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Synthesis of Marine and Estuarine Water Quality Data for

Pacific Northwest National Parks

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Background and Need

Coastal park units in the Pacific Northwest protect and manage marine resources of ecological significance. Olympic National Park (OLYM), Ebey's Landing National Historical Reserve (EBLA), San Juan Island National Historical Park (SAJH), and Lewis and Clark National Historical Park (LEWI) all include shorelines that are exposed to and reflect conditions in the coastal ocean and estuaries. These coastal environments comprise habitats of concern for resource managers in coastal parks. Estuaries, beaches, and nearshore areas provide nursery grounds for many species of ecological, recreational and commercial importance and contribute significantly to visitor experience (e.g., boating, fishing, wildlife viewing) at coastal parks.

Compromised water quality in coastal environments often results from regional population growth and local land use activities. Water quality monitoring data collected by NPS Inventory and Monitoring (I&M) networks and coastal parks allow NPS to evaluate conditions and detect trends within park boundaries. However, because many water quality problems originate outside park boundaries, understanding trans-boundary water quality issues is essential for effective management of shared estuarine and marine resources.

The 2008 NPS Natural Resource Stewardship and Science (NRSS) Strategic Framework identified Ocean and Coastal Resources as NRSS Natural Resource Emphasis Areas. A critical task for the NRSS Ocean and Coastal Resources program is to integrate local and regional water quality data collected outside park boundaries into a format useful for park management decisions. In the face of climate change, resource managers are striving to reduce stressors on park-managed waters to increase the resilience and adaptive capacity of coastal ecosystems. Scientific information about park resources and partnership opportunities with federal, state, and local agencies are key strategies to meet this challenge.

In this report we provide information to 1) indicate the condition of marine and estuarine waters within park boundaries in comparison to conditions in nearby and adjacent waters; 2) indicate the comparative condition of marine and estuarine waters within park boundaries across four coastal parks (OLYM, SAJH, EBLA and LEWI), and 3) identify local and regional water quality issues of importance to management of Pacific Northwest coastal parks. At a regional scale, this data synthesis is intended to provide NPS with an overview of water quality conditions inside and outside park boundaries that can help guide management actions to protect water quality and build and enhance partnerships with other federal, state and local agencies to address common concerns.

Much of the context for water quality in the four parks of interest (EBLA, SALH, OLYM, LEWI) was established in reports published in 2006 and 2007 (Klinger et al. 2006, 2007a-c), and those reports should be consulted for a historical perspective of water quality conditions inside the four coastal park units. The results presented here are based on a new analysis of the available data and are not intended to replicate prior assessments. This report differs from earlier assessments in two important ways: 1) this report focuses on comparisons between water quality inside and outside each of the four parks, to allow managers to determine the extent to which factors external to the park are likely to affect resources inside the park; and 2) this report covers a more recent period of sampling so is better able to reflect current conditions in an era of rapid environmental change.

We obtained data available from a variety of sources in the public domain. These included data collected by or served by the U.S. Environmental Protection Agency, the National Park Service, the STORET database, the Washington State Department of Ecology, and the Washington Department of Health. We restricted our analysis to samples or data collected between 2002 and 2012. We judged that data collected prior to 2000 were less indicative of current conditions, and that data collected after 2012 were less likely to be fully vetted or published in final form when we began our analysis in 2014. Consequently, this report does not report or reflect conditions associated with the Pacific warm anomaly that affected the region in 2014-2015.

We validated our selection of data sources and parameters with experts from state and federal agencies responsible for water quality. We inspected the data carefully and removed from the analysis data that could not be verified. For data that met our selection criteria, we provide box plots to indicate the distribution of individual parameters inside and outside each park unit. We used GIS technologies to map the location of all samples reported. Throughout the report, we prioritized graphic presentations of the data, either as statistical plots or GIS figures, and we direct the reader to those visualizations.

The influence of outside sources on marine and estuarine water quality within coastal park units varies by location according to ocean and coastal circulation processes and by urbanization and inputs from terrestrial sources. The Penn Cove area of EBLA and the portions of LEWI located within the Lower Columbia River Estuary are likely to be most exposed to terrigenous inputs from urban and agricultural sources, and, especially in the case of EBLA, to somewhat retentive circulation conditions. The waters surrounding SAJH are exposed to the Fraser River plume and to influences from the Strait of Juan de Fuca. Within SAJH, circulation and exchange tend to be vigorous especially in the vicinity of American Camp, with consequences for water quality. OLYM is exposed to highly dynamic oceanographic processes driven by the California Current system, including seasonal upwelling and intermittent impingement of the Juan de Fuca Eddy.

Findings

A primary finding of this analysis is that data pertaining to water quality and marine sediment quality are extremely patchy in time and space. With the exception of certain commonly-measured parameters (e.g., temperature, salinity), temporally-coherent and spatially-extensive data were relatively rare. This was especially true for measures of contaminants and toxins.

Hence, a recommendation to emerge from our analysis is to review, refine, and expand sampling of parameters of interest to coastal park managers.

Second, we found that data availability from outside park boundaries exceeded that from inside park boundaries. This is not surprising, since the area sampled outside park boundaries was far larger than that inside park boundaries, and because multiple agencies contribute to sampling outside park boundaries. However, the distribution of the available data somewhat reduced the strength of comparisons that could be made. Further analyses, for example via stratification of sampled sites based on habitat type or nearshore setting, could provide additional insights, but the strength of such analyses will rely on the specific approaches used and will be constrained by data availability.

Third, we detected no consistent directional differences in water or sediment quality inside versus outside park units. Where sharp differences did occur, for example in some measures of salinity or pH inside and outside parks, the differences could be attributed to spatial differences in the collection of samples (for instance, salinity measurements strongly influenced by river outflow, or pH measurements being compared between intertidal and shelf waters).

Fourth, sediment contamination generally was lower inside park boundaries compared with outside. Among the data we analyzed, no sediment samples from either inside or outside park boundaries exceeded the established ERM (effects range maximum).

Recommendations

Based on our findings, we offer the following recommendations:

Data availability constrained our analysis, and data availability was particularly sparse within park boundaries. Consequently, we recommend that park managers review, refine, and expand sampling of parameters necessary for management of park resources. This could include development and implementation of a strategic plan for sample collection and analysis within park boundaries, and the establishment of partnerships with other agencies to develop and maintain sampling programs beyond park boundaries.

Sediment samples were more limited than water quality samples. Sediment samples provide a longer-term record of conditions than do water samples, and they may be especially helpful in describing local (as opposed to regional) conditions. Consequently, we recommend that park managers consider developing and implementing a strategic long-term plan for sediment sampling within park boundaries.

Background

Here we report on the physical and chemical properties of marine and estuarine water inside and outside of four coastal parks in the Pacific Northwest (PNW): Ebey's Landing National Historical Reserve (EBLA), San Juan Island National Historical Park (SAJH), Olympic National Park (OLYM) and Lewis and Clark National Historical Park (LEWI) (Figure 1). All four parks are influenced to varying degrees by Pacific Ocean conditions, local river discharges, and a suite of natural and anthropogenic drivers that work together to determine water and sediment quality inside and outside of each park. OLYM and LEWI are the most coastally located of these parks and are most subject to marine influences. EBLA and SAJH are situated within the Puget Sound region (also known as the Salish Sea; we use both terms in this report) and experience estuarine dynamics associated with strong forcing from both marine and freshwater sources.

Waters along the PNW coast are a part of the larger California Current System (CCS) and comprise the northern reaches of the California Current Large Marine Ecosystem (CCLME). Key coastal oceanographic features in this region that drive variability in water temperature and nutrients include upwelling, downwelling, and the formation of coastal eddies. Along the open coast in the spring and summer months, the prevailing surface current is southward, with a deepwater undercurrent that is northward, while in the fall and winter, the prevailing current is the northward Davidson Current (Hickey and Banas 2003, 2008).

Upwelling is the process by which cold, saline and nutrient rich waters are delivered to surface waters from deeper areas as a result of equator-toward winds. Upwelling often results in production of phytoplankton, fueling secondary productivity in coastal marine food webs (Hickey and Banas 2008). Downwelling is driven by poleward winds and results in warmer coastal waters and net transport of water from offshore to inshore. Upwelling becomes more frequent in the spring, while downwelling is most frequent in the fall and winter. The Juan de Fuca Eddy is a seasonally-recurring major oceanographic feature just offshore of the mouth of the Strait of Juan de Fuca that entrains nutrients from the Strait of Juan de Fuca to create conditions favorable for phytoplankton blooms, including blooms of harmful algae (Hickey and Banas 2008, MacFadyen et al. 2008). Within the Salish Sea, circulation is influenced by riverine forcing and strong tidal fluxes that create energetic mixing at sills. Circulation is characterized generally by seaward flow at the surface and landward flow at depth (Ebbesmeyer and Barnes 1980, Holbrook et al. 1980).

Freshwater input influences salinity and temperature as well as nutrient concentrations, phytoplankton blooms, and the transport of contaminants. As such, rivers act as conduits of freshwater and land-derived nutrients or as transporters of upwelled nutrients from onshore to offshore (Hickey and Banas 2008). They also may transport land-derived contaminants and pathogens. The Fraser River is the largest source of freshwater in the Salish Sea, while the Columbia River is the largest river on the outer coast. The position of the Columbia River plume varies seasonally and can extend north or south of the Columbia River mouth. The plume interacts with local upwelling and downwelling to entrain nutrients and phytoplankton biomass, sometimes trapping nearshore waters along the coast (Hickey and Banas 2003, 2008).

Water and sediment quality in the PNW coastal zone and Salish Sea is also influenced by a variety of anthropogenic drivers including non-point sources of pollution such as wastewater, stormwater, agricultural runoff, and atmospheric deposition. Water quality affects nearshore ecosystems through alterations in the chemical and biological environment, with consequences for biogeochemical processes and for local marine biota and the biological communities they comprise. For example, excess nutrients can alter phytoplankton abundance and ultimately cause changes in levels of dissolved oxygen. Furthermore, toxic contaminants can accumulate in food webs through the process of bioaccumulation, causing acute or lasting damage to wildlife.

The PNW coastal zone and Salish Sea support rich ecosystems that includes nesting birds, marine mammals, salmonids, forage fish and shellfish, all of which are sustained by habitats such as salt marshes, mudflats, eelgrass, rocky reefs and kelp forests (Klinger et al. 2006, Klinger et al. 2007a, Klinger et al. 2007b, Klinger et al. 2007c, Gaydos and Pearson 2011). Moreover, several species that occur in or near PNW coastal parks are listed as threatened or endangered under the U.S. Endangered Species Act. Marine and estuarine water quality is an important factor in the condition of the biological resources under park management and in the recovery prospects for listed species. Water quality also can contribute to the recreational value of coastal areas (Kreitler et al. 2013), enhancing the experience of visitors to these coastal parks.

Ebey's Landing National Historical Reserve

Ebey's Landing National Historical Reserve (EBLA) is located on Whidbey Island within Puget Sound (Figs 1 and 2) and is approximately 17,572 acres in size, consisting of 13,617 acres of land and 3,955 surface acres of water in Penn Cove (Figure 1) (Klinger et al. 2007a). The eastern and western shores of EBLA are subject to differing oceanographic and hydrologic influences. The eastern shore, including Penn Cove, is strongly influenced by forcing from the Skagit and Snohomish Rivers. The western shore is predominantly influenced by marine waters of the Strait of Juan de Fuca and by fluvial forcing from the Fraser River. The influence of the Fraser River is felt the most strongly in the summer months when the prevailing winds are form the north (Banas et al. 2015).

