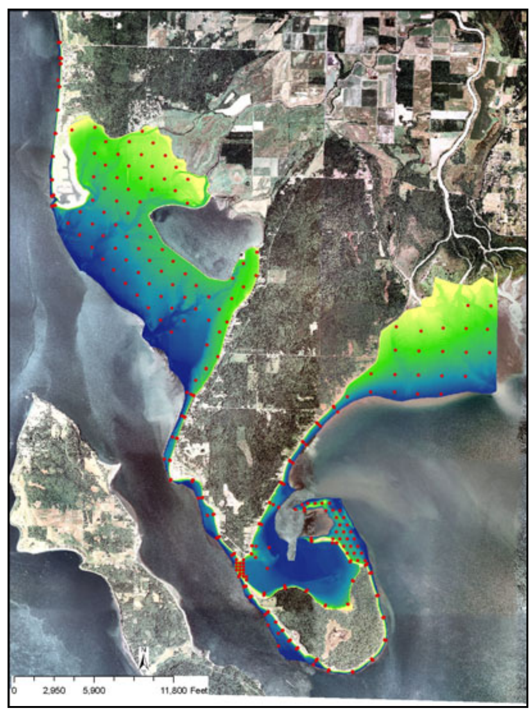
Lummi Intertidal Baseline Inventory

Final Report

Lummi Indian Business Council
Lummi Natural Resources

March 2010

LUMMI INTERTIDAL BASELINE INVENTORY



Lummi Intertidal Baseline Inventory

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Executive Summary

The Lummi Intertidal Baseline Inventory (LIBI) was conducted in order to document the existing diversity, abundance, distribution, and habitats of biological resources that are found on the Lummi Reservation tidelands. The LIBI integrates the results from six field surveys that were conducted in 2008 and 2009 with compatible pre-existing information.

The six surveys were conducted as follows:

- Topographic Survey: this survey used remote sensing with Light Detection And Ranging (LiDAR) to develop a high-resolution digital elevation model of the tidelands.
- Intertidal Biota Survey: this survey documented the diversity, distribution, abundance, and habitat preferences of benthic biota such as clams, snails, and eelgrass.
- Large Bivalve Survey: this survey assessed the distribution and abundance of horse clams specifically.
- Finfish Survey: this survey documented the diversity and monthly abundance of finfish.
- Shorebird and Marine Mammal Survey: this survey documented the diversity and monthly abundance of birds and marine mammals.
- Petroleum Toxicity Baseline Survey: This survey documented present-day concentrations of petroleum-derived chemicals in tideland sediments and clam tissues.

Over 242 separate taxa were documented on Lummi Reservation tidelands during the LIBI. The most abundant benthic taxa encountered were polychaete worms in the family Oweniidae, while the purple varnish/mahogany clam was easily the most abundant bivalve species. The purple varnish/mahogany clam was estimated to number nearly 1.2 billion individuals with a total biomass of 19.9 million pounds. The clam species with the next highest biomass was the butter clam. Butter clams collectively had an estimated biomass of 6.7 million pounds, even though the abundance estimate for this species was only 73 million individuals. The population estimate for Manila clams was 2.4 million pounds of legal-sized clams. This value is not statistically different from existing stock assessment estimates due to large confidence intervals for the LIBI estimate. Maps showing the distribution of selected species are presented in this report. Generally, densities of total benthic biota were highest at tidelands on Brant Island/Brant Flats, Lummi Bay, Point Francis, Hale Passage, and in the lower elevation parts of Neptune Beach. Densities of benthic biota were intermediate in Portage Bay and Lummi Shore Road and lowest on the Nooksack River Delta and the middle and upper elevations of Neptune Beach.

Seasonal and spatial trends in the abundance and diversity of finfish and birds are presented and discussed. Generally, bird abundance and diversity was highest during fall and winter months, while finfish diversity and abundance was highest during spring and summer months. Birds were generally most abundant in Lummi Bay, moderately

abundant in Portage Bay, and least abundant at Neptune Beach, Hale Passage, and the Nooksack Delta. In contrast, finfishes were generally most abundant near the Nooksack Delta, followed by Portage Bay, Hale Passage, Lummi Bay, and finally Neptune Beach.

Environmental factors that had biological significance for individual taxa included tidal elevation, beach slope, wind fetch, substrate particle size, and eelgrass coverage. Overall, community structure was responsive to these same environmental factors along with salinity, percent coverage of acorn barnacles, percent coverage of mussels, and percent coverage of red, brown, and green algae. The five environmental gradients that appeared to have the most biological significance for community structure were tidal elevation, beach slope, substrate particle size, surface coverage of Pacific eelgrass (*Zostera marina*), and salinity.

Petroleum-derivative hydrocarbon concentrations were mostly below detection limits in Manila clam tissues and sediments sampled from 3 tidal elevation strata at sites in Lummi Bay and Portage Spit. However, very low concentrations of Napthalene (15 parts per billion) and Phenathrene (6 parts per billion) were detected in the sediment of the upper elevation sub-sample of the Lummi Bay site. These values are below the 'no effect' marine sediment quality standards criteria adopted by the State of Washington for these compounds.

The results of this project are intended as a pre-disaster reference dataset that can be used to assess the potential adverse impacts from an oil spill or some other disaster, as well as a standard against which post-spill recovery can be measured. In addition, the data are useful for informing resource management decisions, enhancement and aquaculture opportunities, oil spill response planning, vessel navigation, and they improve the current knowledge about the ecology of the Lummi Reservation tidelands. Furthermore, the data can potentially be used to build models that would provide qualitative predictions about changes in community structure resulting from environmental changes.

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Acknowledgements

The Lummi Intertidal Baseline Inventory (LIBI) is primarily the result of a partnership between the Lummi Nation and BP Cherry Point. Other organizations and individuals also made important contributions of expertise, materials, and personnel to the study and these too need to be acknowledged.

BP Cherry Point

The BP Cherry Point Refinery provided primary funding for the Lummi Intertidal Baseline Inventory. Particular thanks to Scott McCreery, Environmental Manager, Dock EIS, BP Cherry Point Refinery who coordinated with LNR to make the LIBI possible.

Lummi Natural Resources Department (LNR)

The authors would like to thank the other LNR staff and departments who volunteered assistance with the LIBI effort:

The Water Resources division provided boats and personnel to ferry the LIBI field crews to remote parts of the tidelands that could not otherwise have been sampled, and to conduct the finfish surveys. Jamie Mattson and Frank Lawrence III helped coordinate and crew the boats. Frank also assisted with the Lampara sampling fieldwork.

Harvest Management Division staff members Adam Pfundt and Don Kruse assisted on several occasions with the finfish sampling. Ryan Vasak and Alan Chapman contributed time participating in the finfish survey and supplied some of the materials for the carts.

Geographic Information System (GIS) Manager Gerry Gabrisch provided advice and assistance with GIS outputs, and technical support enabling the wind fetch model to be created.

Greg Dunphy (LNR Forest and Fish Program) assisted at short notice by providing field backup for LIBI staff.

Lummi Bay Salmon and Shellfish Hatcheries

Linda Delgado and Robert (Bob) Hall at the Lummi Bay Salmon Hatchery provided the primary laboratory space used for sorting the samples and short-term storage facilities for the samples at the Lummi Bay Hatchery. Bob also provided and cooked the salmon for the end of fieldwork celebration BBQ. Lizzie Oberlander at the Lummi Bay Shellfish Hatchery provided some of the materials used in constructing the sampling equipment.

Northwest Indian College (NWIC)

Charlotte Clausing from the Northwest Indian College (NWIC) provided some of the laboratory equipment, supplies, and reference materials used to sort and identify organisms in the LIBI samples. The NWIC also provided a chest freezer that was critical for the storage of field samples prior to sorting. In addition, we were happy to have the assistance of a NWIC intern, Jessica Urbanec, who assisted us with sorting samples and who undertook a separate analysis of the results for the Pacific littleneck clam.

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The NSEA arranged for 20 volunteers to assist with the finfish sampling during the course of the LIBI. Collectively they contributed over 260 hours of volunteer time. These were: Anna Hildebrandt, Nate Lundgren, Zac Stayzac, Faith Sandretzky, Gabe Headly, Gina Trautem, Matt Sturza, Ray Bassonette, Ashlie Simmons, Austin Thomas, Caanan Cowles, David James Jr., Eli Loomis, Jeff Campbell, Jordan Sly, Lindsey Taylor, Patty Bolyard, Rachel Moore, Shawn Barret, and Tana Beus.

Shannon Point Marine Center/Western Washington University

The Shannon Point Marine Center graciously provided a workspace and microscope for one of the LIBI personnel to use for sorting and identifying organisms. Western Washington University also provided some glass sample jars and denatured ethanol for sample preservation.

Opportunity Council

The Opportunity Council provided the services of William (Bill) Hensley, during the field and laboratory time period. Bill probably sorted more of the samples than any other person, and also participated in different LIBI field efforts including the horse clam survey and the dig survey.

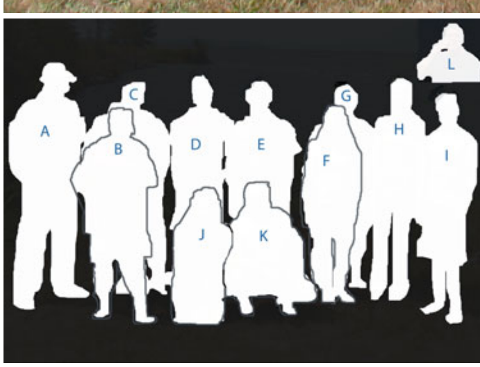
LIBI Field and Laboratory Personnel

This project would not have been successful without the hard work and perseverance of our field and laboratory personnel who worked a tidally dictated schedule often in arduous conditions. It was a pleasure to work with you all.

We also wish to acknowledge the additional assistance of Dacia Wiitala and Julie Barber.

Dacia Wiitala volunteered to conduct most of the monthly bird surveys that were conducted during the LIBI, and helped write the bird survey appendix.

Julie Barber helped after the completion of the fieldwork by identifying the organisms from some of the many samples that were collected, and provided invaluable feedback on identifications gleaned from regional experts at the Shannon Point Marine Center including Eugene Kozloff and Brian Bingham, which improved the accuracy of our own work significantly.



A: Jordan Ballew; B: Jessica Urbanec; C: Anthony George; D: Jonathan Robinson; E: Michael LeMoine, F: Dacia Wiitala; G: Craig Dolphin; H: Julie Barber; I: Dan Haught; J: Delanae Estes; K: Dewey Solomon; L: William Hensley.

It is with gratitude for the support of this very large group of participants that we submit this final data report.

March 2010

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1.0 Introduction

The Lummi people have depended on the natural resources of the tidelands for generations, and collectively they share an unrivalled pool of traditional knowledge about the diversity and the range of many of the organisms that are present on the tidelands. However, traditional knowledge can be very difficult to quantify objectively, and many of the people who know the tidelands best prefer to keep the information private in an effort to protect lucrative harvest locations.

The mission of the Lummi Natural Resources Department (LNR) is to enhance, manage, and protect natural resources into perpetuity for the benefit of the Lummi people in accordance with the policy and procedures of the Lummi Nation. Effectively achieving this mission requires reliable information about where these resources are located, how many are at a particular location, when the resources are present, and what ecological factors affect these resources.

The experience of the Alaskan natives who suffered massive ecosystem disruptions and fishery disasters in Prince William Sound because of the Exxon Valdez oil spill has also provided a salutary lesson for the Lummi Nation. The Natural Resource Damage Assessment (NRDA) of the Exxon Valdez disaster was greatly hampered by the lack of pre-spill baseline ecological data to compare with post-spill conditions. With two neighboring petroleum refineries and an aluminum smelter as well as two more petroleum refineries within 15 miles, the potential for a significant spill to happen within the Lummi Nation’s Usual and Accustomed Area or on the Lummi Reservation tidelands is very real. To protect the tidelands and natural resources of the Lummi Reservation, the LNR has developed an oil spill response plan in coordination with other response organizations and public agencies and has acquired oil spill response equipment and training for use during a spill. However, even with a timely and appropriately scaled response, it is still possible that the shores of the Lummi Reservation could be negatively impacted during an oil spill event and the flow-on effects to the Lummi people could be severe and lasting. In such an event, the damage assessment process must accurately reflect the actual impacts to the Lummi people, and pre-spill ecological data will be vital in making any such assessment.

Because of the need for ecological and population data to support resource management decisions, and the need for a baseline for any future damage assessments, there has been a recognized need by LNR to conduct a baseline inventory of the Lummi Reservation tidelands. The study became possible when BP Cherry Point agreed to provide a one-time grant of $150,000 for that purpose under a jointly agreed-upon scope of work and work plan.

The Lummi Intertidal Baseline Inventory (LIBI) provides an objective ecological baseline against which future conditions may be evaluated. It also provides data that will be helpful for management and enhancement and potentially can be used to provide predictive tools for evaluating environmental changes.

This report provides an overview of the LIBI project and presents selected results from the LIBI surveys combined with pre-existing data from other sources where possible. The specifics of each of the LIBI surveys are reported separately as individual appendices. In addition, a DVD is enclosed that contains the Final Scope of Work (SOW), Final Work Plan (WP), raw data in Access databases, and the geographic information system (GIS) projects used in mapping the results. Additional appendices further describe the digital data that are available on the DVD. This document structure integrates the individual surveys into one narrative while making the detailed results for each survey available in the appendices.

Accordingly, this report first presents the Data Gap Analysis that was conducted as part of the Final Work Plan, then summarizes the field surveys undertaken to fill the data gaps identified in that analysis, and finally integrates the results of the surveys to address the primary goal of describing the taxonomic diversity of the tidelands and assessing the abundance and distributions of selected taxa. In addition, overviews are presented of the tideland environments, habitat preferences of selected benthic taxa, and seasonal changes in relative abundance for transient taxa such as birds, mammals, and finfish.

1.1 Study Area

The Lummi Indian Reservation (Reservation) is located approximately 8 miles northwest of Bellingham, Washington, between the northern extent of Puget Sound and the southern extent of the Strait of Georgia. Situated at the mouth of the Nooksack River, the Reservation is comprised of the Nooksack River and Lummi River deltas, Northwestern uplands, Sandy Point Peninsula, Lummi Peninsula, Portage Island, and the associated tidelands.

The United States of America holds the Reservation tidelands in trust for the exclusive use of the Lummi Nation. The Lummi Nation tidelands extend from the High-Water Line (HWL) down to –4.5 feet Mean Lower Low Water (ft MLLW). The tidelands extend southward from Neptune Beach along the Strait of Georgia to Treaty Rock on the eastern shore of the Nooksack Delta near Bellingham. The tidelands include lands along the Sandy Point peninsula, Lummi Bay, the Lummi Peninsula, the eastern shore of Hale Passage, Portage Island, Brant Island, and the Nooksack Delta (Figure 1.1). The Reservation intertidal lands are in excess of 5,000 acres. In addition, sub-tidal lands to an elevation of –4.5 ft MLLW and the 700-acre seapond facility in Lummi Bay increase the total study area to approximately 7,000 acres.

The Reservation tidelands are generally estuarine with complex interactions of marine waters from the Strait of Georgia and Puget Sound with freshwaters from the Nooksack River, the Lummi River, the Fraser River, the small seasonal surface water discharges from Reservation watersheds, and from ground water discharges through seeps and springs. The freshwater discharges differ across the Reservation tidelands resulting in a diversity of estuarine conditions. In addition, freshwater channels in the Lummi River and Nooksack River floodplains are exposed to the upstream flow of marine waters during higher tides, which introduces salinity-based stratification in the system.

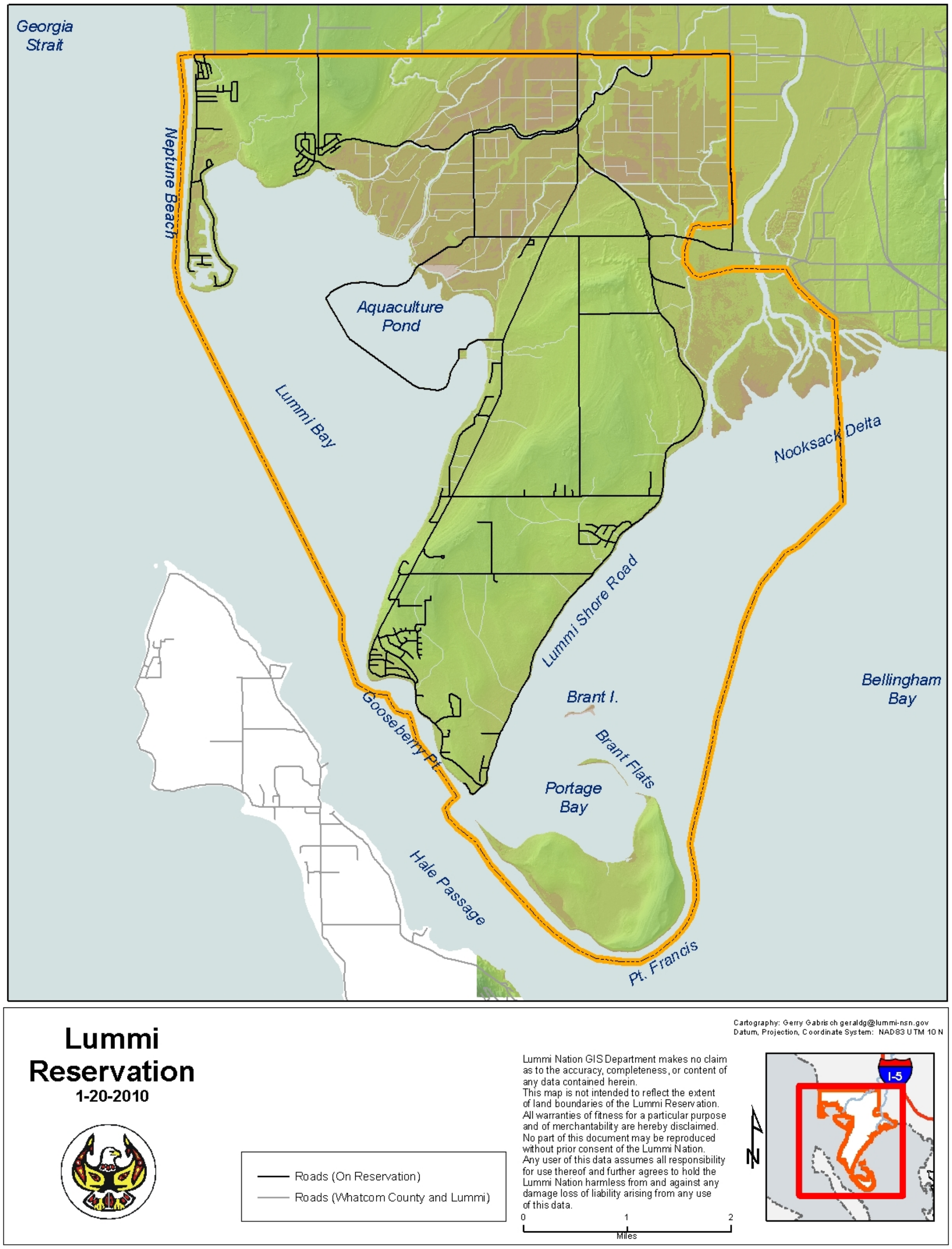


Figure 1.1. Location of the Lummi Reservation, Approximate Boundary, and General Location Names

1.2 Project Overview

The scale of the LIBI study differs greatly from previous surveys conducted on Lummi Reservation tidelands.

Previous surveys of the Reservation tidelands included annual stock assessment surveys conducted from 2002 to 2008, which were optimized to provide estimates of harvestable biomass of Manila clams (Dolphin 2008). These surveys were spatially restricted to only those parts of the tidelands inhabited by this species, and the methodology ignored most of the other species in order to obtain the highest possible sampling efficiency for the target species. In all, over 14,500 data points exist for Manila clams on Reservation tidelands but not for any other species. A sub-set of these data also includes observations of Pacific oyster densities.

Other studies have investigated biological communities on the Reservation tidelands, which usually involved small surficial benthic grab sample methods at a very restricted number of sites (e.g., Spikes *et al*. 2003; Ross and Weispfenning 2004).

In contrast to these earlier efforts, the broad scope of the LIBI required the development and use of multiple methods to gather data about as many species and habitats on the Reservation tidelands as possible. A generalized survey like the LIBI increases the time and effort needed to sample each site due to the need, for example, to extend the sampling depth to include several species of clams and to sift and sort the sediment in order to find small organisms. This time-intensive sampling approach reduces the number of sites that can be sampled with the available resources and within the time permitted by the tidal cycle. Also, because different species may have differing ranges, it is not possible to restrict the area that is sampled.

The goal of quantitative surveys is to provide abundance estimates that are both accurate (unbiased) and precise (narrow confidence limits). Using unbiased sampling methodologies helps to ensure the accuracy of survey estimates. The precision of quantitative estimates largely depends on the number of samples collected. The higher the number of samples collected in a survey, the more precise the final estimate of abundance is likely to be. Thus, time-intensive survey methodologies like those used in the LIBI limit the precision of the estimates produced by restricting the number of samples that can be collected. Given this conflict, the priority of the LIBI was to ensure that the geographic scope and the biological diversity included in the results were maximized, while attempting to derive meaningful quantitative estimates wherever possible.

2.0 Existing Information and Data Gap Analysis

Several organizations have collected physical, chemical, and biological information regarding near-shore areas within and near the Reservation. The Lummi Natural Resources Department staff conducted an initial literature review of all publications, reports, and memoranda related to the LIBI in order to identify information gaps and to prioritize future field activities. This section briefly summarizes the information available and discusses the compatibility of this information with the results of the LIBI study. A more extensive overview of the literature reviewed is presented in Appendix L.

2.1 Water Quality

The United States Geologic Survey (USGS) evaluated surface and ground water quality on the Reservation from 1971 to 1973. The USGS staff conducted surface water sampling of temperature, dissolved oxygen, conductivity, pH, and nutrients and collected samples of heavy metals and organic compounds at 13 sites within the Nooksack River estuary (Parker 1972; Parker 1974). The same studies described channel forms and movements of water within the complex estuary system on the Reservation. Parker also recorded Nooksack River stage related to river discharge and tidal heights, and the presence of a marine "salt wedge" within the Nooksack River. Brown *et al.* (2004) observed a similar "salt wedge" present within the Nooksack River channel during high tide events. The upstream extent of this "salt wedge" was located and mapped by LNR staff during conditions of high tide and low river discharge in 2000 (Lummi Water Resources Division, unpublished data).

Surface water quality on the Reservation has been extensively monitored since 1993 by the LNR (LWRD 2008), and by the Washington State Department of Health (WADOH) pursuant to the Shellfish Consent Decree (Order Regarding Shellfish Sanitation, *United States v. Washington [Shellfish]*, Civil Number 9213, Subproceeding 89-3, Western District of Washington 1994). The WADOH is responsible to the federal Food and Drug Administration (FDA) to ensure that the National Shellfish Sanitation Program (NSSP) standards for certification of shellfish growing waters are met on the Reservation. The LNR monthly surface water quality monitoring program for the Reservation encompasses both fresh and marine waters (Figure 2.1). Monitored parameters include temperature, dissolved oxygen, salinity, specific conductance, pH, nutrients, bacteria, and total suspended solids among others (LWRD 2008). The water quality information collected by the LNR and the WADOH were used to describe differences in water chemistry that may affect distribution or abundance of biota across the Reservation tidelands. In addition to the LNR core water quality program, other projects have investigated, for example, pre-project and post-project parameters for specific restoration projects around the intertidal waters of the Reservation (Brown *et al.* 2004 and LNR unpublished).

Toxic compounds associated with industrial processes, urban runoff, and the presence of marinas are monitored quarterly at five index locations on the Reservation. The Lummi Water Resources Division collects samples for analysis of heavy metals, hydrocarbons, and organic compounds within streams and storm water drainages that drain oil-refining facilities neighboring the Reservation, and also within the Sandy Point Marina (LWRD 2008). Past sampling efforts from the Puget Sound Ambient Monitoring Program (PSAMP) and Environmental Monitoring and Assessment Program (EMAP) collected toxic compounds in sediment and intertidal invertebrates on and near the Reservation (WADNR 1995; Partridge *et al.* 2005).

In coordination with LNR staff, the Washington State Department of Ecology in 1998 and 2002 collected samples to analyze toxic petroleum compounds and their derivatives in sediments and biota tissues on Reservation tidelands (Partridge *et al.* 2005; Partridge 2007). These samples mixed multiple species of biota within the tissue analysis whereas specific information about baseline concentrations in Manila clam tissues is of particular concern to the LNR. This concern arises because Manila clams provide an important commercial and subsistence harvest, and contamination of shellfish by these compounds can result in the suspension of shellfish harvest. It was also unknown whether urban run-off had elevated the concentrations of these chemicals in recent years. Baseline information on these petroleum-derived hydrocarbons was needed to assess when closed shellfish beds can be safely re-opened following a spill. Accordingly, the LIBI final work plan (LeMoine *et al.* 2009) placed a high priority for data collection on the current concentrations of Polycyclic Aromatic Hydrocarbons (PAH) in Manila clams.

