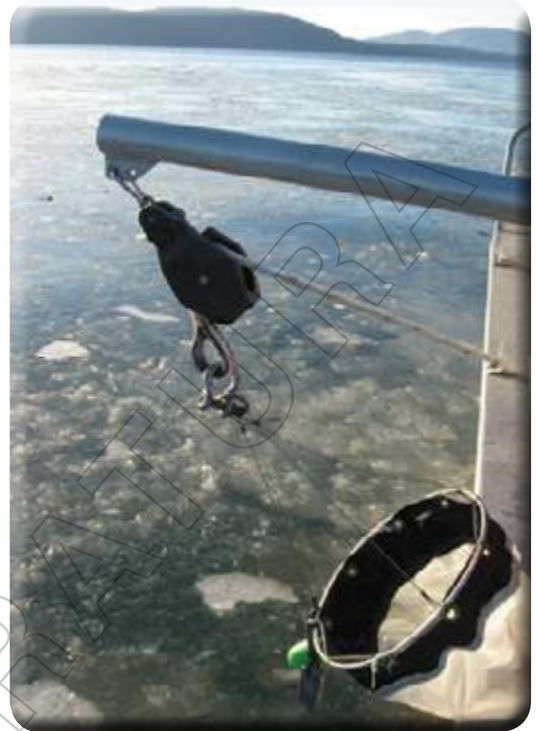
data parameters recorded in Padilla Bay (i.e., temperature, light availability, and water depth) provides evidence that *Zostera* spp. are most likely responding positively to a transition from cooler temperatures and lower light conditions in 2011 to more favorable growing conditions in subsequent years, and that this effect may potentially favor the performance of *Z. japonica* over *Z. marina*.

In addition to the eelgrass biomonitoring described above, PBNERR will continue to seek funding to monitor interannual variability on a baywide scale by means of acquisition of airborne imagery on extreme summer low tide. When possible, these images will be complemented by monitoring of ground reference sites throughout Padilla Bay during summer. Coverage of estuarine vegetation will then be delineated using hybrid methods of automated segmentation and/or the on-screen protocol developed by Bulthuis and Shull (2006). Other vegetative communities that will be monitored with these methods include *Spartina* spp., native salt marsh, and macroalgal mats.

In 2015, researchers from the University of Washington Friday Harbor Labs (UW-FHL) joined in the eelgrass biomonitoring effort to conduct a side-by-side survey of eelgrass wasting disease and investigated the prevalence of the pathogenic protist (*Labyrinthula zosterae*) in Padilla Bay eelgrass. This preliminary work by UW-FHL will help guide inclusion of metrics for eelgrass wasting disease in our annual monitoring and is also an example of the value of establishing a monitoring infrastructure that can foster collaborative efforts. PBNERR staff will continue to seek funding opportunities and collaborations to support and enhance our biomonitoring and research of eelgrass in Padilla Bay.

#### ***Plankton community abundance, composition***

***and respiration:*** Monitoring of zooplankton abundance in the water column was initiated in 2007 to identify the phenological variability of various marine and intertidal invertebrates in Padilla Bay and explore the use of zooplankton community composition as an integrative ecological indicator of ecosystem change. Surveys entailed surface and vertical tows using a 153  $\mu$ m plankton net at three of the SWMP water quality monitoring sites in Padilla Bay (Gong buoy, Bayview, and Ploeg) (Fig. 3.7). In 2015 sample analysis was expanded to include class-level identification of echinoderm larvae, motivated by an interest in evaluating recruitment potential of juvenile seastars following widespread mortality of adults in Padilla Bay the previous year. Recent analyses



**Figure 3.7 Collection of zooplankton is conducted throughout the year in conjunction with SWMP sampling.**

reveal recurring annual patterns in the most abundant predatory species (i.e., copepods and larvaceans) and a predictable community succession throughout the year. These data also reveal a dramatic shift in the timing of this annual succession in 2013 and 2014, presumably related to large scale climatic shifts.

Another aspect of plankton community dynamics that has been initiated in 2015 is estimating rates of water column oxygen consumption and CO<sub>2</sub> production, which will be conducted monthly at SWMP monitoring sites. This monitoring effort is to assess the biological contribution of planktonic processes to ambient dissolved CO<sub>2</sub> concentrations, pH (as a surrogate for ocean acidification) and hypoxia, and begin to document long-term changes in water-column metabolism as a result of increasing temperatures and nutrient/organic matter loading associated with coastal eutrophication. In a related effort, PBNERR has also begun conducting water column profiles at two deep water (20 and 70 meters) locations to examine water column structure, deep water circulation, and identify potential inputs of low pH water of marine origin into Padilla Bay.

### **Student Research at PBNERR**

Each year over the past decade, PBNERR has awarded a Research Assistantship in Estuarine Science and Coastal Zone Management to graduate students conducting Master's or Ph.D. thesis research in the Reserve. The total amount of the award is \$5,000 and distributed over a 12-18 month period in support of the student's research. In 2015, through support from the Padilla Bay Foundation, PBNERR was able to offer two graduate student assistantships. One student from Western Washington University is investigating the role of eelgrass in carbonate chemistry and ocean acidification, while the student from University of Washington is investigating interactions between eelgrass and both native and non-native oysters in Padilla Bay. Support for two annual assistantships will continue as long as funds are available through the generous contributions of the Padilla Bay Foundation. Funding for the assistantships are currently supported by the Tesoro Corporation and Borman Family Foundation, but are also sought from a variety of sources including private foundation grants, coastal zone management grants to the states, and Reserve operations funds. Proposals are requested from students, reviewed by scientists who serve on the Padilla Bay Foundation and other relevant experts in the field, and awarded as contracts to the students.

Student research at the reserve is not limited to projects supported by the PBNERR Graduate Assistantship. Many undergraduate and graduate students work in the Reserve as part of thesis projects at neighboring institutions. Current projects being conducted in the reserve include an investigation of eelgrass wasting disease (Ph.D. student at UW Friday Harbor Labs), inclusion of PBNERR in regional eelgrass surveys conducted by students at Northwest Indian College, and investigations of eelgrass, carbonate chemistry, and carbon sequestration by graduate students at Western Washington University.

## **Cooperative Research with Other Scientists**

Another element of the PBNERR research program is cooperative investigations with other scientists or institutions. Padilla Bay research staff work cooperatively with scientists from a variety of institutions, with levels of involvement ranging from an advisory role to providing field or laboratory support, and even participating as principal investigators. PBNERR is able to promote research involving outside investigators by offering use of laboratory space and equipment, assistance in the field, sharing of PBNERR monitoring data, use of field instruments, GIS support, overnight facilities, and research vessel support. Most collaborative projects are funded through external institutions and/or programs and consequently vary from year to year. Examples of current or recent collaborative research efforts at PBNERR include a Washington SeaGrant funded projects to investigate the effect of sulfides on eelgrass performance (Drs. Shull and Yang, Western Washington University) and another proposal to track health, recruitment and recovery of juvenile seastars following widespread mortality associated with seastar wasting disease (Drs. Miner, Arellano and Kodner, Western Washington University). Other ongoing projects in Padilla Bay include: an investigation of sea-level rise and rates of sedimentation through the deployment of a network of surface-elevation tables (SETs) that includes an adaptation of the Marsh Equilibrium Model (MEM) to compute carbon sequestration and marsh response to sea level rise; deployment of DuraFET pH sensors to conduct an investigation of diel, seasonal and spatial variability of pH and pCO<sub>2</sub> in Padilla Bay; and participation in the USGS Western Ecological Research Center (WERC) multidisciplinary Coastal Ecosystem Response to Climate Change (CERCC) program.

## **Volunteer-Based Research and Monitoring**

Another aspect of research and monitoring at PBNERR entails the involvement of public audiences. Volunteers currently assist with the eelgrass biomonitoring project and zooplankton study, but the greatest participation is through the volunteer-based Skagit Stream Team. As part of this project, teams of volunteers monitor fecal coliform and physical water quality parameters in Joe Leary Slough, No Name Slough, Bay View Drainage, other streams and within the Padilla Bay watershed and elsewhere in Skagit County. Monitoring data and field sampling protocols from several years of Stream and Storm Team activities are currently being used by Washington Department of Ecology to help develop a fecal coliform TMDL for Padilla Bay.

## **System Wide Monitoring Program (SWMP)**

As with all the NERRS, long-term monitoring is an integral part of the work conducted at PBNERR. Ongoing monitoring efforts include full participation in collection of physical water quality, water column nutrient, and meteorological parameters associated with NERRS System-wide Monitoring Program (1995-present). As described previously, PBNERR has initiated several other long-term biological monitoring efforts to complement SWMP, including zooplankton community abundance and diversity in the pelagic zone (2007-present), rocky intertidal communities through participation in the Multi-



Agency Rocky Intertidal Network (2009-present), and biomonitoring of submerged aquatic vegetation in the extensive eelgrass beds of Padilla Bay (2011-present) (Fig. 3.8). As of 2015, monthly grab sample collection has expanded to also include water column metabolism (i.e., rates of oxygen consumption/CO<sub>2</sub> production) as a measure of the potential biological contribution of planktonic processes to hypoxia and ocean acidification.



**Figure 3.8 Research diver sampling sub-tidally in Padilla Bay.**

Four water quality sites have been established in Padilla Bay (Fig. 3.9) where physical water quality parameters (temperature, salinity/conductivity, turbidity, dissolved oxygen, and pH) are continuously measured at 15-minute intervals. Bay View Channel site and Ploeg Channel site are located amidst extensive eelgrass beds and represent the southern and northern reaches of Padilla Bay, respectively. Joe Leary Estuary site (formerly Joe Leary Slough site) is located near the mouth of tidally influenced Joe Leary Slough on the eastern side of Padilla Bay. The Joe Leary Slough site was removed in July of 2009 because of persistent infill and was replaced with Joe Leary Estuary site, which is located on the marine side of the tide gates in the slough. In addition, water column profiles are now being collected at two deep water (20 and 70 meters) locations (Gong Deep and Guemes Channel) to examine water column structure, deep water circulation, and identify potential inputs of low pH water of

marine origin into Padilla Bay. A chlorophyll fluorescence sensor has been added to the EXO Sonde deployed at the Gong buoy.