Penn Cove comprises an especially significant water resource within EBLA and for Puget Sound more generally. This deeply incised formation offers a sheltered harbor that supports biological communities representative of the region. As a consequence, Penn Cove has served as an important center of sustenance and commerce for thousands of years, since well before the arrival of European explorers. Penn Cove sustains fisheries for finfish and shellfish, including salmon, mussels, and clams. First harvested by the Coast Salish people, some of these species are still cultivated in Penn Cove today.

Land use in EBLA is primarily agricultural/open space (42%) and woodlands (36%), with some residential use (11%) and wetlands (5%), while commercial and urban use are ~1% of the land use (Klinger et al. 2007a).

The marine and estuarine waters surrounding EBLA reflect its location within Puget Sound, which is home to ~6 million people between Seattle to Vancouver and is rapidly increasing in population. It contains multiple urban centers as well as a mixture of sub-urban and semi-rural throughout the region. As summarized in Klinger et al. (2007a), impacts to the coastal environment of Puget Sound include land use activities such as forest practices, agriculture, land clearing and the construction of dams and dikes as well as point-source pollution (sewage disposal, industrial discharge) and non-point source pollution such as surface water run-off, fossil fuel combustion and atmospheric deposition. The marine environment has been altered by shoreline modification, dredging and filling, cable and pipeline installation, bridge construction, vessel operations, aquaculture, and the introduction of toxic contaminants. All of these stressors act together to alter the physical and chemical basis for coastal wildlife and food webs and are important to interpreting water quality data collected from areas outside and inside the park.

San Juan Island National Historical Park

San Juan Island is located within the San Juan Archipelago (Figures 1 and 3) in the northern reaches of Puget Sound (also referred to as the Georgia Basin and the Salish Sea). SAJH is exposed to estuarine dynamics dominated by outflow from the Fraser River and balanced by inputs of marine water from Washington's outer coast. The influence of the Fraser River is the strongest in the summer months (Banas et al. 2015). Seasonal and intermittent intrusions of upwelled waters from Washington's outer coast impinge on SAJH, with influences on water condition.

SAJH consist of two tracts of land. English Camp comprises 529 acres near the northern end of the island and American camp comprises 1,223 acres at the southern end of the island (Figure 3). Both sites include marine shorelines and wetlands.   The southern shores of American Camp face the eastern basin of the Strait of Juan de Fuca and are exposed to prevailing winds. Habitats on this shore include a rocky headland, gravel pocket beaches, a long sandy beach that functions as a collection zone for woody debris. English camp, at the north end of the island, is more protected and is characterized by shallow waters, bordered by Westcott Bay to the north and Garrison Bay to the west (Klinger et al. 2006).

The marine habitats of SAJH consists of mudflats, native eelgrass (*Zostera marina*) and salt marsh plant Salicornia as well a suite of rocky intertidal taxa including rockweeds, barnacles and kelps (Dethier 1993, Klinger et al. 2006). Both Westcott and Garrison Bays experienced severe declines in *Zostera marina* in between 2000 and 2003 (Wyllie-Echeverria et al. 2003), the causes of which are not known but are speculated to be associated with land use changes, perhaps in combination with other unknown factors. The intertidal habitats of SAJH are used by a variety fish including the forage fish surf smelt, sandlance and herring (Fradkin 2004). The west side of San Juan Island, including the waters adjacent to American Camp, is commonly used for feeding by southern resident killer whales, which are listed as endangered under the U.S. Endangered Species Act.

The urban and suburban stressors that apply to water quality in and around EBLA also apply to SAJH. In addition to land use activities, SAJH is exposed to hazards associated with shipping traffic in Haro Strait and the threat of increasing export of petroleum products from the area around Bellingham. Moreover, local circulation the eastern basin of the Strait of Juan de Fuca can expose SAJH to pollutants and contaminants emanating from southern Vancouver Island, including the city of Victoria.

Olympic National Park

Located in the extreme northwest corner of Washington state, Olympic National Park (OLYM) is the largest of the four parks treated in this report. It comprises approximately 1 million acres, 477of which are considered marine and coastal (Figure 4) as well as approximately 11,000 acres of wetlands (Klinger et al. 2007b).

Oceanographically, OLYM is subject to strong influences from the California, Alaska, and Davidson currents, and to the larger dynamics of the North Pacific Gyre. It experiences seasonal upwelling and downwelling, and productivity is generally high (Hickey and Banas 2003). The Juan de Fuca Eddy, which forms over the Juan de Fuca canyon to the northwest of OLYM, can create conditions favorable for substantial phytoplankton blooms, including blooms of harmful algae (MacFadyen et al. 2008). Seasonally, the Columbia River Plume flows northward, trapping nearshore waters against the coast and exerting influence on the marine water properties of OLYM (Hickey et al. 2005).

The coastal strip of Olympic National Park is home to a rich diversity of marine taxa, including intertidal communities that occupy rocky, cobble and sandy habitats. Intertidal and subtidal kelp habitats are prominent, especially in the northern areas of the park; sandy habitats dominate in southern areas of the park. A diversity of bivalve species occur in OLYM, including culturally- and commercially important razor clams. Forage fish such as smelt and more than 70 stocks of salmonids also are present (Klinger et al. 2007b). The shorelines of OLYM, and particularly the offshore rocks and seastacks, are used by nesting birds including the threatened brown pelican (*Pelecanus occidentalis*), the marbled murrelet (*Brachyramphus marmoratus*) and the bald eagle (*Haliaeetus leucocephalus*) (Klinger et al. 2007b).

Development in OLYM is generally low, although forest practices in upland areas affect rivers that drain into the nearshore waters of the park. For example, Tallis (2006) found that the density of logging activity was correlated with increased nutrients (nitrogen and phosphorus) in local rivers. Runoff from Highway 101, which runs along the coast through much of the park, and point-source discharges in Neah Bay, La Push, Sappho, and Forks are other potential sources of contaminants to the marine waters inside and adjacent to Olympic National Park (NPS 1999, Klinger et al. 2007b). Its location on the west coast renders OLYM susceptible to atmospheric deposition of airborne contaminants resulting from trans-Pacific transport such as mercury (Strode et al. 2008)(NADP 2016).

Lewis and Clark National Historical Park

Lewis and Clark National Historical Park (LEWI) is located in the lower Columbia River Estuary (CRE) within Youngs Bay and Necanicum Subbasins (Figure 5). The park is approximately 3,400 acres in size with 40 miles of coastline. The legislative boundary of LEWI includes seven units: Cape Disappointment State Park, Middle Village Station Camp, Dismal Nitch, Fort Clatsop, Sunset Beach State Recreation Area, Yeon, and Salt Works. The Cape Disappointment and Sunset Beach sites are managed by the state parks but are included in NPS inventory and monitoring activities. The other sites are wholly-legislated state parks over which NPS has no authority. For the purposes of this report, the ‘in park’ samples all fall within the seven units.

The marine and aquatic habits within LEWI include sandy beaches, rocky headlands, and significant subtidal soft sediment habitat within the CRE, all of which support a variety invertebrate, bird, fish and mammal species. Tidal wetlands within the park provide habitat for salmonid species listed as threatened or endangered under the U.S. Endangered Species Act (ESA), and the forest at Cape Disappointment provides habitat for marbled murrelets which are listed as threatened under the ESA.

The lower Columbia River Estuary in which LEWI is situated is dominated by estuarine dynamics. The Columbia River and its tributaries are the major sources of freshwater within and around LEWI. Flow on the Columbia River is controlled by dams upstream of LEWI. These dams dampen water fluctuations that otherwise would result from an unimpeded freshet. Marine influences come from the Pacific Ocean just outside the Lower Columbia River Estuary.

Beyond the consequences of impedance of flow by dams on the Columbia River, potential sources of water and sediment pollution inside and outside of LEWI include municipal and industrial wastewater discharges, stormwater runoff, timber harvesting, agricultural activities, landfill operations, sand and gravel pit activities, recreational use, marine watercraft traffic and atmospheric deposition (NPS WRD 1994, Klinger et al. 2007c).

Methods

Purpose

The purpose of this analysis is to describe the quality of marine and estuarine waters and sediments inside and outside park boundaries over the period 2000-2012. Our analysis relies on previously collected data available in the public domain. We limited our analysis to the data collected between 2000 and 2012. We excluded data collected earlier than 2000 because of uncertainties about the degree to which such data reflect existing conditions, and we truncated our analysis in 2012 because data collected after that date generally were unavailable in the public domain in a form that had been fully vetted or verified at the time we began our analysis in 2014.

Spatial delineation

We defined areas inside and outside each park using a combination of established park boundaries, best professional judgment, and expert opinion regarding the likely influence of ocean processes, surface circulation, and geomorphology in the vicinity of each park. We determined the marine areas 'outside' each park as follows: 1) For EBLA, we defined the outside waters to include a) those east of Penn Cove and Whidbey Island, within the Whidbey Basin (termed "Out WI"), which we distinguished from b) a larger body of outside waters surrounding the San Juan Archipelago to the sill north of Bellingham Bay, and the eastern portion of the Strait of Juan de Fuca to the sill at Port Angeles (Figure 2). We made this distinction because the waters east of Penn Cove and Whidbey Island, commonly referred to as the Whidbey Basin, are subject to physical process that differ from those outside Whidbey Basin. 2) For SAJH, outside waters were identical to those for EBLA, except that they did not include the waters east of Whidbey Island (Figure 3). 3) For OLYM, outside waters consisted of waters north, south and offshore of the park, following the boundaries of the Olympic Coastal National Marine Sanctuary (Figure 4). 4) For LEWI, outside waters consisted of waters north and south of the park, as well as within the Lower Columbia River Estuary to the northwest corner of Puget Island (Figure 5). We included in our analysis data from samples taken within 300 m of MHHW (Mean Higher High Water).

Water quality data

We searched widely for sources of relevant data in the public domain and consulted with experts to ensure that significant sources were not missed or omitted. Following this search, we accessed the EPA STORET and Washington EIM databases and included all water quality data collected from 2000 to 2012 within the boundaries of the four national parks of interest as well as the areas adjacent to them (Figure 6). To these sources we added data collected by the Washington Department of Ecology Marine Monitoring Program, the Washington Department of Health, and the EPA National Coastal Condition Assessment (NCCA) (Table 1). Data collected by the

NCCA for 2010 was accessed in April 2015 and has not undergone all levels of internal quality control. For the Department of Ecology Marine Water Quality Program data, we included data available from their website (http://www.ecy.wa.gov/programs/eap/mar_wat/mwci.html), which consisted of CTD profile data from 2000-2012 and discrete data from 2000-2006. We included EPA NCCA program data collected in 1999. The water parameters we included were temperature, salinity, pH, dissolved inorganic nitrogen (nitrate + nitrite + ammonium), silicate, phosphate, dissolved oxygen, secchi depth, enterococci, fecal coliforms, and chlorophyll *a* (Table 2). This resulted in a total of 229,000 data points for water collected between 1999 and 2012 (Table 3). For data collected as part of a depth profile, we report both the maximum and minimum values from each depth profile.

Because the data were collected by different agencies and monitoring programs, they differed in methods of collection, sample analysis, laboratory protocols, and quality assurance/control procedures. There was variability in the way that non-detects were reported, particularly in the databases STORET and EIM.