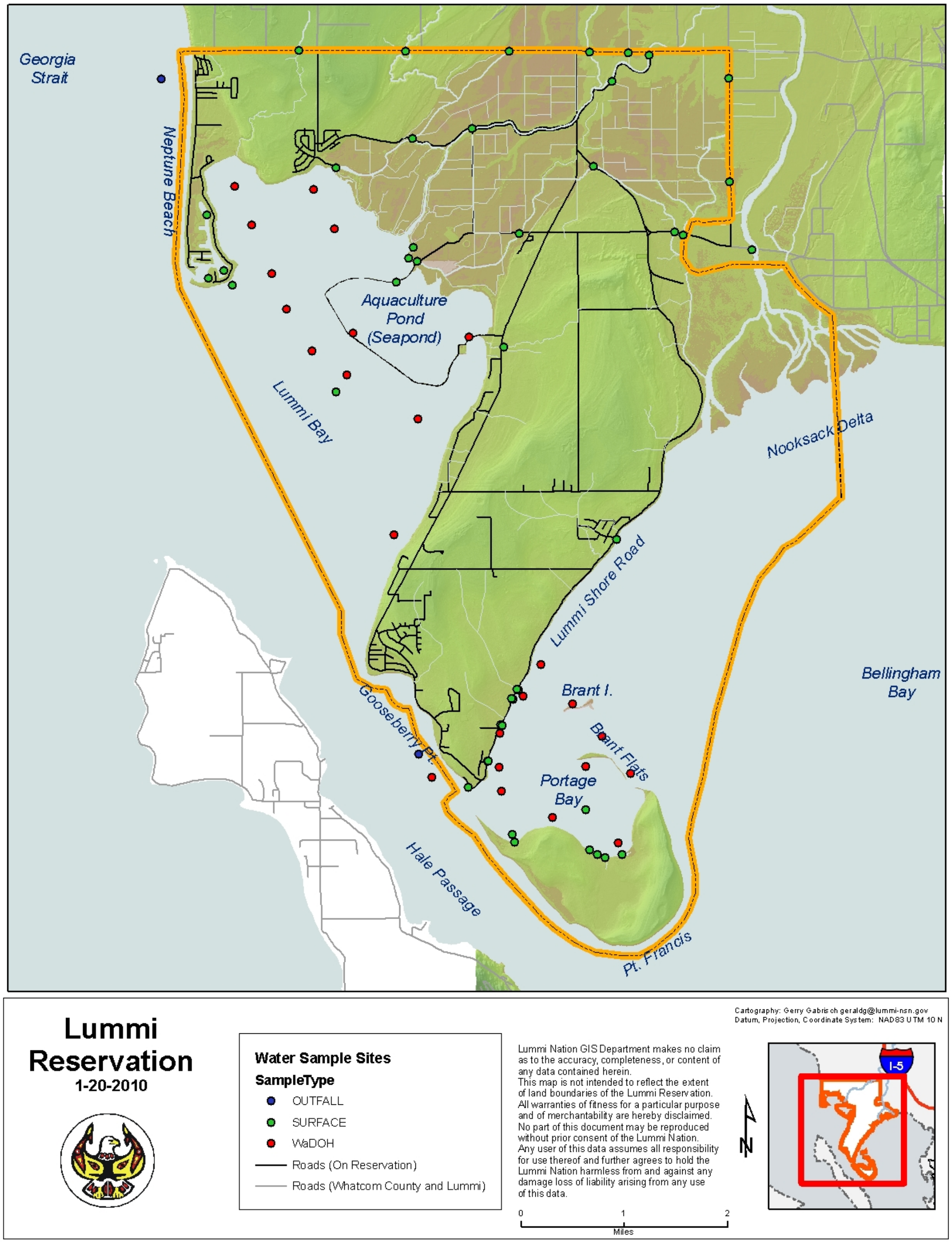


Figure 2.1. Ongoing Surface Water Quality Monitoring Sites

2.2 Physical Habitat Assessments

Physical habitats such as aquatic vegetation and sediments had been described across the Reservation prior to the LIBI. Intertidal vegetation distribution and substrate distribution were mapped across Reservation tidelands using remote sensing techniques developed by the Washington State Department of Natural Resources (WADNR) (WADNR 1995). The WADNR performed the first extensive mapping of eelgrass meadows on the Reservation tidelands and depicted vast eelgrass meadows within Lummi Bay, Portage Bay, and along the eastern shore of Hale Passage. The WADNR also mapped intertidal surface substrate types and provided a continuous spatial coverage of surface substrate types that range from silt and sand to cobbles across the Reservation. Substrate maps provided by WADNR are complete, but the maps do not provide the needed resolution to analyze habitat conditions for intertidal biota at a local scale. More detailed descriptions of the Reservation intertidal sediments are available through ground-based beach profiles of the upper intertidal habitats across the Reservation (Johannessen 1997; Johannessen 1998; Johannessen 1999a; Johannessen 1999b; Johannessen and Chase 2002; Johannessen and Chase 2003; Johannessen and MacLennan 2007). These reports, prepared for the LNR, provided a complete picture of sediment processes along upper intertidal areas including beach nourishment effectiveness on Lummi Shore Road, historic shoreline change, sediment distribution, and the role of feeder bluffs for providing sediment to beaches.

Existing physical habitat assessments had largely focused on characterizing impacts to habitats and biota from completed or planned construction projects. Marine habitats inside and outside of the Seapond dike were described before and after Seapond construction in Lummi Bay and were mapped for comparison (Heath *et al.* 1975). The LNR investigated habitat conditions in northern Lummi Bay to address potential impacts from construction of a proposed marina within the Seapond (Lummi Fisheries 1984, U. S. Fish and Wildlife Service 1985, U.S. Army Corps of Engineers 1988). The Lummi Bay marina was never constructed. More recent field surveys of substrates and vegetation by LNR staff were conducted in the Seapond while monitoring harvest quotas (Dolphin 2005).

It was clear from the literature review that extensive data already exist which describe and map physical habitats on the Reservation. However, only a few examples existed that explicitly linked habitat conditions to biotic diversity and abundance (Brown *et al.* 2004). In contrast, the LIBI characterized habitats in conjunction with biotic assessments so that relationships between environmental parameters and the biota could be documented.

Of the possible habitat measures, surface elevation is the most important single factor in species presence and abundance for intertidal communities (Raffaelli and Hawkins 1996). Surface elevations had previously been measured along portions of the Reservation upland areas and the intertidal fringes through a variety of methods, including Light Detection And Ranging (LiDAR) and surface geomorphic measurements. However, the mid-intertidal and lower intertidal surface elevations (below approximately +5 ft MLLW) were not as accurately measured for most of the Reservation tidelands. Available

National Oceanic and Atmospheric Administration (NOAA) bathymetric observations are too coarse to assist in useful mapping of intertidal areas (NOAA unpublished data). This left the lower intertidal boundary (−4.5 ft MLLW) of the Reservation only loosely defined.

The LIBI Final Work Plan (LeMoine *et al*. 2009) identified the mapping of intertidal surface elevations as a critical priority for data collection during the LIBI study due to the lack of data for mid and lower tidal areas and the known ecological importance of this factor. The availability of these data is also potentially useful for planning purposes and navigation.

2.3 Intertidal Benthos

Monitoring of Manila clams (*Venerupis philippinarum*) occurs annually across the Reservation tidelands. The distribution and abundances of this species is well documented, and harvests are managed for long-term sustainability (Cochrane 1990, Dolphin 2002, Dolphin 2007, Dolphin 2008). Excluding the harvest from the Lummi Bay Aquaculture Pond (Seapond), the mean commercial Manila clam harvest over the last decade had been approximately 273,000 pounds per year (lb/yr) with the majority of clams harvested from Lummi Bay. The relatively large harvest from Lummi Bay was due to a number of factors including the closure of approximately 180 acres of shellfish beds in Portage Bay to commercial harvest from 1996 to 2006 due to fecal coliform densities that exceeded the National Shellfish Sanitation Program (NSSP) standards.

During the annual Manila clam surveys, the presence of other clam species was noted including: bentnose clams (*Macoma nasuta*); purple varnish/mahogany clams (*Nuttallia obscurata*); eastern soft shell clams (*Mya arenaria*); Pacific littleneck clams (*Leukoma staminea*); bay mussels (*Mytilus trossulus*); Pacific oysters (*Crassostrea gigas*); and European flat oysters (*Ostrea edulis*). These surveys did not sample at depths adequate to detect butter clams (*Saxidomus giganteus*), horse clams (*Tresus nuttalli and Tresus capax*), or geoduck clams (*Panopea abrupta*). Only one clam survey (Dolphin 2002) had been conducted that excavated samples to depths adequate to detect butter clams and horse clams. However, this survey was restricted to the tidelands on Brant Island and a portion of Brant Flats (north of Portage Island).

Dungeness crab (*Cancer magister*) is known to settle and rear for up to two years in intertidal areas of the Reservation (Dinnel *et al*. 1986). Although knowledge of recruitment in intertidal areas on the Reservation was limited, Dungeness crab settlement, recruitment, and adult abundance had been estimated from limited data collected in Lummi Bay (Dinnel *et al*. 1986; McMillan 1991). Dinnel *et al*. (1986) described the process of settlement of megalops larvae at upper intertidal areas through the summer and their subsequent seaward migration as they increased in size. Dungeness crab densities were measured at a few locations in Lummi Bay and used to extrapolate the total crab abundance across Lummi Bay. Juvenile Dungeness crab abundances were reported to be low in Lummi Bay compared to other areas. However, because of limited sampling, these estimates may not be accurate (Dinnel *et al.* 1986; McMillan 1991). Distribution information about other parts of the Reservation tidelands is also limited. Dungeness crabs settle in a variety of intertidal habitats across the Reservation (McMillan 1991; Dolphin and LeMoine, personal observation) and comparisons between juvenile crab densities in differing habitats or geographical areas could not be made.

Intertidal benthic fauna that is not actively harvested by the Lummi Nation had even less documentation available. Such organisms include all cnidaria, flatworms, nemerteans, annelids, sipunculids, gastropod mollusks, phoronids, branchiopods, echinoderms, and urochordates. Spikes *et al*. (2003) and Ross and Weispfenning (2004) had described species richness and biomass of benthic macroinvertebrates at 23 sites spread across the Nooksack River delta, Lummi Bay delta, and Portage Bay (cited in Brown *et al*. 2004). Lummi Bay and Portage Bay showed the highest species diversity and the highest biomass across all sites examined. A separate survey by Martin (1973) indicated that differences between the intertidal benthic populations found in Lummi Bay and Portage Bay may be caused by freshwater outflows from the Nooksack River. Within Lummi Bay, intertidal benthic fauna was found to be similar both inside and outside of the Seapond structure (U.S. Army Corps of Engineers 1988). Near the Reservation, benthic fauna abundances had been intensively investigated to document effects from industrial effluent in the Whatcom Waterway (Shea *et al*. 1981; Broad *et al*. 1984; Becker *et al*. 1989). Despite these efforts, distributions of ecologically important benthic taxa that may indirectly support harvestable fisheries on the Reservation tidelands were unknown and future changes in their populations could not be tracked.

Although the Manila clam population had been well documented over recent years (Dolphin 2002, Dolphin 2007), populations of most other benthic fauna had not been well described on the Reservation previous to the LIBI study. The distribution and abundance of Pacific littleneck clams, cockles, butter clams, geoduck clams, and horse clams, were uncertain even though they are important to subsistence harvests. Juvenile Dungeness crabs are found throughout the intertidal areas of the Reservation, but their abundance across the Reservation and over time had only been sparsely documented. The distribution and abundance of other taxa present on the Lummi Reservation tidelands was almost completely unknown.

Accordingly, the LIBI Final Work Plan (LeMoine *et al*. 2009) identified the need to collect data that can be used to describe the distribution and abundance of these important benthic species, and also to document intertidal community assemblages and their habitats as a high priority objective.

2.4 Finfish Communities

Finfish, such as salmon (family Salmonidae) and forage fishes (families: Osmeridae, Ammodytidae, and Clupeidae) had been extensively assessed using beach seine methods in the upper intertidal areas on and near the Reservation (MacKay 2004a; MacKay 2004b; MacKay 2005; MacKay and Pfundt 2005 unpublished data); trawl surveys of forage fish (Lemberg *et al*. 1997; Bargmann 1998; Stick 2005); and beach spawn surveys of forage fish (Pentilla 1996; Stick 2005; Northwest Indian College unpublished data). Beach seine work performed by LNR staff (MacKay and Pfundt 2005 unpublished data) had identified the presence of out-migrating juvenile salmon smolts along intertidal areas and assessed salmon residence in intertidal habitats (Figure 2.2). In addition, LNR staff had described the seasonal presence of forage fish, and had performed lower intertidal and subtidal finfish surveys in and off the Nooksack Delta in Bellingham Bay to augment beach seine surveys. The Washington Department of Fish and Wildlife (WDFW) had performed trawls to assess forage fish populations, specifically Pacific herring, and had described a dramatic decrease in adult herring abundances throughout the southern Strait of Georgia. The WDFW had also conducted spawn surveys (e.g., Pentilla 1995) and had documented a decrease in spawn and spawning area over the last 20 years for Pacific herring (*Clupea pallasii*), sand lance (*Ammodytes hexapterus*), and surf smelt (*Hypomesus pretiosus*).

Despite these efforts, prior finfish assessments on the Reservation tidelands had not provided a complete picture of intertidal finfish assemblages. Beach seine activities of upper intertidal areas and trawls of pelagic waters had not included the eelgrass meadows of Portage Bay and Lummi Bay and necessarily had excluded sites where the water depth had been too great for the sampling gear to be used. Several fish species other than salmon and forage fish had not been consistently identified or enumerated during some studies skewing the assessments of past fish assemblages. Greenling (Hexgrammidae), true cod (Gadidae), sand flounders (Paralichthyidae), righteyed flounders (Pleuronectidae), midshipmen (Batrachoididae), and surf perch (Embiotocidae) were known to be present in intertidal areas, and juveniles of these groups of fish were also known to rear in intertidal areas (Hart 1980). Lummi people harvest some of these fish on a subsistence basis. Fish assemblages in the mid and lower intertidal were generally undocumented during high tide prior to the LIBI.

Given the comparatively extensive body of existing information for finfish and limited project resources, the LIBI Final Work Plan (LeMoine *et al*. 2009) identified the need to obtain additional finfish data as a moderate priority.

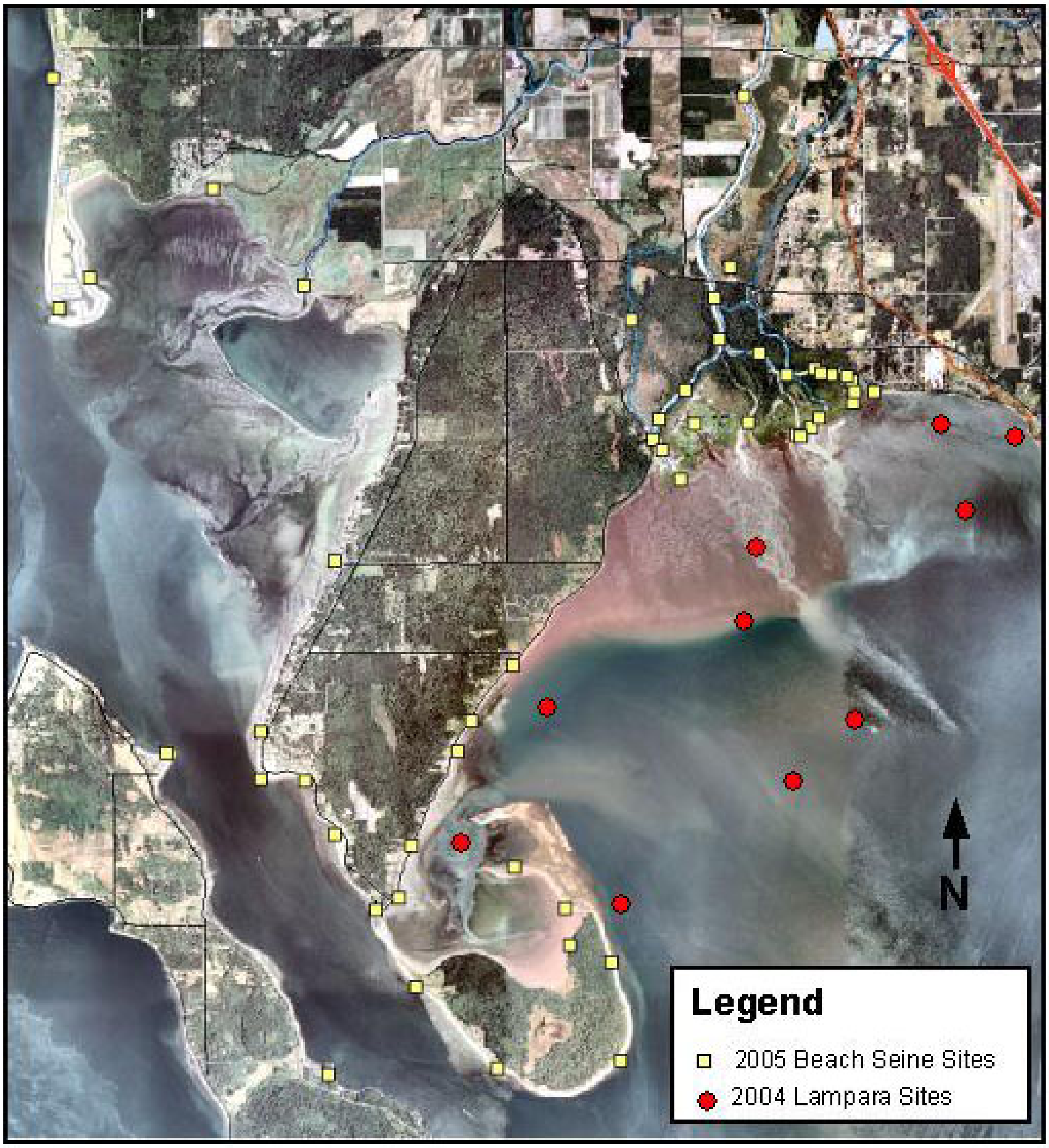


Figure 2.2. Finfish Collection Areas by Gear Type

2.5 Shorebird Populations

Shorebirds censuses had occurred across the Reservation and Whatcom County for discreet times and for specific species. The Whatcom County shorebird one-day winter census has been an ongoing volunteer effort by the North Cascades Audubon Society since 1967. Based on the collected information, trends in bird populations could be described across Whatcom County and at nine locations on the Reservation (North Cascades Audubon Society 2008; Bower 2003; Bower *et al.* 2005). A secondary effort to characterize shorebird populations across the San Juan Islands and Strait of Georgia had concluded that Bellingham Bay was a biologically productive area for shorebirds (Webber 1974; Manuwal *et al.* 1979). Assessments of particular species had also occurred on the Reservation. The abundance, habitat needs, and seasonal diet of peregrine falcons were assessed in Lummi Bay (Anderson *et al.* 1984). Bald eagles and peregrine falcons had been assessed in the Cherry Point area extending to Sandy Point (Shapiro and Associates 1994).

However, there was very little information available on shorebird populations during the summer season. Since a complete baseline assessment needs to include all seasons and all species, the LIBI Final Work Plan (LeMoine *et al*. 2009) identified a need for a comprehensive shorebird census but assigned a relatively low priority to this requirement.

2.6 Summary and Prioritization of Data Needs

Although there have been numerous previous investigations of the Reservation tidelands, there were still significant information gaps for many intertidal natural resources. To summarize the information available previous to the LIBI study, the extent of the information was tabulated both spatially (Table 2.1) and temporally (Table 2.2).

Table 2.1. Data Sources Available Previous to the LIBI, by Geographic Area.

Environmental Parameters	Sandy Point	Lummi Bay	Sea Pond	Hale Passage	Portage Island	Portage Bay	Brant Island	Lummi Shore	Nooksack Delta
Water Quality									
Petroleum Toxins (PAH)		-				-			
Conventionals (DO, Temp, Salinity, pH, Chla)	✓	✓	✓	✓	✓	✓	✓	✓	✓
Physcial Habitats									
Tidal Elevations (LiDAR)	-			-				-	
Surface Sediment Type	✓	✓	✓	✓	✓	✓	✓	✓	✓
Vegetation Type	✓	✓	✓	✓	✓	✓	✓	✓	✓
Benthic Monitoring									
Subsurface Sediments									
Dungenes Crab and Other Surface Organisms		-							
Manila Clams and Native Littlenecks		✓	✓			✓	✓		
Horse clams, Butter clams, and Geoducks			✓				-		
Other Subsurface Organisms		-	✓			-			
Finfish Assessments									
Salmon	✓	-		✓	✓	-	✓	-	-
Herring	✓	✓		✓	✓	✓	✓	✓	✓
Sand Lance and Surf Smelt				-	-		-	✓	✓
Shorebird Census									
Bird Counts	✓	✓	✓	✓	✓	✓	✓	✓	✓

(✓): Data sufficient to include in LIBI final report, (-): Data exist but not sufficient to include in the LIBI final report: ( ): Data do not exist

Table 2.2. Data Sources Available Previous to the LIBI, by Year.

Environmental Parameters	1960's	1970's	1980's	1990 to 1994	1995 to 1999	2000 to 2002	2003 to 2005	2006	2007	2008
Water Quality										
Petroleum Toxins (PAH)						-	-		-	
Conventionals (DO, Temp, Salinity, pH, Chla)		✓	✓	✓	✓	✓	✓	✓	✓	✓
Physcial Habitats										
Tidal Elevations (LiDAR)							-		-	✓
Surface Sediment Type					✓	-	-	-	-	
Vegetation Type					✓	-	-	-	-	
Benthic Monitoring										
Subsurface Sediments										
Dungenes Crab and Other Surface Organisms			✓							
Manila Clams and Native Littlenecks					-	-	✓	✓	✓	✓
Horse clams, Butter clams, and Geoducks							-			✓
Other Subsurface Organisms							-	-	-	
Finfish										
Salmon					-	-	✓	✓	-	-
Herring		-	✓	✓	✓	✓	✓	✓	✓	✓
Sand Lance and Surf Smelt			-	-	-	-	✓	✓	-	✓
Shorebird Census										
Bird Counts	-	-	-	✓	✓	✓	✓	✓	✓	✓

(✓): Data sufficient to include into LIBI final report: (-): data exist but not sufficient to include in the LIBI final report; ( ): Data do not exist

Many of the gaps in the available information arise from the focus of previous studies that were specific to one species, did not cover the entire study area, or did not provide spatial information useful for mapping purposes. In some cases, information gaps resulted from the lack of any previous work related to a specific topic, or else time series data were lacking.

Based on the quantity and quality of preexisting information, the data gaps revealed in Table 2.1 and Table 2.2, the relative importance of the various species to the Lummi people, and the resources available to the LIBI project, the data gaps to be addressed during the LIBI field work were identified and prioritized as follows:

Priority Data Gap Description

1. Intertidal surface elevation model for all of the Reservation tidelands.
2. Information about existing levels of petroleum-derived toxins such as Polynuclear Aromatic Hydrocarbons (PAH's) in shellfish and sediments across the Reservation and over time.
3. Spatially located distribution and abundance data for all benthic fauna across the full extent of the Lummi Reservation tidelands.
4. Finfish assemblage data for mid-intertidal to low-intertidal habitats across the Lummi Reservation during all seasons.
5. Ecological data to document associations with biota.
6. Shorebird census of all species during all seasons.

The field component of the LIBI aimed to address each of these data needs. However, there were insufficient resources to ensure that all data gaps could be filled for every species and every area. Accordingly, the different kinds of information that might be potentially obtained from some of the field efforts were prioritized. For example, collecting data relating to inter-annual variation was ruled out during the scoping phase of the project due to budgetary constraints and the higher prioritization given to the requirements to document taxonomic diversity, abundance, and spatial distributions over such a large spatial scale.

3.0 Field Surveys

Six separate field surveys were conducted as components of the Lummi Intertidal Baseline Inventory to address the data gaps identified in the Final Work Plan (LeMoine *et al.* 2009). In this section each of these surveys are described in summary form. More detailed descriptions of each survey are presented in the appendices.

3.1 Overview of Surveys

3.1.1 Topographic Data Collection

The highest-priority data need identified in the LIBI Final Work Plan (LeMoine *et al.* 2009) was to obtain comprehensive surface elevation data for the largest possible extent of the study area. Because this goal was not attainable using traditional cadastral survey methods, remote sensing methods were used. Two remote sensing options for tidelands are boat-mounted technologies (e.g., side-scan sonar) used during high tide or aircraft-mounted technologies used during low tide. Due to the narrow swath width in very shallow water, the boat-mounted remote sensing technology was cost prohibitive. Likewise, advanced water-penetrating LiDAR that can measure subtidal elevations to depths of approximately 30 feet, and could accurately delineate the –4.5 ft MLLW contour, was cost prohibitive. As an alternative, the LNR contracted with Watershed Sciences (257B SW Madison Street, Corvallis, OR 97333) to conduct LiDAR remote sensing of the Lummi Reservation tidelands during the lowest summertime daylight tides in July 2008. The full report provided by Watershed Sciences is attached to this report in Appendix G.

Watershed Sciences reported that the resulting data have a relative vertical accuracy of less than 0.33 feet (10 cm), and an absolute vertical accuracy of 0.11 feet (3.4 cm). The deliverable products from this contract included a digital elevation model of the Lummi Reservation tidelands with a horizontal resolution of 3 feet (91cm), and with reported surface elevations relative to the 1988 North American Vertical Datum (NAVD88).

This survey successfully achieved the goal of obtaining comprehensive, high-resolution data for surface elevations across most of the Lummi Reservation tidelands. The surface elevation model derived from these data, combined with previously conducted LiDAR data for the upper portion of Lummi Bay, and converted to the local tidal datum Mean Lower Low Water (MLLW), is shown in Figure 3.1. Elevations below –2.5 ft MLLW could not be sampled uniformly in this survey due to the position and movement of the tides during the LiDAR flights. A report detailing the analysis of the LiDAR survey data is included as Appendix H.

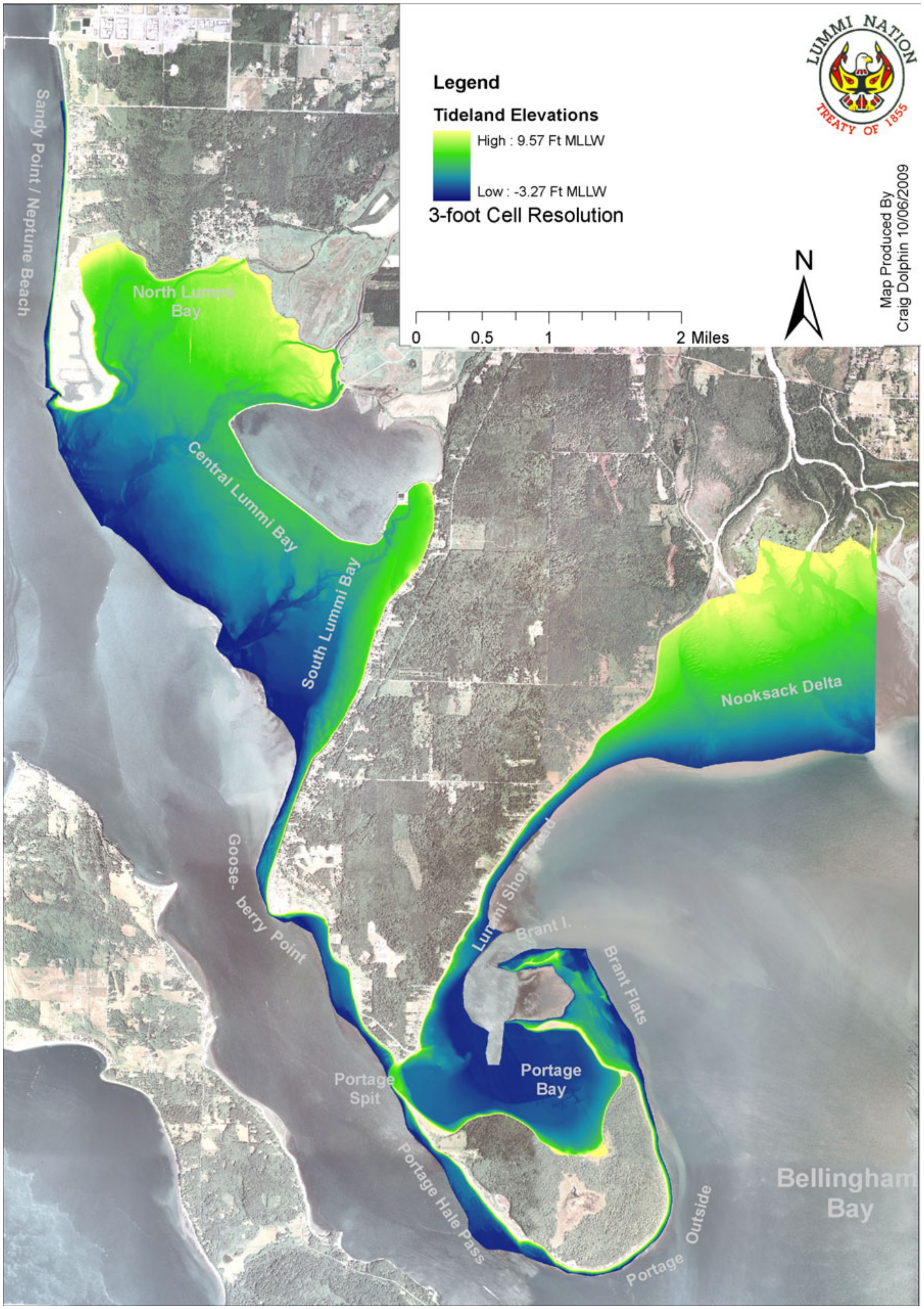


Figure 3.1. Digital Elevation Model of Tideland Elevations (ft MLLW) in the Study Area

3.1.2 Intertidal Biota Survey

To determine the diversity of intertidal benthos across the Reservation tidelands and to delineate the distribution and abundance of these species, samples of epibenthic organisms and infauna were collected across the Reservation tidelands with a maximum sampling depth of 12 inches. These samples were frozen, then sorted and identified in the laboratory, before being preserved in denatured ethanol. Habitat measures and photographs were also documented at each site. A total of 366 sites were sampled during this survey (Figure 3.2), exceeding the target of 318 sites that was outlined in the Final Work Plan (LeMoine *et al*. 2009) by 15%.