Nutrients and chlorophyll-*a* are measured at two spatial and temporal scales as part of SWMP. Grab samples are collected from all four monitoring sites and processed for orthophosphate, ammonium, nitrite and nitrate, silicate, chlorophyll-*a*, phaeophytin, total nitrogen, total dissolved nitrogen, total phosphorus, total dissolved phosphorus and total suspended solids. Additionally, the Bayview Channel site is sampled hourly (diel) over an entire tidal cycle scheduled around the lowest tide of the month and analyzed for chlorophyll *a*, phaeophytin, PO<sub>4</sub>, NH<sub>4</sub>, NO<sub>2</sub>, NO<sub>3</sub>, and Si(OH)<sub>4</sub>.

Weather related factors are measured at a weather station located at the Padilla Demonstration Farm at the southeast corner of Padilla Bay. Parameters that are measured include rainfall, wind speed and direction, air temperature, relative humidity, barometric pressure, and photosynthetically active radiation (PAR; 400-700 nm). Data are recorded continuously throughout the year at 15-minute intervals.

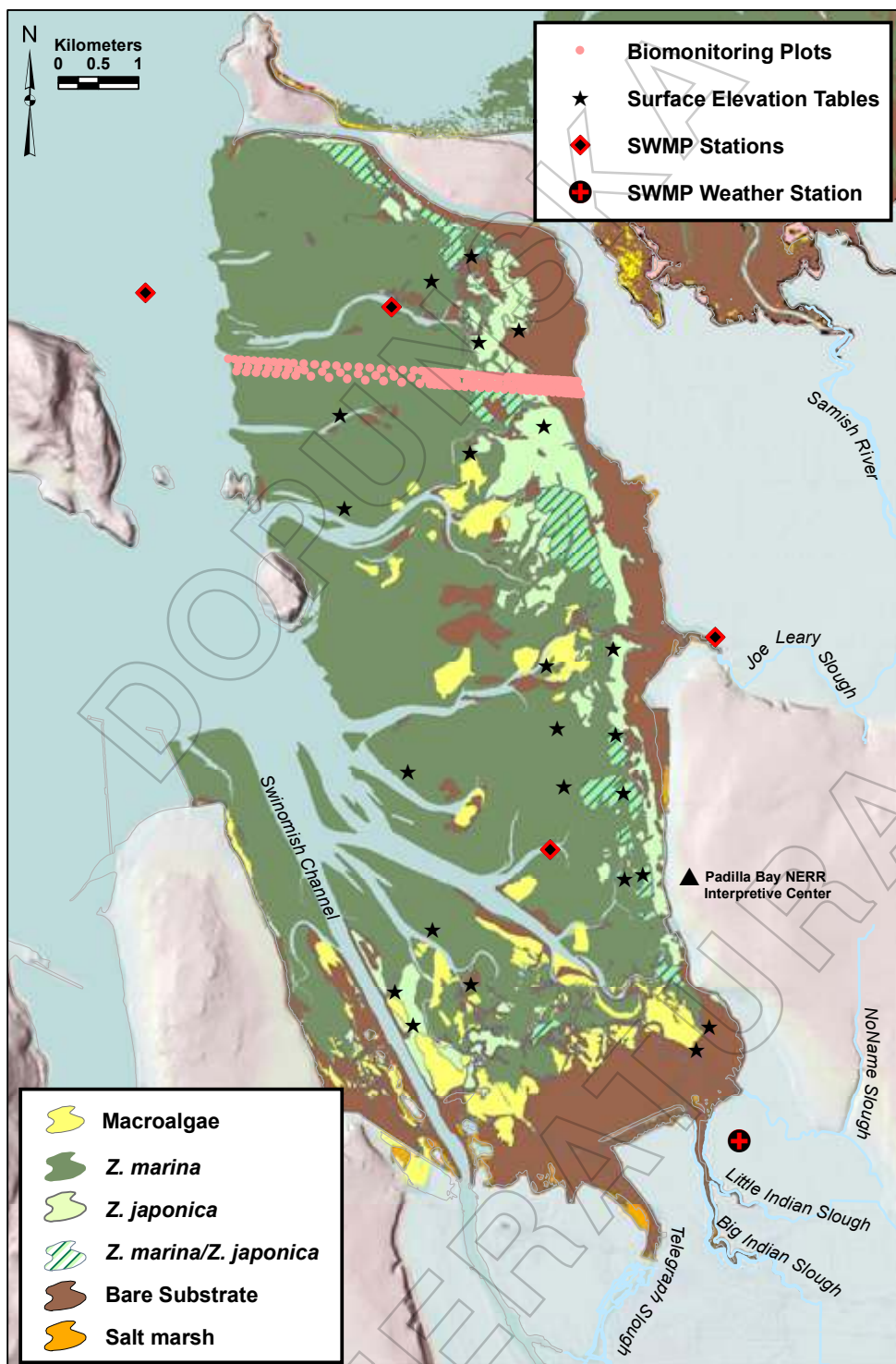


Figure 3.9 Map of Padilla Bay NERR including 1) location of SWMP water quality and meteorological stations, 2) location of SAV biomonitoring transect, 3) location of surface elevation tables (SETs), and 4) distribution of submerged and emergent eelgrass, macroalgae, and salt marshes in Padilla Bay as delineated from aerial photos taken during summer 2004.

## Cooperative Monitoring Projects

For the past several years, researchers at WWU (Dr. John Rybczyk and graduate student Katrina Poppe) have been maintaining SETs in Padilla Bay (Figs. 3.9, 3.10). We will continue to work with these researchers to support and expand the coverage of SETs in Padilla Bay, as this is an important aspect of establishing a Sentinel Site (SSAM1) monitoring program. Another cooperative monitoring effort that has recently evolved and will continue into the future is collaboration with Dr. Brooke Love (WWU) in the deployment of high-precision SeaFET pH sensor at the SWMP monitoring stations. These data will help in QA/QC of in situ pH data, as well as provide high-precision estimates of the diel, tidal and seasonal fluctuation of pH in Padilla Bay waters. It is anticipated

that these collaborative monitoring efforts will continue, and PBNERR will continue to develop cooperative monitoring with the Puget Sound Partnership, Ecology, and other monitoring by local, state, and tribal agencies.



**Figure 3.10 WWU graduate student and PBNERR research assistant Katrina Poppe taking measurements at a surface elevation table (SET) in Padilla Bay. Photo credit: Abe Lloyd.**

### Information Dissemination

Results of research conducted at PBNERR and monitoring data collected as part of SWMP and other efforts are distributed in a variety of formats. Data from SWMP are available real-time via the CDMO data portal, as well as served through the regional Northwest Association of Networked Ocean Observing Systems (NANOOS). PBNERR produces a technical report series that is available as hard copies and as PDFs

on the PBNERR website. This series provides a mechanism for thesis research, research conducted by PBNERR Research Assistants, WCC/AmeriCorps Assistants, and other research at Padilla Bay to be made available to a wider audience. Padilla Bay also contributes to the Puget Sound Environmental Monitoring Program (PSEMP) Annual Report, which provides a regional synthesis of monitoring data and context for the monitoring data collected at Padilla Bay. PBNERR will also contribute to the monthly “Eyes Over Puget Sound” Marine Conditions update coordinated by the Marine Waters Workgroup at Washington Department of Ecology. On a regional and national scale, PBNERR staff, students and affiliated researchers regularly attend and present at Scientific Meetings and Conferences, including the Pacific Estuarine Research Society (PERS) regional meeting and the Coastal and Estuarine Research Federation (CERF) national meeting. Finally, the Padilla Bay web site provides a portal for accessing information about the research



program, student research opportunities, and reports and summaries of research in Padilla Bay. We are in the process of developing a searchable database of all the research projects (and related data and publications) that have been and are being conducted in Padilla Bay. This database will eventually serve as a publicly-accessible, web-based portal for those interested in research in Padilla Bay. Soon to be accessible via the PBNERR website are a series of story maps providing a user-friendly, publicly accessible view of eelgrass research and Sentinel Site buildout at the Reserve.

## **Integration with Other Sectors**

***Integration with Padilla Bay stewardship.*** Natural resource management and stewardship at Padilla Bay requires monitoring of many species and other natural resources at several spatial and temporal scales. A primary area of overlap between research, monitoring, and stewardship is assessing the distribution of salt marsh vegetation using GIS, aerial photography, and employing modified SAV/emergent macrophyte monitoring protocols. Other opportunities for collaboration include obtaining baseline data on benthos in Padilla Bay, water quantity data for selected freshwater inflows into Padilla Bay, contaminants in the sediments and freshwater sources, surveys for forage fish spawning areas in Padilla Bay, monitoring for invasive species (e.g., European green crab *Carcinus maenas*), and research on the feasibility and the possible impacts of re-introducing Olympia oyster (*Ostrea lurida*) in Padilla Bay.

***Integration with Padilla Bay education.*** Padilla Bay research staff will continue to work with education staff on mutual projects, assist in the development of materials based on Padilla Bay research, improve the Padilla Bay web site for public information, contribute articles for the Padilla Bay newsletter, and incorporate interpretive displays on research and monitoring in the exhibits. The PBNERR Research Coordinator has extensive professional experience, training, and an interest in science education. This collaboration between research and education is formalized through the NOAA Environmental Literacy Grant that the Research Coordinator has transferred to PBNERR and Washington Department of Ecology, titled “Advancing Climate Literacy through Inservice and Pre-Service Educators (ACLIPSE)”. This is a collaborative project with science educators at the UC Berkeley Lawrence Hall of Science and the Ocean Observatories education team at Rutgers University and works towards integrating real-time and web-based data sources into middle school classrooms. Products from this project include numerous inquiry-based activities to have students engage with data in support of concepts in ocean and climate science, and an undergraduate course and curriculum to train pre-service and in-service teachers how to integrate ocean and estuarine observing data into the classroom. The modules and workshops resulting from this project will be offered to local educators involved with Padilla Bay.