For each water quality parameter, we constructed boxplots to depict the full range and central tendencies of the data. For DIN, phosphate and dissolved oxygen, we depicted EPA guidelines for “Poor”, “Fair” and “Good” water quality as yellow and red lines (EPA 2012). For fecal coliforms, we showed criteria used by the Washington Department of Health (Woolrich 2012) and National Shellfish Sanitation Program of 14 colonies/100mL and 43 colonies/100mL. For Enterococci, we depicted the criteria used by the EPA Beach program of 35 colonies/100mL (http://www.ecy.wa.gov/programs/eap/beach/)(Schneider 2004).

Sediment quality data

We used sediment quality data collected from a single source, the EPA National Coastal Condition Assessment, that included broad spatial coverage and intermittent samples from 1999 to 2010 (Table 4, Appendix A). Data collected by the NCCA in 2010 was accessed in April 2015 and has not undergone all levels of internal quality control. Table 4 depicts the contaminants, number of samples, and years for which data were available. To provide a basis for interpretation of these data in the context of sediment quality, we used the Effects Range Minimum (ERL) criteria proposed by Long et al. (1995), which is the level at which 10% of the studies reviewed produced harmful biological effects. We also report the Effects Range Maximum (ERM), which is the level at which 50% of the studies reviewed produced harmful effects (Long et al. 1995). We present the sediment data as boxplots, to show the full range and central tendencies of the data. Sediment parameters, units and effects range low (ERL) and effects range maximum (ERM) are presented in Table 5. We adopted the approach of Caffrey et al. (2015) to create a report card diagram that codes the results for each contaminant in each location by color (green, yellow, and red). Colors were assigned based on the highest measurement in each location (i.e., if a single sample exceeded the ERL or ERM thresholds).

Thus, the red or yellow color of each table entry could be determined by a single high sample value.

Marine and estuarine water and sediment quality inside and around Pacific Northwest Parks

Water quality

Water temperature (Figure 7) and salinity (Figure 8) both were highly variable, likely driven by the season during which samples were collected as well as proximity to sources of freshwater. Samples within LEWI and within the Columbia River Estuary (CRE) were the least saline, while samples collected inside and outside EBLA were more variable. Samples collected around the San Juan Islands (Outside SAJH/EBLA) showed more marine influence (Figure 8). The single sample collected within OLYM was from the mouth of a creek and thus had very low salinity (Figure 8). Some samples were collected from tidal locations where it is likely that evaporation had occurred, resulting in salinity values of >40 PSU (Figure 8). Appendix A shows the locations of all water samples for each parameter in each park.

Aqueous pH varied between approximately 6 and 9 pH units, with two samples exceeding pH 9 in the waters inside Whidbey Island (Figure 9). The samples with the highest acidity (pH <6) were from inside LEWI and the CRE (Figure 9). The marine samples outside OLYM and outside the CRE generally showed the lowest acidity (Figure 9). pH values are a function of the underlying carbon chemistry of the water mass plus the influence of local production (which can elevate pH), local respiration and decomposition (which can reduce pH), freshwater inputs (which can increase or decrease pH), and other local processes. Hence, a degree of spatial and temporal variation in acidity is to be expected. Moreover, the standard method of collecting pH data over the study period used methods that are no longer considered best practices for determining pH in seawater; hence interpretation of these data should be made with caution, especially with regard to trends over time. Measurements of seawater pH using best practices have been made in a few locations in OLYM and SAJH since 2014, and these measurements will prove useful once they are verified and published.

Silicate concentrations were lowest in waters outside OLYM and highest and most variable in the Salish Sea outside EBLA/SAJH, possibly driven by the influence of the Fraser River (Figure 10). Samples with silicate concentrations >10 mg/L were collected near Bellingham Bay (Figures 2,3). Dissolved inorganic nitrogen (DIN) was lowest in the marine waters outside OLYM, which showed variation with depth such that some of the maximum values approached the 0.5 mg/L EPA criterion for “good” water quality, while the minimum concentrations were much lower (Figure 11). Locations outside EBLA/SAJH displayed the highest concentrations of DIN (Figure 11), driven by samples collected in tidally influenced low-lying agricultural areas near Samish Bay (Figures 2,3). Phosphate concentrations also were highest outside of

SAJH/EBLA (Figure 12). Samples that exceeded the EPA criterion for “poor” water quality were collected in Lummi Bay and Bellingham Bay, and from a single profile from inside EBLA (Figures 2,3). Phosphate concentrations displayed variation with depth such that some maximum concentrations outside LEWI and OLYM exceeded the EPA criterion for “good” water quality while the minimum concentrations did not (Figure 12).

Dissolved oxygen (DO) is critical to metabolic function in marine organisms. DO is influenced by processes of water mixing, as well as by primary production and respiration. Photosynthesizers such as macroalgae, eelgrass, and phytoplankton produce oxygen during the day and consume oxygen at night, while non-photosynthetic microbes and metazoans consume oxygen via respiration. Conditions of low oxygen (hypoxia) can be created by enhanced growth of phytoplankton followed by microbial decomposition of the organic matter produced. Dissolved oxygen concentrations were generally above the EPA criterion for “good” water quality, with the exception of some samples taken from outside EBLA/SAJH, all of which were taken from tidal locations draining agricultural areas in Samish Bay (Figure 2,3). Dissolved oxygen varied with depth, particularly in the marine waters of outside OLYM and LEWI (Figure 13).

Secchi disk depth is a visual measure of water clarity. Water clarity is important for light penetration and the growth of submerged aquatic vegetation such as kelp and eelgrass. Secchi disk depth was generally smaller Outside EBLA east of Whidbey Island than the waters surrounding the San Juan Islands, likely driven by the influence of the Skagit River. Both locations had some Secchi depths as high as 15 m (Figure 14). There were no Secchi depth data inside or outside OLYM.

Enterococci levels were highly variable in all locations, with samples generally falling below the recommended guidelines for swimming beaches established by the EPA BEACH program (Schneider 2004); however, in all locations, some samples fell above this level (Figure 15). Fecal coliform levels were generally lower than the guidelines established by the Washington Department of Health Shellfish Program (Woolrich 2012), although in all locations with the exception of Willapa Bay, some samples exceeded the value over which there may be some risk to human health (43 organisms/100mL) (Woolrich 2012) (Figure 16).

Chlorophyll *a* concentration is a measure of phytoplankton abundance or density. Phytoplankton form the base of marine food webs and are an essential component of healthy marine ecosystems. However, excess nutrients can fuel phytoplankton growth to levels that result in the formation of phytoplankton blooms. Microbial decomposition of a fading bloom can produce hypoxic or anoxic conditions. Hence, chlorophyll *a* concentrations can be used to indicate rates of primary production to support food webs and to indicate the potential for hypoxic or anoxic conditions to develop. The EPA’s National Coastal Condition Assessment program criteria for “poor” water quality are above 20 ug/L and above 5 ug/L for “fair” water quality (EPA 2012). Chlorophyll *a* concentrations were the highest in the areas outside EBLA/SAJH and east of

Whidbey Island, with multiple values exceeding the EPA criteria for Poor water quality (Figure 17). Local land use activities such as agriculture, shoreline development, and failing septic systems plus inputs from local rivers all are likely contributors to elevated nutrient and bacterial concentrations in and around EBLA and SAJH.

Sediment quality

None of the sediment contaminants measured inside or outside any of the parks exceeded the Effects Range Maximum (ERM) values used by the EPA National Coastal Condition Assessment (Long et al. 1995, EPA 2012). Appendix A shows locations of all sediment samples for each park.

Low molecular weight PAHs

A relatively small number of samples exceeded the ERL for low molecular weight PAHs. Many of the these samples were taken from the Everett Harbor area, an industrialized area that is the locus of substantial maritime activity, and others came from areas close to commercialized harbors or marinas. A total of four samples of 2-Methylnapthalene exceeded the Effects Range Low (ERL) value (Figure 18). One of these samples was taken from outside EBLA, east of Whidbey Island from the Everett Harbor in 2000, and three others came from outside OLYM, from Makah Bay in 1999. Four samples of Acenapthene exceeded the ERL (Figure 19). These were from a site in the Everett Harbor in 2000, two samples outside EBLA/SAJH in Anacortes and Bellingham marinas and one sample outside LEWI in the Columbia River Estuary (CRE). Two samples of Acenapthylene exceeded the ERL (Figure 20). These were both from outside EBLA, from east of Whidbey Island in the Everett Harbor and outside EBLA/SAJH from the Bellingham Harbor, both in 2000. One sample of Anthracene exceeded the ERL value (Figure 21). This sample was outside of EBLA on the east side of Whidbey Island from the Everett Harbor in 2000. Similarly, there was one sample outside of EBLA on the east side of Whidbey Island that exceeded the ERL for Fluorene (Figure 22), also from Everett Harbor in 2000. Addtionally, there were four sediment samples from outside EBLA/SAJH exceeded the ERL value for Fluorene (from Bellingham Bay, Anacortes, Discovery Bay and Port Townsend Bay) as well as three samples from outside OLYM (Figure 22), from Makah Bay in 1999. Five samples of Napthalene exceeded the ERL value, one outside EBLA east of Whidbey Island from the Everett Harbor in 2000, two from outside EBLA/SAJH from the Bellingham Harbor and from Anacortes in 2000, and two from outside LEWI in the Columbia River Estuary in Youngs Bay in 1999, both the value of 240 ug/g dry weight (Figure 23). Two samples of Phenanthrene exceeded the ERL (Figure 24), one outside EBLA from the east side of Whidbey Island in the Everett Harbor and one outside EBLA/SAJH, from the Bellingham Harbor, both in 2000.

High molecular weight PAHs

One sample of the high molecular weight PAHs Benz(a)anthracene, Benzo(a)pyrene, Chrysene, Fluoranthene and Pyrene exceeded the ERL value, from outside EBLA from east of Whidbey

Island (Figures 25-29), from the Everett Harbor in 2000. Two samples met or exceeded the ERL value for Dibenz(a,h)anthracene (Figure 30), from outside EBLA east of Whidbey Island in the Everett Harbor in 2000 and from Outside LEWI in the Columbia River Estuary in 2000. A single sample, from outside EBLA east of Whidbey Island exceeded the ERL for total PAH (Figure 31), from the Everett Harbor in 2000.

Trace metals

Trace metals occurred at detectable levels in samples collected from areas outside of all four parks (Figures 32-40). The levels of trace metals were generally at or below the ERL, with some exceptions (noted below). The distribution of trace metals showed no discernable pattern, and no hot-spots of trace metals were observed.