This survey filled data gaps by obtaining spatially located distribution and abundance data for all benthic taxa across the full extent of the Lummi Reservation tidelands and also to provide environmental data that could be used to document ecological associations between the observed biota and their habitats. The complete report for the intertidal biota survey is attached as Appendix A. Additional reports are also provided in Appendix H that explains the spatial analysis of known environmental gradients that were used to conduct a preliminary ecological analysis of the results (Appendix I).

3.1.3 Large Bivalve Survey

Horse clams and geoduck clams are particularly difficult to survey because they typically live between 18 and 36 inches below the surface. As a result, the Intertidal Biota Survey was not expected to reliably sample these species. In order to inventory these deep-dwelling clams, a supplementary survey was conducted that counted siphon shows of adult horse clams and geoduck clams around the Reservation tidelands. The complete report from this supplementary survey is attached to this report in Appendix B. In total, 1,238 unbiased observations of siphon densities were documented, and a further 130 deliberately biased observations were recorded for the topmost horse clam siphon encountered while conducting shore perpendicular transects (Figure 3.3). Observations of the topmost horse clam siphon were excluded from population abundance estimates.

3.1.4 Finfish Survey

The finfish survey filled data gaps by consistently documenting the diversity and relative abundance of finfish across the Reservation throughout the year. The finfish survey was conducted using a lampara net to obtain monthly samples of finfish at 16 sites distributed across the Lummi Reservation tidelands and the adjacent nearshore (Figure 3.4). Due to the moderate priority assigned to this data gap and logistical limitations, some areas were not sampled including Brant Island, Brant Flats, Point Francis, and the central portion of the Nooksack Delta. The complete report that details the methods, results, and analysis of this survey is attached to this document as Appendix C.

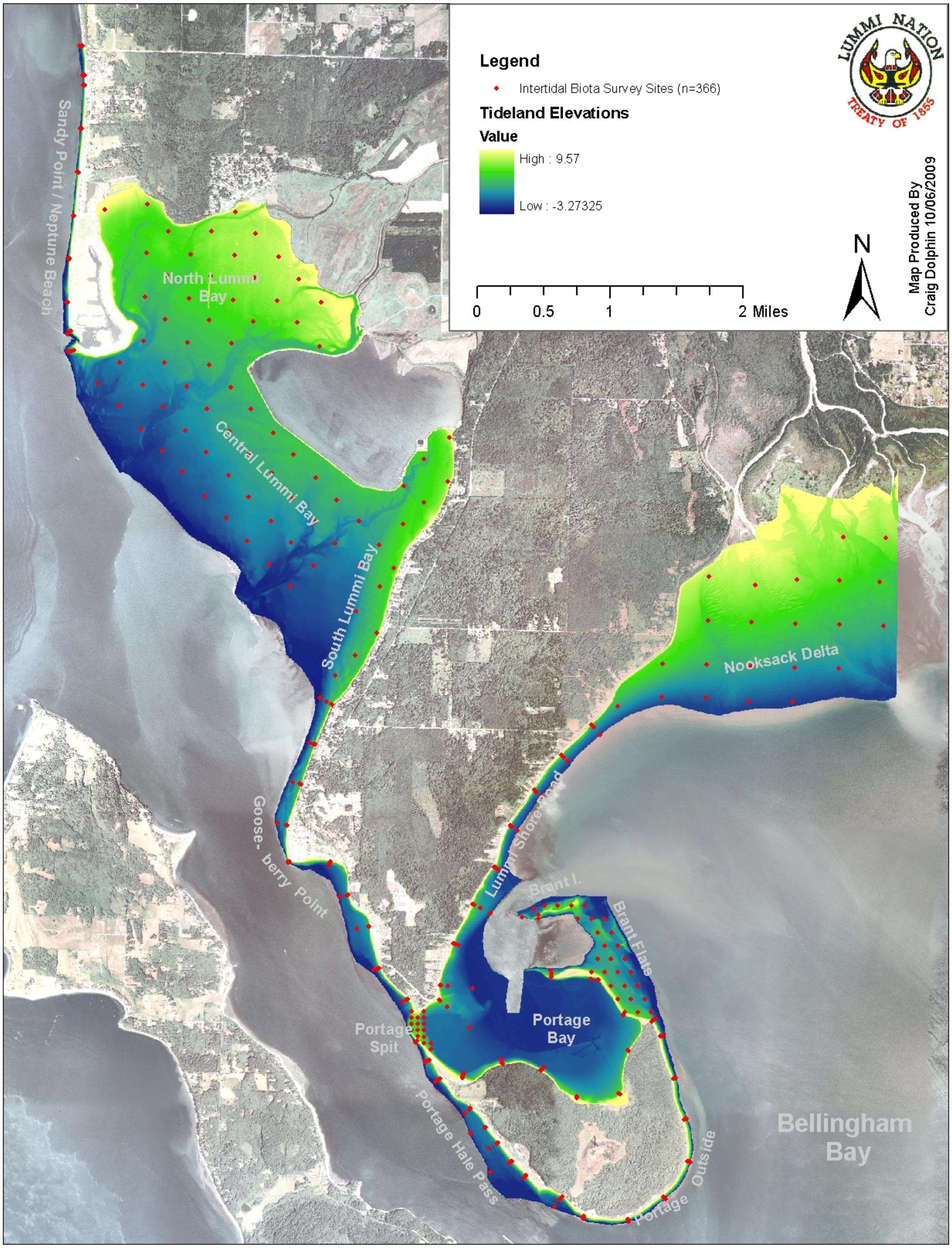


Figure 3.2. Intertidal Biota Survey Sites

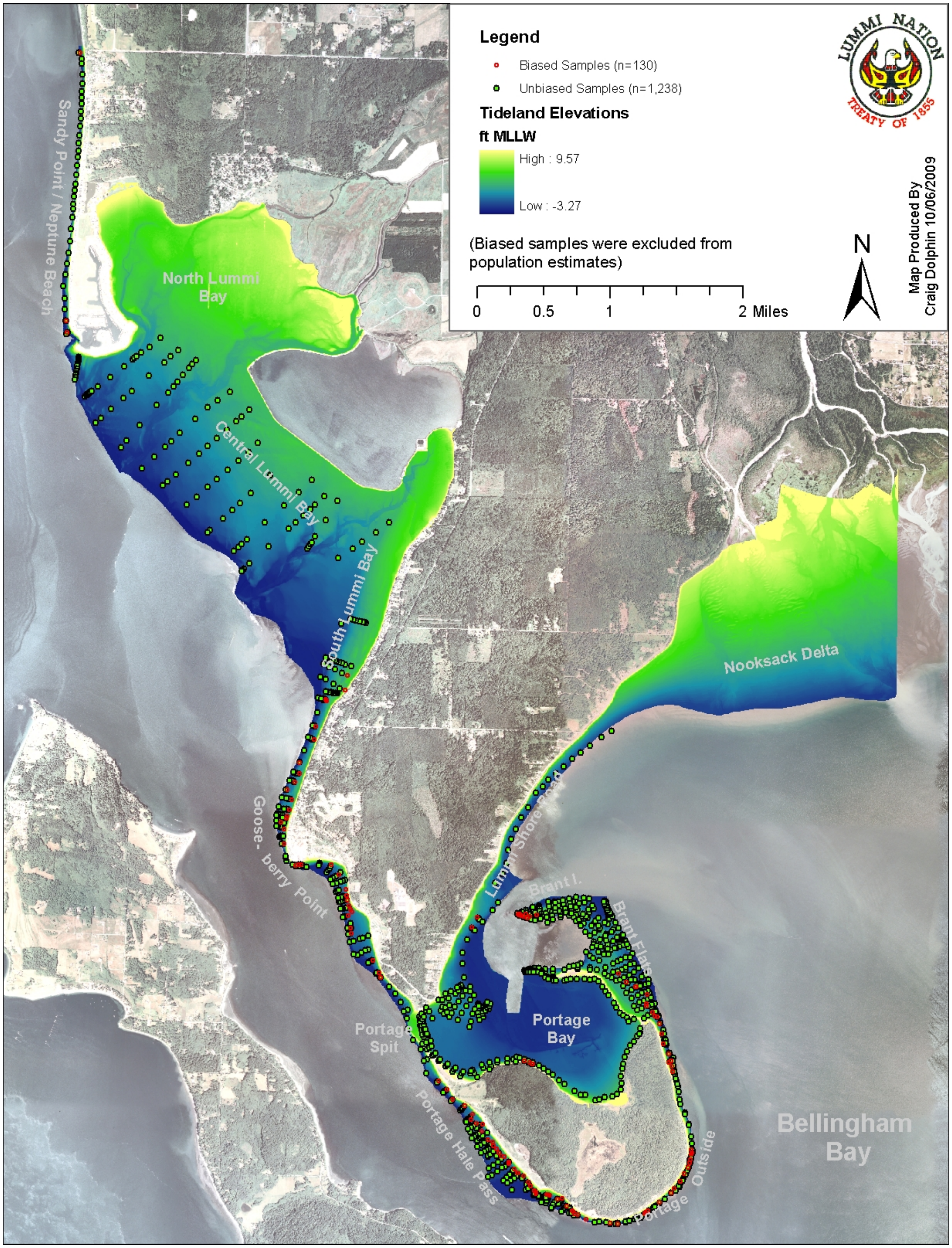


Figure 3.3. Large Bivalve Survey Sites

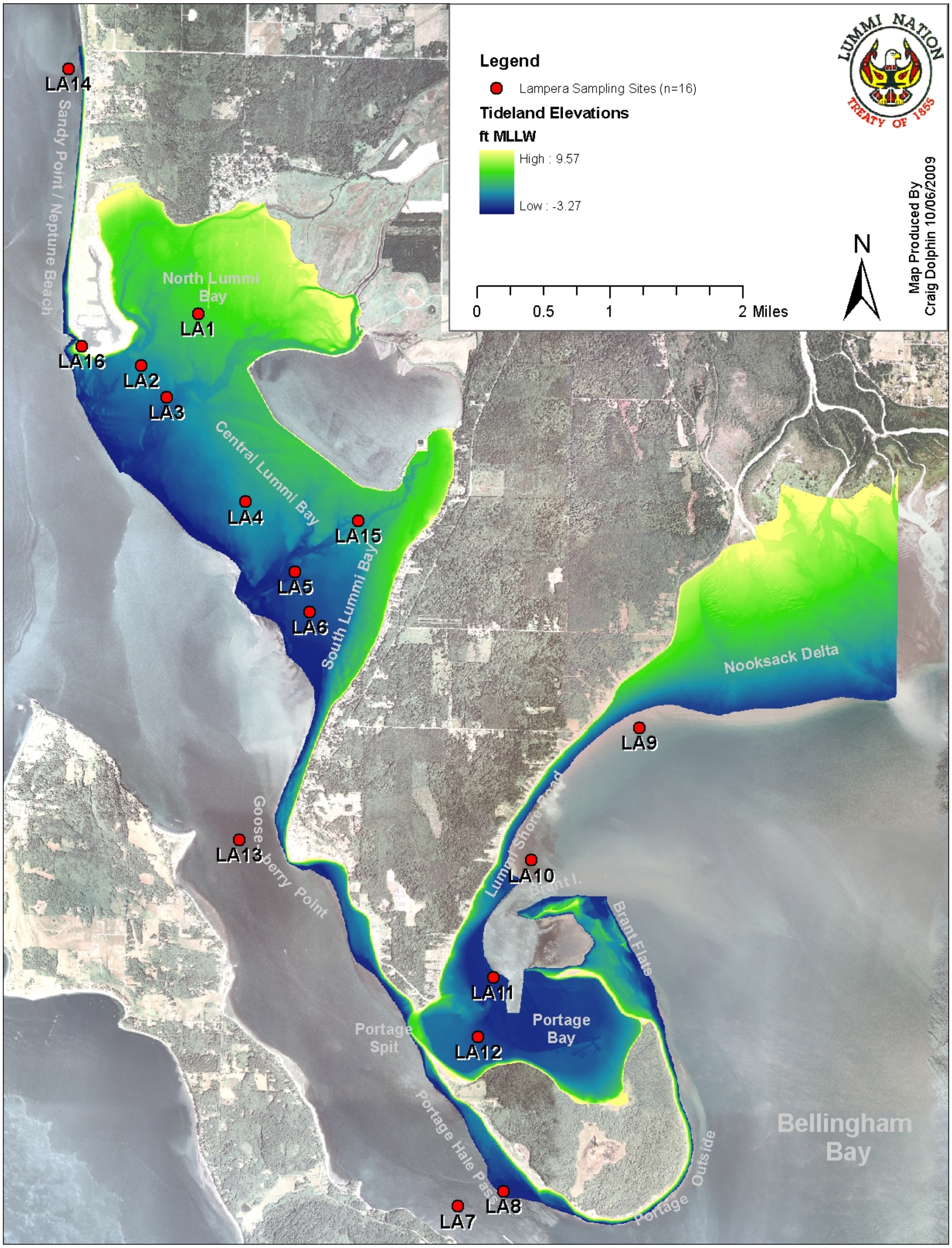


Figure 3.4. Finfish Survey Sites

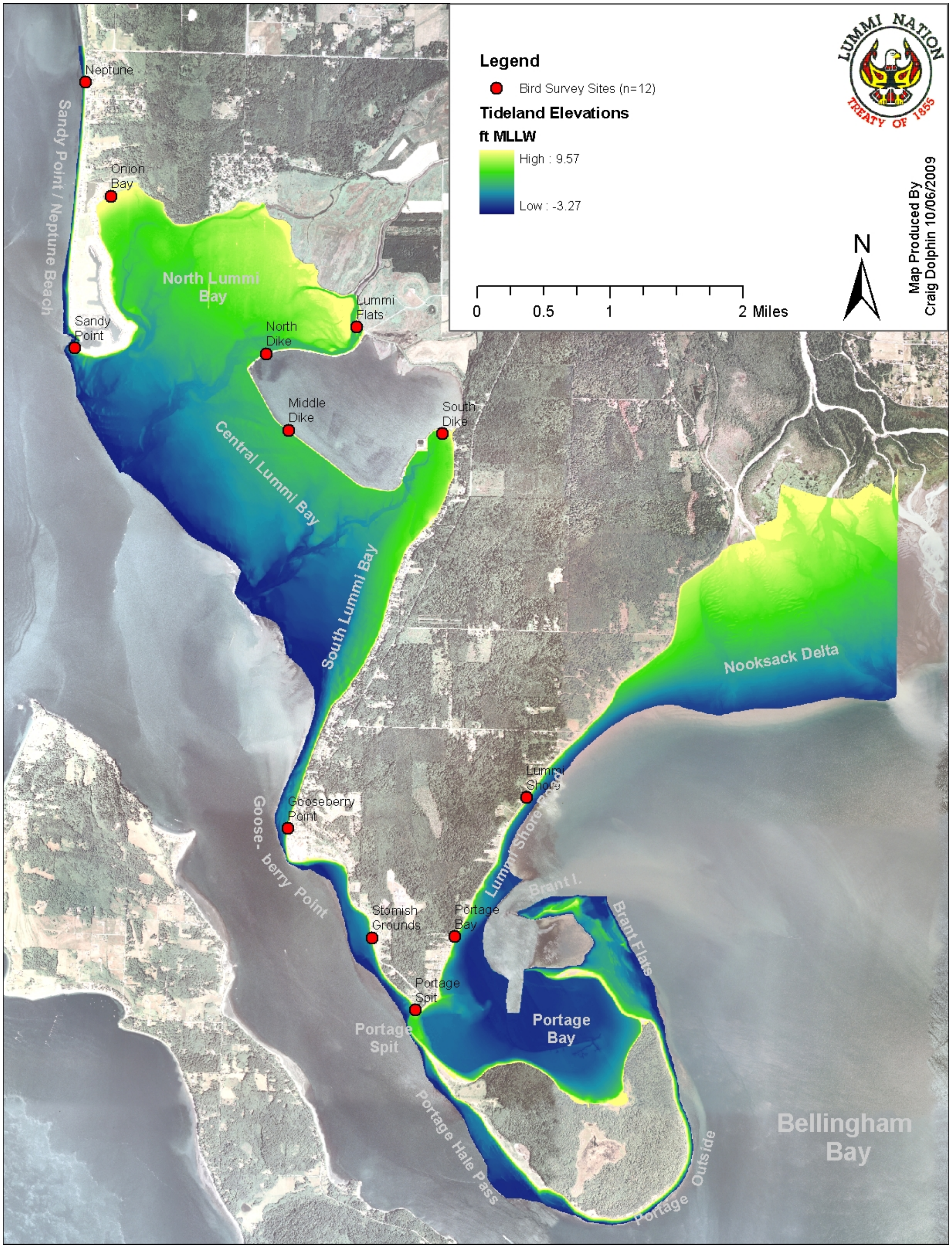


Figure 3.5. Bird and Marine Mammal Survey Sites

3.1.5 Shorebird and Marine Mammal Survey

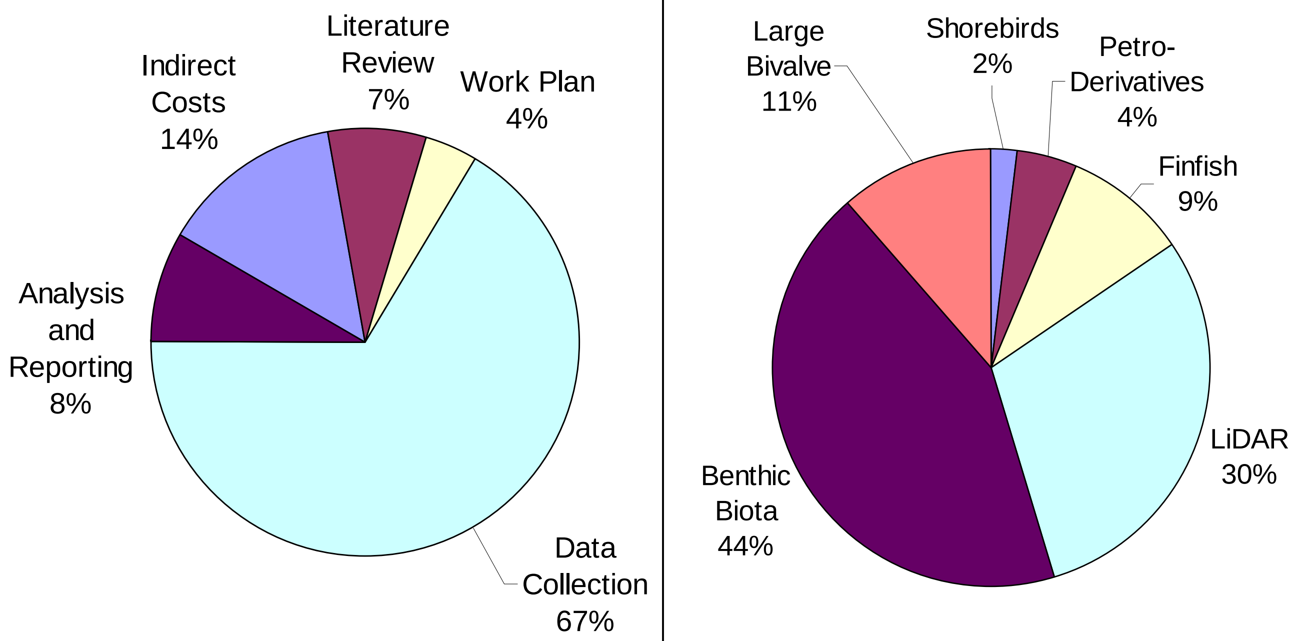
The Shorebird and Marine Mammal survey attempted to fill data gaps by documenting the diversity and relative abundance of shorebirds and marine mammals across the Reservation throughout the year. A monthly visual survey was conducted at 12 sites across the Lummi Reservation tidelands (Figure 3.5). Due to the low relative priority of this data need and logistical limitations, some areas could not be sampled. These areas included Brant Flats, Portage Island, and the central portion of the Nooksack Delta. The complete report that details the methods, results, and analysis of this survey is attached to this document as Appendix D.

3.1.6 Petroleum Hydrocarbon Survey

The second highest priority identified for the LIBI study was to obtain information about the existing levels of petroleum-derived toxins such as Polynuclear Aromatic Hydrocarbons (PAH) in shellfish and sediments across the Reservation over time. Accordingly, samples of tideland sediments and Manila clams were collected at a site in central Lummi Bay and a second site on Portage Spit testing three tidal elevation strata at each site. Additional sites, species, and temporal differences were not included in the survey due to the high costs of conducting the laboratory analysis for these chemical compounds. A complete report detailing the methods and results of this survey are presented in Appendix E, and briefly summarized in Section 3.4 of this document.

3.1.7 Budget Allocation

The Lummi Intertidal Baseline Inventory budget was $150,000, which was based on a one-time allocation provided by BP Cherry Point. Due to this limited budget, Lummi Natural Resources contributed additional staff resources to the project. The majority of the overall LIBI budget was allocated to the collection of new data (Figure 3.6a). Figure 3.6b shows that the majority of those data collection costs were allocated to the intertidal biota/large bivalve surveys, and to the remote sensing/LiDAR survey.



A. Percent allocations to LIBI tasks and indirect costs from the BP Cherry Point allocated budget of $150,000.

B. Percent allocations for specific monitoring tasks allocated from the 67% ($99,500) for data collection.

Figure 3.6. LIBI Budget Allocations

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4.0 Geographical Area Definitions

Throughout this report different geographic areas of the Reservation tidelands are referenced. These areas were defined during the development of the project based on easily recognizable geographic features and observed boundaries of substrate/slope characteristics. Because the Intertidal Biota Survey was conducted at a higher spatial resolution than the Finfish Survey and the Bird and Marine Mammal Survey, it was necessary to aggregate the results of the Intertidal Biota Survey to the same spatial resolution that was attained in the other surveys in order to combine the results of the different surveys.

Figure 4.1 shows the extent and names of the sub-areas used in the Intertidal Biota Survey. The area definitions used in this report are related to the sub-areas used for the Intertidal Biota Survey as shown in Table 4.1. As described previously, the Brant Island/Brant Flats, Point Francis, and the central portion of the Nooksack Delta were not sampled for finfish and birds due to logistical considerations.

Table 4.1. Study Area Definitions

Area	Associated Intertidal Biota Survey Sub-Areas		
Neptune Beach	Sandy Point / Neptune Beach	-	-
Lummi Bay	Lummi Bay North	Lummi Bay Central	Lummi Bay South
Portage Bay	Portage Bay	Portage Spit	Lummi Shore Road
Hale Passage	Gooseberry Point	Portage Hale Pass.	-
Point Francis	Portage Outside	-	-
Brant Area	Brant Island / Brant Flats	-	-
Nooksack Delta	Nooksack Delta	-	-
Seapond	Not Surveyed in LIBI. Data from Dolphin 2005		

Portage Spit was included with the larger Portage Bay area rather than with the Hale Passage area because previous studies by the Washington Department of Health showed a net movement of water from Portage Bay to Hale Passage during high tide (Meriwether 2001). Lummi Shore Road was included within Portage Bay because the majority of the benthic biota in this sub-area was found towards the southern end of the sub-area.

The Lummi Bay Seapond was not formally inventoried as part of the LIBI project due to the existence of data from two previous venturi-suction dredge surveys (Dolphin 2005).

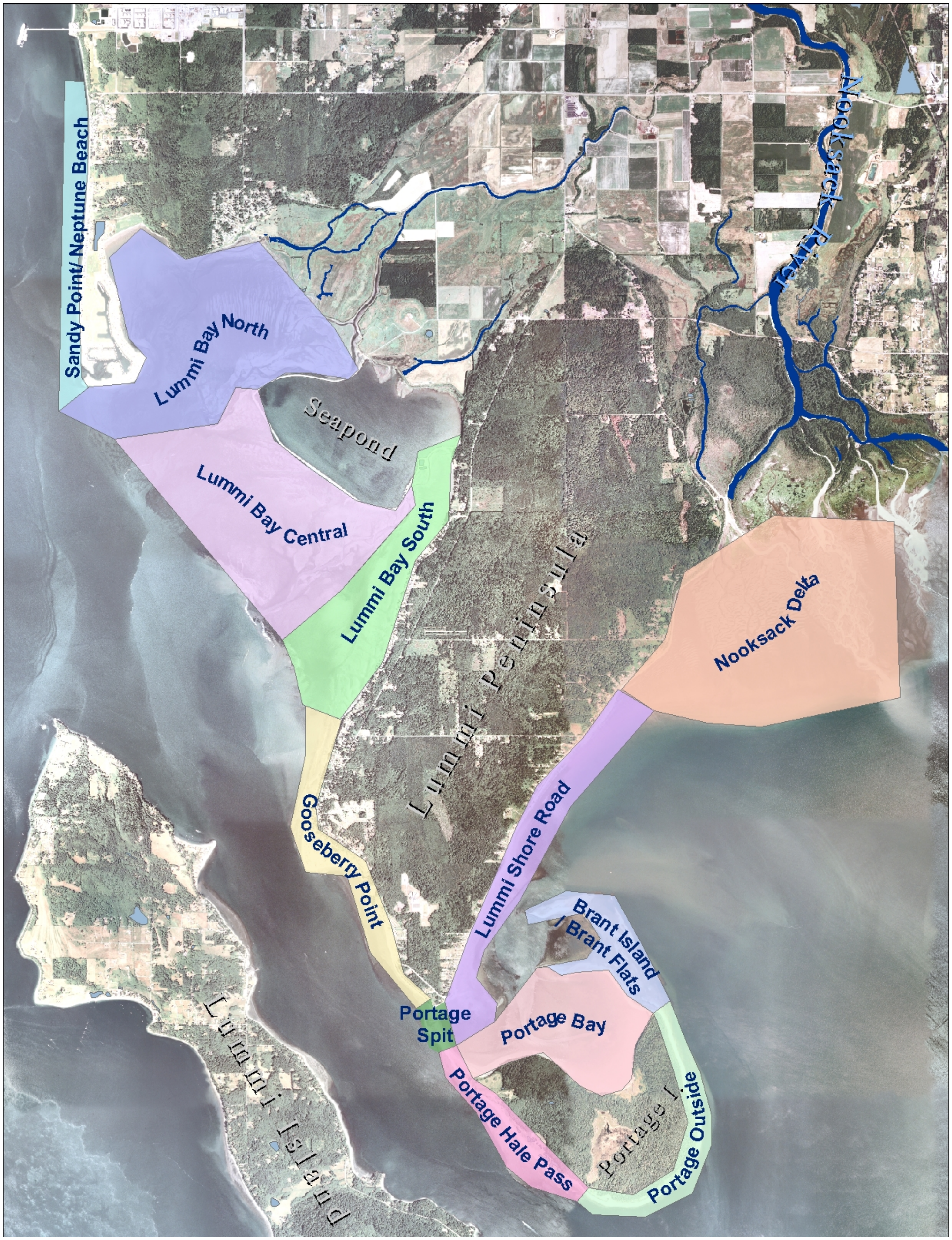

Figure 4.1. Sub-Area Designations Used in the Intertidal Biota Survey

5.0 Taxonomic Diversity

Data gathered during the Intertidal Biota Survey, the Large Bivalve Survey, and the Shorebird and Finfish Surveys were analyzed to document the taxonomic diversity on the Reservation tidelands and at specific locations.