***Integration with CTP at Padilla Bay.*** Padilla Bay research staff will work with CTP staff in development and implementation of training classes and helping use research and monitoring findings to better inform managers, decision makers and other participants in the CTP program. Through the NOAA ACLIPSE project, several modules will be de-

veloped to provide basic conceptual and scientific understanding of climate change and promote climate literacy. To the degree that it is helpful, these will be offered to supplement programs offered by the CTP program at PBNERR.

### **Program Efficacy and Evaluation**

PBNERR has a wide range of research and monitoring endeavors, which produce data and findings that are disseminated through a variety of formats. The quality of these data is validated through several mechanisms. All data collected as part of the SWMP monitoring adheres to strict monitoring and analytical protocols developed by NERR CDMO, as well as additional in-house QA/QC procedures designed to assure high quality data. Data are submitted quarterly and annually to CDMO for approval. PBNERR contributes research and monitoring findings to the annual peer-reviewed PSEMP report and monthly data reviews. The focus and quality of research conducted by the PBNERR Research Assistants is validated by a panel of expert external reviewers who help determine those research projects that are of high scientific quality and are also well aligned with the research and management priorities of PBNERR.

### **Research Impacts and Outcomes**

Several deliverables and outcomes have been realized by the Research and Monitoring Program that have had a direct effect on target audiences and scientific goals.

**Research Assistantships** are a means by which PBNERR is able to provide funding opportunities for graduate students, expand the scope of research conducted at the reserve, and foster collaboration with regional academic institutions. In collaboration with the Padilla Bay Foundation, PBNERR has continued to offer one research assistantship each year to a graduate student conducting research in Padilla Bay. In 2015, the Research Coordinator worked with the Padilla Bay Foundation to acquire funding to support an additional research assistantship. Through donations from the Tesoro Corporation and the Borman Family Foundation, PBNERR has offered two separate 18-month, \$5000 assistantships. The two most recent recipients include Cale Miller (Western Washington University Huxley College of the Environment) who is investigating effects of native and non-native seagrasses on pH and carbonate chemistry and Alex Lowe (University of Washington Department of Biology) who is investigating the ecology of the native oyster *Ostrea lurida* across stress gradients in Padilla Bay. An additional impact of the research assistantship is the elevated level of collaboration it fosters between the advisors and Padilla Bay.

**Submissions to the Annual PSEMP Report.** The annual PSEMP report is a synthesis of patterns and trends in water quality monitoring throughout the Puget Sound/Salish Sea. This year (2015) was the first year that PBNERR contributed to the annual report, including a synthesis of the annual variability and long term trends in salinity and water temperature in Padilla Bay, and an invited two-page section highlighting the research and monitoring being conducted at PBNERR with eelgrass and rocky intertidal habitats.

There are three notable impacts of the inclusion of Padilla Bay content in the annual report. First, the Northwest Straits/Central Salish Sea is poorly represented in terms of real-time water-quality monitoring, and Padilla Bay SWMP infrastructure and data fill a large data gap in the annual synthesis. Second, inclusion of PBNERR in the PSEMP report achieves the goal of increasing the representation of Padilla Bay research and monitoring among other Washington Department of Ecology programs. Third, annual submissions to the report provides an incentive and context for using SWMP data to address regional-scale questions and issues.

***PBNERR MARINE Biomonitoring Data*** is unique in that it is a marine monitoring project that was initiated prior to the mass mortality associated with SSWS and was able to capture the widespread mortality, and track recovery and recruitment. This helps provide a context for researchers to conduct additional work in Padilla Bay.

***Presentations at conferences*** are another means by which research findings are disseminated. The Research Coordinator and other PBNERR staff presented work being done at the reserve at the 2015 Coastal and Estuarine Research Federation (CERF) conference held in Portland, Oregon and expect to present at similar conferences in the next five years.

***WCC/AmeriCorps research assistantships*** provide an important opportunity for young professionals in the natural resource field to gain experience in research, monitoring and contribute to the PBNERR. One objective is to provide these assistants with mentoring in an independent research project and authentic research experience. The 2015 assistant conducted an independent research project investigating and quantifying growth rates of resident seastars, which contributed to an ongoing collaboration with a faculty member at Western Washington University who is investigating seastar wasting syndrome in Padilla Bay and other regional waters.

***External funding opportunities*** are a means by which PBNERR engages in collaboration and seeks support for research infrastructure. The Research Coordinator has worked with Dr. Ben Miner and other co-PIs at Western Washington University as a partner on a Washington SeaGrant proposal to investigate the recruitment and biodiversity of seastar larvae in the Salish Sea. The proposal has moved through the pre-proposal stage to full submission, and has been reviewed positively by the reviewing committee. Funding is likely, which will support additional zooplankton monitoring in Padilla Bay and provide additional equipment for enumeration and quantification of echinoderm larvae.

## **Research Program Needs and Opportunities**

PBNERR continues to maintain an active research program and conducts high-quality data collection as part of SWMP. However, new research opportunities and evolving NERR monitoring priorities may exceed the existing capacity and infrastructure at PBNERR. Most critical of these is the need to establish a PBNERR SSAM1 Sentinel Site focused on Submerged Aquatic Vegetation and in doing so accurately evaluate changes in

local sea-level rise, as well as the biological and ecological consequences of these changes and those associated with larger-scale climate change. Aging monitoring equipment and the need to deploy sondes at greater water depth and conduct real-time water column profiles is another area where PBNERR has equipment and infrastructure needs related to upgrading the Reserve's YSI sonde inventory.

### **Establishing Padilla Bay as a Sentinel Site (Sentinel Site Application Module 1)**

Present day sedimentation rates in Padilla Bay are less than historical levels and eustatic sea level rise is accelerating (Rybczyk and Kairis 2010), placing the extensive *Zostera* (eelgrass) meadows in the bay at risk of eventual submergence. Coastal managers have keen interest in the elevation dependencies of the intermixed *Zostera* species, due to the recent declaration of the introduced species *Zostera japonica* as a noxious weed. Further, salt marsh vegetation along the perimeter of the bay depends on water levels and marsh elevation, therefore precise monitoring of elevation, sediment accumulation and water levels are essential for addressing all of these questions.

PBNERR is developing the critical infrastructure and data analysis capacity to evaluate the ecological and physical effects of climate change and sea-level rise on Padilla Bay and adjacent waters. Existing biomonitoring efforts and SET placements in Padilla Bay are making a valuable contribution, but need to be supplemented by additional capacity and infrastructure for a complete Sentinel Site build-out. These include improved capacity for accurate and precise determination of water level at monitoring stations and SETs in Padilla Bay, developing a local geodetic control network tied to the National Spatial Reference System (NSRS) so water-level and bathymetry measurements are collected on the same vertical datum, and installation of additional SETs throughout Padilla Bay, specifically in the saltmarsh and along the biomonitoring transect. Finally, we need guidance from NGS to develop a local geodetic control network tied to the National Spatial Reference System (NSRS) so measurements are collected on the same vertical datum.

The current observational infrastructure includes:

- Submerged Aquatic Vegetation (SAV) transects to monitor changes in spatial distribution and community composition of vegetated habitats PBNERR.
- Twenty-three Surface Elevation Tables (SETs) installed and monitored throughout the mudflat with plans (funding dependent) to add SETs in the saltmarsh and along biomonitoring transect;
- SWMP Water Quality data (specifically water height) and PBNERR meteorological data;
- Multi-decadal aerial image analysis of shoreline and vegetation community boundaries;
- Two USGS water levels installed in 2013 and an additional one-year installation (mid-2015) at the historic tidal bench mark at the north end of

Swinomish Channel; and

- Potential for enhanced circulation modeling by Battelle and USGS.

## **Other Desired Expansion of Capacity and Equipment**

***Building and Sharing a Geospatial Research Database:*** Numerous scientists and other researchers visit Padilla Bay each year to conduct a wide range of studies and field experiments at specific locations within the bay. In addition, PBNERR has archived technical reports and summaries from over 30 years of research conducted at Padilla Bay. However, other than through institutional knowledge or archived paper documents, this vast body of information is virtually inaccessible to both Padilla Bay staff and others interested in research at Padilla Bay. PBNERR staff are currently in the preliminary stages of developing a map-based, queriable geospatial database of all the studies conducted in Padilla Bay, including the location of the study, data collected, investigator, and summary of research findings. This will help provide valuable context for future work in Padilla Bay, as well as allow for large spatial- and temporal-scale syntheses of research findings and knowledge about this unique estuarine ecosystem. Successful development of this database would require digitization of existing research reports for which only hard copies exist, software and architecture to build a queriable geospatial database, and upgrade/redesign of the PBNERR website to host the database for both internal and external users. Although functional, the PBNERR website is antiquated and doesn't reflect the highly professional and high caliber research, monitoring and education at Padilla Bay. An improvement in this area would benefit all sectors at PBNERR. Furthermore, many other NERRs are hoping to establish similar web-based databases as a resource to end-users. Development of a database at PBNERR could serve as a model and/or template for other reserves.

***Expansion of Sonde Monitoring Capacity:*** Research and monitoring at PBNERR is moving into the realm of ocean/estuarine acidification and exploring the oceanographic interactions between Padilla Bay and surrounding waters. This will require continuous monitoring of deep waters in Padilla Bay (i.e., Gong Deep station), as well as conducting water column profiles at deep water stations to determine the extent of marine water intrusion and estuarine circulation dynamics. The current YSI sonde infrastructure limits the ability to achieve these goals, based on the inability to conduct real-time water column profiling and depth limitations of existing sondes that prevent deep water deployment. Four additional Xylem EXO sondes with profiling hardware (i.e., handheld unit and field cable) would meet this need and greatly advance our ability to assess effects of marine inputs of corrosive, low pH water of marine origin.