Sediment samples exceeding the ERL value for arsenic were collected from inside and outside EBLA, both in the area common to EBLA/SAJH and east of Whidbey Island, and from outside LEWI and in the Columbia River Estuary. However, the median values in all cases were lower than the ERL, indicating fewer than half of the samples exceeded the ERL (Figure 32). One to two samples from inside and outside EBLA/SAJH and east of Whidbey Island exceeded the ERL for cadmium (Figure 33). The two samples from outside EBLA/SAJH that exceeded the ERL for cadmium were from Discovery Bay and the waters around Orcas Island in 1999 and 2004, respectively. The two samples that exceeded this value from outside EBLA east of Whidbey Island were from the Everett Harbor and near Mukilteo in 2000. Samples inside and outside LEWI were below the ERL for cadmium (Figure 33). Single samples from Grays Harbor and Willapa Bay exceeded the ERL value for cadmium (Figure 33), both of which were collected in 2006. Median values outside all four parks were lower than the ERL for chromium, however all four of these areas had some samples that exceeded this value (Figure 34). A single sample from within EBLA collected in 2000 exceeded the ERL for sediment chromium whereas the single sample from within OLYM collected in 1999 was below the ERL (Figure 34). Exactly half of the samples (n=15) collected outside EBLA east of Whidbey Island exceeded the ERL for copper (Figure 35). The three samples outside of EBLA/SAJH that exceeded the ERL for copper were collected from Discovery Bay, Bellingham Harbor, and Orcas Island in 1999, 2000 and 2004, respectively. Fourteen (3%) sediment samples of copper outside LEWI in the Columbia River Estuary exceeded the ERL value, as did 17% of the samples from Grays Harbor and a single sample from Willapa Bay, collected in 2006 (Figure 35). Sediment samples for lead were below the ERL inside and outside all four parks, with the exception of two samples from outside LEWI in the Columbia River Estuary (Figure 36), both of which had a concentration of 74 ug/g and were collected in 1999. Median concentrations of mercury were lower than the ERL inside and outside of all parks for which there were samples collected (Figure 37). The three samples outside EBLA/SAJH that exceeded the ERL value for mercury (Figure 37) were all from Bellingham Bay from 2000 and 2005. Thirty-six percent (n=11) of the samples collected outside EBLA east of Whidbey Island exceeded the ERL for mercury, as did four samples from outside LEWI in the Columbia River Estuary and two samples from Willapa Bay (Figure 37). Four samples exceeding the ERLfor mercury outside LEWI in the Columbia River Estuary were collected from Youngs Bay, mid-estuary, and Youngs River (collected in 1999) and from the Chinook Harbor (collected in 2010). By contrast, some median nickel sediment concentrations met or exceeded the ERL value in all locations, with the exception of the single sample collected within OLYM (Figure 38). Nearly all samples collected for silver were below the ERL value with the exception of the single sample inside EBLA(Figure 39), and one sample east of Whidbey Island just in the Saratoga Passage, both from 2000. One sample collected in the marine waters outside LEWI in 2003 exceeded the ERL value for silver, as did a single sample outside OLYM (Figure 39) also collected in 2003 from the continental shelf, approximately 30km offshore. Four samples outside LEWI in the Columbia River Estuary exceeded the ERL silver in sediment (Figure 39), collected from mid estuary and Youngs Bay in 1999 and outside Youngs Bay and near the mouth of the estuary in 2010. One sediment sample for zinc exceeded the ERL value (Figure 40), this was collected outside EBLA east of Whidbey Island in the Everett Harbor in 2000.

Pesticides and PCBs

Two samples exceeded the ERL for the pesticide 4,4’-DDE (Figure 41). These were collected from outside EBLA/SAJH in Port Townsend Bay in 2000 and Grays Harbor from 2000 and 2006, respectively. Two samples collected from outside SAJH/EBLA exceeded the ERL for total DDT, one collected in Discovery Bay in 1999 and one collected in Port Towsend Bay in 2000. Three samples collected in the Columbia River Estuary in 2000 exceeded the ERL for total DDT (Figure 42), one near Megler, WA in 2000, one in Young’s Bay in 1999 and one near Knappton, WA in 2000 A single sample exceeded the ERL for sediment total PCBS (Figure 43), collected outside EBLA east of Whidbey Island from the Everett Harbor in 2000.

Summary by Park

Ebey's Landing National Historical Reserve

Water quality

Median temperatures were comparable inside and outside of EBLA, with higher temperatures observed outside of EBLA/SAJH and in the waters east of Whidbey Island than within park boundaries(Figure 7). Salinities were higher in areas outside EBLA/SAJH than within EBLA and Out WI (Figure 8), likely because of increased freshwater influence on the east side Whidbey Island. Silicate concentration was much more variable outside EBLA/SAJH than Out WI, which may reflect the stronger influence of the Fraser River (Figure 10). Samples with concentrations exceeding 10mg/L were collected near Bellingham Bay (Figures 2, 3). The single sample of silicate from within EBLA was higher than the median values of out EBLA/SAJH and Out WI, but within the range of both (Figure 10). The single depth profile for Dissolved Inorganic Nitrogen (DIN) was comparable to the medians outside EBLA/SAJH and Out WI, while the Out EBLA/SAJH samples contained some values that were very high (Figure 11), the highest of which were collected adjacent to agricultural areas near Samish Bay. Similarly, outside EBLA/SAJH also had some phosphate concentrations that exceeded the EPA criterion for "poor" water quality (Figure 12), which were collected in Lummi Bay and Bellingham Bay. The maximum value from the single depth profile collected within EBLA also exceeded this value. The minimum phosphate value from profile within EBLA was below the EPA criterion for "good" water quality (Figure 12). The median maximum values for phosphate concentrations in the waters east of Whidbey Island (Out WI) exceeded the criteria for "fair" water quality and the median phosphate concentration outside EBLA/SAJH was very close to this value (Figure 12). The single profile for dissolved oxygen (DO) within EBLA varied with depth such that the minimum value was lower than the EPA criterion for "fair" water quality while the maximum value was higher than the criterion for "good" water quality (Figure 13). Outside EBLA/SAJH and Out WI showed similar median DO concentrations but Out EBLA/SAJH showed some concentrations that were lower than the criterion for "poor" water quality whereas Out WI did not (Figure 13). Median fecal coliform concentrations were lower than the value set by the National Shellfish Sanitation Program (NSSP) inside EBLA as well as Out SAJH and Out WI, however all three areas had some samples that exceeded the maximum criterion of 43 colonies/100ml (Figure 16). The maximum chlorophyll *a* concentration from a single depth profile within EBLA exceeded the EPA criterion for "fair" water quality while the minimum was just below this value (Figure 17). The minimum profile concentrations for chlorophyll *a* outside EBLA/SAJH and Out WI were mostly below the criteria for "good" water quality although some values in both locations exceeded the criterion for "poor" water quality (Figure 17).

There were no data from inside EBLA for pH, Secchi depth or Enterococci within the timeframe of this analysis (2000-2012).

Sediment quality

The single sediment sample that was collected within EBLA for all parameters was in July 2000. The sediment sample concentrations that were higher than the Effects Range Low value (ERL) within EBLA were for arsenic (Figure 32), cadmium (Figure 33), chromium (Figure 34), copper (Figure 35), nickel (Figure 38) and silver (Figure 39) (Table 4).

San Juan Island National Historical Park

No water or sediment quality data were reported within the boundaries of SAJH over the timeframe of this analysis (2000-2012).

Olympic National Park

Water quality

A single sample for water temperature taken inside OLYM in 1999 was within the range of those reported outside (Figure 7), while salinity was very low (Figure 8), presumably because this sample was taken from the mouth of Kalaloch Creek. pH was much lower in this creek than the marine waters outside of OLYM (Figure 9); this is not unusual for river water. The single sample collected within the park fell within the maximum and minimum ranges of silicate, phosphate and DIN (Figures 10, 11, 12). Both maximum and minimum DIN concentrations were below the EPA criterion for "good" water both inside and outside of OLYM (Figure 11), while some of the maximum profile concentrations exceeded this value for phosphate (Figure 12). The sample within OLYM fell with the range of maximum and minimum DO concentrations outside the park (Figure 13). The maximum profile concentrations all exceeded the criterion for "good" water quality while some minimum profile concentrations were lower than the criterion for "fair" water quality (Figure 13). For enterococci, 3% of the 1,151 samples collected outside OLYM were above the threshold set by the EPA BEACH program, while 3 of the 18 samples collected within the park exceeded this value (Figure 15). The majority of the fecal coliform samples collected outside the park were below the maximum value set by the NSSP, 43 colonies/100mL, but 8.7 % of the 977 samples exceeded this value (Figure 16). The single sample for chlorophyll *a* within OLYM was within the range of the maximum and minimum profile concentrations outside the park (Figure 17). The majority of the maximum profile chlorophyll a concentrations fell within the "fair" water quality designation, while nearly all of the minimum concentrations were in the "good" category (Figure 17).

No data were reported for Secchi depth inside or outside OLYM or fecal coliform data within the park over the timeframe covered by this analysis (2000-2012).

Sediment quality

The single sediment quality sample for all parameters within OLYM was collected in 1999 and none of the parameters measured in this sample exceeded the ERL concentration (Table 4).

Lewis and Clark National Historical Park

Water quality

Temperature ranges within LEWI were similar to those measured in the marine waters outside the park (Out) and lower than those collected outside the park within the Columbia River Estuary (CRE) (Figure 7). Salinity within LEWI was much lower than outside the park off of the west coast while more similar to the lower end of the range of values outside the park within CRE (Figure 8). pH ranges were much higher Outside LEWI than within the park or Out CRE (Figure 9). Median maximum dissolved oxygen concentrations were all above the EPA criterion for "good" water quality inside LEWI as well as both Out and Out CRE (Figure 13). The minimum concentrations were in the "good" range for inside LEWI and Out CRE while majority of the profile minimum data fell within the "fair" range Outside LEWI in the marine waters west of the park (Figure 13). The median enterococci concentrations inside and outside LEWI were below the criterion established by the EPA BEACH program, with some samples outside the park exceeding this value (Figure 15). Fecal coliform concentrations were also largely below the minimum criteria used by the NSSP outside the park, with some values falling above the maximum concentration (Figure 16). Ranges of maximum chlorophyll *a* concentrations outside LEWI and outside CRE were similar, while minimum concentrations outside LEWI were lower than those outside CRE (Figure 17).

No data for nutrient or secchi, fecal coliform, or chlorophyll *a* were reported from within LEWI over the timeframe of this analysis (2000-2012). No data pertaining to sediment quality in LEWI over the study period was available from the EPA National Coastal Condition Assessment (our source of sediment contaminant data). However, isolated observations of sediment contamination have been reported. For example, sediment samples taken from the Fort Clatsop unit in 2006 showed levels of arsenic that exceeded limits established by the Oregon Department of Environmental Quality, and sampling at a second site in 2014 also found arsenic. These observations are not included in our graphical analyses.

Conclusions and Recommendations

1. Data availability constrained the analysis. Data pertaining to marine and estuarine water quality and sediment quality in and around four PNW coastal parks are extremely patchy in time and space. With the exception of certain commonly-measured parameters (e.g., temperature, salinity), temporally-coherent and spatially-extensive data were relatively rare. This was especially true for measures of contaminants and toxins. Hence, a recommendation to emerge from our analysis is to review, refine, and expand sampling of parameters of interest to coastal park managers.

2. Data availability from outside park boundaries exceeded that from inside park boundaries. This is not surprising, since the areas sampled outside park boundaries were far larger than that inside park boundaries, and because multiple agencies contribute to sampling outside park boundaries. However, the distribution of the available data reduced the strength of comparisons that could be made and prevented finer-scale analyses that could provide additional insights. We recommend that park managers develop and implement a strategic plan for sample collection and data analysis inside park boundaries, and partner with other agencies to develop and maintain a useful sampling program outside park boundaries.

3. *We detected no consistent directional differences in marine and estuarine water or sediment quality inside versus outside park units.* Where sharp differences did occur, for example in some measures of salinity or pH inside and outside parks, the differences could be attributed to spatial differences in the collection of samples (for instance, salinity measurements strongly influenced by river outflow, or pH measurements being compared between intertidal and shelf waters).

4. *The highest sediment contaminant concentrations were observed outside of park boundaries.* This finding could be attributable to industrial activities that occur outside park boundaries. Notably, among the data we analyzed, no sediment samples from either inside or outside park boundaries exceeded the established ERM (effects range maximum).