Organisms encountered in the LIBI project were identified to different taxonomic levels (see Figure 5.1) depending on the survey method, conditions, and the identification resources available. At times the ability to make a positive identification was complicated by the age and/or condition of the specimen or by the lack of the required level of specialist taxonomic expertise. Accordingly, the taxonomic resolution of the LIBI depends mainly on the type of organism. Fishes, crabs, echinoderms, shrimps, snails, limpets, chitons, clams, marine mammals, and birds were typically identified to the species level wherever possible. Annelids and amphipods were usually identified to the family level. Other organisms such as bryozoans, hydrozoans, sponges, peanut worms, flat worms, pycnogonids, chironomids, and others were identified only at much higher taxonomic levels (e.g., phylum or order).

Kingdom
↳**Phylum**
↳**Class**
↳**Order**
↳**Family**
↳**Genus**
↳**Species**

Figure 5.1. Major Taxonomic Levels Used in Biology

Where identifications could not be made at the lowest usual level for the taxonomic group (because of damage to the specimen or for some other reason), the organism was identified at a higher level depending on the best professional judgment of the investigator. The specific details of the taxonomic labels used, and the relationship and dependencies between the labels used at different taxonomic levels, is outlined in Appendix E. Most of the samples collected during the Intertidal Biota Survey were preserved in 95% ethanol to allow for re-examination in the future by qualified regional experts to improve the taxonomic resolution for these groups.

Table 5.1 indicates the presence of species by area based on the integrated results of the different LIBI surveys and previous work available to the authors. Overall, the LIBI project documented the presence of 242 taxa including some that were only identified at taxonomic ranks higher than genus. Additional taxa may be present in the study areas that were not encountered during the survey due to seasonal and methodological limitations or sampling error.

The data in Table 5.1 illustrate that there are some data gaps remaining for birds and finfish in the Brant area and around Point Francis. These areas were not surveyed during the LIBI bird or finfish surveys. Similarly, the Lummi Bay Aquaculture Pond (Seapond) was not included in the LIBI project field effort. Previous survey data for this area has been focused primarily on clams and visual counts of large crabs and fishes, and the presence or abundance of smaller organisms has not been captured. In addition, the LIBI bird survey did not separate counts for birds that were conducted in Lummi Bay from those that were noted on the Seapond. Many of the bird species that are noted present in Lummi Bay are also found on the Seapond.

Table 5.1. Taxa Present on Lummi Reservation Tidelands, by Geographical Area

Taxon			Geographical Sub Areas									Supplementary Source(s)
			On-Reservation	Neptune Beach	Lummi Bay	Hale Passage	Portage Bay	Point Francis	Brant Area	Nooksack Delta	Seapond	
Annelids	Polychaetes	Bamboo Worms (Family Maldanidae)	+	+	+	+	+	+	+	+		
		Beach Worms (Family Onuphiidae)	+	+	+	-	+	-	-	-		
		Blood Worms (Family Glyceridae)	+	+	+	+	+	+	+	+		
		Bristle Cage Worms (Family Flabelligeridae)	+	-	+	-	-	+	+	-		
		Feather Duster Worms (Family Sabellidae)	+	-	+	+	+	+	+	-		
		Goddess Worms (Family Nephytidae)	+	+	+	+	+	+	+	+		
		Iridescent Worms (Family Lumbrineridae)	+	+	+	+	+	+	+	+		
		Lug Worms (Family Arenicolidae)	+	+	+	+	+	-	+	+		
		Opheliidae (Family Opheliidae)	+	-	-	-	+	-	+	-		
		Pile Worms (Family Nereidae)	+	+	+	+	+	+	+	+		
		Sand Worms (Family Oweniidae)	+	+	+	+	+	+	+	+		
		Scale Worms (Halosydna brevisetosa)	+	+	+	+	+	-	+	-		
		Spaghetti Worms (Family Cirratulidae)	+	-	+	+	+	+	+	+		
		Spaghetti Worms (Family Terebellidae)	+	-	+	+	+	+	-	-		
		Three-Section Tube Worms (Family Chaetopteridae)	+	-	+	+	+	+	+	-		
		Tusk Worms (Family Pectinariidae)	+	-	-	+	+	+	-	-		
Birds	Alcids	Marbled Murrelet (*Brachyramphus marmoratus*)	+	-	-	+	-			-		
		Pigeon Guillemot (*Cepphus columba*)	+	+	-	+	-			-		
	Buntings & Sparrows	Snow Bunting (*Plectrophenax nivalis*)	+	-	+	-	-			-		
	Corm-orants	Double-Crested Cormorant (*Phalacrocorax auritus*)	+	+	+	+	+			+		
		Pelagic Cormorant (*Phalacrocorax pelagicus*)	+	+	+	+	-			+		
	Corv-ids	American Crow (*Corvus brachyrhynchos*)	+	-	+	+	+			+		
	Ducks	American Widgeon (*Anas americana*)	+	+	+	+	+			+		
		Barrow's Goldeneye (*Bucephala islandica*)	+	+	+	+	+			+		
		Black Scoter (*Melanitta nigra*)	+	-	+	-	-			-		
		Bufflehead (*Bucephala albeola*)	+	+	+	+	+			+		
		Common Goldeneye (*Bucephala clangula*)	+	+	+	+	+			+		

(A plus symbol denotes that the taxon has been observed in the indicated area. A minus symbol indicates that the taxon has not been recorded as present during surveys that could have sampled the organism. Blank cells indicate that there have been no surveys likely to encounter the species conducted in the area. All data is derived from the LIBI surveys, or from previous data/observations made by the authors.)

Table 5.1. Taxa Present on Lummi Reservation Tidelands, by Geographical Area

Taxon			Geographical Sub Areas									Supplementary Source(s)
			On-Reservation	Neptune Beach	Lummi Bay	Hale Passage	Portage Bay	Point Francis	Brant Area	Nooksack Delta	Seapond	
Birds	Ducks	Common Merganser (*Mergus merganser*)	+	+	+	+	-			-		
		Eurasian Widgeon (*Anas penelope*)	+	-	+	-	-			-		
		Gadwall (*Anas strepera*)	+	-	+	-	-			-		
		Greater Scaup (*Aythya marila*)	+	+	+	+	+			+		
		Green-Wing Teal (*Anas carolinensis*)	+	-	+	-	-			-		
		Harlequin Duck (*Histrionicus histrionicus*)	+	+	+	-	-			-		
		Hooded Merganser (*Lophodytes cucullatus*)	+	-	+	-	-			-		
		Longtailed Duck (*Clangula hyemalis*)	+	+	+	+	+			+		
		Mallard (*Anas platyrhynchos*)	+	+	+	+	+			+		
		Northern Pintail (*Anas acuta*)	+	-	+	+	+			+		
		Red-Breasted Merganser (*Mergus serrator*)	+	+	+	+	+			+		
		Surf Scoter (*Melanitta perspicillata*)	+	+	+	+	+			+		
		White-Winged Scoter (*Melanitta fusca*)	+	+	+	+	+			+		
	Geese	Brant (*Branta bernicla*)	+	+	+	+	+			+		
		Canada Goose (*Branta canadensis*)	+	+	+	-	+			-		
	Grebes	Horned Grebe (*Podiceps auritus*)	+	+	+	+	+			+		
		Red-Necked Grebe (*Podiceps grisegena*)	+	+	+	+	-			-		
		Western Grebe (*Aechmophorus occidentalis*)	+	+	+	+	+			+		
	Gulls	Bonaparte's Gull (*Larus philadelphia*)	+	+	+	+	-			-		
		California Gull (*Larus californicus*)	+	-	+	-	-			-		
		Glaucous-Winged Gull (*Larus glaucescens*)	+	+	+	+	+			+		
		Herring Gull (*Larus argentatus*)	+	-	+	+	-			-		
		Mew Gull (*Larus canus*)	+	+	+	+	+			+		
		Ring-Billed Gull (*Larus delawarensis*)	+	+	+	+	+			-		
	Herons	Great Blue Heron (*Ardea herodias*)	+	+	+	+	+			+		
	King-fishers	Belted Kingfisher (*Ceryle alcyon*)	+	+	+	+	+			-		
	Loons	Common Loon (*Gavia immer*)	+	+	+	+	+			+		
		Pacific Loon (*Gavia pacifica*)	+	+	-	+	-			-		
		Red-Throated Loon (*Gavia stellata*)	+	+	-	+	+			-		
	Owls	Long-Eared Owl (*Asio otus*)	+	-	+	-	-			-		

Table 5.1. Taxa Present on Lummi Reservation Tidelands, by Geographical Area

Taxon			Geographical Sub Areas									Supplementary Source(s)
			On-Reservation	Neptune Beach	Lummi Bay	Hale Passage	Portage Bay	Point Francis	Brant Area	Nooksack Delta	Seapond	
Birds	Plovers	Black Turnstone (*Arenaria melanocephala*)	+	+	+	+	-			-		
Birds	Plovers	Dunlin (*Calidris alpina*)	+	+	+	-	-			+		
Birds	Plovers	Killdeer (*Charadrius vociferus*)	+	+	+	+	-			-		
Birds	Plovers	Western Sandpiper (*Calidris mauri*)	+	-	+	-	-			-		
Birds	Raptors	Bald Eagle (*Haliaeetus leucocephalus*)	+	+	+	+	+			+		
Birds	Raptors	Northern Harrier (*Circus cyaneus*)	+	-	+	-	-			-		
Birds	Raptors	Peregrin Falcon (*Falco peregrinus*)	+	-	-	-	-			+		
Birds	Raptors	Redtailed Hawk (*Buteo jamaicensis*)	+	-	+	-	+			-		
Birds	Swallows	Barn Swallow (*Hirundo rustica*)	+	+	+	-	-			-		
Birds	Swallows	Cliff Swallow (*Petrochelidon pyrrhonota*)	+	-	+	-	-			-		
Birds	Terns	Caspian Tern (*Sterna caspia*)	+	+	+	+	+			-		
Coelente-rates	Anemones	Actiniana Anemone (*Actiniana* species)	+	-	-	-	-	-	+	-		
Coelente-rates	Anemones	Epiactis Not Identified (*Epiactis* species)	+	-	-	+	-	-	-	-		
Coelente-rates	Anemones	Moonglow Anemone (*Anthopleura artesimia*)	+	+	+	+	+	+	+	-		
Coelente-rates	Anemones	Stubby Rose Anemone (*Urticina coriacea*)	+	-	+	+	-	+	-	-		
Arthropods	Amphipods	Caprellid Amphipod (*Caprella* species)	+	+	+	+	+	-	+	-		
Arthropods	Amphipods	Corophiid Amphipod (Family Corophiidae	+	+	+	+	+	+	+	+		
Arthropods	Amphipods	Gammarid Amphipod (Family Gammaridae	+	+	+	+	+	+	+	+		
Arthropods	Amphipods	Sandhopper (*Trasorchestia traskiana*)	+	+	-	-	-	-	-	-		
Arthropods	Amphipods	Tanaid Amphipod (Order Tanaidacea)	+	-	+	-	-	-	-	-		
Arthropods	Barnacles	Acorn Barnacle (*Balanus glandula*)	+	+	+	+	+	+	+	-		
Arthropods	Barnacles	Smooth Acorn Barnacle (*Balanus crenatus*)	+	+	+	+	+	+	+	-		
Arthropods	Barnacles	Tiny Brown Barnacle (*Chthamatus dalli*)	+	+	-	+	+	-	-	-		
Arthropods	Hermit Crabs	Grainy Hermit Crab (*Pagurus granosimanus*)	+	+	+	+	+	+	+	-		
Arthropods	Hermit Crabs	Hairy Hermit Crab (*Pagurus hirsutiusculus*)	+	+	+	+	+	+	+	-		

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			On-Reservation	Neptune Beach	Lummi Bay	Hale Passage	Portage Bay	Point Francis	Brant Area	Nooksack Delta	Seapond	
Arthropods	Isopods	Eelgrass Isopod (*Idotea resecata*)	+	+	+	+	+	+	-	-		
		Ghost Shrimp Isopod (*Phyllodurus abdominalis*)	+	-	-	-	-	+	-	-		
		Monterey Idotea (*Idotea montereyensis*)	+	-	-	-	-	+	-	-		
		Pill Bug Isopod (*Gnorimospaeroma oregonense*)	+	+	+	+	+	+	+	-		
		Rockweed Isopod (*Idotea wosnesenskii*)	+	-	-	+	-	+	+	-		
	Mites	Red Velvet Mite (*Neomolgus littoralis*)	+	-	-	-	+	-	-	-		
	Shrimps	Betaus harrimani (*Betaus harrimani*)	+	-	+	+	+	-	-	-		
		Blacktail Shrimp (*Crangon nigricauda*)	+	-	+	-	-	+	-	+		
		Blue Mud Shrimp (*Upogebia pugettensis*)	+	+	+	-	-	-	-	-		
		Broken Backed Shrimp (*Heptacarpus* species)	+	-	-	-	-	+	-	-		
		California Bay Shrimp (*Crangon franciscorum*)	+	-	+	-	-	-	-	-		
		Coonstripe Shrimp (*Pandalus danae*)*	+		+							4
		Crangonid Shrimp (Family Crangonidae)	+	+	+	+	-	-	-	-		
		Ghost Shrimp (*Neotrypaena californiensis*)	+	+	+	+	+	+	-	-		
		Herdman Coastal Shrimp (*Heptacarpus herdmani*)	+	-	+	-	+	-	-	-		
		Hippotylid Shrimp (*Eualus biunguis*)	+	-	+	+	-	-	-	-		
		Mysid Shrimp (*Neomysis* species)	+	-	-	+	-	-	-	-		
		Shortscale Eualid (*Eualus suckleyi*)	+	-	+	-	-	-	-	-		
		Spot Prawn (*Pandalus platyceros*)	+	-	-	-	+	-	-	-		
		Stout Crangon (*Crangon alba*)	+	-	+	-	+	-	-	-		
	True Crabs	Dungeness Crab (*Cancer magister*)	+	+	+	+	+	+	+	-	+	1
		Graceful Decorator Crab (*Oregonia gracilis*)	+	-	-	+	-	-	-	-		
		Kelp Crab (*Pugettia producta*)	+	+	+	+	+			-		
		Lyre Crab (*Hyas lyratus*)	+	-	+	-	-			-		
		Hairy Helmet Crab (*Telmessus cheiragonus*)	+	+	+	+	+	-	+	-	+	1
		Oregon Shore Crab (*Hemigrapsus oregonensis*)	+	+	+	+	+	+	+	-		
		Pea Crab (*Pinnixa faba*)	+	+	+	+	+	+	+	-		
		Purple Shore Crab (*Hemigrapsus nudus*)	+	-	-	+	+	+	-	-		
		Pygmy Rock Crab (*Cancer oregonensis*)	+	-	-	-	-	+	-	-		
		Red Rock Crab (*Cancer productus*)	+	+	-	-	-	-	-	-	-	1
		Schmitt Pea Crab (*Pinnixa schmitti*)	+	-	+	+	-	-	+	-		
		Scleroplax granulata (*Scleroplax granulata*)	+	-	-	+	+	-	+	-		
		Tube Dwelling Pea Crab (*Pinnixa tubicola*)	+	+	+	+	+	+	+	-		

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Taxon			Geographical Sub Areas									Supplementary Source(s)
			On-Reservation	Neptune Beach	Lummi Bay	Hale Passage	Portage Bay	Point Francis	Brant Area	Nooksack Delta	Seapond	
Echinoderms	Brittle-stars	Brittlestar Long Rayed (*Amphiodia* species)	+	+	+	+	+	+	+	-		
Echinoderms	Brittle-stars	Red Brittlestar (*Ophiopholis aculeata*)	+	-	-	+	-	-	-	-		
Echinoderms	Sand Dollars	Sand Dollar (*Dendraster excentricus*)	+	-	+	+	-	+	+	-		
Echinoderms	Sea-stars	Purple Ochre Seastar (*Pisaster ochraceus*)	+	-	-	-	-	-	+	-		
Echinoderms	Sea-stars	Six Rayed Star (*Leptasterias* species)	+	-	+	-	-	-	-	-		
Finfish	Elasmo-branchs	Pacific Spiny Dogfish (*Squalus acanthias*)	+	-	+	-	-			-		
Finfish	Flatfishes	Pacific Sanddab (*Citharichthys sonididus*)	+	-	+	+	+			-		
Finfish	Flatfishes	Speckled Sanddab (*Citharichthys stigmaeus*)	+	-	+	-	-			-		
Finfish	Flatfishes	Starry Flounder (*Platichthys stellatus*)	+	+	+	+	+			+		
Finfish	Forage Fishes	American Shad (*Alosa sapidissima*)	+	-	-	-	-			+		
Finfish	Forage Fishes	Anchovy (*Engraulis mordax*)	+	-	-	-	-			+		
Finfish	Forage Fishes	Longfin Smelt (*Spirinchus thaleichthys*)	+	-	-	-	+			+		
Finfish	Forage Fishes	Pacific Herring (*Clupea pallasi*)	+	+	+	+	+			+	+	3
Finfish	Forage Fishes	Sandlance (*Ammodytes hexapterus*)	+	-	+	+	-			+	+	3
Finfish	Gadid	Pacific Cod (*Gadus macrocephalus*)	+	+	+	+	-			-	+	3
Finfish	Gadid	Pacific Tomcod (*Microgadus proximus*)	+	-	-	-	-			+		
Finfish	Gobies	Arrow Goby (*Clevelandia ios*)	+	-	+	-	+			-		
Finfish	Greenling	Kelp Greenling (*Hexagrammos decagrammus*)	+	+	+	-	-			-		
Finfish	Greenling	Lingcod (*Ophiodon elongates*)	+	-	-	-	+			+		
Finfish	Greenling	Whitespotted Greenling (*Hexagrammos stelleri*)	+	-	+	+	+			-		

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Taxon			Geographical Sub Areas									Supplementary Source(s)
			On-Reservation	Neptune Beach	Lummi Bay	Hale Passage	Portage Bay	Point Francis	Brant Area	Nooksack Delta	Seapond	
Finfish	Gunnels	Crescent Gunnel (*Pholis laeta*)	+	+	+	+	+	-	-	-		
		Penpoint Gunnel (*Apodichthys flavidus*)	+	+	+	+	-	+	-	+		
		Saddleback Gunnel (*Pholis ornata*)	+	+	+	+	+	+	-	-		
	Lamp-reys	Lamprey (*Lampetra* species)	+	-	-	-	-			+		
	Prickle-backs	Cockscomb Prickleback (*Anoplarchus purpurescens*)	+	-	-	-	-	+	-	-		
		Snake Prickleback (*Lumpenus sagitta*)	+	+	+	-	+			-		
	Salmonids	Chinook (*Oncorhynchus tshawytscha*)	+	+	+	+	+			+		
		Chum (*Oncorhynchus keta*)	+	+	+	+	+			+		
		Coho (*Oncorhynchus kisutch*)	+	+	+	+	+			+		
		Cutthroat (*Oncorhynchus clarki*)	+	+	-	-	-			-		
		Pink (*Oncorhynchus gorbuscha*)	+	-	-	+	-			-	+	3
		Steelhead (*Oncorhynchus mykiss*)	+	-	-	+	+			+		
	Sculpins	Buffalo Sculpin (*Enophrys bison*)	+	-	+	+	+	-	-	-		
		Leister Sculpin (*Euophrys lucasi*)	+	-	-	+	-	-	-	-		
		Sailfin sculpin (*Nautichthys oculofasciatus*)	+	-	+	-	-			-		
		Tidepool sculpin (*Oligocottus maculosus*)	+	-	+	-	-			-		
		Staghorn Sculpin (*Leptocottus armatus*)	+	+	+	-	-	-	-	-	+	1
	Stickle-backs	Three Spine Stickleback (*Gasterosteus aculeatus*)	+	+	+	+	+	-	-	+		
	Surf Perches	Pile Perch (*Rhacochilus vacca*)	+	-	+	+	+			+		
		Shiner Perch (*Cymatogaster aggregata*)	+	+	+	+	+			+		
		Surf Smelt (*Hypomesus pretiosus*)	+	+	+	+	+			+		2
	Syngn-athids	Syngnathids: Bay Pipefish (*Syngnathus leptorhynchus*)	+	+	+	+	+			+		
	Toad-fishes	Plainfin Midshipman (*Porichthys notatus*)	+	-	+	+	+	-	-	+		4

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			On-Reservation	Neptune Beach	Lummi Bay	Hale Passage	Portage Bay	Point Francis	Brant Area	Nooksack Delta	Seapond	
Macroalgae	Green	Ulva (*Ulva* species)	+	+	+	+	+	+	+	-	+	1
		Green Rope (*Acrosiphonia* species)	+	-		-	-	+	-			
	Brown	Green Acid Kelp (*Desmarestia ligulata*)	+	+		-	-	-	-			
		Rockweed (*Fucus distichus*)	+	+		+	+	+	-			
		Sea Cauliflower (*Leathesia difformis*)	+	-		-	-	+	-			
		Short Stiped Alaria (*Alaria marginata*)	+	-		-	-	-	+			
		Sugar Kelp (*Saccharina latissima*)	+	+	+	+	-	+	+			4
		Wireweed (*Sargassum muticum*)	+	+		-	-	-	-		+	
		Witches Hair (*Desmarestia aculeata*)	+	+		+	-	+	+			
	Red	Bleached Burnett (*Cryptosiphonia woodi*)	+	-		-	-	+	-			
		Bleachweed (*Prionitis* species)	+	+		+	+	+	+			
		Coarse Sea Lace (*Microcladia borealis*)	+	-		-	-	-	-			
		Irish Moss (*Chondrus crispus*)	+	-		+	-	-	-			
		Red Ribbon (*Palmaria mollis*)	+	+		-	+	-	-			
		Rusty Rock (*Hildenbrandia* species)	+	+		+	-	+	+			
		Turkish Towel (*Chondracanthus exasperatus*)	+	+		+	-	-	-			
		Turkish Washcloth (*Mastocarpus* species)	+	-		+	+	-	+			
Marine Mammals	Pinnipeds	Harbor Seal (*Phoca vitulina*)	+	-	+	+	+		+	+		4
		Sea Lion (*Zalophus californianus*)	+	+	-	-	-		+	-		4
Miscellaneous	Miscellaneous Animal	Bryozoan Not Identified (Phylum Bryozoa)	+	-	-	+	+	-	-	-		
		Chironomids (Family Chironomidae)	+	-	+	-	-	-	-	-		
		Hydrozoan (Class Hydrozoa)	+	-	+	-	-	-	-	-		
		Peanut Worm (Phylum Sipunculidae)	+	-	-	+	-	+	-	-		
		Sea Spider (Class Pycnogonida)	+	-	-	+	-	-	-	-		
		Tan Ribbon Worm (*Cerebratulus* species)	+	-	+	+	+	+	+	-		
		White Ribbon Worm (*Amphiphorus* species)	+	+	+	+	+	+	+	+		

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			On-Reservation	Neptune Beach	Lummi Bay	Hale Passage	Portage Bay	Point Francis	Brant Area	Nooksack Delta	Seapond	
Mollusks	Bivalves	Bentnose Clam (*Macoma nasuta*)	+	-	+	+	+	-	+	-	+	1
Mollusks	Bivalves	Butter Clam (*Saxidomus giganteus*)	+	+	+	+	+	+	+	-	-	1
Mollusks	Bivalves	Cockle (*Clinocardium nuttalli*)	+	+	+	+	+	+	+	+	-	1
Mollusks	Bivalves	Cryptomya (*Cryptomya californica*)	+	+	+	+	+	+	+	-	-	1
Mollusks	Bivalves	Fine Lined Lucine (*Parvalucina tennuisculpta*)	+	-	+	+	-	-	-	-	-	1
Mollusks	Bivalves	Geoduck Clam (*Panopea abrupta*)	+	-	+	+	-	-	-	-	-	1
Mollusks	Bivalves	Horse Clam (*Tresus* species)	+	+	+	+	+	+	+	-	-	1
Mollusks	Bivalves	Jack Knife Clam (*Solen sicarius*)	+	-	-	+	-	-	-	-	-	1
Mollusks	Bivalves	Macoma balthica (*Macoma balthica*)	+	-	+	+	+	+	+	+	-	1
Mollusks	Bivalves	Macoma inquinata (*Macoma inquinata*)	+	+	+	+	+	+	+	+	+	1
Mollusks	Bivalves	Macoma secta (*Macoma secta*)	+	-	+	+	-	-	-	-	-	1
Mollusks	Bivalves	Mahogany Clam (*Nuttalia obscurata*)	+	+	+	+	+	+	+	+	-	1
Mollusks	Bivalves	Manila Clam (*Venerupis phillipinarum*)	+	-	+	+	+	+	+	-	+	1
Mollusks	Bivalves	Pacific Littleneck (*Leukoma staminea*)	+	+	+	+	+	+	+	-	-	1
Mollusks	Bivalves	Pacific Blue Mussel (*Mytilus trossulus*)	+	+	+	+	+	+	+	-	-	1
Mollusks	Bivalves	Pacific Oyster (*Crassostrea gigas*)	+	-	+	-	+	-	+	-	+	1, 6
Mollusks	Bivalves	European Flat Oyster (*Ostrea edulis*)	+	-	-	-	-	-	-	-	+	1
Mollusks	Bivalves	Purple Dwarf Venus (*Nutricola tantilla*)	+	-	+	+	+	+	+	-		
Mollusks	Bivalves	Robust mysella (*Rochefortia tumida*)	+	-	+	-	-	-	-	-		
Mollusks	Bivalves	Softshell Clam (*Mya arenaria*)	+	+	+	+	+	+	+	-	+	1
Mollusks	Bivalves	Straight Fan Horsemussel (*Modiolus rectus*)	+	-	+	-	-	-	-	-	-	1
Mollusks	Bivalves	Telina Clam (*Tellina* species)	+	-	+	+	+	+	+	-	+	1
Mollusks	Bivalves	Thin Shelled Littleneck (*Callithaca tenerrima*)	+	-	+	+	-	-	+	-	-	1
Mollusks	Bivalves	Western Ringed Lucine (*Lucinoma annulatum*)	+	-	+	+	-	+	+	-	-	1
Mollusks	Bivalves	Wrinkled Montacutid (*Nearomya rugifera*)	+	-	-	+	-	-	-	-	-	1
Mollusks	Chitons	Coopers Chiton (*Lepidozona cooperi*)	+	+	-	-	-	-	-	-		
Mollusks	Chitons	Woody Mopalia (*Mopalia lignosa*)	+	+	-	-	-	+	+	-		