## **Research and Monitoring Objectives and Actions**

Many of the actions below address multiple goals and objectives. In the interest of avoiding redundancy, these actions have been described in their first iteration and referenced thereafter. Examples include establishment of a research database, coordinating annual gatherings of researchers and scientists at Padilla Bay, contributing to the annual

PSEMP report, attending and presenting at professional meetings, and hosting the annual Padilla Bay Research Symposium.

**CORE GOAL 1: Improve scientific understanding of coastal ecosystems and in doing so inform management of natural resources and work towards resilience and sustainability of Padilla Bay and the surrounding coastal ecosystems.**

Objective 1: Identify and promote research priorities at PBNERR from 2016-2020 that advance our understanding of the habitats, ecology, organisms, diversity and/or ecosystem functions of Padilla Bay.

Action: The RC will establish and maintain an ongoing, adaptive list of research priorities that is revised annually and addresses questions and/or challenges consistent with the five-year goals of the Reserve and is aligned with management priorities for Washington State and NERRS.

Action: The RC and research staff will expand research and monitoring efforts to include the following:

- Routine monitoring of water-column plankton communities at SWMP stations;
- Routine measurements of oxygen consumption, productivity, and/or other ecologically relevant rate processes at SWMP stations;
- Conduct routine water-column profiles at two deep stations in Padilla Bay; and
- Semi-annual monitoring of rocky intertidal habitats following the Multi-Agency Rocky Intertidal Network (MARINe) sampling protocol.

Action: The RC and research staff will increase the analysis of SWMP and other monitoring data collected within the Reserve to identify long-term trends and provide a more comprehensive understanding of ecological change in Padilla Bay and the greater Salish Sea. Contribute annual analyses to PSEMP report and monthly analyses to Ecology's Eyes Over Puget Sound.

Action: The RC will host annual gathering of regional researchers, scientists, resource managers, Padilla Bay research staff, and/or informed stakeholders to identify regional research and management goals and inform the research priorities at PBNERR.

Action: The RC will re-establish the Research Advisory Committee and consult this group in making decisions regarding program direction, allocation of student funding, and proposal review.

Action: The RC and collaborators will use PBNERR research priorities to provide focus and guidance for:

- Independent research projects conducted by students and interns;

- Focus and direction for the annual PBNERR research assistantships for undergraduate/graduate students;
- Research collaborations with external researchers, university faculty and other natural resource scientists; and
- Research proposals submitted by PBNERR for internal and/or external funding.

Objective 2: Provide resources, data and support from 2016-2020 to approved, independent research projects within the Reserve's boundary and watershed.

- Action: Research projects within the Reserve will be reviewed and evaluated by the RC, research staff and Research Advisory Committee to determine consistency with Reserve goals, promote synergy with other ongoing projects, and identify any potential conflicts with existing research.
- Action: The Padilla Bay Foundation will provide annual support for graduate student research through the Padilla Bay Research Assistantship (pending continued funding through the Padilla Bay Foundation).
- Action: The institution will provide equipment, watercraft, and staff support as available for relevant research projects within the Reserve.
- Action: The RC will promote use and incorporation of spatial, biogeographic and monitoring data collected at PBNERR into independent research projects conducted in Padilla Bay, achieved by articulating this as a priority in the graduate assistantship proposal solicitations and familiarizing other outside researchers with the geospatial database.
- Action: The RC and research staff will actively participate in internal and external programs that offer support for student research, internships and/or apprenticeships at PBNERR.

Objective 3: Enhance communication and collaboration among the scientific and resource management community from 2016-2020 to improve knowledge of PBNERR habitats, species, diversity, ecosystem functions and advance management objectives for Washington State.

- Action: The RC and GIS Analyst will create, populate and maintain a searchable and publicly-accessible database of the research projects that have been conducted at PBNERR.
- Action: The RC and research staff will contribute a synthesis of PBNERR monitoring data each year to the Puget Sound Ecosystem Monitoring Program (PSEMP) annual report.

- Action: Members of the Reserve research team will attend and present findings at relevant scientific and professional conferences; Research findings that make a substantive scientific contribution will be submitted to peer-reviewed journals for publication.
- Action: The PBNERR RC will meet regularly with management and research entities in the greater Puget Sound region, including but not limited to the Ecology/SEA Technical Team, Northwest Straits Commission, and PSEMP Advisory Board.
- Action: The following actions are also listed in greater detail as part of Goal 1, Objective 1 above: The RC will re-establish the Research Advisory Committee and host an annual gathering to share knowledge, research findings, and discuss solutions to challenges.
- Action: PBNERR research staff will work with other eelgrass scientists in the Pacific Northwest in a variety of workgroups, expert panels, and committees to provide the best possible scientific information in guiding policy and management for eelgrasses in the region.

**CORE GOAL 2: Foster through improved knowledge and understanding a community of informed citizens, students and decision-makers so they can make wise personal and professional choices that benefit the health of Puget Sound and the Salish Sea.**

Objective 1: Scientific data and research findings will be shared with the broader scientific, resource management, and stakeholder communities from 2016-2020.

- Action: The RC and GIS Analyst will make reserve technical reports, reprints, research projects, and data available through the Padilla Bay Geospatial Research Database and accessible through the web via the PBNERR website.
- Action: In collaboration with the Padilla Bay Foundation and pending continued funding, the research team will host an annual Research Symposium to share and disseminate ongoing research at PBNERR to scientific and public audiences (also addresses Objective 2 below).
- Action: The RC and research staff will develop products that communicate trends and observations revealed by improved analysis of long-term monitoring data and share these with appropriate management and stakeholder communities.
- Action: The RC and research staff will attend relevant scientific and professional conferences (also listed and described in greater detail as part of Goal 1, Objective 3 above).



Objective 2: Engage citizens, students and other non-scientists in research at PBNERR and other aspects of the process of science and research from 2016-2020.

- Action: The RC will collaborate with the Coastal Volunteer Program at PBNERR to continue volunteer-based support of research and monitoring (e.g., zooplankton counts, eelgrass surveys, rocky intertidal surveys, fecal coliform monitoring by Stream and Storm Teams, etc.).
- Action: The RC and Reserve staff will use professional development for teachers to facilitate the use of PBNERR SWMP data in middle and high school STEM classrooms.

Objective 3: Research findings will be made available to Reserve visitors, students, CTP participants and other interested public audiences from 2016-2020.

- Action: The RC and research staff will host annual Research Symposium (see Goal 2, Objective 1 above).
- Action: Current research projects and/or findings will be presented by the RC and research staff in the Interpretive Center via posters, educational displays or electronic media (e.g., information kiosk).

Objective 4: The Research Coordinator will communicate regularly with the Education and CTP Coordinators to identify opportunities for integration of research into planned activities, project and programs during 2016-2020.

- Action: The RC will work with the Education and CTP Coordinators to develop and implement meaningful contributions to educational programs, classes and workshops at PBNERR.
- Action: Every year from 2016-2020, there will be at least one education program that includes a presentation by one or more Reserve research staff members.
- Action: Every year from 2016-2020, there will be at least one opportunity for education and CTP staff members, or other qualified volunteers to participate in a research projects in the lab or in the field.

**CORE GOAL 3: Promote an improved understanding by citizens and public officials of the impacts of climate change on human and natural resource communities so they can make well-informed, sustainability-based decisions.**

Objective 1: PBNERR will support and actively engage in research during 2016-2020 that addresses the effects of climate change on the Padilla Bay ecosystem and coastal waters of the Salish Sea.

- Action: The RC, research staff and GIS Analyst will work together to make progress towards establishing a Sentinel Site at PBNERR to evaluate the effect of sea-level rise and other climate-related perturbations on intertidal ecosystems (pending funding).
- Action: The RC, research staff and collaborators will engage in and promote research projects that investigate the role of eelgrass in ocean acidification, carbon sequestration, and potential mitigation of elevated carbon dioxide in coastal waters.
- Action: The RC and research staff will use SWMP data to evaluate long-term and other climatic changes in water quality parameters of Padilla Bay and adjacent waters of the Salish Sea.
- Action: The RC and research staff will share findings from climate related research with scientific, management and public audiences and engage with Education and CTP Coordinators to enhance their efforts in climate literacy (See Goal 2 above).
- Action: Contribute to the series of climate-related courses being offered by CTP at Padilla Bay from 2016-2020.

**CORE GOAL 4: Manage the Reserve's natural resources in a sustainable manner for the benefit of the ecosystem and the public.**

Objective 1: Provide scientific information and research findings that support the efforts of local and regional resource managers during the 2016-2020 period.

- Action: The RC and research staff will work with the Stewardship Coordinator to identify priority areas of interest and/or concern related to management of Padilla Bay natural resources.
- Action: The RC will use these priority areas to guide the focus of graduate research assistantships, research projects.

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## Chapter 4 - Education Program Plan

### Introduction

Humans have inhabited the shorelines of Padilla Bay for thousands of years. First, Native Americans found shelter and sustenance here, then explorers came hoping to claim land, then trappers and traders, then settlers moved across the United States from the east. Some settlers changed the landscape in ways others before them had not. Padilla Bay is an estuary “orphaned” from the Skagit River due to river and ocean dikes built by settlers to reduce flooding and “reclaim” land from the sea. This rich environment between the Cascade Mountain range and the inland Salish Sea is where Padilla Bay lies. It is a perfect example of the riches of an estuary, with its extensive eelgrass beds, and the impacts of people on their environment. Our education programs focus on helping all ages better understand estuaries and what they can do to sustain them.