Importantly, we found that existing sediment samples within parks were insufficient to draw meaningful or robust comparisons. We recommend that park managers consider developing and implementing a strategic plan for sediment sampling. Sediment chemistry is less temporally variable than water chemistry, is more likely to reflect local (as opposed to regional) conditions, and offers a more robust representation of overall conditions with respect to contaminants and toxins. Hence, sediment data are better suited for comparisons of the sort made in this report. The utility of such an approach is exemplified by the Washington Department of Ecology’s Regional Stormwater Monitoring Program (RSMP) which was developed to measure the effects of stormwater on nearshore marine environments in Puget Sound. Within that program, the Puget Marine Nearshore Sediment monitoring program collects data on sediment quality.

Finally, the shorelines and nearshore areas of the four PNW coastal parks provide enormous social and ecological benefits. These benefits are likely to grow as environmental change accelerates. Continuing to steward these areas for future generations should be an important priority for coastal managers.

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Table 1. Data sources and data collecting entities of water and sediment parameters

Data Source	Collecting Entity
U.S. Environmental Protection Agency/Washington Department of Ecology	National Coastal Condition Assessment
EIM	Carbaryl Concentrations in Willipa Bay
	Clallam County-Wide Monitoring CCWF Task 3
	Dungeness/Matriotti Creek TMDL
	Island County: NW Whidbey Island: Swan Lake (aka Bos Lake, Swantown Lake, West Beach Lake) water quality monitoring
	Marina Copper Study
	Mats Mats Bay Water Quality Improvement Program
	Puget Sound Boatyard Receiving Water Study
	Samish Basin Watershed Water Quality Monitoring Project
	Stillaguamish River Watershed Fecal Coliform, Dissolved Oxyg
	Volunteer Water Quality Monitoring: Baseline Monitoring of Columbia River Tributaries
	WA State BEACH (Beach Environmental Assessment, Communication, and Health) Program
LEWI NP	National Park Service
STORET	LummiNation (Washington)
	Quinault Indian Nation
	Oregon Department of Human Services
	Samish Indian Nation
	Shoaltwater Bay Tribe (Washington)
	STILLAGUAMISH TRIBE OF INDIANS
	Swinomish Indian Tribal Community
	Tulalip Tribes
Washington Department of Ecology	Washington Department of Ecology Marine Water Quality Program
Washington Department of Health	Washington Department of Health Water Quality Monitoring Program

Table 2. Water parameters and units

Parameter name	Unit
Temperature	C
Salinity	PSU
pH	
Dissolved Inorganic Nitrogen	mg/L
Silicate	mg/L
Phosphate	mg/L
Dissolved Oxygen	mg/L
Secchi	m
Enterococci	#/100ml
Fecal Coliform	#/100ml
Chlorophyll *a*	ug/L

Table 3. Number of samples for water quality data parameters and years for which data are presented.

Parameter	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Chl a	44	181	116	164	221	209	202	117	113	103	98	152	120	124
Dissolved Inorganic Nitrogen	45	188	117	122	142	129	102		8	13	2	44	26	30
Dissolved Oxygen	44	654	332	286	274	215	174	240	275	225	105	32	228	158
Enterococci			56	13	51	937	1358	1156	1102	1086	1448	1168	1363	1190
Fecal Coliform		2624	3052	3040	3164	3175	3045	2993	3085	3110	2831	2958	3133	3073
pH	44	58	55	90	81	40	14	127	168	108	43	32	238	166
Phosphate	44	182	104	92	137	128	102		6	8		42		
Salinity	44	3696	3522	3375	3483	3423	3158	3322	3511	3467	3037	2995	3598	3406
Secchi		353	328	279	213	212	185	206	79	87	62			
Silicate	31	162	104	92	130	102	89		2	8				
Temperature	44	2987	3320	3144	3379	3359	3192	3116	3275	3348	2907	2890	3359	3236

Table 4. Number of samples for sediment contaminant data parameters and years for which data are presented

	1999	2000	2002	2003	2004	2005	2006	2010
Metals								
Arsenic	43	45	47	57	56	25	36	39
Cadmium	43	45	47	57	56	25	36	39
Chromium	43	45	47	57	56	25	36	39
Copper	43	45	47	57	56	25	36	39
Lead	43	45	47	57	56	25	36	39
Mercury	43	45	47	57	56	25	36	39
Nickel	43	45	47	57	56	25	36	39
Silver	43	45	47	57	56	25	36	39
Zinc	43	45	47	57	56	25	36	39
PAH								
2-Methylnaphthalene	43	45	47	57	56	25	36	39
Acenaphthene	43	45	47	57	56	25	36	39
Acenaphthylene	43	45	47	57	56	25	36	39
Anthracene	43	45	47	57	56	25	36	39
Benz(a)anthracene	43	45	47	57	56	25	36	39
Benzo(a)pyrene	43	45	47	57	56	25	36	39
Chrysene	43	45	47	57	56	25	36	39
Dibenz(a,h)anthracene	43	45	47	57	56	25	36	39
Fluoranthene	43	45	47	57	56	25	36	39
Fluorene	43	45	47	57	56	25	36	39
Phenanthrene		25	47	57				39
Pyrene	43	45	47	57	56	25	36	39
Total PAH	43	45	47	57	56	25	36	39
Pesticides								
4,4'-DDE	43	45	47	57	56	25	36	39
Total DDT	43	45	47	57	56	25	36	39
PCB	43	45	47	57	56	25	36	39
Total PCB	43	45	47	57	56	25	36	39

Table 5. Sediment parameters , units and effects range low (ERL) and effects range maximum (ERM) as determined by Long et al. 1995

Category	Parameter	Units	ERL	ERM
Metals	Arsenic	ug/g dry weight	8.2	70
	Cadmium	ug/g dry weight	1.2	9.6
	Chromium	ug/g dry weight	81	370
	Copper	ug/g dry weight	34	270
	Lead	ug/g dry weight	46.7	218
	Mercury	ug/g dry weight	0.15	0.71
	Nickel	ug/g dry weight	20.9	51.6
	Silver	ug/g dry weight	1	3.7
	Zinc	ug/g dry weight	150	410
PAH	**Low Molecular Weight**			
	2-Methylnaphthalene	ng/g dry weight	70	260
	Acenaphthene	ng/g dry weight	16	500
	Acenaphthylene	ng/g dry weight	44	640
	Anthracene	ng/g dry weight	85.3	1,100
	Fluorene	ng/g dry weight	19	540
	Naphthalene	ng/g dry weight	160	2,100
	Phenanthrene	ng/g dry weight	240	1,500
	High Molecular Weight			
	Benz(a)anthracene	ng/g dry weight	261	1,600
	Benzo(a)pyrene	ng/g dry weight	430	1,600
	Dibenz(a,h)anthracene	ng/g dry weight	63.4	260
	Fluoranthene	ng/g dry weight	600	5,100
	Chrysene	ng/g dry weight	384	2,800
	Pyrene	ng/g dry weight	665	3,160
	Total PAH	ng/g dry weight	4,022	44,792
Pesticides	4,4'-DDE	ng/g dry weight	2.2	27
	Total DDT	ng/g dry weight	1.6	46
PCB	Total PCB	ng/g dry weight	22.7	180

Table 6. Sediment contaminant sample sizes for each sampling area. Green shading indicates that all values were below the effects range low value (ERL)(Long et al. 1995), yellow shading indicates that at least one sample was above the ERL and red shading would indicate at least one sample above the effects range maximum (ERM)(Long et al. 1995). Note that EBLA Out and SAJH Out are the same group of samples.

	EBLA			LEWI					OLYM		SAJH	
	In	Out	Out WI	In	Out	Out CRE	Out GH	Out WB	In	Out	In	Out
Metals												
Arsenic	1	45	30	0	28	107	39	65	1	33	0	45
Cadmium	1	45	30	0	28	107	39	65	1	33	0	45
Chromium	1	45	30	0	28	107	39	65	1	33	0	45
Copper	1	45	30	0	28	107	39	65	1	33	0	45
Lead	1	45	30	0	28	107	39	65	1	33	0	45
Mercury	1	45	30	0	28	107	39	65	1	33	0	45
Nickel	1	45	30	0	28	107	39	65	1	33	0	45
Silver	1	45	30	0	28	107	39	65	1	33	0	45
Zinc	1	45	30	0	28	107	39	65	1	33	0	45
PAH												
2-Methylnaphthalene	1	45	30	0	28	106	39	65	1	33	0	45
Acenaphthene	1	45	30	0	28	106	39	65	1	33	0	45
Acenaphthylene	1	45	30	0	28	106	39	65	1	33	0	45
Anthracene	1	45	30	0	28	106	39	65	1	33	0	45
Fluorene	1	45	30	0	28	106	39	65	1	33	0	45
Naphthalene	1	45	30	0	28	106	39	65	1	33	0	45
Phenanthrene	1	23	20	0	27	11	18	38	0	30	0	23
Benz(a)anthracene	1	45	30	0	28	106	39	65	1	33	0	45
Benzo(a)pyrene	1	45	30	0	28	106	39	65	1	33	0	45
Chrysene	1	45	30	0	28	106	39	65	1	33	0	45
Dibenz(a,h)anthracene	1	45	30	0	28	106	39	65	1	33	0	45
Fluoranthene	1	45	30	0	28	106	39	65	1	33	0	45
Pyrene	1	45	30	0	28	106	39	65	1	33	0	45
Total PAH	1	45	30	0	28	106	39	65	1	33	0	45
Pesticides												
4,4'-DDE	1	45	30	0	28	105	39	65	1	33	0	45
Total DDT	1	45	30	0	28	105	39	65	1	33	0	45
PCB												
Total PCB	1	45	30	0	28	105	39	65	1	33	0	45

Legend
Green = all samples below ERL
Yellow = at least one sample above ERL
Red = at least one sample agove ERM
Numbers indicate total sample size

Figure 1. Map of all four Pacific Northwest National Parks (EBLA = Ebey's Landing, SAJH = San Juan Historical Area, OLYM = Olympic National Park, LEWI = Lewis and Clark National Park). Areas inside each park are colored green and areas we considered as "adjacent" to each park are designated by hash marks.