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Mollusks	Limpets	Eelgrass Limpet (*Lottia parallela*)	+	-	+	+	+	-	-	-		
Mollusks	Limpets	Limpet Not Identified (Clade Patellogastropoda)	+	+	-	-	-	-	-	-		
Mollusks	Limpets	Mask Limpet (*Tectura persona*)	+	+	+	+	+	+	+	-		
Mollusks	Limpets	Plate Limpet (*Tectura scutum*)	+	+	-	+	+	+	+	-		
Mollusks	Limpets	Shield Limpet (*Lottia pelta*)	+	+	-	+	-	+	-	-		
Mollusks	Sea-slugs	Bubble Snail (*Haminoea* species)	+	-	+	+	-	-	-	-		
Mollusks	Sea-slugs	Dorid Nudibranch (Superfamily Doridoidea)	+	-	-	-	-	+	-	-		
Mollusks	Snails	Black Turban (*Tegula funebralis*)	+	-	-	-	+	-	-	-		
Mollusks	Snails	Checkered Periwinkle (*Littorina scutulata*)	+	+	+	+	+	+	+	-		
Mollusks	Snails	Chink Shells (*Lacuna* species)	+	+	+	+	+	+	-	-		
Mollusks	Snails	Horn Shell (*Batillaria attramentaria*)	+	-	+	+	+	+	+	-		
Mollusks	Snails	Lewis' Moon Snail (*Polinices lewisii*)	+	+	-	-	-	-	-	-		
Mollusks	Snails	Odostomia (*Odostomia* species)	+	-	+	+	+	+	+	-		
Mollusks	Snails	Orobitella (*Orobitella rugifera*)	+	-	-	-	-	+	-	-		
Mollusks	Snails	Puppet Margarites (*Margarites pupillus*)	+	-	-	+	-	-	-	-		
Mollusks	Snails	Sitka Periwinkle (*Littorina sitkana*)	+	+	-	+	+	+	+	-		
Mollusks	Snails	Trochid Snail (Family Trochidae)	+	-	-	+	-	-	-	-		
Mollusks	Snails	Turbonilla Snail (*Turbonilla* species)	+	-	-	-	-	-	+	-		
Mollusks	Snails	Turridae (*Ophiodermella inermis*)	+	-	-	+	-	-	-	-		
Mollusks	Whelks	Amphissa columbiana (*Amphissa columbiana*)	+	-	+	+	+	-	+	-		
Mollusks	Whelks	Channelled DogWinkle (*Nucella canaliculata*)	+	-	-	-	-	+	-	-		
Mollusks	Whelks	Dire Whelk (*Lirabuccinum dirum*)	+	+	-	+	+	-	+	-		
Mollusks	Whelks	Frilled Dogwinkle (*Nucella lamellosa*)	+	+	+	+	+	+	+	-		
Mollusks	Whelks	Japanese Nassa (*Nassarius fraterculus*)	+	-	+	+	+	-	+	-		
Mollusks	Whelks	Ribbed Dogwinkle (*Nucella emarignata*)	+	-	-	+	-	-	-	-		
Mollusks	Whelks	Western Lean Nassa (*Nassarius mendicus*)	+	-	+	-	+	+	+	-		
Porifera	Sponges	Sponge Not Identified (Phylum Porifera)	+	-	-	+	-	-	-	-		

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Vascular Plants	Eel-grass	Japanese Eelgrass (*Zostera japonica*)	+	-	+	+	+	+	+	-	-	1
Vascular Plants	Eel-grass	Pacific Eelgrass (*Zostera marina*)	+	-	+	+	+	+	+	+	+	1,5
Vascular Plants	Salt-marsh	Pickleweed (*Salicornia virginica*)	+	-	+	-	-	-	+	+		4
Vascular Plants	Salt-marsh	Saltmarsh Dodder (*Cuscuta salina*)	+	-	+	-	-	-	+	+		4

Key to Additional Sources

1. Dolphin, C.H. Unpublished Data. Results of venturi suction dredge surveys of the Lummi Bay Aquaculture facility in 2002 and 2005.
2. Dolphin, C.H. Unpublished Data. Lampara Survey of Bellingham Bay and Hale Passage in 2005.
3. Dolphin, C.H. Unpublished Data. Dip net collection of juvenile finfish inside northern tidegate of the Lummi Bay Aquaculture facility in May 2008.
4. Dolphin, C.H. Personal Observation
5. LeMoine, M. Personal Observation
6. Dolphin, C.H. Unpublished Pacific Oyster Survey Data.

6.0 Abundance

6.1 Benthic Fauna

Figure 6.1 shows the relative abundance of taxa of benthic fauna that were present in the samples collected at the 366 sites across the Reservation tidelands.

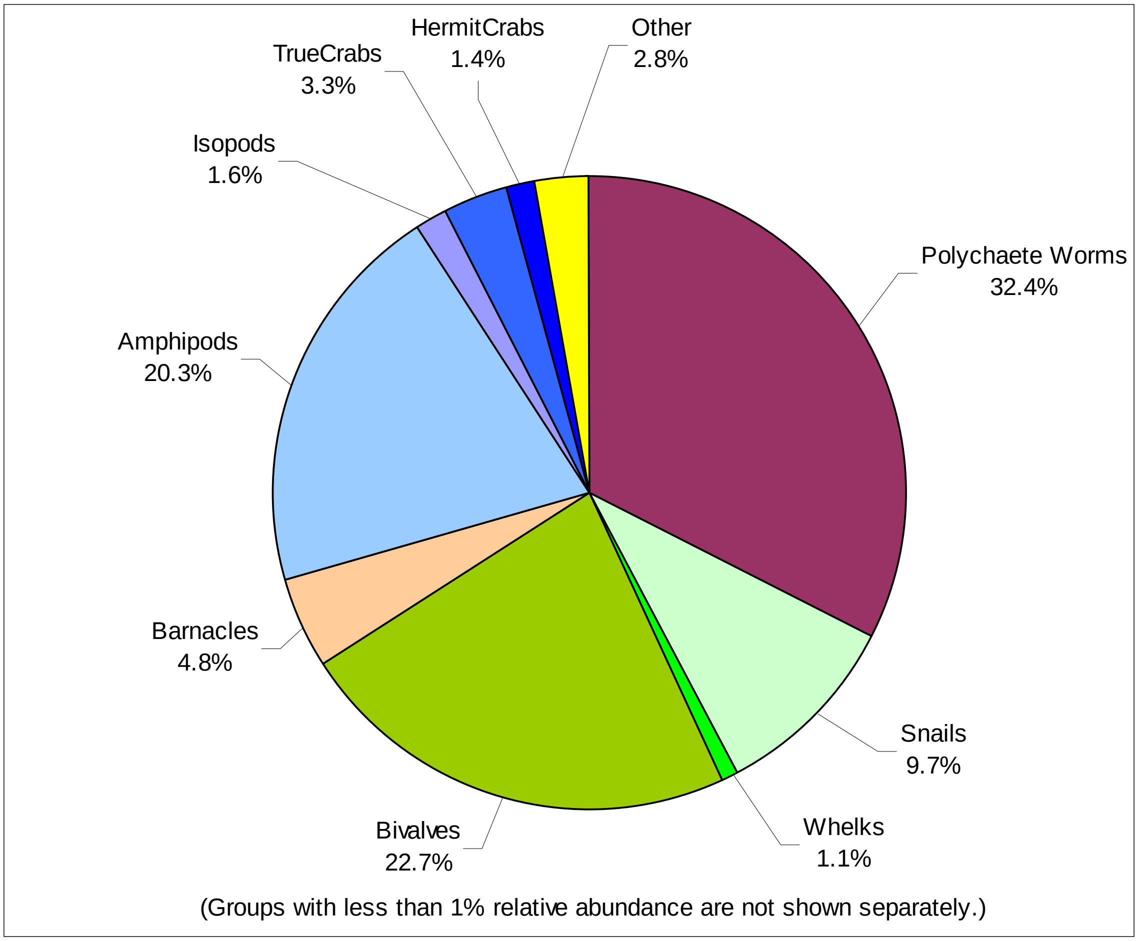
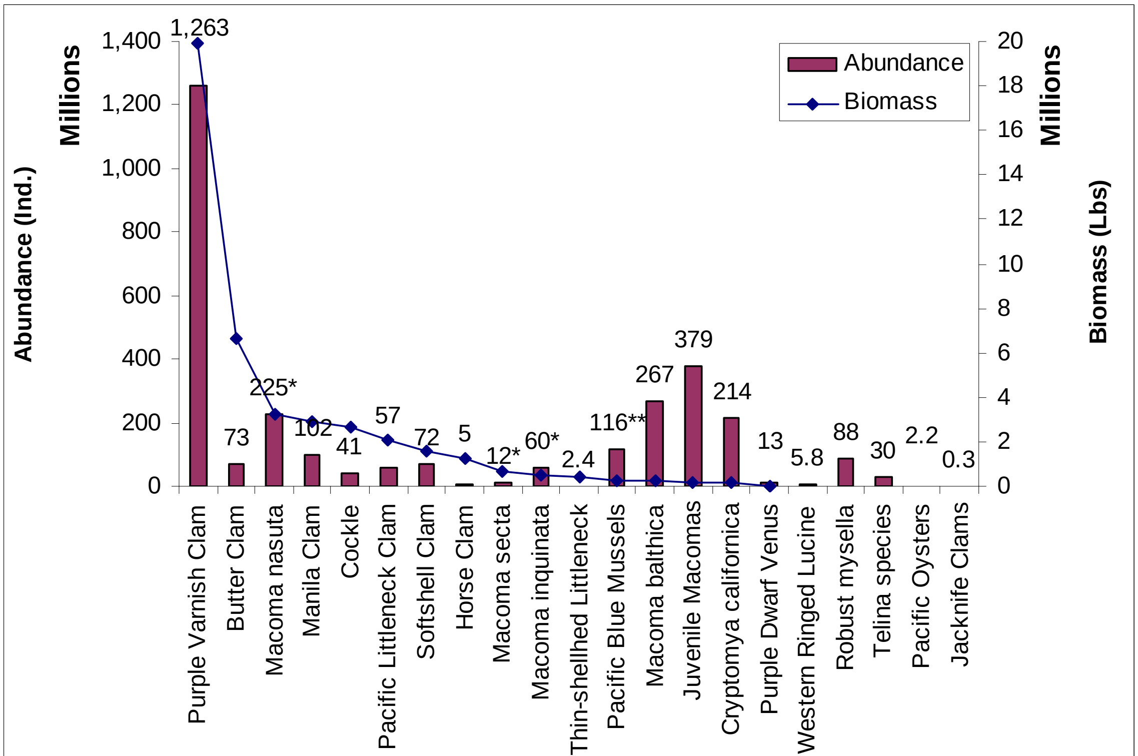


Figure 6.1. Relative Abundance of Benthic Fauna in LIBI Samples

Most abundant were polychaete worms (dominated by worms in the family Oweniidae, which were also the most abundant single taxon encountered during the survey). Bivalves represented the second most abundant group of organisms, and this was primarily due to the abundance of purple varnish/Mahogany clams and clam species in the *Macoma* genus. Amphipods were the third most common group of fauna encountered in the samples due to the very high abundance of *Caprella* sp. amphipods. Amongst the snails, the most common taxa were horn shells (*Batillaria attramentaria*) followed by two periwinkle species (*Littorina* sp.) The most abundant of the whelks was the western lean nassa (*Nassarius mendicus*). The most abundant barnacle was the acorn barnacle (*Balanus glandula*). The most abundant true crab was the Oregon shore crab (Hemigrapsus oregonensis) while the hermit crabs were divided equally between hairy hermit crabs (*Pagurus hirsutiusculus*) and grainy hermit crabs (*P. granosimanus*). The most abundant isopod was the pill bug isopod.

Absolute abundance was calculated only for bivalves. The estimated absolute abundance and biomass of bivalves is presented in Figure 6.2. The most abundant bivalve species was the purple varnish/mahogany clam, which was estimated to number 1.26 billion individuals (excluding young of the year) and has a collective biomass of approximately 19.9 million pounds (lbs). The only other clam population that has a comparable biomass are butter clams, which collectively have an estimated biomass of 6.7 million pounds. The large biomass of butter clams is primarily due their much heavier individual weights, because the estimated abundance of butter clams is a comparatively low 73 million individuals. The Manila clam biomass estimate from the LIBI survey was comparable in magnitude to estimates derived in previous survey work. Overall, there are 102 million Manila clams estimated to inhabit the Lummi Reservation tidelands, which had a collective biomass of 2.9 million pounds (of which 2.4 million pounds was harvestable, based on a 38 millimeter minimum size criterion). Further discussion of other species is provided in Appendix A.



These results exclude biomass or abundance from the Lummi Bay Seapond. Numbers indicate the numerical abundance (millions of individuals) of species.

* Individuals <20-mm shell length are considered separately.

** Not all mussels were retained in samples. See methods in Appendix A

Figure 6.2. Comparison of Abundance and Biomass Estimates for Bivalves on the Lummi Reservation Tidelands

6.2 Benthic Flora

Absolute abundance was calculated for Pacific eelgrass (*Zostera marina*) and Japanese eelgrass (*Zostera japonica*) shoots on Reservation tidelands. Overall, the number of shoots of Japanese eelgrass was estimated to be approximately 900 million and the number of shoots of Pacific eelgrass was estimated to be approximately 680 million shoots. However, the blades of Japanese eelgrass are much narrower and relatively short compared to Pacific eelgrass. Consequently, Pacific eelgrass is a much more obvious species and provided greater surface coverage across the tidelands than Japanese eelgrass does (Figure 6.3). It should be noted that more Pacific eelgrass was present, but not counted, at lower elevations than were surveyed during the Intertidal Biota Survey.

Although macroalgae were not counted as individuals, it is clear that green macroalgae (almost entirely *Ulva* spp.) is particularly abundant around the tidelands, with lesser amounts of brown and red macroalgae also contributing vegetative cover in some areas. Saltmarsh communities are present in some locations, particularly northern Lummi Bay and the Nooksack Delta, but these communities are generally located just above the upper vertical boundary of the area that was surveyed in this study.

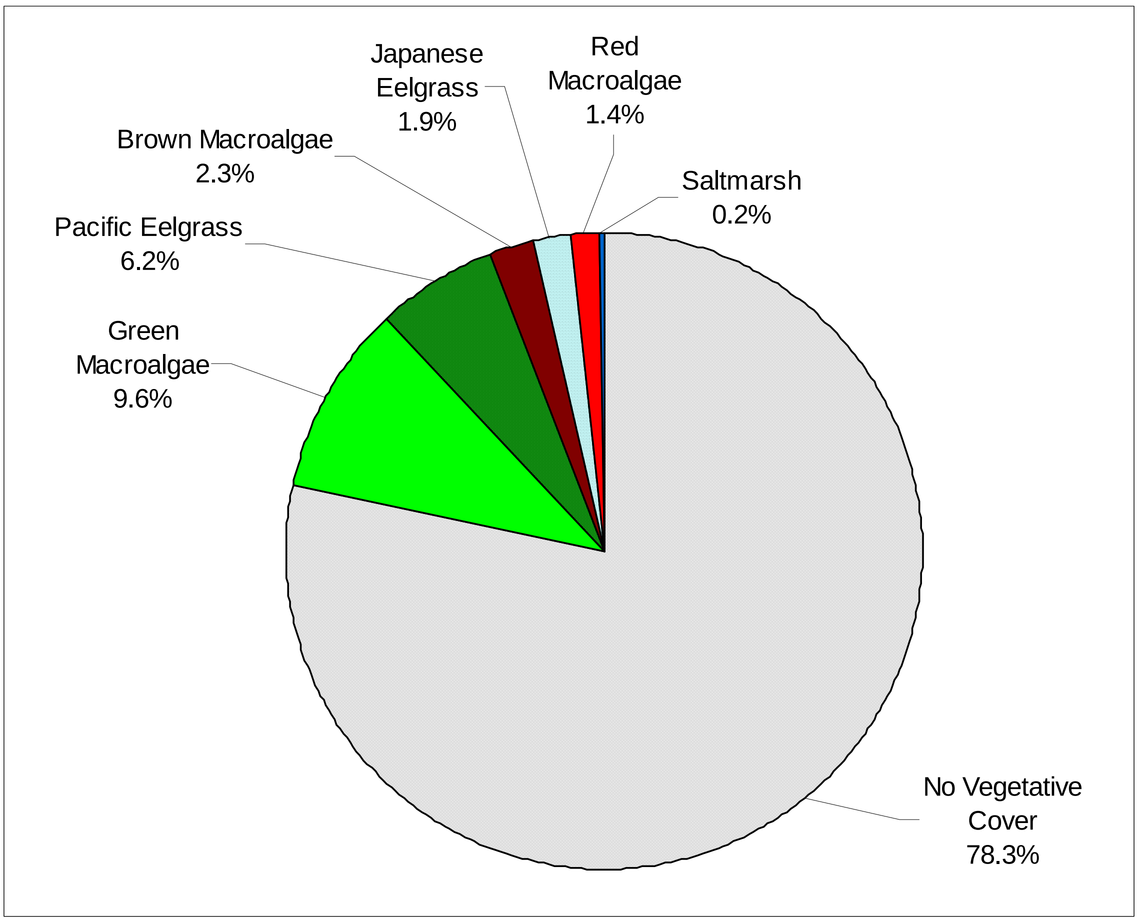


Figure 6.3. Vegetative Surface Coverage Estimated from 366 Intertidal Biota Survey Sites

6.3 Finfish

The majority of finfish encountered during the finfish survey were sticklebacks (35%), forage fishes (29%), surf perches (27%), pricklebacks (5%), and salmonids (2%) (Figure 6.4). The stickleback species encountered was the three-spine stickleback. The most common forage fish was the Pacific herring and the most common surf perch was the shiner perch. The most abundant prickleback was the snake prickleback (*Lumpenus sagitta*). Chinook salmon, coho salmon, chum salmon, pink salmon, steelhead, and cutthroat trout were all encountered on the Reservation tidelands, with the most commonly encountered species being Chinook salmon. Generally, finfish abundance on the tidelands varied seasonally with the highest catches occurring during the summer months (Appendix C).

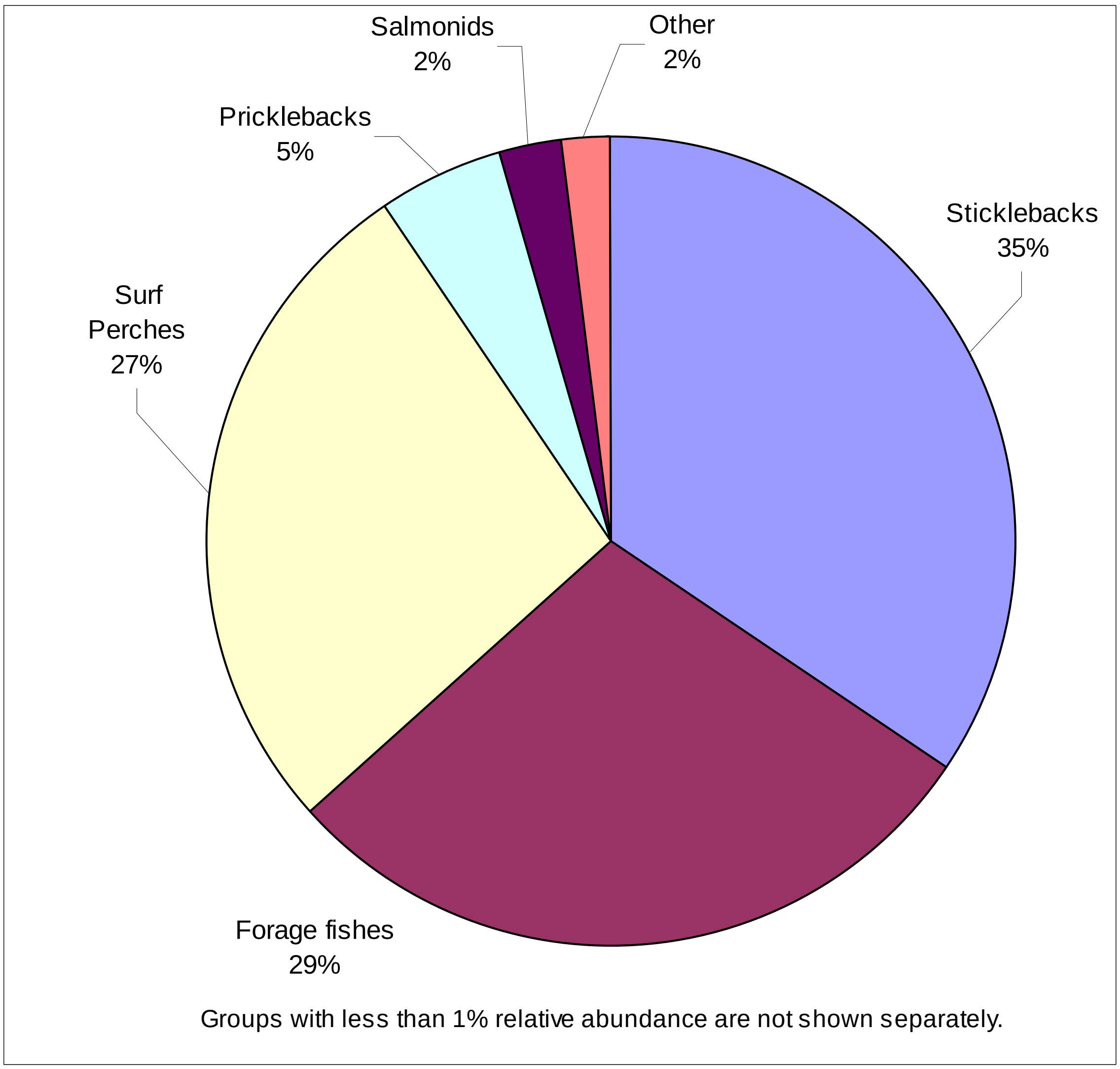


Figure 6.4. Relative Abundance of Finfish Groups in Lampara Catches

6.4 Birds and Marine Mammals

Generally, the majority of birds observed were migratory waterfowl including ducks (77%) and geese (8%), but gulls (8%), cormorants (2%), and plovers (2%) were also relatively common (Figure 6.5). The most abundant duck species were northern pintail, american widgeon, mallard, greater scaup, and surf scoter. The glaucous-winged gull was the most abundant gull, and the brant was the most common goose. The double-crested cormorant was the most common of the cormorant species observed, and the dunlin was the most common plover species encountered. Generally, bird abundance varied seasonally with the highest counts occurring during the fall and winter months (Appendix D).

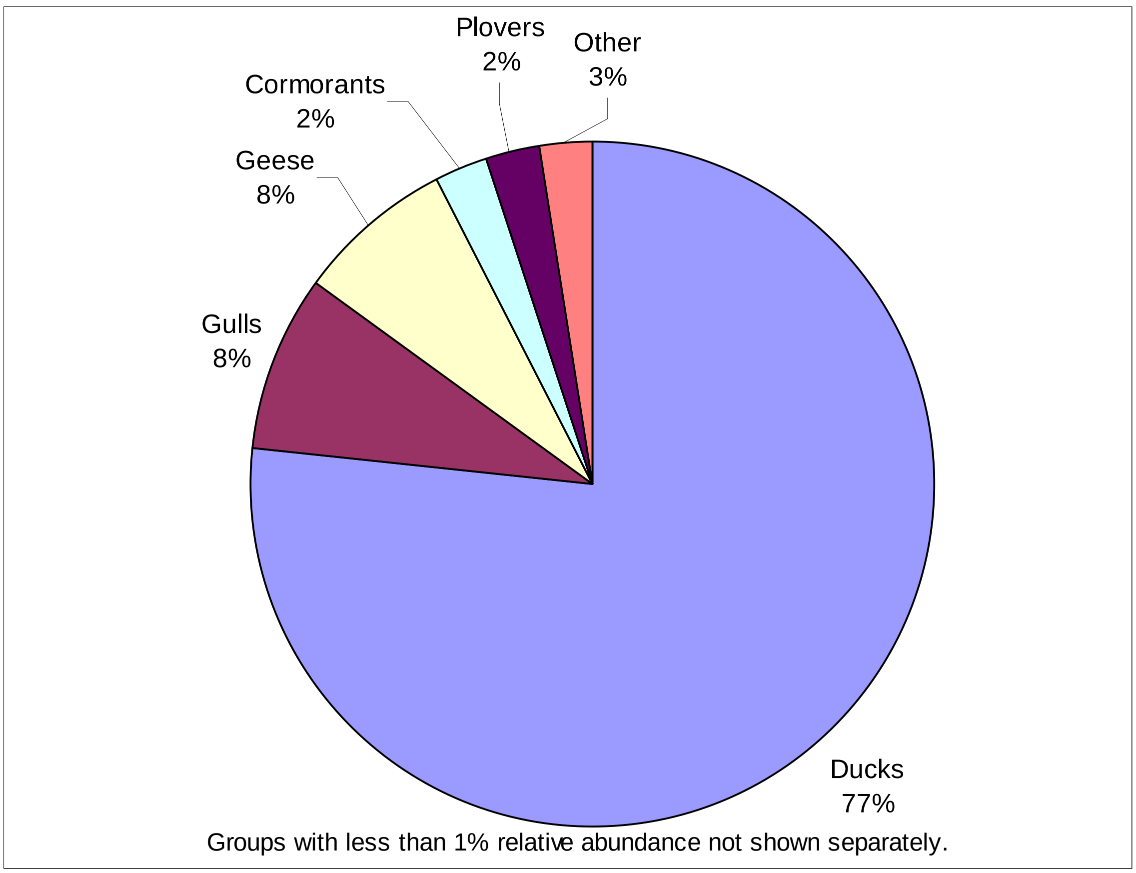


Figure 6.5. Relative Abundance of Bird Groups

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7.0 Environment

7.1 Description of Environment by Area

The substrate characteristics of the study area were described and enumerated during the Intertidal Biota Survey. As shown in Figure 7.1 through Figure 7.5, the study area was subdivided into seven geographic areas: Neptune Beach, Lummi Bay, Hale Passage, Point Francis, Brant, Portage Bay, and Nooksack Delta.

Neptune Beach is a highly exposed (Figure 7.1) and relatively steep (Figure 7.3) shore that is dominated by mobile fine-gravel and sand substrates, without significant amounts of mud over most of the vertical extent of the beach (Figures 7.2 and 7.4). However, at the bottom part of the beach there is a moderately narrow rocky/mud-sand platform that is present at the northern and southern ends of the beach, but not the middle part of the shoreline. Adjacent to the Sandy Point Marina channel entrance, and at the northern end of the beach, this platform is primarily composed of mixed coarse substrates and features a diverse macroalgae community (Figure 7.5). There are also dense kelp beds that are visible offshore in the northern-most part of the area. The remainder of the platform is an eelgrass meadow growing on a mixture of mud and sand substrates. This eelgrass meadow was not sampled in the Intertidal Baseline Inventory because it happened to fall between the systematically assigned transect locations.