### NERRS Education Program

The National Estuarine Research Reserve System’s mission includes an emphasis on education, interpretation, and outreach. Education at each reserve is designed to fulfill the Reserve System goals as defined in the regulations (15 C.F.R Part 921(b)):

- Enhance public awareness and understanding of estuarine areas and provide suitable opportunities for public education and interpretation;
- Conduct and coordinate estuarine research within the system, gathering and making available information necessary for improved understanding and management of estuarine areas;

To sustain these system goals, the 2011-2016 Reserve System Strategic Plan outlines education objectives that support the focus areas of climate change, habitat protection and water quality:

- Enhance the capacity and skills of teachers and students to understand and use Reserve System data and information for inquiry-based learning; and
- Increase estuary literacy and promote active stewardship among public audiences through the development and delivery of tools and programs addressing climate change, habitat protection, and water quality.

The Reserve System provides a vehicle to increase understanding and awareness of estuarine systems and improve decision-making among key audiences to promote stewardship of the nation’s coastal resources. Education and interpretation incorporate

science-based content into a range of programs and methodologies that are systematically tailored to key audiences around priority coastal resource issues.

Reserves conduct formal and informal education activities, as well as outreach activities that target culturally diverse audiences of educators and students, environmental professionals, resource users and the general public. Education and public programs, interpretive exhibits and community outreach programs integrate elements of Reserve System science, research and monitoring activities and ensure a systematic, multi-faceted, and locally focused approach to fostering stewardship.

The Reserve System is committed to preparing tomorrow's future leaders with the knowledge and understanding of the nation's oceans and coasts to be responsible stewards. To fulfill this commitment, the Reserve System has created the K-12 Estuarine Education Program (KEEP) to increase the estuary literacy of students, teachers and the general public. The KEEP Program helps students and teachers learn about essential coastal and estuarine concepts, develop data literacy skills and strengthen their critical thinking, team building, and problem-solving skills. K-12 and professional development programs for teachers include the use of established coastal and estuarine science curricula aligned with state and national science education standards and frequently involves both on-site and in-school follow-up activity.

Community education is another priority for the Reserve System. Community education programs foster behavioral change to promote resource conservation. These programs work with audiences whose choices directly impact the integrity of estuaries and their associated watersheds.

## **Padilla Bay NERR Program Context**

### **Geographic Scope**

Most of the Reserve's education programs are taught on-site at the Reserve. For this reason, most participants come from within a reasonable travel distance, west of the Cascade Mountains in Whatcom, Skagit, Snohomish, and Island counties (Fig. 4.1). Sometimes programs take place at sites away from the Reserve but still within those same four counties. Rarely, Reserve educators travel further afield to other parts of the Salish Sea Watershed. These decisions are made on a case-by-case basis depending on an assessment of the value of the program balanced against the cost to resources such as staff time and transportation.

### **Market Analysis/Needs Assessment**

The Reserve Education Program completed a Market Analysis and a Needs Assessment for K-12 programs in 2011 (Riggs 2011; Alexander 2012). The Market Analysis was a survey of environmental education programs in Skagit, Snohomish, Whatcom and Island



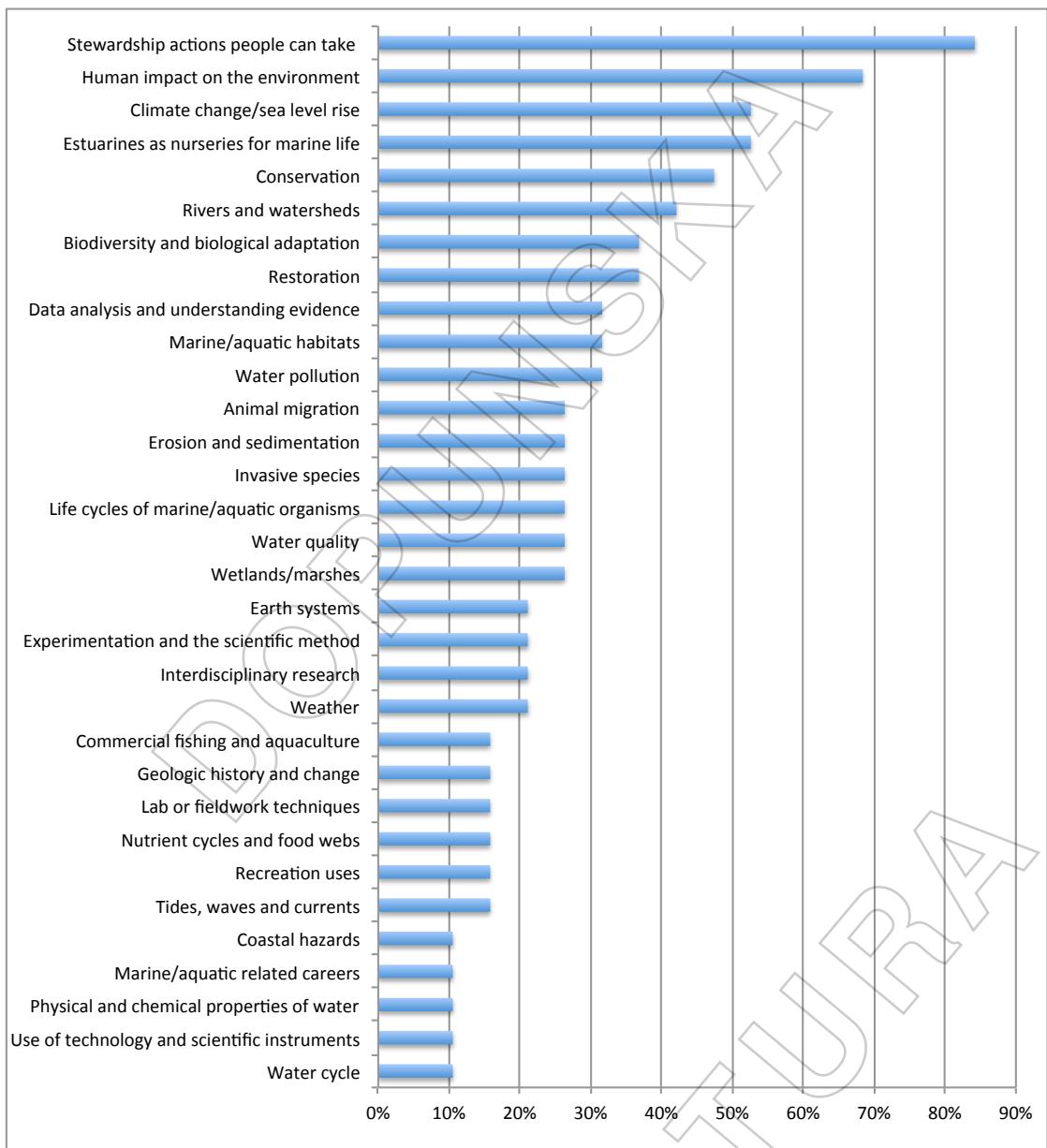
**Figure 4.1 Map of four-county local service area.**

counties. The purpose was to improve understanding of how the Reserve fits into the regional environmental education community and to help prepare for the needs assessment. The needs assessment was a survey of K-12 classroom teachers in the same four counties to help Reserve educators understand the needs of teachers in the region. The final reports from both of these projects are available in the publications section of the Reserve web page (<http://padillabay.gov/publications.asp>). The topics local service providers think need more attention are shown in Fig. 4.2.

“Stewardship actions people can take,” “Climate change and sea level rise,” “Human impact on the environment,” and “Estuaries as nurseries” are topics that the Reserve will continue to cover in K-12 programs.

The Needs Assessment showed that over 80% of responding teachers were aware that a National Estuarine Research Reserve exists in the state of Washington. Of those that were aware, over 80% reported having utilized Reserve educational services or products in the past. These data seem high but possibly it is because teachers that know about the Reserve and use Reserve services are more likely to respond to the request to take the survey.

Some teachers that were aware of the Reserve have not used services provided by the Reserve. The most common reason given for this is that they did not know about the services that were available. This shows a need for increased outreach to teachers. In



**Figure 4.2 Topics local environmental education service providers think need more attention.**

the next five years, Reserve educators will place a higher value on presentations to this audience.

Responding teachers also said that lack of time is the greatest barrier to teachers attending teacher workshops. Teachers said they are more likely to attend workshops that are one day in length than multi-day workshops. When asked about the preferred method to receive teacher information from the Reserve, workshops in their district were favored and workshops at the Reserve were next. Printed materials were less favored and distance learning (using technology that allows not face-to-face communication

such as video conferencing and the Internet) was least favored. For the next five years these results will be used in designing teacher workshops.

### **Logic Model/Evaluation Tools**

In 2010-11, a professional outside evaluator was contracted to help the Reserve's education program develop a logic model and evaluation tools for upper elementary school field trips (grades 4 through 8) and teacher training workshops (Stromholt 2010; Stromholt 2011). The evaluation tools were administered, tested, and refined by the education staff and consultant and the data were analyzed by the consultant. Figs. 4.3 and 4.4 are examples of results from the evaluations administered by teachers to students. Findings were summarized in final reports available on the publications web page (<http://padillabay.gov/publications.asp>).

*The consultant concluded "that the Padilla Bay programs have a positive impact on students and teachers alike. Students were able to recall many of the important lessons they learned during their time at Padilla Bay Reserve and consistently demonstrated enthusiasm for the programs. Teachers had an overwhelmingly positive response to the professional development training they received from Padilla Bay and have shared what they have learned with their students and other teachers. Several teachers reported a willingness to share their work and examples of student learning with Padilla Bay in an effort to show the merits of the program."*

The Reserve does not currently use the evaluation tools, although they are still available to teachers online, as the education programs have not changed. In the next five years, Reserve educators will develop a logic model and develop and implement evaluation tools for other audiences such as lower elementary (grades K through 3) or teacher workshops.