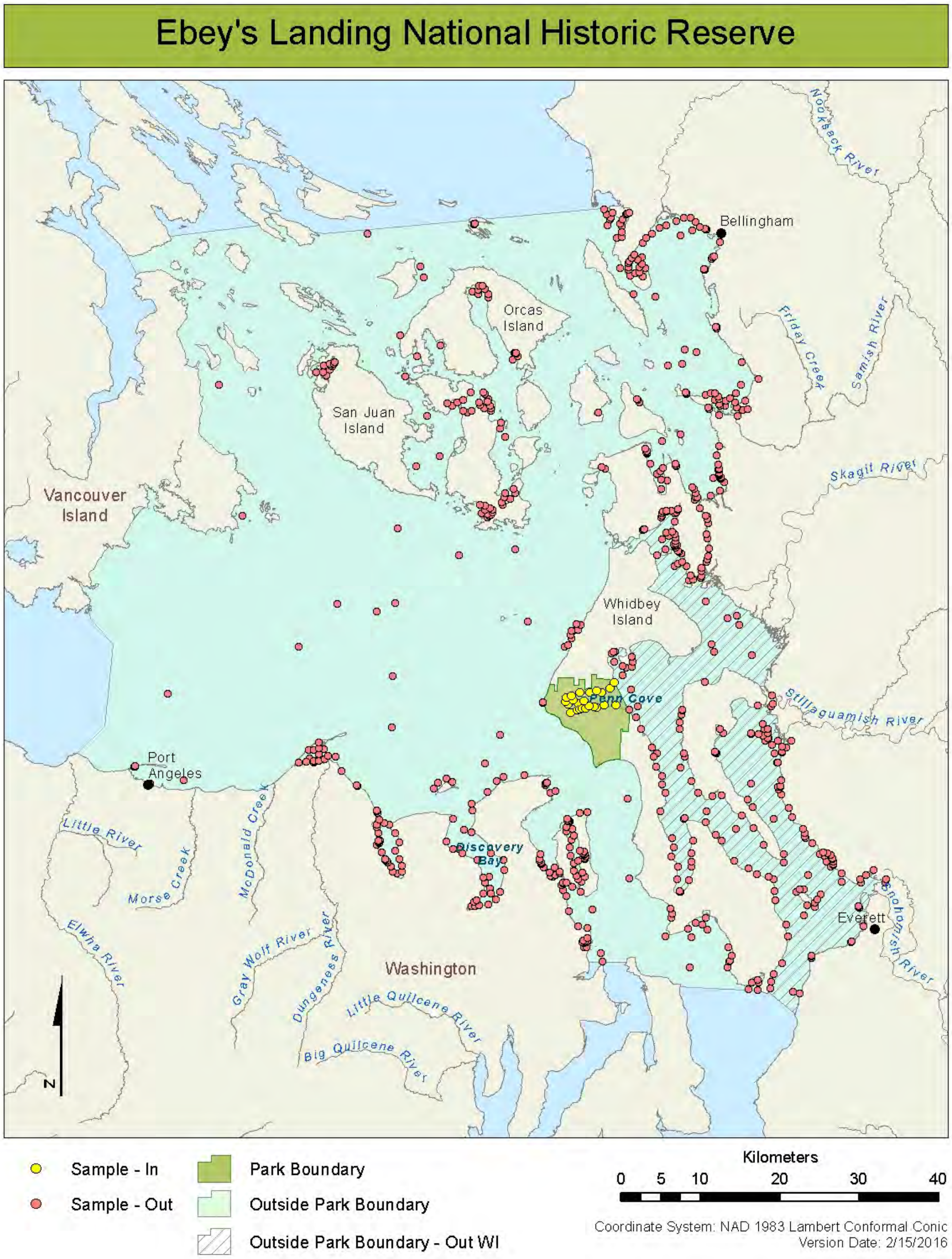


Figure 2. Map of Ebey's Landing National Historic Reserve showing water and sediment samples inside and outisde of the park.

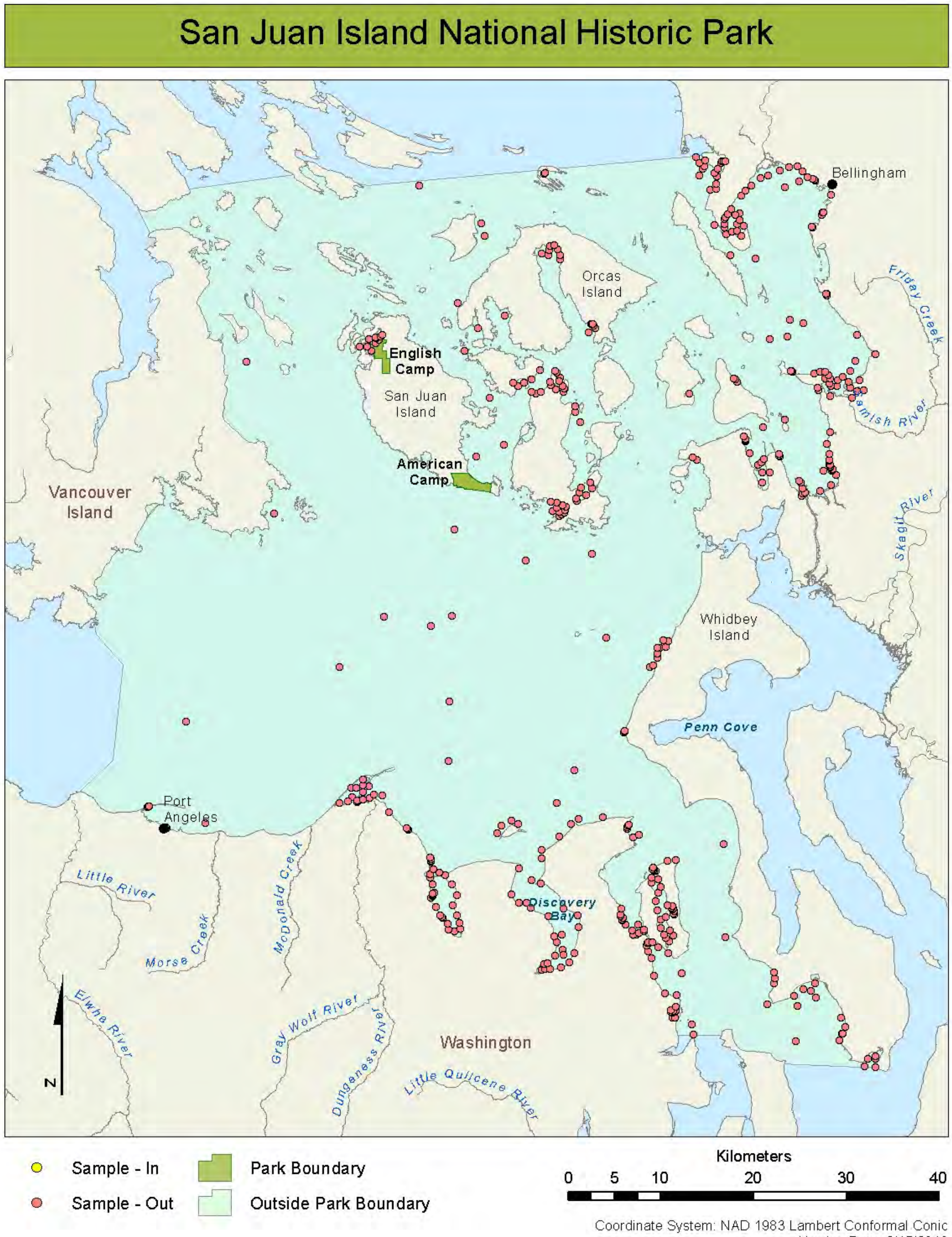


Figure 3. Map of San Juan Island National Historic Park showing water and sediment samples inside and outside of the park.

Figure 4. Map of Olympic National Park showing water and sediment samples inside and outside of the park.

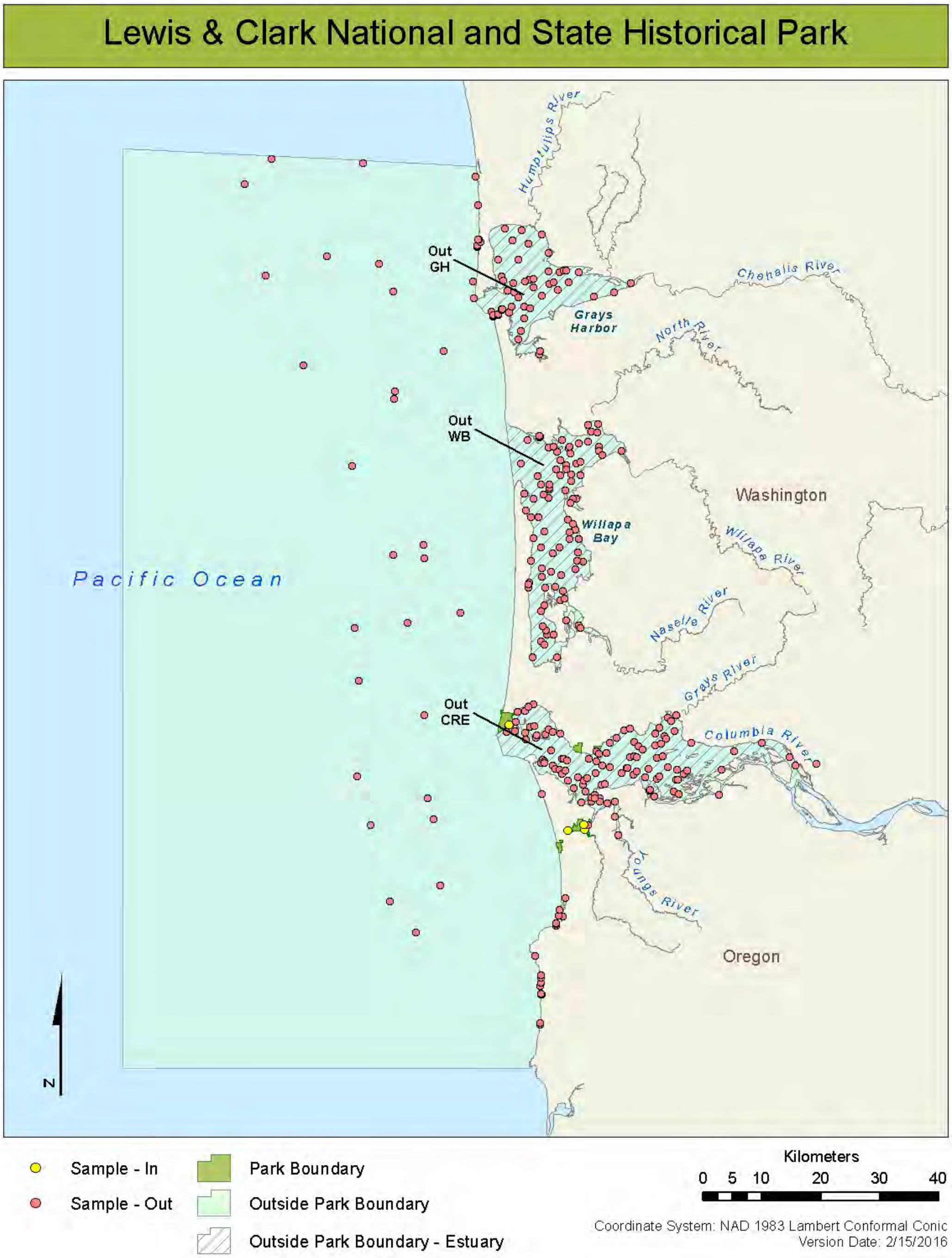


Figure 5. Map of Lewis and Clark National and State Historic Park showing water and sediment samples inside and outside of the park.

Figure 6. Map of all four Pacific Northwest National Parks (EBLA = Ebey's Landing, SAJH = San Juan Historical Area, OLYM = Olympic National Park, LEWI = Lewis and Clark National Park). Areas inside each park are colored green and areas we considered as "adjacent" to each park are colored blue. Dots water and sediment samples.