Lummi Bay is mostly comprised of sand and mud substrates, with limited amounts of gravel near the top of the beach along some parts of the shoreline including Sandy Point and along the Lummi Peninsula (Figures 7.2 and 7.4). An exposed sandy berm exists along the waterward extent of Lummi Bay that acts to retain extensive pools of shallow seawater along the outer third of the bay (Figure 7.3). The outermost portions of the bay are very exposed to wind and wave energy with a gradual reduction of exposure across the middle elevations. Finally, some very protected areas can be found in the upper portions of northern Lummi Bay and south Lummi Bay (Figure 7.1). A pickleweed (*Salicornia virginica)* salt marsh is present near the upper tideline in northern Lummi Bay. Below this, a rich film of diatoms was observed across much of the upper intertidal elevations. In the middle elevations, expansive meadows of Japanese eelgrass are present, which extend down the shore where they have a limited zone of overlap with the dense meadows of Pacific eelgrass that are dominant at the lower elevations. The Pacific eelgrass meadows mix with *Ulva* spp. and occasionally sugar kelp near the subtidal fringe and in places with permanent standing seawater (Figure 7.5). The Lummi River discharges through two freshwater channels that are located at the northern portion of Lummi Bay; the larger of these channels forms the boundary between the northern and the central sub-areas of Lummi Bay. The Seapond has two outflow channels that cross the Lummi Bay tidelands. The northernmost tide-gates release water into a short channel that intercepts the primary Lummi River channel. The southernmost tide-gates are associated with a much longer channel, which was used as the boundary between the central and southern sub-areas of Lummi Bay.

Hale Passage has a mixture of fine and coarse substrates (Figure 7.4) but typically is characterized as having embedded gravels/cobbles near the top and middle parts of the beach, with a broad sand/mud platform near the waterward extent of the beach (Figure 7.2). At the subtidal fringe there are also shore-parallel bars of exposed sand along parts of the shoreline. The width of the sand/mud platform varies depending on whether it is located on a point, in a bay, or sheltered from current. The primary vegetation present in this area are expansive meadows of Pacific eelgrass on the lower elevation mudflats, mixed with large foliose macroalgae (*Ulva*, sugar kelp) near the subtidal fringe.

The tidelands in the Point Francis area are exposed (Figure 7.1), slope steeply (Figure 7.3), and are dominated by a barnacle-covered array of cobbles, boulders, and gravel, which also extends downwards into the subtidal zone. The subtidal fringe is covered by a diverse array of macroalgae on the rocky substrates (Figure 7.5), and occasionally some Pacific eelgrass patches can also be found. There are also localized pockets of exposed sand/shell (Figure 7.4).

The Brant area is a highly heterogeneous mixture of substrates including: cobble fields; shore-parallel bar/swale complexes; broken shell/fine gravel; protected mud/sand/gravel; and exposed flats of clean sand mixed with sub-surface gravels and cobble (Figures 7.2 and 7.4). Generally, the bar/swale complexes are typically embedded-gravel/cobble bars that are separated by swales of predominantly fine sediments and dense meadows of Pacific eelgrass. The amount of mud within the fine sediments ranges from no mud at the lower end of the beach where the substrates are fully exposed to the southeast wind to being dominated by mud in the areas of the lower beach that are fully protected from wave energy. Many of the bars in this area also have diffuse beds of oysters, barnacles, and broken shell (Figure 7.5).

Portage Bay tidelands are comprised of a vast platform of very soft exposed mud in the most sheltered parts of the bay, and by isolated cobbles, boulders, and embedded gravels along sections of the upper shoreline (Figures 7.2 and 7.4). Small pockets of Pacific eelgrass are scattered across the mudflat (Figure 7.5). An unnamed freshwater creek that drains a large wetland area also discharges into the middle of this bay from Portage Island.

The Portage Spit sub-area is primarily composed of a mixture of mud/sand/gravel overlain by a dense mat of mussels on the middle elevations. There is also a loose field of coarse gravels on the side facing Hale Passage.

The Lummi Shore Road tidelands are primarily dominated by a broad fine-sediment platform at lower elevations, which is mostly a mixture of sand and mud at the surface but is underlain by a hardpan clay layer that starts at depths from 2 inches or deeper below the surface. This platform has extensive Pacific eelgrass meadows in the protected parts of the shoreline near Portage Bay, but these meadows become more fragmented as exposure to wind/wave energy increases, and are absent before reaching the Nooksack Delta.

The Nooksack Delta substrates are mostly homogenous expanses of exposed coarse sand, with some driftwood fragments mixed in at some upper locations and some soft mud near the subtidal fringe in the middle part of the delta (Figures 7.2 and 7.4). Vegetation in the Nooksack Delta area is mostly restricted to pickleweed salt marsh beyond the upper extent of the study area and some small isolated stands of Pacific eelgrass near the subtidal fringe. However, there was no vegetative coverage at the sites that were sampled (Figure 7.5).

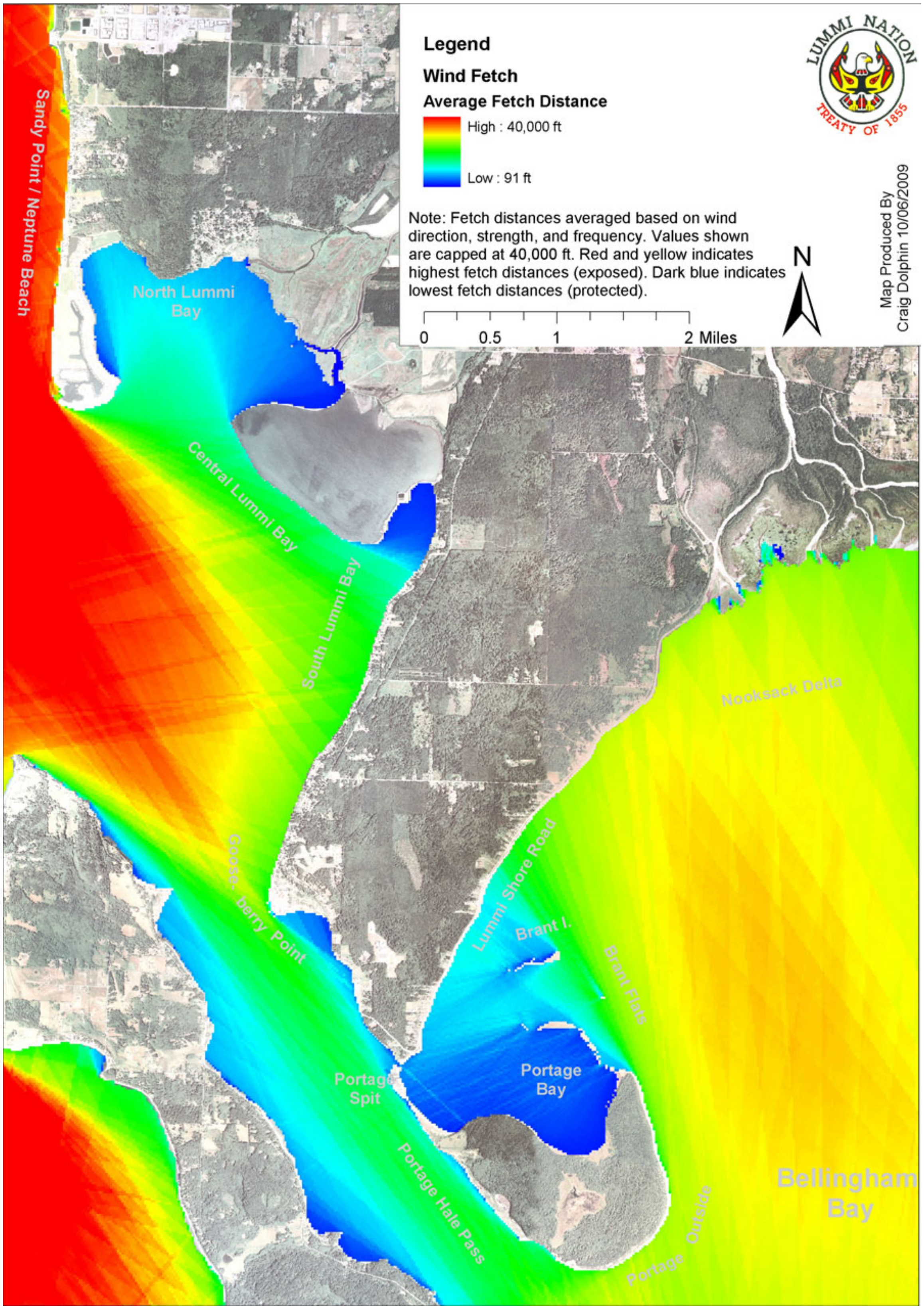

Figure 7.1. Average Wind Fetch Distance (Appendix H)

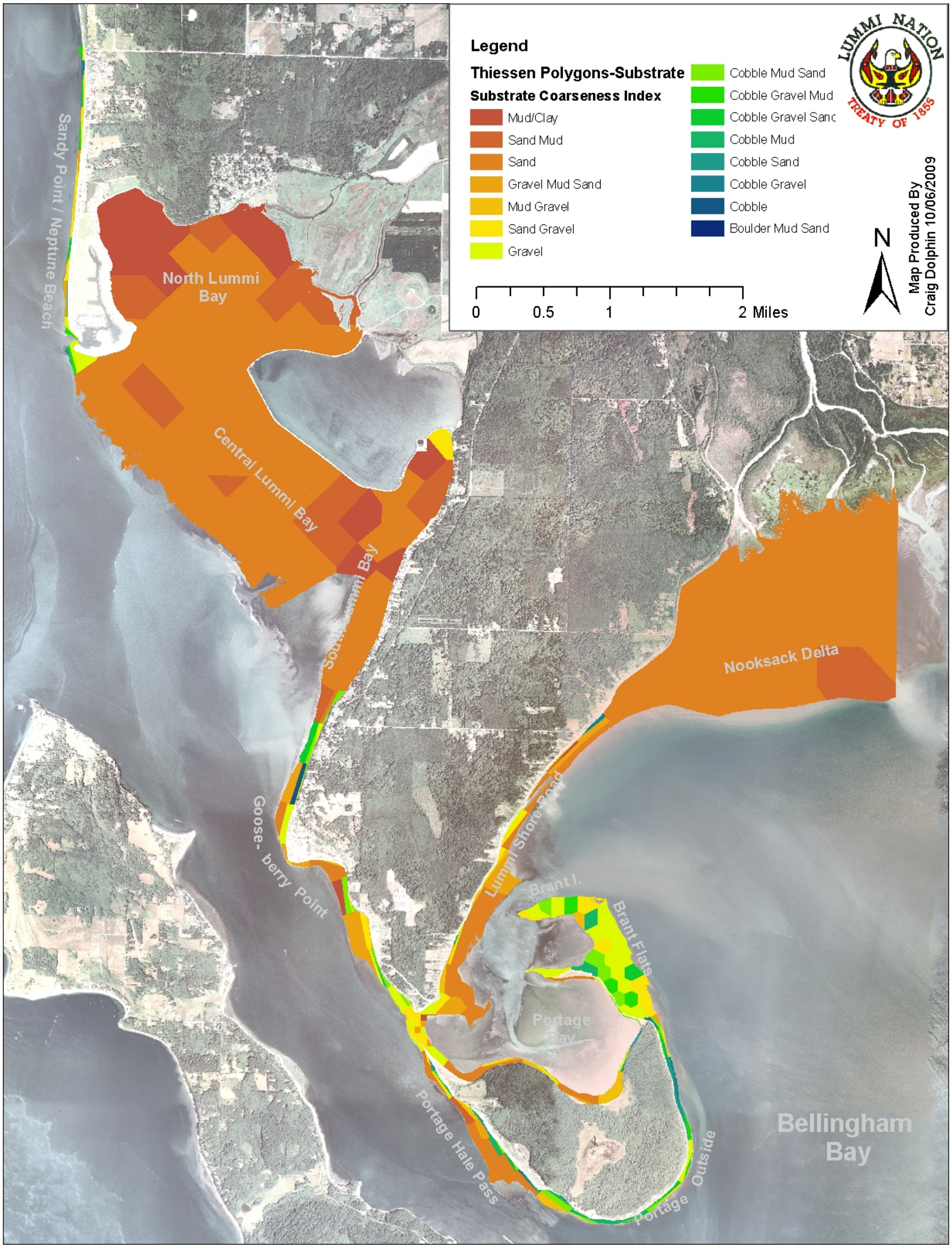

Figure 7.2. Tideland Substrate Classifications (Appendix H)

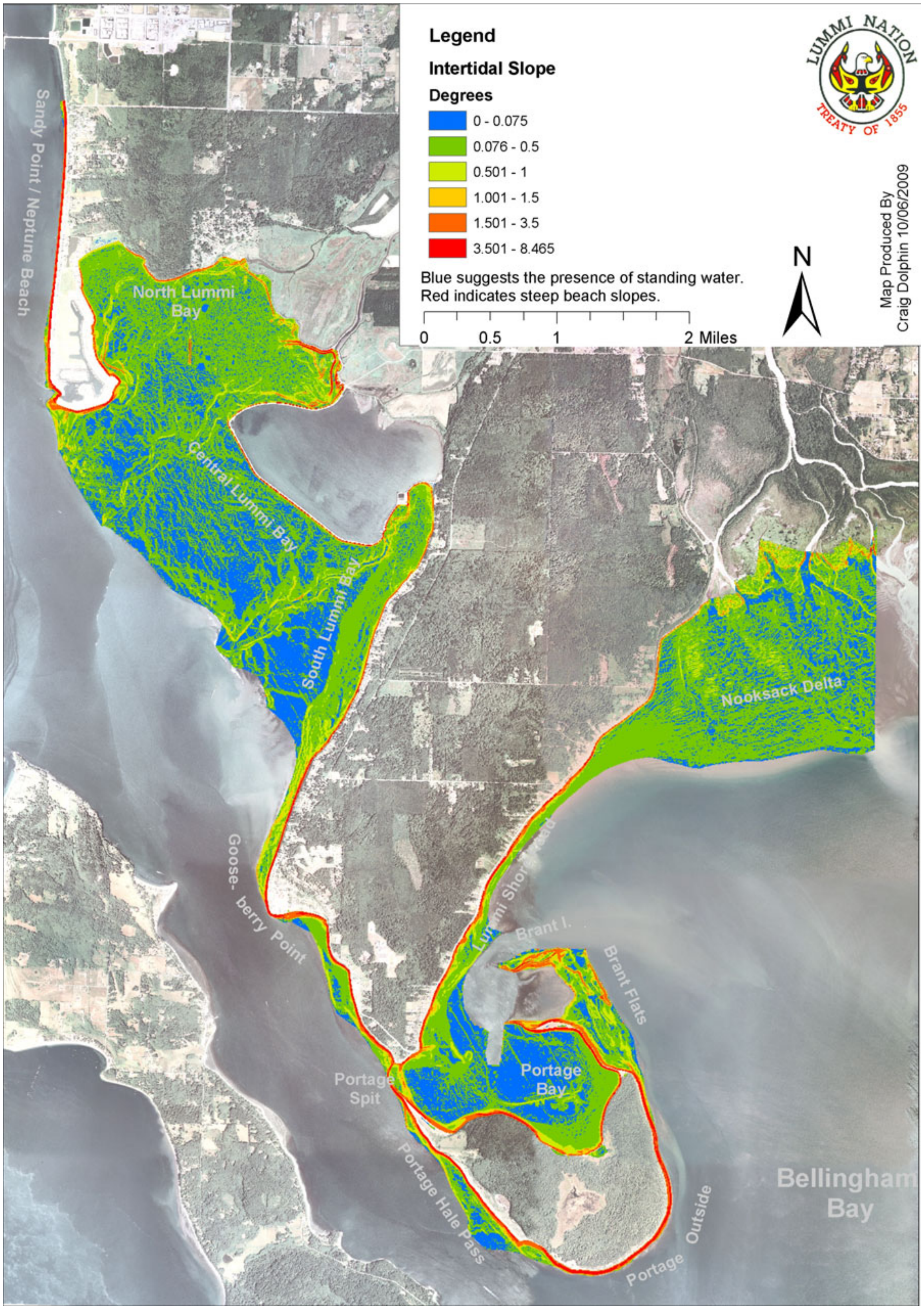

Figure 7.3. Beach Slopes (Appendix H)

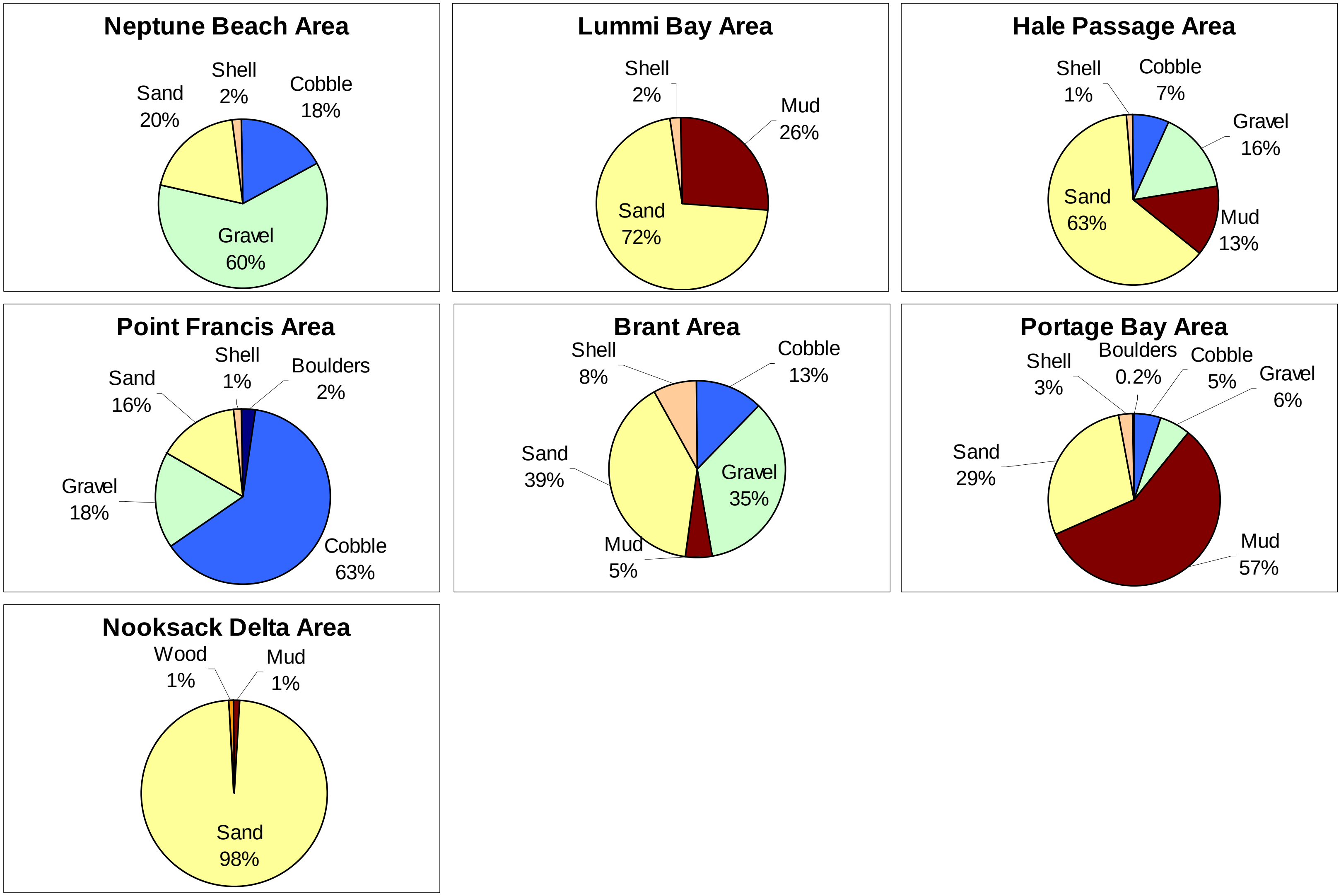

Figure 7.4. Comparison of Surface Substrates by Geographical Area

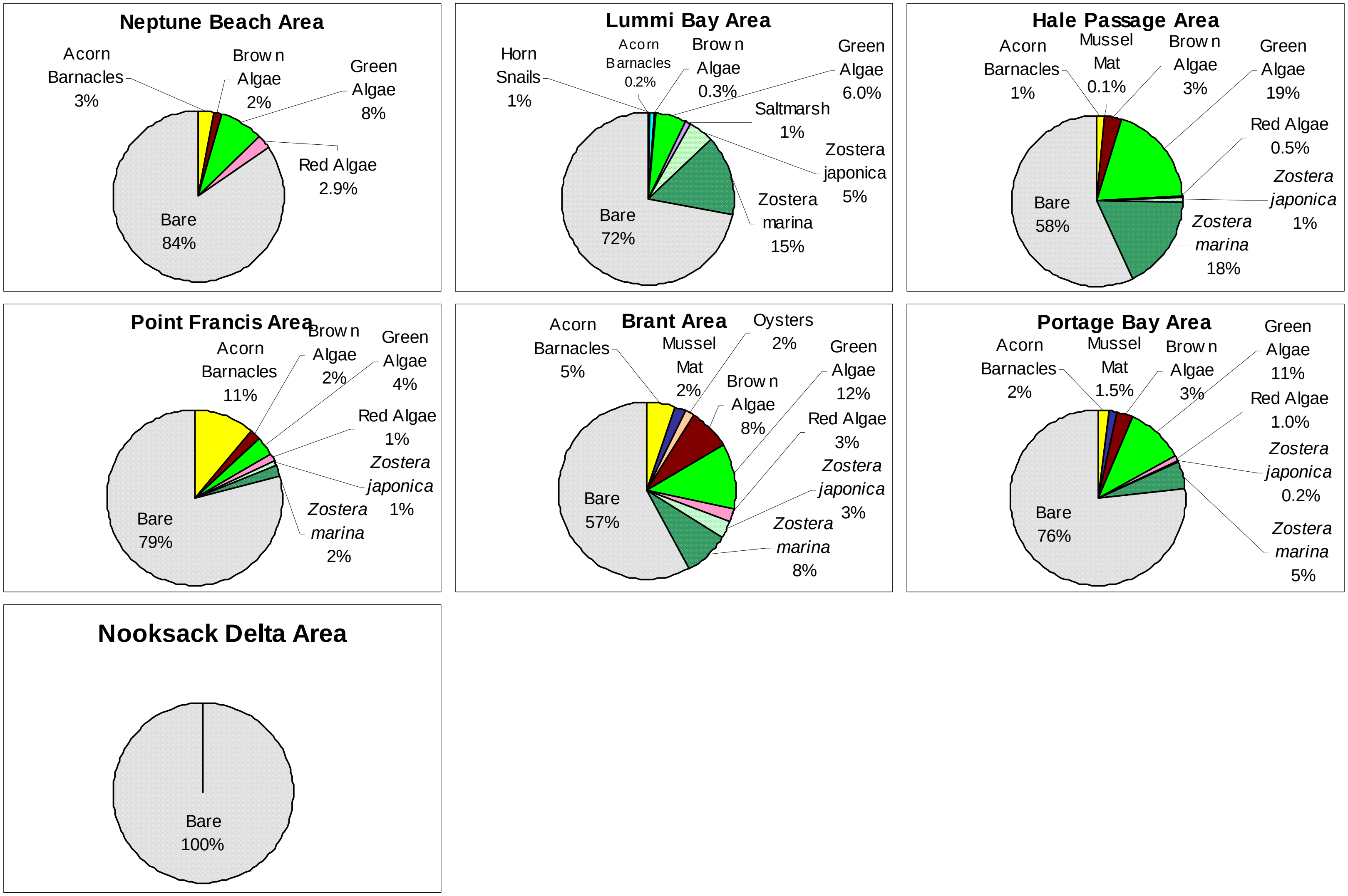

Figure 7.5. Comparison of Surface Coverages by Geographical Area

7.2 Environmental Gradients

The LIBI Final Work Plan (LeMoine *et al*. 2009) identified the need to document the ecological interactions between habitat variables and biota. To achieve this objective, habitat variables were derived through a Geographical Information System (GIS) analysis (Appendix H), and from field data collected during the Intertidal Biota Survey. These variables were analyzed using a Detrended Correspondence Analysis (DCA) to determine which measured environmental gradients may be influencing the diversity and abundance of communities that are present on the Reservation tidelands (Appendix I).

Overall, several environmental gradients were identified that each related significantly to the diversity and abundance of communities found among sites across the Reservation tidelands. These gradients were: tidal elevation, beach slope, salinity, substrate size (Substrate Coarseness Index), percent coverage of acorn barnacles, percent coverage of mussels, percent coverage of Japanese eelgrass, percent coverage of Pacific eelgrass, and percent coverage of red, brown, and green algae.

The five environmental parameters that appeared to have the most biological significance were tidal elevation, beach slope, substrate coarseness index values (substrate size), surface cover of Pacific eelgrass, and salinity. Each of these environmental variables influence different taxa in different ways, which consequently helps explain the observed differences in community structure between sites. For example, Figure 7.6 illustrates the overlapping vertical ranges of populations of some selected clam species based on beach elevation. The correlations between these variables and selected species are provided in Appendix A.

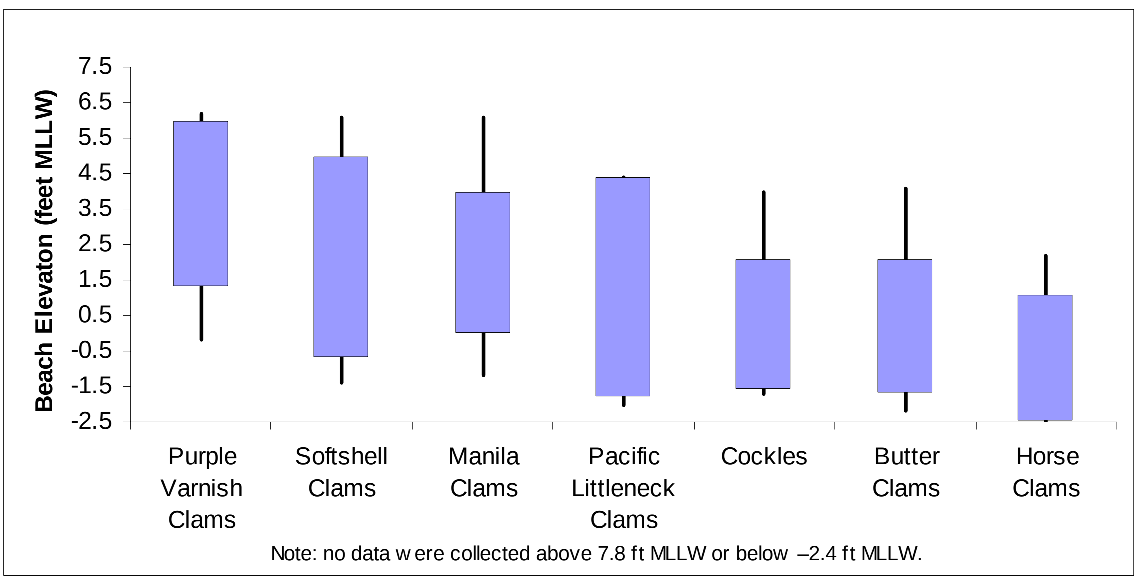

Figure 7.6. Vertical Population Limits and 90% Ranges for 7 Intertidal Clam Species Based on the Results of the LIBI Intertidal Biota Survey

7.3 Environmental Baseline (Hydrocarbons)

Baseline concentrations of organic compounds from petroleum and petroleum by-products in Lummi Bay and Portage Spit were generally below detectable levels (Appendix F). However, very low concentrations of Napthalene (15 parts per billion [ppb]) and Phenathrene (6 ppb) were detected in the sediment of the upper elevation sub-sample of the Lummi Bay site.