### **New Educational Standards in Washington State**

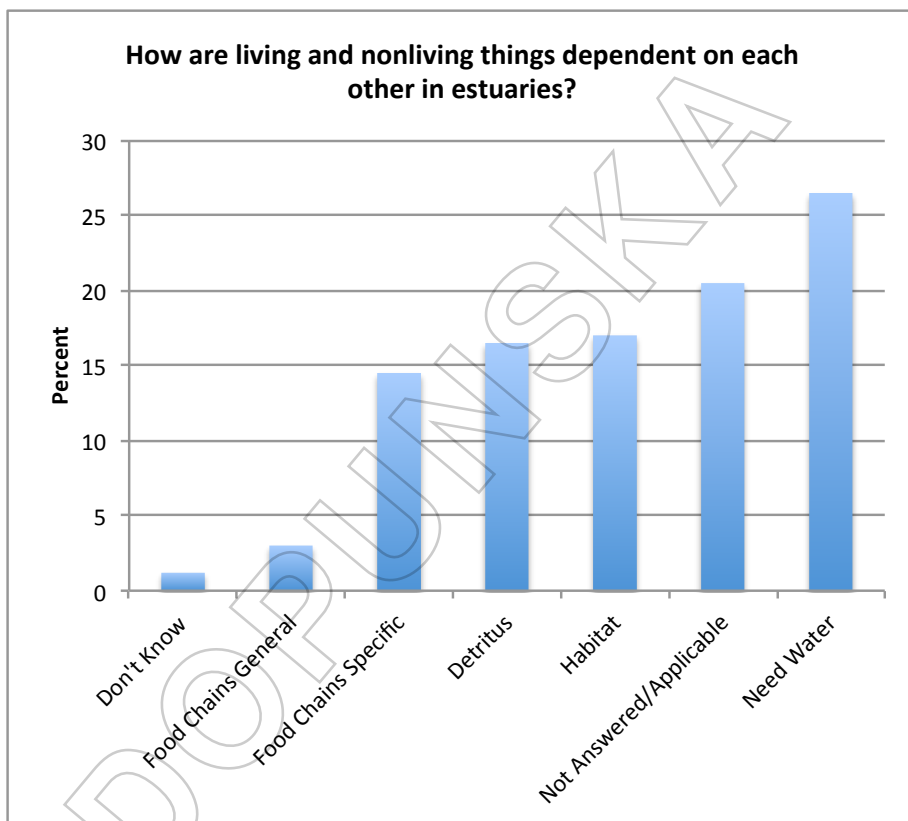
There have been changes in formal education in Washington State that may have an impact on future programs. New educational standards were developed and adopted including the Next Generation Science Standards and the Integrated Environmental and Sustainability Learning Standards. In the next five years the Reserve will align K-12 education programs with these new standards.

### **Target Audiences**

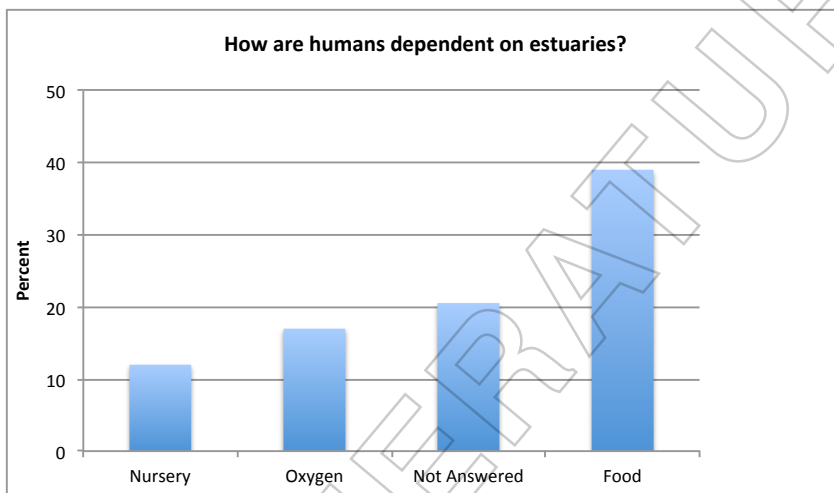
The Reserve's target audiences range from children to adults and students to teachers. All are willing, self-selected participants that come for advertised programs or that request a program for their group.

Programs aimed at *adults* include monthly programs on a range of topics such as "Sounds of Fall Migration", "Wild Edible and Medicinal Plants", and "Introduction to





**Figure 4.3** Responses showing that students participating in Reserve education programs for grades 4-8 can describe interdependencies in estuaries. Responses are recorded as percentage of student respondents.



**Figure 4.4** Responses show that students participating in Reserve education programs for grades 4-8 can describe human dependencies on estuaries. Responses are recorded as percentage of student respondents.

Hawks.” The Reserve contracts with local experts for these programs. Some of the programs use the outdoor trails.

*Family programs* target families with children and include public programs such as Mudflat Safaris and Beach Seines. These programs take place on the beach. Mini Explorers (3-5 years old) and Junior Ecologists (6-9 years old) meet every month for a different lesson in estuarine ecology.

*Students* (pre-K through 12th grades) come with their teachers and parent volunteers to learn about estuaries in on-site programs (Level 1 and Level 2 estuary curriculum and the interpretive exhibits).

Outreach programs inform the *general public* or specific groups about Reserve services. This may include displaying a portable exhibit at a community event like Fidalgo Bay Day or giving a brief talk to a target audience such as teachers.

*Teachers* benefit from teacher workshops (such as Teachers on the Estuary or TOTE) offered by the Reserve. TOTE workshops follow guidelines that include incorporating System Wide Monitoring Program (SWMP) data.

### **Reserve Education Programs**

The Reserve education program serves over 11,000 people each year (Fig. 4.5). Group composition can be further divided as in Fig. 4.6. The various programs offered can also be split into three categories: group programs, public programs and outreach programs.

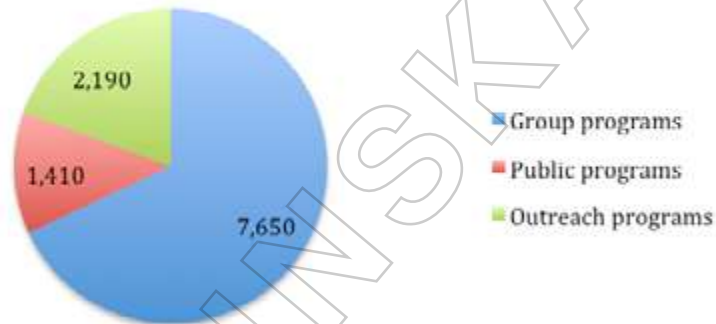
*Group programs* are for groups of 10 to 60 people that contact the Reserve to request a presentation. These groups learn about estuary systems, how estuaries relate to the audience and what the audience can do to keep these systems healthy. These programs are specially designed to meet the learning needs of the group.

More than half (60%) of all the people who attend education programs at the Reserve come with classes on school field trips, making this the strongest component of the K-12 Estuary Education Program (KEEP). Each school brings one adult for every five to seven students so these parent volunteers are also a significant audience. Many of them would not otherwise choose to attend an environmental program.

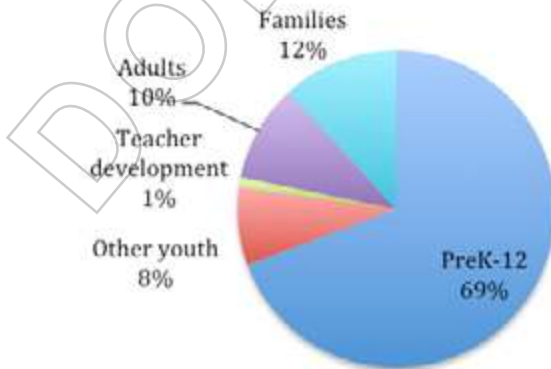
Children who come as part of a group such as scouts or other youth programs outside of school are less than 10% of the total audience. Groups of adults, including college classes and civic groups also make up less than 10% of the total audience. Families that attend public programs targeting children at various age ranges make up just over 10% of the total audience.

*Public programs* are planned and scheduled by education staff members, advertised in the newsletter and individuals and families can sign up. The purpose of public programs

**Figure 4.5 Number of individuals attending programs  
from July 1, 2014 - June 30, 2015**



**Figure 4.6 Breakdown of group program attendees.**



is the same as group programs – to learn about estuary systems, how the audience relates to these systems and what the audience can do to keep these systems healthy.

The purpose of *outreach programs* is to inform people about Reserve activities so audiences know how they can participate and have their needs met. As a result of the Needs Assessment of K-12 teachers, outreach to teachers will increase in the next five years.

The Reserve also offers *professional teacher development* on various subjects and in different delivery formats to increase the amount and effectiveness of environmental education in schools. The State Office of Public Instruction authorizes the Reserve to offer professional continuing education credits (Washington State Clock Hours). This is a great incentive for teachers to attend the workshops. The Reserve is planning to implement a workshop in the summer of 2016 for middle school teachers to learn about a new ocean acidification curriculum. This workshop will meet the standards of a Teach-

ers on the Estuary (TOTE) workshop. Other TOTE workshops will also be implemented in future years.

## Priority Issues

The Padilla Bay Strategic Framework (Chapter 2) identifies Strategic Priorities and this section illustrates how the Education Program will address these priorities.

- 1) *Climate change impacts.* Since 2008 the Education Specialist has been assigned responsibility for climate change education. This includes educating the public about climate change and carbon reduction strategies to reduce greenhouse gas emissions. The Education Specialist and the seasonal educator (employee of the Padilla Bay Foundation) participated in a study circle of the National Network for Ocean and Climate Change Interpretation (NNOCCI) in the fall of 2015. This will result in more effective planning and implementation of climate change interpretation over the next five years.
- 2) *Water quality in estuaries and watersheds.* The Education Specialist oversees the “Stream Team” program where water samples are collected locally and tested for the presence of fecal coliform. The Reserve K-12 curriculum also teaches personal behaviors that students can do to help keep water clean.
- 3) *Invasive species impacts.* Reserve education programs, including public programs, teacher workshops, adult groups and K-12, will continue to include information about the dangers of introducing non-native species. Participants will learn to identify non-native species and strategies to avoid new introductions.
- 4) *Loss of shoreline processes.* The K-12 program will continue to identify examples in Padilla Bay of human alterations to the shoreline and teach how these changes have reduced estuary health. Reserve educators will continue to present a popular historical program about the building of dikes in the area. This program includes information about current shoreline restoration projects.
- 5) *Habitat loss in estuaries and watersheds.* This is another subject covered in the K-12 program. It is cited as one of many reasons for declining populations of salmon and Orca whales. Though students have little control over habitat loss, these losses serve as motivation for behaviors students do have control over such as picking up dog waste, reducing the use of automobiles and practicing thoughtful conservation when visiting the beach.