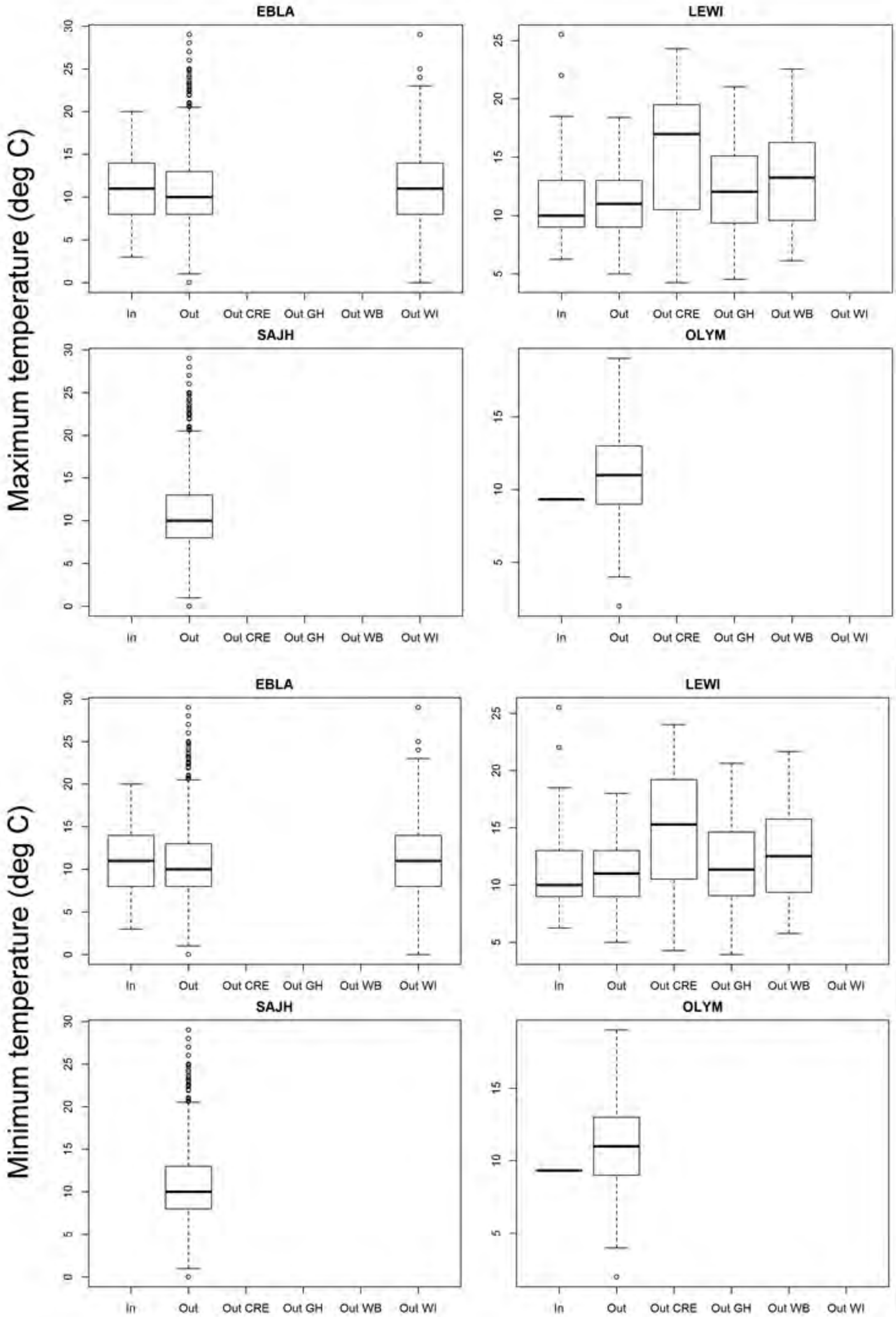


Figure 7. Boxplots of maximum and minimum water temperature (°C) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance.

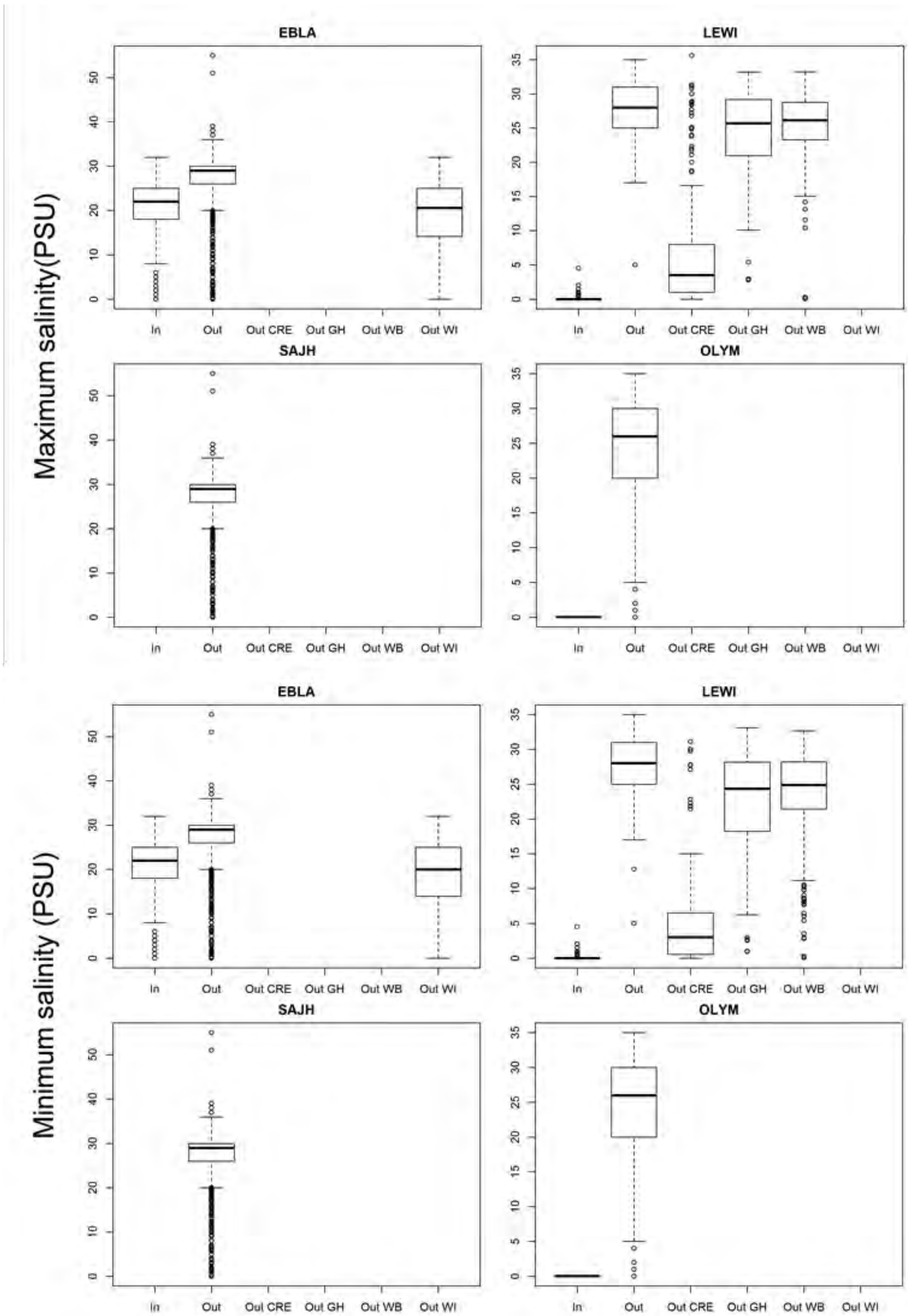


Figure 8. Boxplots of maximum and minimum water salinity (PSU) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance.

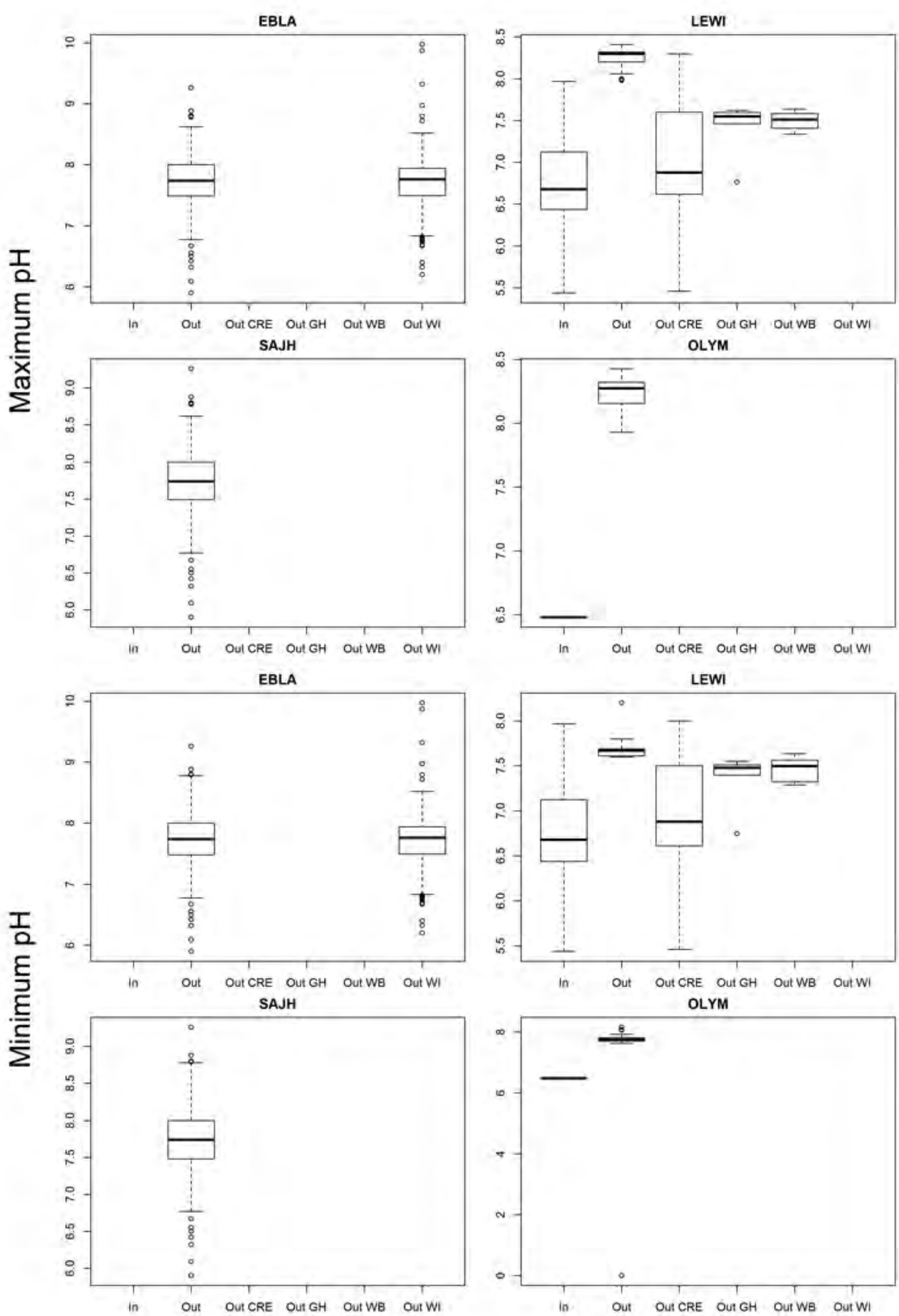


Figure 9. Boxplots of maximum and minimum water pH inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance.