Neither the Lummi Nation nor the Federal government have adopted sediment quality criteria. Washington State has adopted a ‘no effect’ marine sediment quality criteria of 99 parts per million (ppm) for Napthalene, and 100 ppm for Phenathrene (WAC 172-204-320 (a)). The concentrations observed in this study for these two chemicals are significantly below these ‘no effects’ sediment quality criteria for these chemicals in marine sediments.

8.0 Spatial Trends

8.1 Taxonomic Diversity

Neptune Beach, Hale Passage, Portage Bay, and the Nooksack Delta were all surveyed using a wide array of methods. The survey methods had the potential to detect over 99% of all of the taxa that are known to be present on the Reservation tidelands (Table 5.1). Macroalgae were not recorded for Lummi Bay because the two field teams with expertise in macroalgae identification did not sample at low elevation sites in Lummi Bay. Accordingly, only 94% of the taxa in Table 5.1 had a reasonable chance of detection in Lummi Bay during the LIBI.

The lowest relative taxonomic diversity was found on the Nooksack Delta where only 28% of taxa listed in Table 5.1 were encountered. Neptune Beach and Portage Bay had intermediate diversity results with 48% and 52% of taxa present in those areas respectively. Lummi Bay and Hale Passage both had high relative taxonomic diversity, with 73% and 68% of the taxa in Table 5.1 present in those areas.

No bird surveys or finfish surveys were conducted in the Brant area or the Point Francis area, which eliminated the possibility of detecting 35% of the total number of taxa recorded in Table 5.1 in those two areas. Taking this into account, the diversity in the Brant Area was equivalent to 49%, and the Point Francis Area had a diversity equal to 52% of the taxa listed in Table 5.1. If bird surveys and finfish surveys had been conducted in those two areas, then it is likely that the final diversity would have equaled or exceeded that found in Lummi Bay and Hale Passage.

8.2 Spatial Distributions

Spatial distributions were mapped for species of particular interest as outlined in the LIBI Final Work Plan (LeMoine *et al*. 2009), based solely on the data collected during the project. These maps for selected species of interest (e.g., butter clams, horse clams, cockles, scoters, Pacific herring, and others) are presented in Appendices A, B, C, and D.

Except for Manila clams and (to a lesser extent) Pacific oysters, there was comparatively little pre-existing data with sufficient spatial metadata that could be combined with the LIBI data. Six years of annual Manila clam survey data were combined with the results from the LIBI Intertidal Biota Survey and the resulting distribution map for Manila clams is shown in Figure 8.1. A subset of the Manila clam survey data also contained counts of Pacific oysters. These data were combined with the LIBI data for Pacific oysters and the resulting distribution map is shown in Figure 8.2.

Overall, the density of total benthic organisms was highest at the Brant Area, Lummi Bay, Point Francis, and Hale Passage (Figure 8.3). Densities were slightly lower in Portage Bay and lowest overall at the Nooksack Delta. Densities were most variable at Neptune Beach due to the dichotomy in habitats in that area: the middle and upper part of the beach was almost entirely devoid of biota, while the lowest part of the beach was very productive.

Generally speaking, birds were more numerous in Lummi Bay and Portage Bay and were least numerous on Neptune Beach and Bellingham Bay (Figure 8.4). However, bird abundance was also more variable in Lummi Bay and Portage Bay due to the seasonal migratory behavior of the ducks and geese that are present in these areas during the winter but that are generally absent during the summer.

The highest catches of finfish were in Bellingham Bay, followed by Portage Bay, Hale Passage, Lummi Bay, and lastly Neptune Beach (Figure 8.5). Catch variability was highest in Bellingham Bay and Hale Passage. In the case of Hale Passage, the high average abundance and large catch variability was primarily due to the results from one outlying day when catches in this area contained thousands of three-spined sticklebacks (*Gasterosteus aculeatus*). In the case of Bellingham Bay, the high average abundance and large variation is due to the presence of large numbers of fishes from three species on multiple occasions. These species were Pacific herring (*Clupea pallasii*), three-spine stickleback, and shiner perch (*Cymatogaster aggregata*).

No data on forage fish spawning was collected during the LIBI. However, distribution maps of forage fish spawning results from previous studies are presented in Appendix C.

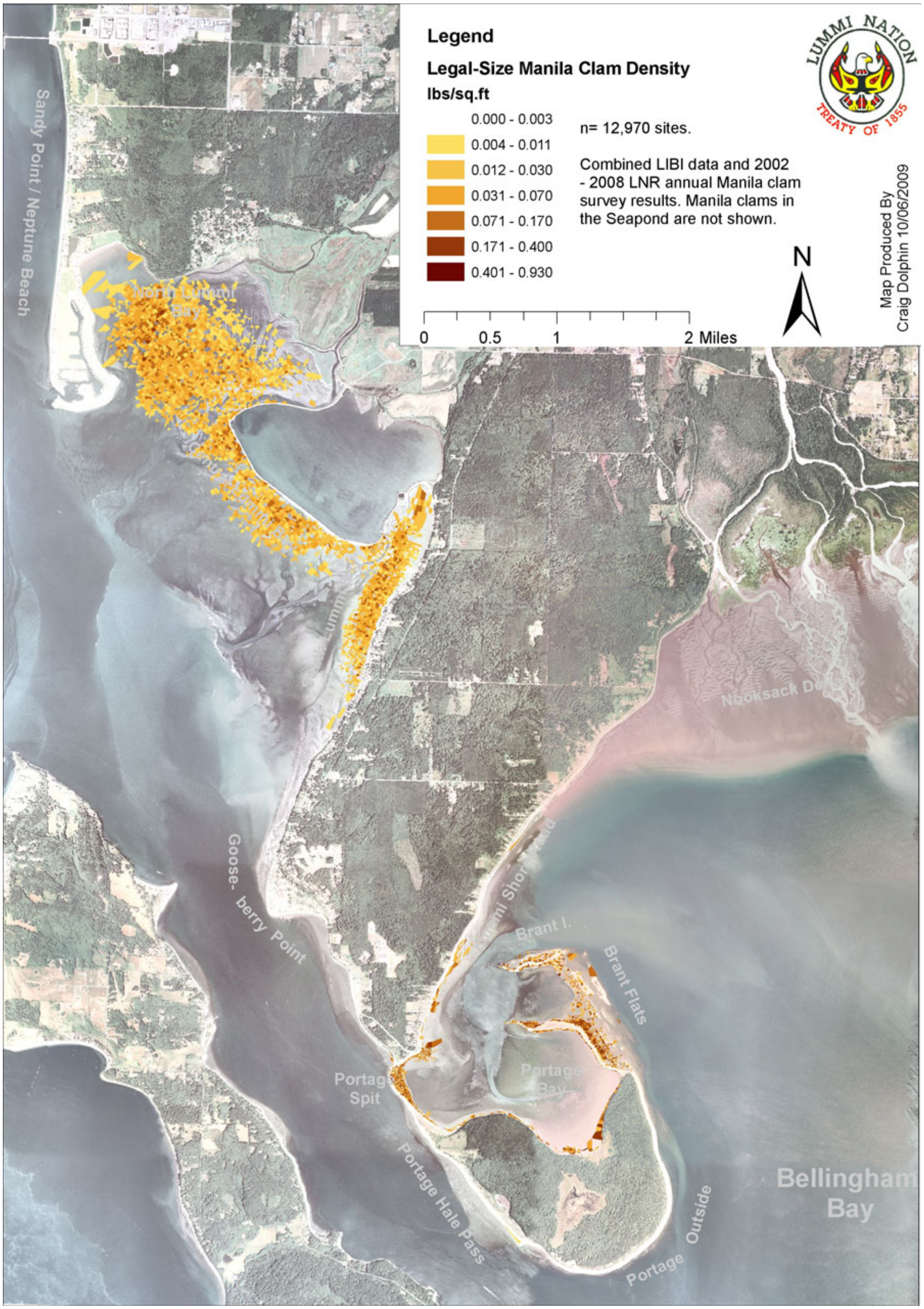

Figure 8.1. Biomass Density of Intertidal Legal-Sized Manila Clams

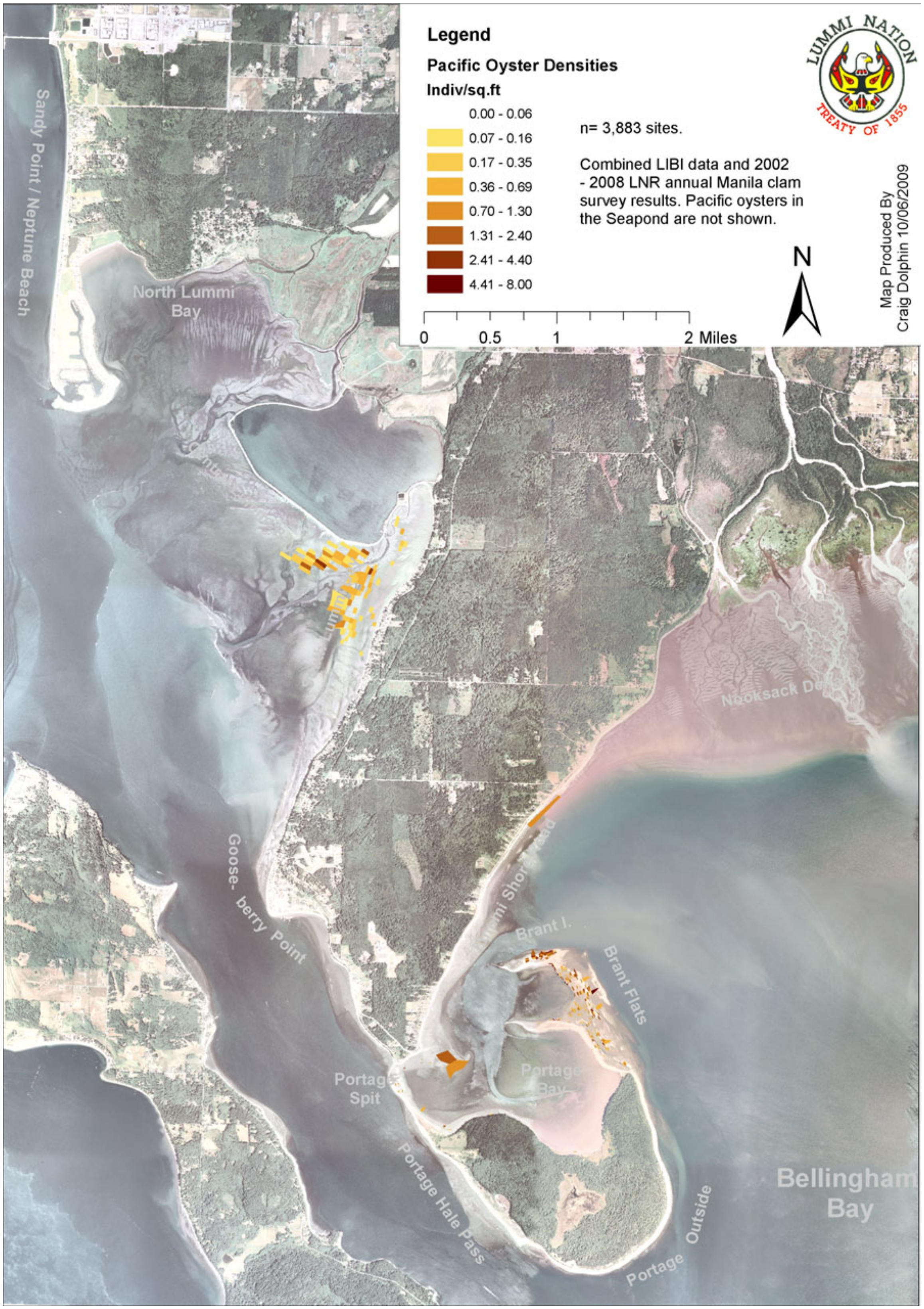

Figure 8.2. Densities of Pacific Oysters

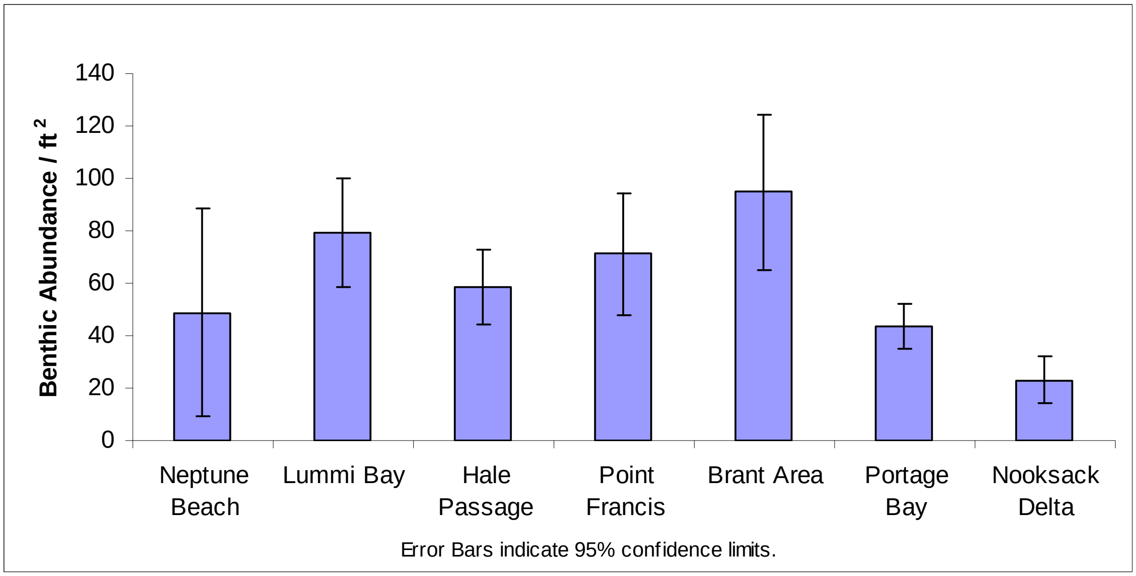

Figure 8.3. Average Abundance of Benthic Organisms, by Area

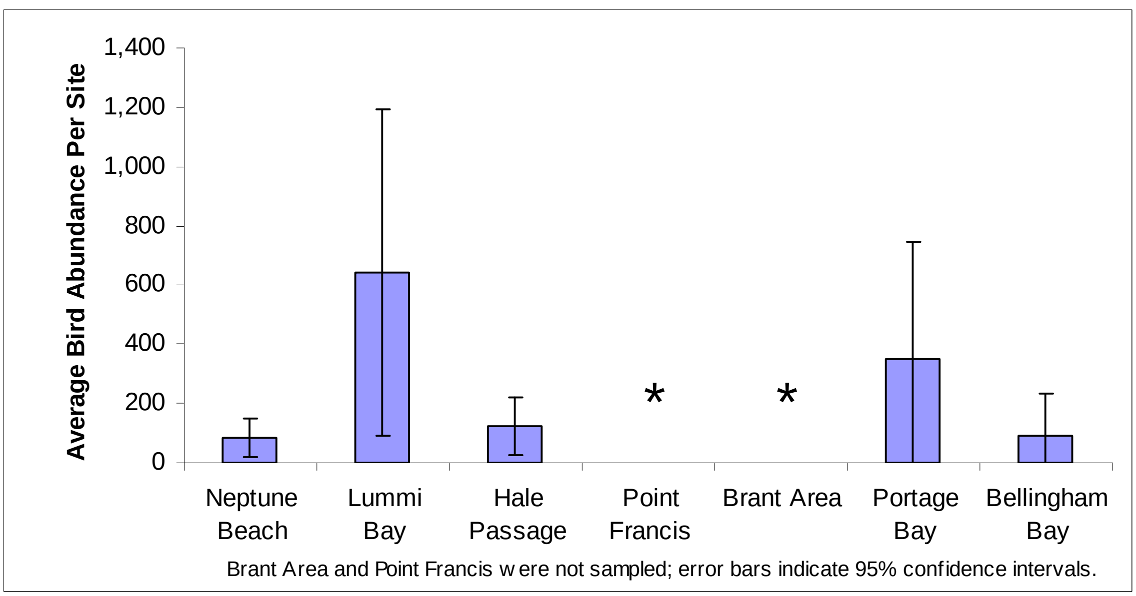

Figure 8.4. Average Bird Count per Site, by Area

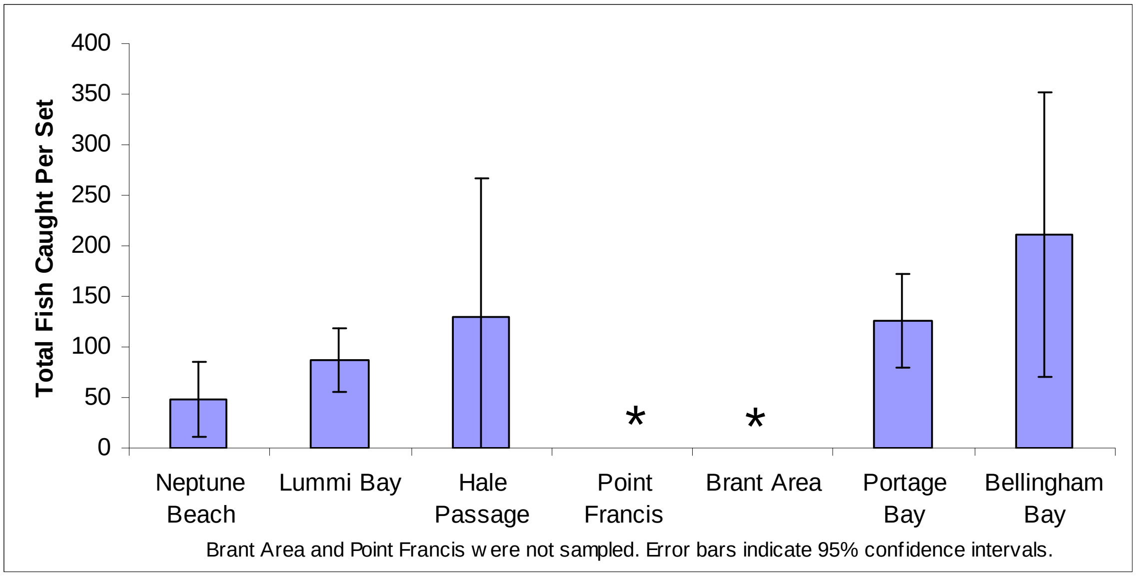

Figure 8.5. Average Catch of Finfish per Set, by Area

9.0 Temporal Analysis

Monthly data were collected for finfish and birds allowing seasonal comparisons to be made for these taxa. However, seasonal comparisons cannot be made for benthic biota because most of the benthic sampling took place during a period of only four months during the spring and summer of 2009. Overall, the temporal pattern of diversity and abundance for finfish was opposite to that for birds: finfish were most diverse and abundant during the summer months, and birds were most diverse and abundant during the winter months.

9.1 Finfish

The diversity of fishes that were caught at sites varied over time and across habitat types, but generally the diversity of fish species was highest in the summer months (May through October) and lowest during the autumn and winter months (November through April) as shown by Figures 9.1 and 9.2. Similarly, the total abundance of fishes caught was highest during the summer months and lowest in the winter months (Figure 9.3). Seasonal trends in the relative abundance of selected finfish species (e.g., Chinook salmon, ling cod, Pacific herring and others) are presented individually in Appendix C.

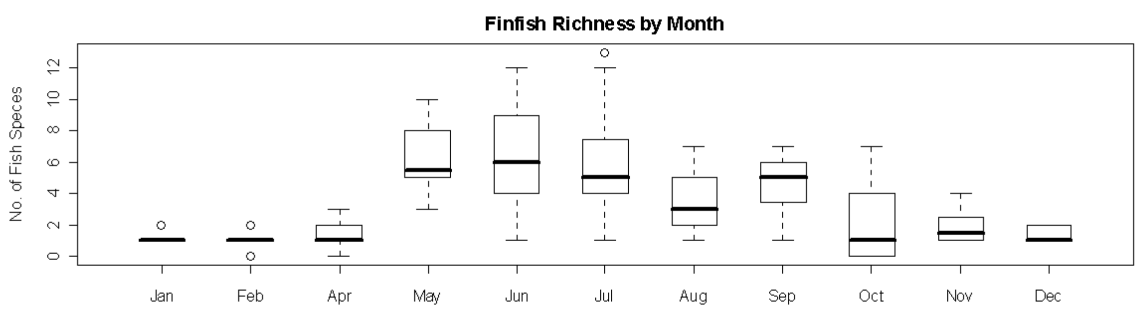

Figure 9.1. Monthly Trends in the Taxonomic Richness of Finfish on the Lummi Reservation Tidelands

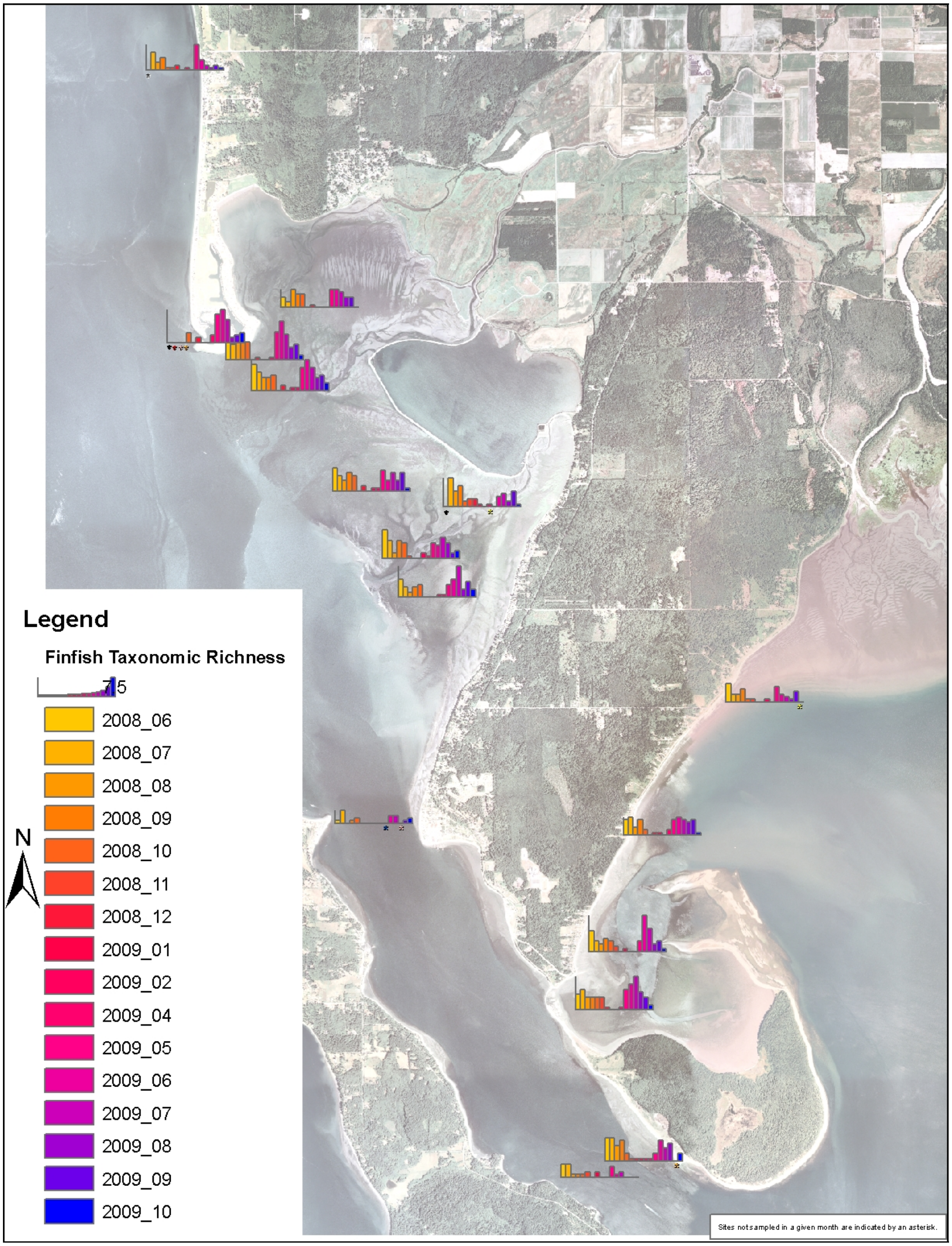

Figure 9.2. Taxonomic Richness of Finfish by Sampling Month and Site

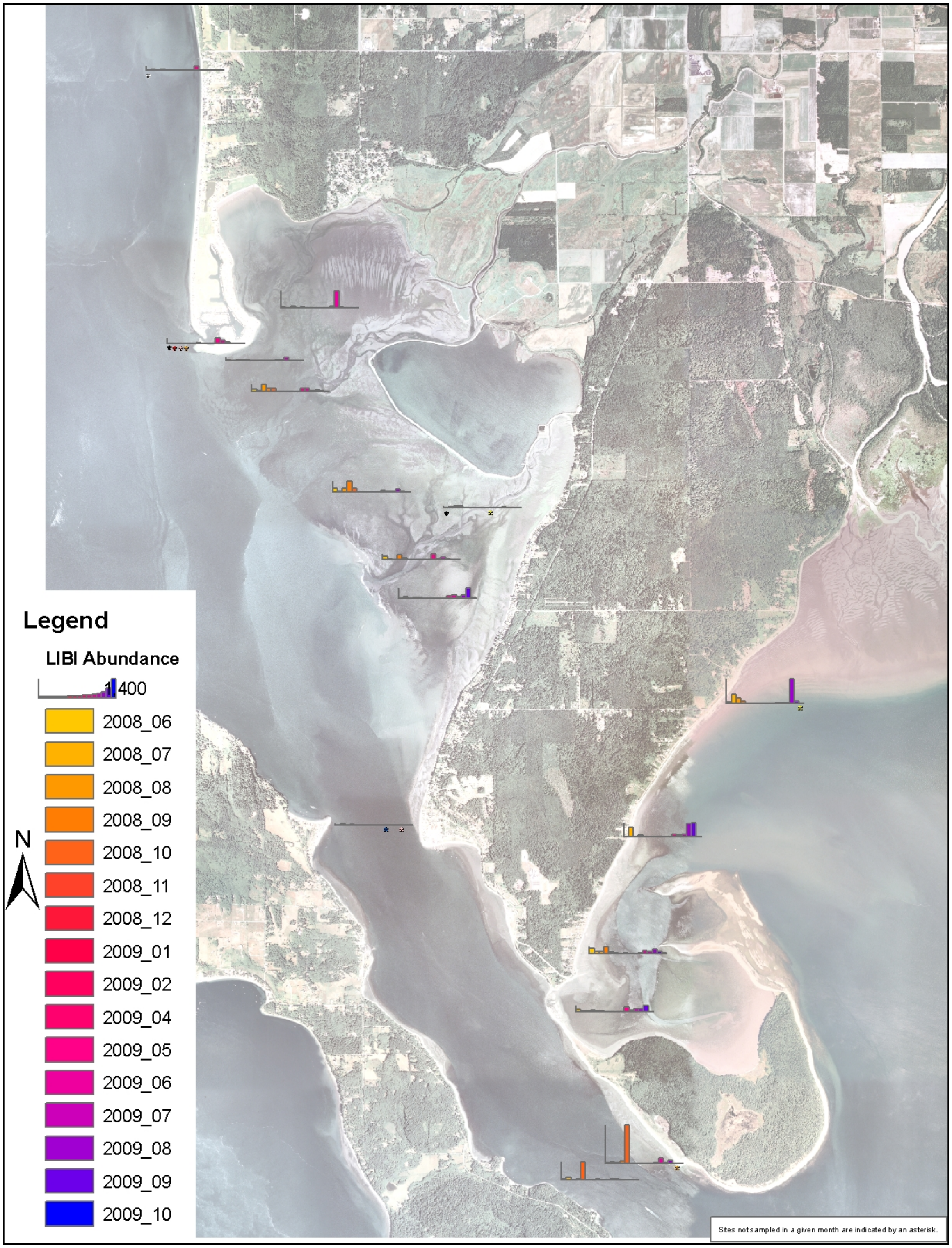

Figure 9.3. Total Abundance of Finfish Caught by Month and Site

9.2 Birds and Marine Mammals

The diversity of birds that were counted in the study area varied over time and was generally highest during winter months (October through April) and lowest during the summer (May through September). Figure 9.4 shows the taxonomic richness of birds by sampling month and Figure 9.6 shows the taxonomic richness of birds by sampling month and site. Similarly, the total abundance of birds observed on the Reservation tidelands was lowest during the summer and considerably higher during the winter months. Figure 9.5 shows the relative abundance of birds by sampling month and Figure 9.7 shows the total abundance of birds counted by sampling month and sample site. The bird survey was not was conducted during August 2009 due to logistical constraints.