## Alignment with NERRS Strategic Plan

All Reserve education programs directly address the “People” goal of the 2011-2016 NERRS Strategic Plan (Objective 2). The goal states “NERRS education and training increases participants’ environmental literacy and ability to make science-based decisions related to estuaries and coastal watersheds” while Objective 2 promotes “Increas-

ing estuary literacy and promoting active stewardship among public audiences through the development and delivery of tools and programs addressing climate change, habitat protection and water quality.”

Teachers on the Estuary (TOTE) workshops address Objective 1 of the “People” goal which promotes “Enhancing the capacity and skills of teachers and students to understand and use NERRS data and information for inquiry-based learning.” A TOTE teacher workshop was implemented by the Reserve for three years (2009 through 2011) with Bay-Watershed Education Training (B-WET) funding. Over the next five years new TOTE workshops will be developed and implemented as funding and staff time allow. Additional staffing and funding are required to make this a sustainable addition to the Reserve education program.

## **Padilla Bay NERR Program Capacity**

### **Staff**

The Reserve Education Team consists of two full-time professional educators (Education Coordinator and Education Specialist). These two leaders have Masters degrees in Environmental Education and over 25 years of experience each in these positions. In addition, one AmeriCorps member works with the Education Team each year. Also, for several years now the Padilla Bay Foundation has hired a seasonal temporary educator to help with school field trips in the spring. Adult citizen volunteers assist with school field trips that go to the beach, as docents in the exhibits, and with outreach at conferences and festivals. Unpaid interns also help with all aspects of the education program. The Padilla Bay Foundation created a Volunteer Coordinator position in late 2014 to strengthen the volunteer program.

### **Volunteers**

Adult volunteers help with various tasks in the education program. They help with school field trips at the beach, setting up equipment, and roving from group to group to make sure students stay on task. Back at the Interpretive Center, volunteers help set up the microscopes in the classroom with live samples of organisms the group finds at the beach. They then help students use the microscopes and clean up at the end of the day.

Sometimes volunteers act as docents in the exhibits and aquarium. Volunteers also assist with outreach at conferences and festivals. Unpaid interns (such as Hollings scholars or students from local colleges and universities) also help with all aspects of the education program.

### **Facilities**

The Reserve has indoor exhibits and interpretive signs on trails that augment education programs. Public indoor exhibits are open Wednesday through Sunday (10:00 a.m. –

5:00 p.m.) and the outdoor trails (Upland and Observation Deck) are open during daylight hours and offer interpretation through signs and booklets.

The education program utilizes several rooms in the Breazeale Interpretive Center for education and interpretation. Educators use the theater which seats 50 for group programs. They also use the classroom with its 15 microscopes, the main exhibit area which consists of interpretive displays about human and natural interactions in estuaries and watersheds, the “hands-on” room with games, puzzles, puppets and books that can keep learners engaged for hours, and the aquarium display that houses live organisms found in Padilla Bay. For larger groups, there is also a large conference room that can be used for education and accommodates 60-100 people.

Most of the Reserve education groups access the beach at Bay View State Park (about a quarter-mile south of the Interpretive Center) because of its accessibility. However, the beach below the Interpretive Center is available and can be used if the beach at Bay View is closed for any reason.

### **Partners in Education**

The Padilla Bay Foundation provides numerous valuable services to the Education Program. They often serve as the fiscal agent on grants that the state agency either cannot receive or would be cumbersome to work with. The Foundation also hires a seasonal temporary educator to help with the increased workload of school field trips in the spring and they generously provide money and equipment to support education programs.

Skagit ECO Network is a collaborative network of local environmental, conservation and stewardship organizations working together to improve the watershed and estuarine environments in Skagit County. The efforts of this group are coordinated, guided and supported by the Puget Sound Partnership (Partnership), an EPA National Estuary Project. The Partnership provides training, capacity building, funding and other forms of support to Skagit ECO Network and 11 other local networks surrounding the Puget Sound. This ECO Network structure facilitates unified messaging and the Partnership shares vital social research about watershed residents.

Bay View State Park provides access to the beach and a site for a shed for Reserve education equipment. Reserve educators provide technical assistance to the State Park for education and interpretation projects.

The Education Program works hand-in-hand with the Skagit Conservation District to implement the “Stream Team” and “Storm Team” programs. The Stream Team is a highly successful citizen science project for monitoring fecal coliform. Stream Team volunteers collect water samples on a schedule (October-June) at long-term sites. The Stream Team data is used by cities (Burlington, Mount Vernon and Anacortes), Skagit County, Washington State Department of Ecology, and the county and state health departments.

The Storm Team collects water samples during storm events year round. The sites can change year-to-year based on the needs of the County and the Health Department.

Taylor Shellfish Farm and Blau Oyster Company are shellfish farmers who strongly advocate for water quality projects in Skagit County. They provide shellfish for education programs and events here at the Reserve. Taylor Shellfish also helps plan the “Storming the Sound” conference, a conference for environmental educators, and has been a partner on B-WET grant applications for TOTE. The Reserve provides a traveling exhibit at public outreach events hosted by Taylor Shellfish.

The Northwest Educational Service District (NWESD) is one of 12 regional educational units in the state. Each collectively provides services and expertise to dozens of school districts. NWESD provides expertise to advise the Reserve education program with grant applications and to help plan and implement projects such as teacher workshops. They also attend and make presentations at “Storming the Sound.”

Watershed Masters, Friends of Skagit Beaches and Salish Sea Stewards are all examples of local volunteer programs that provide training to adult citizens and require participants to contribute volunteer time to conservation and environmental activities. Reserve educators help train these citizens who in return become knowledgeable, motivated volunteers.

School districts and individual teachers participate in KEEP school field trips. They also help market teacher workshops and provide support for grant applications. They can also be strong advocates for the Reserve in situations when staff members cannot.

Skagit County Public Works helps plan “Storming the Sound” and provides recycling and waste reduction services at large public events.

The Skagit Conservation Education Alliance (SCEA) is a non-profit organization dedicated to conserve and enhance the natural ecosystems in Skagit County watersheds. The Reserve provides office space and works with SCEA to plan and implement workshops, events and festivals such as the “Youth Earth Summit” and “Storming the Sound.” The Reserve participates in various activities led by SCEA such as a coordinated watershed letterbox activity and the planning and placement of signs aimed at encouraging good behavioral choices.

The Samish Indian Nation helps organize “Storming the Sound” and is also active in the Skagit ECO Network. The Reserve also participates in the Fidalgo Bay Research Conference.

Educators from the Reserve offer classes and programs for several universities in the region, especially Western Washington University (WWU) and Skagit Valley College. The Reserve participates in the Huxley College Environmental Career Fair at WWU and pro-

vides internships to their students. They in turn present at “Storming the Sound” and the “Youth Earth Summit.”

Shannon Point Marine Center, a division of WWU, provides water and animals for the aquaria and participates in various outreach programs such as “Storming the Sound.” They use Reserve facilities for access to field sites for research.

Snohomish County Surface Water Management partners with Reserve educators to offer the “Watershed Words” teacher workshop.

North Cascades Institute (NCI) uses Padilla Bay facilities for some of their natural history programs and the Reserve works with NCI on projects such as the Beach Summer Camp and the International Birding Day.

Washington State Department of Ecology provides three Washington Conservation Corps/AmeriCorps members at the Reserve, all of which help in the Education Program (one full-time and two part-time).

### **Padilla Bay NERR Education Program Delivery**

The K-12 Estuary Education Program (KEEP) is a national initiative that includes professional teacher development, hands-on field experiences and web-based resources for K-12 teachers and students. School field trips meet the direction and standards of KEEP and remain the highest priority of the Reserve’s Education Program. These classroom and field-based experiences with children will continue in the next five years (Fig. 4.7). Students receive from their own teachers, pre- and post-trip lessons in their school classrooms before and after the on-site field trip to the Reserve. Suggested lessons and other curricular materials are available for free to the teachers via the Reserve’s web page ([www.padillabay.gov](http://www.padillabay.gov)).

The National Estuarine Research Reserve System prioritized Teachers on the Estuary (TOTE) workshops that include instruction on how to access and use NOAA data and other products. These TOTE workshops follow a nationally standardized format for professional teacher training developed by Reserve educators. TOTE was implemented by the Reserve using B-WET funding for three years beginning in 2009. In 2016, with NOAA Environmental Literacy funds, the Reserve will develop and implement a TOTE workshop about the Ocean Sciences Sequence for grades 6 to 8. This will help teachers use NOAA and SWMP data to teach about the causes and effects of climate change. New funding sources must be identified to make TOTE a sustainable program at the Reserve.

Climate change education is a national priority addressed by the Reserve in public programs and community education. New interpretive signs at the start of the Upland Trail will be completed in 2016 and will include a display on climate change and the Reserve’s alternative energy installations. Reserve educators include climate change education in two conferences, the “Youth Earth Summit” and “Storming the Sound.”





**Figure 4.7 Education Coordinator Glen Alexander with a school field trip to the beach.**

Skagit Stream Team is a highly successful citizen science program that will continue in the next five years. Adult citizen volunteers are trained to collect water quality data and water samples in streams located in priority Skagit County watersheds while others are trained to process the water samples in a laboratory to monitor for fecal coliform and turbidity. The Skagit “Stream Team” program utilizes standard operating procedures and a Quality Assurance/Quality Control Plan to train participants and to assure that data are collected properly. An elite group, the “Storm Team”, collects samples following storm events and their data are trusted by local and state regulatory agencies that make decisions about opening and closing recreational and commercial harvest of shellfish.

“Storming the Sound” is an annual one-day conference for environmental educators in this four-county target region. This event attracts about 150 educators from both formal and non-formal education spheres. Substitute reimbursement is offered to encourage teachers to take time away from school to attend. The conference is a forum for participants to share new programs, new information about environmental topics and best practices in environmental education.

The annual “Youth Earth Summit” is a one-day conference for high school environmental clubs. Each year, 80-100 high school students and their advisors gather for a day of speakers, workshops, and discussions. They have the opportunity to hear about projects, accomplishments, and challenges at other schools, and meet community volunteers who can help with their projects. Past student projects have included photovoltaic solar panels on school buildings, a water bottle filling station, environmental videos, waste audits, and community campaigns addressing pet waste.

Outreach to the community happens largely at local events, such as “Fidalgo Bay Day.” A portable exhibit is displayed at these events and presents a selection of images and text appropriate to various audiences. A microscope is used with a video camera to display images of live estuary organisms to attract interest and attention. This portable exhibit is used at community festivals, fairs and conferences. Reserve educators also make presentations to community groups upon request.

### **Marketing/Communication**

The quarterly Padilla Bay Newsletter advertises public programs offered at the Reserve. It includes articles about current research, community events, stewardship activities, priority issues of climate change, habitat protection, and water quality, and local natural history. Reserve policy encourages the use of a digital version of the newsletter and reduces the need for paper and postage. It reaches an audience of about 800 people.

The extensive Reserve web site has a section for each department: Research, Education, GIS, Stewardship, the International Brant Monitoring Program and the Padilla Bay Foundation. Users can sign up for public programs, get information about Reserve services and download publications. They can even submit data to the Brant Observation Log.

### **Integration With Other Programs**

The Reserve Stewardship Coordinator makes presentations at teacher workshops and works with the Education Department to identify stewardship projects for other education program audiences such as students and adult citizen groups. These participants help with upland restoration and non-native plant control.

The Research Sector keeps Reserve educators informed about current research projects by including educators in field projects and presentations and providing opportunities to learn about estuary science from scientists. These scientists are also generously available to educators when needed for scientific expertise. Also, Reserve scientists make presentations for various education audiences, especially teacher workshops and college groups. They also host high school job shadows. The Reserve GIS Analyst helps provide maps and graphics as needed for programs, visual aids and publications.

### **Impacts and Outcomes**

Education programs are designed to increase estuary literacy and change behaviors to improve estuary health. Literacy includes understanding what an estuary is and how it is important biologically, economically, culturally and aesthetically. Education programs focus on the value of estuary resources to the learner and how the learner is related to these resources. Except in outreach programs educators always include information, discussion and inquiry about what the learner can do to help keep estuaries healthy. Social research provided by Washington State’s Puget Sound Partnership guides the education program. Their research and expertise have identified specific behavior changes

to promote: specific behaviors related to visiting the beach, boating, car maintenance, alternative transportation, septic maintenance, pets and gardening. The Partnership also provides a toolbox of resources for educators.

## **Padilla Bay NERR Education Program Needs and Opportunities**

### **Needs**

The Reserve lacks resources to meet this list of identified needs:

- The education program could expand programming and reach with a larger staff of professional educators.
- A computer lab or collection of handheld devices would allow implementation more digital aspects of the K-12 Estuary Education Program (KEEP) such as Estuaries 101 and access to SWMP data.
- The ability to take education programs out into the bay on boats would enhance learning as all field-trips are currently shore-based. The Reserve would need appropriate boats and policies in place to allow for boat-based learning.
- With additional funding the Reserve could facilitate transportation to the Reserve for audiences that currently find this a barrier.
- Another need is for improved water quality at Bay View State Park, where students experience the field-based portion of the estuary education programs. The beach has been closed several times due to high fecal coliform counts. Skagit County continues to work on this issue.

### **Opportunities**

The Padilla Bay Foundation added a Volunteer Coordinator to their staff in 2014 and is providing volunteer coordination services for the Reserve. Over the next five years this will provide more volunteers that are better trained and able to assist with education programs.

A new Research Coordinator was hired in 2015 after the previous coordinator retired. This new coordinator has extensive experience, training, and interest in science education. The education staff sees an opportunity for increased integration of the education and research sectors because of this.

The education program will increase programming targeting the local Hispanic community, the largest underserved population in the county. For the next five years, a priority for hiring will be candidates with Spanish language skills. Partnerships will be explored with organizations that supply services to this population.

## Education Program Objectives and Actions

**SUPPORT GOAL 2: The Reserve supports a collaborative work environment that involves stakeholders, staff members, volunteers and partners.**

Objective 1: The Education Coordinator will maintain strategic education partnerships throughout 2016-2020.

Action: The Education Coordinator will maintain strategic partnerships (e.g., the Padilla Bay Foundation, Skagit ECO Network, Northwest ESD, and Skagit Conservation District) to further Reserve interests in this time period.

Objective 2: The Education Coordinator understands the needs of education stakeholders from 2016-2020.

Action: A new Needs Assessment will be completed during this performance period.

Objective 3: The education program will encourage volunteer participation from 2016-2020.

Action: The Education Coordinator will provide volunteer job descriptions to the PBF Volunteer Coordinator and update those annually.

Action: In this time period, the education staff will participate in volunteer trainings and appreciation events at the request of the Volunteer Coordinator.

Action: The Education Coordinator will meet monthly with the PBF Volunteer Coordinator to identify volunteer needs in the education program.

Objective 4: The education program will work with partners from 2016-2020 to accomplish education goals.

Action: The Education Coordinator attends Skagit ECO Network meetings. The Network is supported by the Puget Sound Partnership.

Action: The Northwest Educational Service District advises education staff on grant applications and helps plan teacher workshops.

Action: The education program works with the Padilla Bay Foundation on grants and submits requests for a seasonal educator and education equipment.

Action: Education staff work with the Skagit Conservation Education Alliance (SCEA) to plan workshops, events and festivals.

Action: Education staff work with Snohomish County Surface Water Management to offer a “Watershed Words” teacher workshop.

**CORE GOAL 1: Improved scientific understanding of coastal communities leads to informed management of natural resources and resilient and sustainable ecosystems.**

Objective 1: The Education and Research Coordinators will communicate regularly about planned activities, project and programs to identify opportunities for integration during 2016-2020.

Action: Every year during 2016-2020, there will be at least one education program that includes a presentation by one or more Reserve research staff members.

Action: Every year during 2016-2020, there will be at least one opportunity for education staff members and qualified volunteers to participate in a research project in the lab or in the field.

Action: In 2016 a new TOTE workshop about ocean acidification will be developed by Reserve education and research staff members.

Objective 2: The Education Specialist will collaborate with the Skagit Conservation District or Skagit County Water Quality Program from 2016-2020 to offer citizen science programs such as Stream Team and Storm Team.

Action: The Skagit Conservation District and Education Specialist will train volunteers annually to collect water samples at locations in the watershed from October to June and test for fecal coliform.

Action: The Skagit Conservation District and Education Specialist will train volunteers annually to collect water samples at fixed sites during storm events year round and test for fecal coliform.

**CORE GOAL 2: Informed citizens, students and decision-makers have the knowledge and understanding to make wise personal and professional choices that benefit the health of Puget Sound and the Salish Sea.**

Objective 1: The education staff will offer effective education programs and teacher trainings that focus on the values of estuary systems and appropriate stewardship behaviors during 2016-2020.

Action: The education staff will implement the K-12 Estuary Education Program (KEEP) each year in this time period with 100 field trips for 7,000 students.

Action: The education staff will offer programs for 1,000 adults per year in this time period with an increased focus on personal choices

and behavioral change.

Action: The Reserve will align programming with the new federal Next Generation Science Standards that have been adopted by the state.

Action: Reserve educators will identify a target audience other than upper elementary (grades 4-8) and develop a logic model and develop and implement evaluation tools for lower elementary (grades K-3) or teachers participating in workshops.

Objective 2: The education staff will offer effective teacher training that focuses on the values of estuary systems and appropriate stewardship behaviors during 2016-2020.

Action: The Education Coordinator will write two grant applications per year during this time period to seek funding to develop and implement Teachers on the Estuary (TOTE) workshops.

Action: The education staff will offer 300 hours of professional development for 80 teachers for attendance and participation in Reserve-led classes, seminars, and presentations in this time period.

Objective 3: The education staff will identify and reach out to underserved audiences from 2016-2020.

Action: There will be a priority to hire candidates with Spanish language skills and partnerships will be expanded with other organizations that supply services to this underserved population.

Action: The Education Coordinator will seek partnerships to develop opportunities for underserved audiences in this time period.

Action: The Education Coordinator will seek funding to promote and implement programs for underserved audiences in this time period.

Objective 4: The education staff will work with partners to offer "Storming the Sound" annually from 2016-2020.

Action: The education staff will offer "Storming the Sound" annually.

**CORE GOAL 3: Citizens and decision-makers understand the impacts of climate change on human and natural resource communities and can make informed decisions.**

Objective 1: Education staff will implement programs that help citizens to reduce carbon emissions and help them adapt to a changing climate from 2016-2020.

Action: The education staff will offer a one-day annual Climate Change Volunteer Summit for adults working on climate change issues.

Action: The education staff will work with partners and volunteers to organize the Youth Earth Summit (YES) annually. It is a one-day annual conference for about 100 members of high school environmental clubs and will provide training on climate change, among other activities.

Objective 2: The Education Coordinator will seek grant funding over the 2016-2020 time period to develop climate-oriented classes for citizens.

Action: The Education Coordinator will apply to B-WET if that funding is available in this time period.

Action: The education staff will apply for the National Network for Ocean and Climate Change Interpretation (NNOCCI) funding for professional development to organize a Study Circle (a cross-disciplinary learning group) for building knowledge around ocean, climate, and cultural sciences if that funding is available in this time period.

Action: The Education Coordinator will review grant opportunities as they arise and apply for them if they fit the climate education needs of citizens or stakeholders.