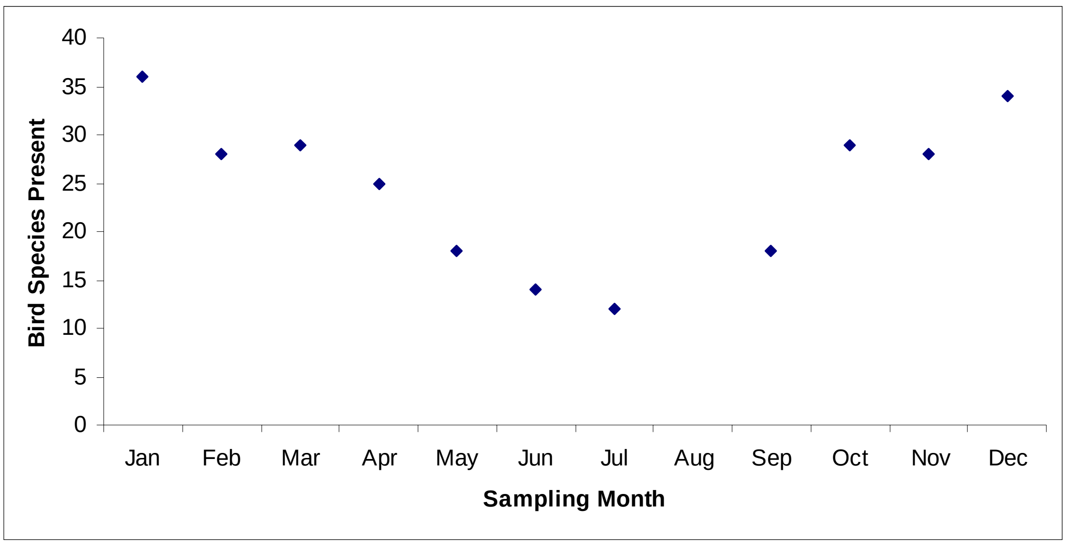

Figure 9.4. Taxonomic Richness of Birds by Sampling Month

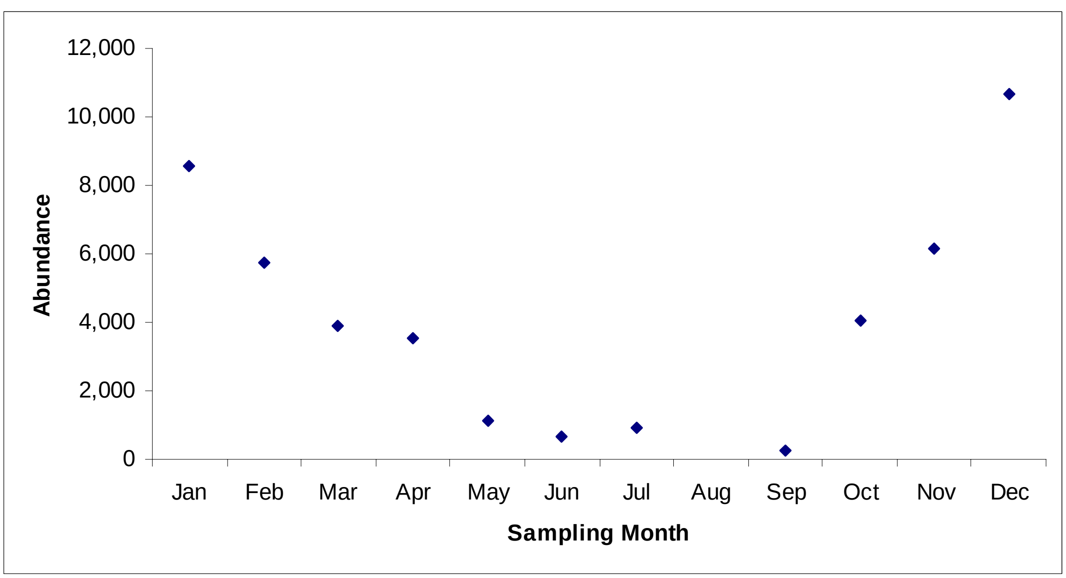

Figure 9.5. Relative Abundance of Birds by Sampling Month

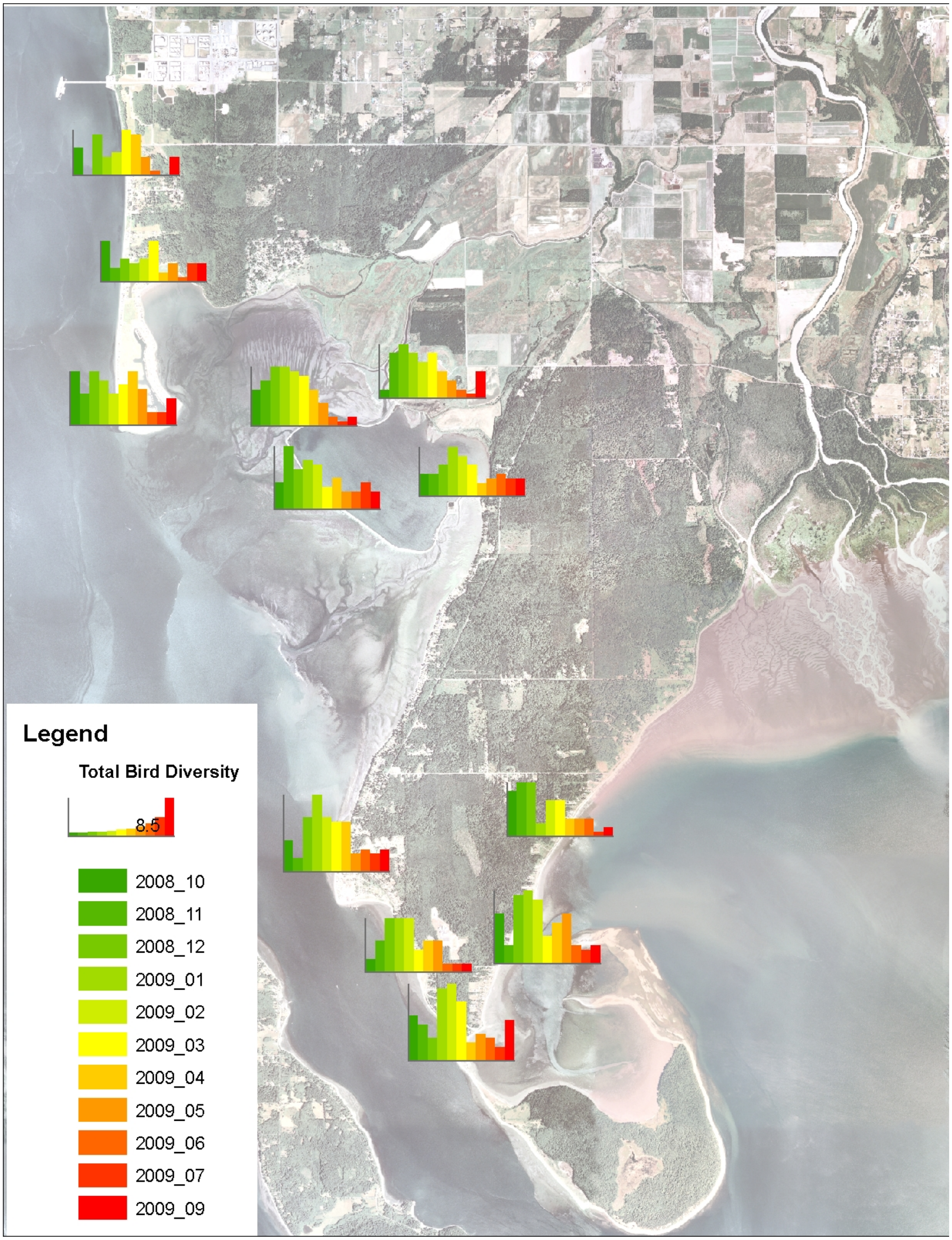

Figure 9.6. Taxonomic Richness of Birds Counted by Month and Site

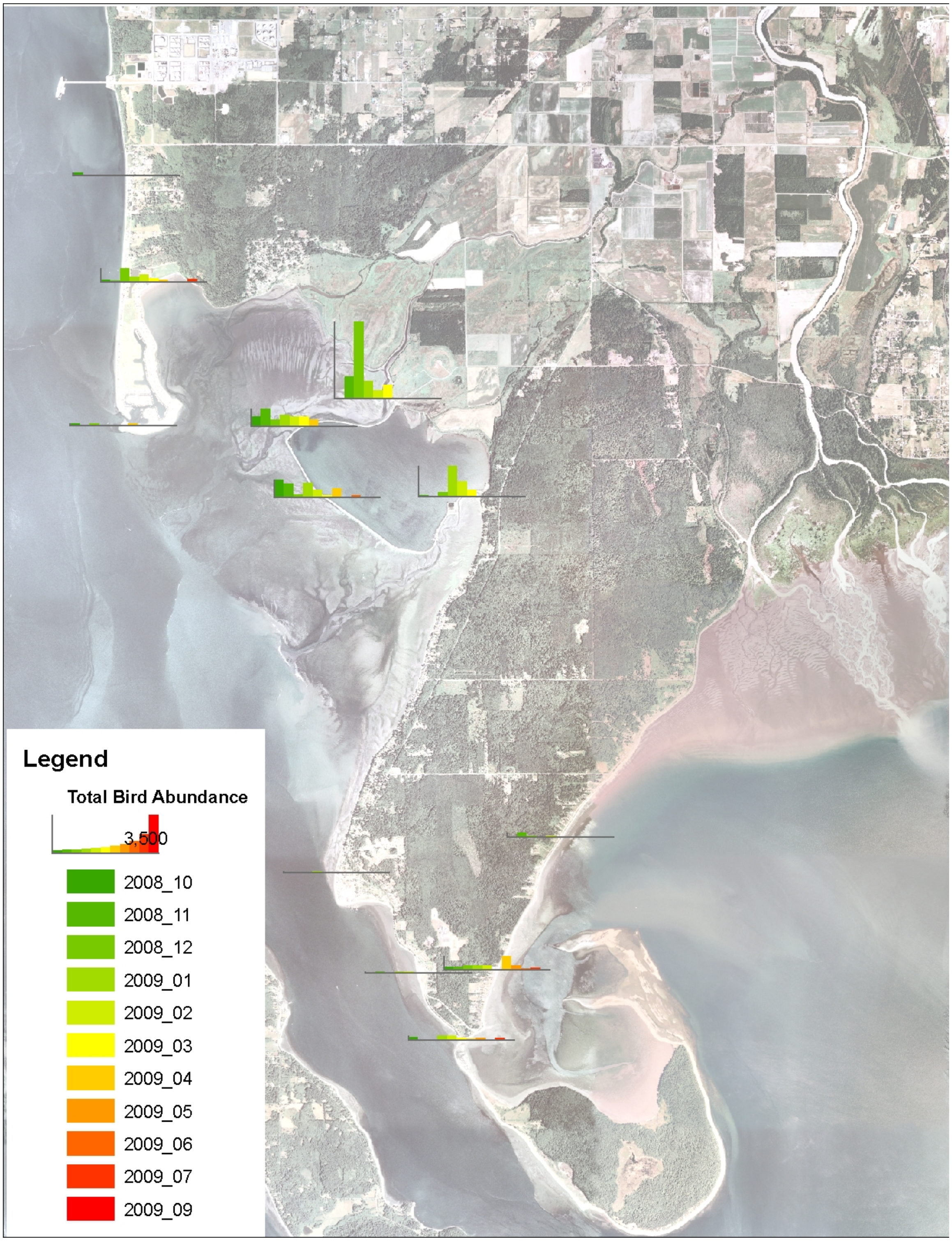

Figure 9.7. Total Abundance of Birds Counted by Month and Site

Seasonal trends in abundance for selected bird taxa of interest (e.g., bald eagles, great blue herons, ducks, geese) are presented separately in Appendix D.

Harbor seals and sea lions were generally most common in April and May, which is possibly related to the increase in finfish abundance beginning at that time of the year and with the outmigration of salmon smolts from the Nooksack River.

9.3 Larval Settlement Timing

Due to logistical constraints and budget, seasonal and inter-annual trends were not explicitly included in the design of the Intertidal Biota Survey. Despite these limitations, information relating to the timing of settlement for various species was gleaned from the dataset by post-stratifying the results according to sampling month and elevation. Since different sites were surveyed each month, it is possible that any trends observed are due to differences in the sites rather than seasonal differences.

The monthly average density of young-of-the-year clams (seed) for six species of clams is shown in Figure 9.8. It was expected that clam seed would accumulate throughout the summer months as a result of larval settlement, leading to steadily higher seed densities each month, until settlement ceased and wintertime mortality began to reduce the number of seed significantly. However, the results were not consistent with this hypothesis.

There was some suggestion that the densities of butter clam and purple varnish/mahogany clam seed tend to be at their highest abundance in June, softshell clam seed densities at their highest in April and May, and Manila clam and Pacific littleneck clam seed densities at their highest in July. Cockle seed densities did not appear to have any discernible trend within the time period covered by the study. However, there is too much variation in the data, and the absolute densities measured are too low for any significant patterns to be noted. It is also possible that the short duration of the field effort did not span the entire period of time that would permit before-settlement, during-settlement, and after-settlement comparisons to be made.

Nonetheless, the densities of clam seed for most species seemed to decline soon after reaching their ‘peak’. This suggests that perhaps mortality rates during summer time may be a more important factor than was previously thought. Additional work targeted towards identifying the timing of larval settlement of the various clam species will be required to better understand this ecological aspect of the tidelands.

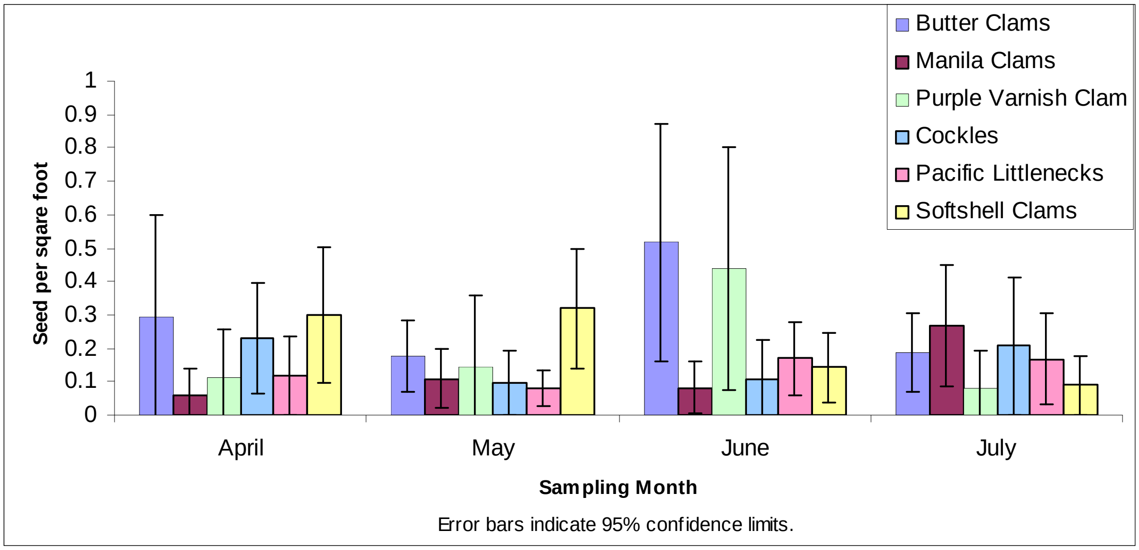

Figure 9.8. Comparative Clam Seed Densities Observed Within the 90% Vertical Limits for each Species, by Sampling Month

Likewise, the densities of crab megalops larvae (*Cancer* sp.) and post-settlement first-instar Dungeness crab juveniles were compared after post-stratifying the results by month and tidal elevation. The results suggest that the main settlement of megalops larvae occurred in June leading to the appearance of significant numbers of juveniles in July (Figure 9.9). These results are consistent with previous work on Dungeness crab settlement timing in Lummi Bay (Dinnel *et al*., 1986).

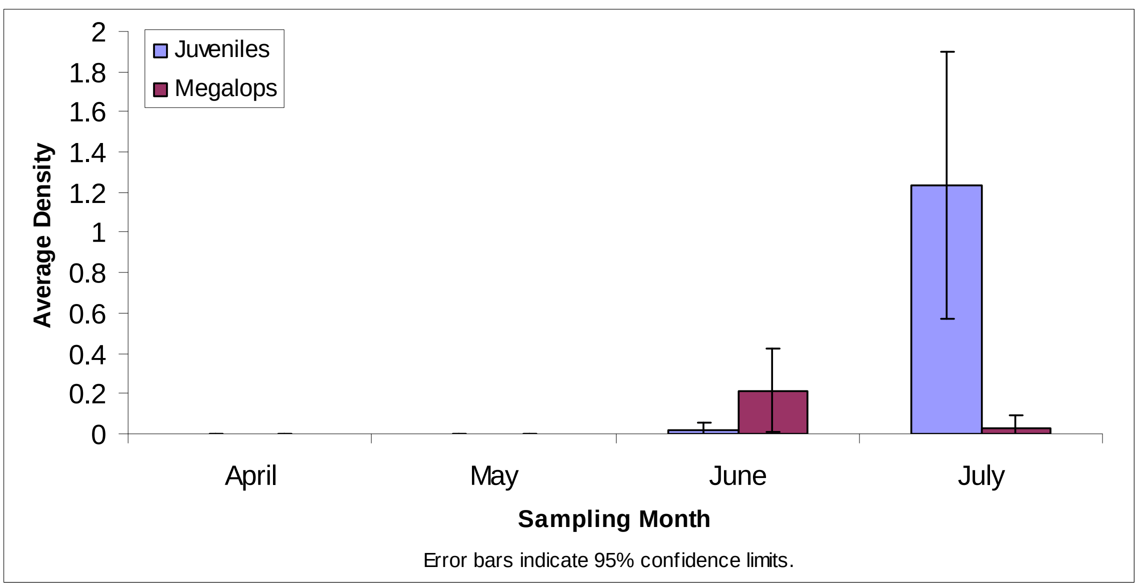

Figure 9.9. Comparison of the Average Density of Dungeness Crab Juveniles and *Cancer* sp. Megalops for Low-Elevation Sites versus Sampling Month

10.0 Summary and Conclusions

The primary purpose of the Lummi Intertidal Baseline Inventory (LIBI) project was to document the diversity, quantity, and distribution of natural resources present across the Reservation tidelands. Priority was given to documenting diversity first, species distribution and habitats second, abundance estimates third, and lastly obtaining seasonal trends (LeMoine *et al.* 2009).

Overall, pre-existing information was difficult to locate and access because much of it exists as unpublished data, memoranda, or technical reports. Additionally, the data that were available were seldom collected at a spatial or temporal scale sufficient to satisfactorily document the resource across the entirety of the tidelands. The quantity and quality of pre-existing information was best for Manila clams, Pacific oysters, birds, and finfish. However, the spatial resolution and quantity of the pre-existing information for the majority of benthic species was not useful for addressing the goals of the LIBI. Likewise, elevation and habitat data for the tidelands was either available only for a small portion of the tidelands or was collected at too coarse of a spatial scale to be useful for site classification or ecological analysis. Accordingly, the LIBI project devoted most of its resources to the collection of data to fill identified data gaps.

Based primarily on the results of these field efforts, the LIBI project has succeeded in providing a comprehensive list of 242 taxa that were documented using a variety of survey techniques. However, the taxonomic resolution of this list varies amongst different groups, and the list also does not include meiofauna, bacteria, or other organisms that would not be retained with a No. 10 (2-mm) mesh screen.

The LIBI project successfully provided the first spatially located dataset that includes the majority of taxa that are found on the Reservation tidelands, and can be used to generate spatial distributions for these taxa in a Geographic Information System environment. These data were successfully integrated with the limited number of pre-existing datasets that were also spatially located and had sufficient spatial resolution. The data also includes a variety of spatially located habitat measures that were found to help explain patterns in overall community structure and population distributions across the Reservation tidelands. The most important of these environmental factors were found to be elevation (tidal height), beach slope, substrate coarseness index values (substrate size), surface cover of Pacific eelgrass, and salinity.

The LIBI project provided data that allows relative and absolute abundance estimates to be calculated for most benthic populations (excluding macroalgae). In addition, biomass estimates were calculated for most of the bivalve species. As expected, however, the limited number of sites that could be sampled resulted in confidence limits for many population estimates that are relatively large for most taxa. Relative population estimates were also determined for birds, marine mammals, and finfish. However, the unquantifiable sampling efficiency of the methods used to survey these taxa precludes the ability to estimate absolute abundance of these organisms.

Seasonal trends in diversity and relative abundance were documented for birds, marine mammals, and finfish across much of the spatial extent of the tidelands. Generally abundance and diversity of birds was highest in winter, whereas diversity and abundance of finfish was highest in summer. However, portions of the tidelands on the south and east of Portage Island, and the middle portion of the Nooksack Delta were not included in the spatial coverage of the birds and marine mammals survey or the finfish survey. Seasonal results for benthic populations were not explicitly measured, and could only be inferred from comparisons within a limited time period of four months.

Finally, pre-spill concentrations of petroleum-based chemicals were successfully quantified, in both the sediments and clam tissues from two locations, and baseline levels of these contaminants are generally below detection using current technology.

11.0 Future Work

Although the LIBI project has significantly contributed to filling many of the data gaps outlined in the LIBI Final Work Plan, some gaps still remain and additional data could improve the precision of the results obtained to date.

One of the desired outcomes of the LIBI was to ascertain the location of the –4.5 ft MLLW elevation contour that is the seaward boundary of the tidelands. Unfortunately, the cost of using water-penetrating LiDAR was prohibitive given the available budget, and this product was not achieved. However, because most of delta has already been mapped by the LIBI project and the remaining unmapped area is at the low elevations of the tidelands, high accuracy boat-mounted sonar could be used to map the remaining extent economically because the greater depths allow for a wider swath width. Although there is no additional funding to conduct such a survey separately, there is work planned to conduct such a survey of the Nooksack Delta by the United States Geological Survey (USGS). By taking advantage of the now existing LiDAR data, the USGS study area will be extended to include other portions of the Reservation tidelands and provide a unified digital elevation model based on the two data sources (Eric Grossman USGS, pers. com.). It is hoped that the –4.5 ft MLLW contour will be delineated for much of the Reservation tidelands as part of that effort.

The spatial distribution of Dungeness crab settlement across the Reservation tidelands has yet to be documented adequately. To achieve this goal will require a study that is narrowly focused to sample only in suitable elevations and habitats, and that can be rapidly conducted over a large geographical area.

There are still some areas of the Reservation that have yet to be surveyed for seasonal relative abundance of birds, marine mammals, and finfish. These areas include the outside shoreline of Portage Island, Brant Island, Brant Flats, and the middle portion of the Nooksack delta. These areas are relatively difficult to access. Additional work is required to fill in the missing data for these locations. Likewise, a portion of the Lummi Bay tidelands was not included in the Intertidal Biota Survey due to the difficulty of reaching sites in that area with the necessary equipment and because the sites had up to 2 feet of standing water present. These sites could be surveyed using a different methodology such a boat-mounted venturi suction sampling device.

There are currently no plans or resources allocated for additional sampling of the tidelands. The number of samples collected in the Intertidal Biota Survey was too low for satisfactorily precise abundance estimates to be obtained, particularly if the results for sub-areas are calculated independently. If additional resources were made available, it would be desirable to increase the number of sites on high-priority beaches that have important natural resources and that may be most at risk in the event of an oil spill. Sites in Lummi Bay, Hale Passage, and Portage Spit should be prioritized in any such study.

The natural resources within the Lummi Bay Aquaculture Pond (Seapond) have been surveyed previously in 2002 and again in 2005. However, the scope of those surveys was narrower than the scope of the LIBI and focused solely on clams with some additional information for Dungeness crabs and starry flounders. Future work in this area would be needed to also document populations of all other benthic taxa (e.g., polychaete worms, anemones), finfish, and birds.

A large number of samples were collected and preserved as part of this project. These samples have been turned over to the Northwest Indian College to use as a teaching resource and for long-term storage. If additional funding were made available, regional experts could be contracted to improve the taxonomic resolution of the taxa listed in Table 5.1 by identifying taxa, such as polychaete worms, to the species level instead of only to higher taxonomic levels. This would increase our knowledge of the diversity of the tidelands and may be beneficial for assessing the impact of future environmental changes or disasters.

Although a number of environmental variables were considered in the preliminary ecological analysis, one potentially important environmental factor, the magnitude of tidal water currents, was not included in this analysis. To assess the effect of water currents, we obtained data for the maximum surface velocities that have been modeled for ebb and flood tides in the study area (Yang and Khangaonkar 2008; Khangaonkar *et al*. 2009). Unfortunately, the data were not received in time to be included in the analysis without delaying the publication of this report significantly. However, the maximum current velocity at each of the Intertidal Biota Survey sites has been included in the Dig Survey Database on the LIBI DVD so that interested parties might readily include this factor in an ecological analysis in the future.

The LIBI project protocols and methodology were designed to be used across a wide range of conditions and habitat types, and could readily be used for surveys of other tidelands beyond the borders of the Lummi Reservation. Because a large oil spill could impact the Lummi people by adversely affecting tidelands outside the borders of the Lummi Reservation but within the Usual and Accustomed Area of the Lummi Nation, there is interest within the Lummi Natural Resources Department to partner with other groups to expand the coverage of the survey to include other tidelands.

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