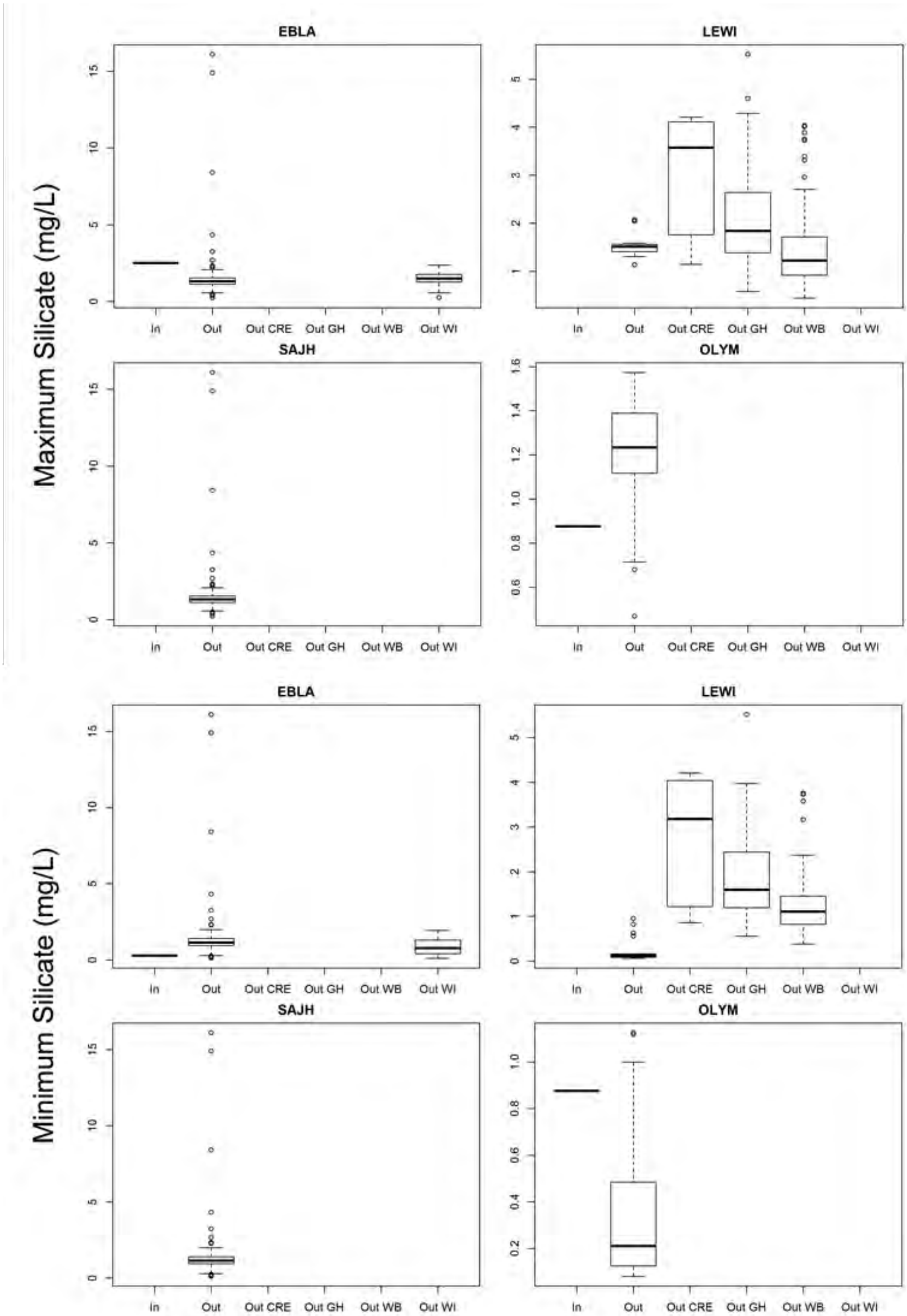


Figure 10. Boxplots of maximum and minimum water silicate (mg/L) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance.

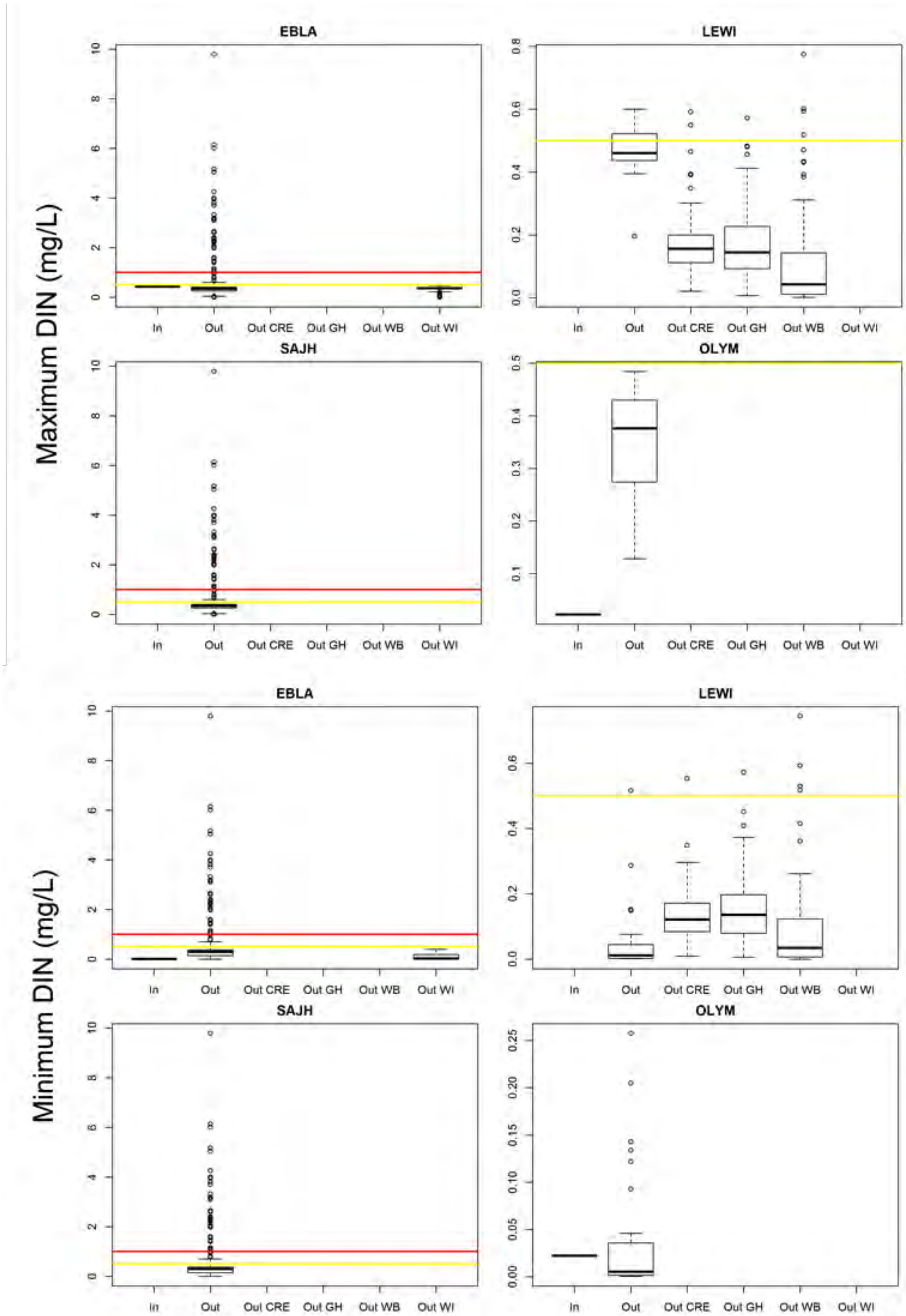


Figure 11. Boxplots of maximum and minimum water Dissolved Inorganic Nitrogen ($NO_3+NO_2+NH_4$)(DIN)(mg/L) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow and red lines represent EPA criteria (EPA 2012).

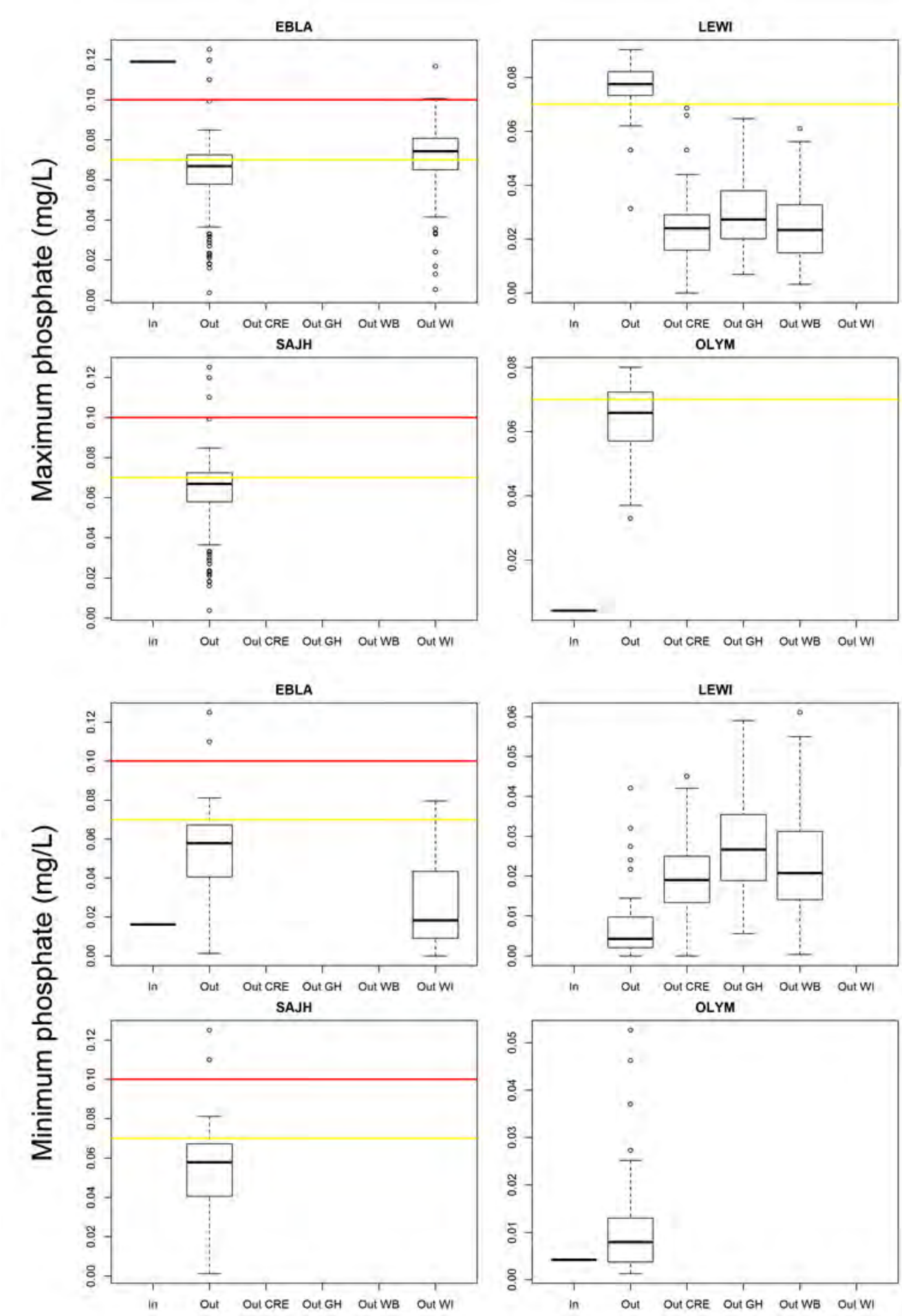


Figure 12. Boxplots of maximum and minimum water phosphate (mg/L) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow and red lines represent EPA criteria (EPA 2012).

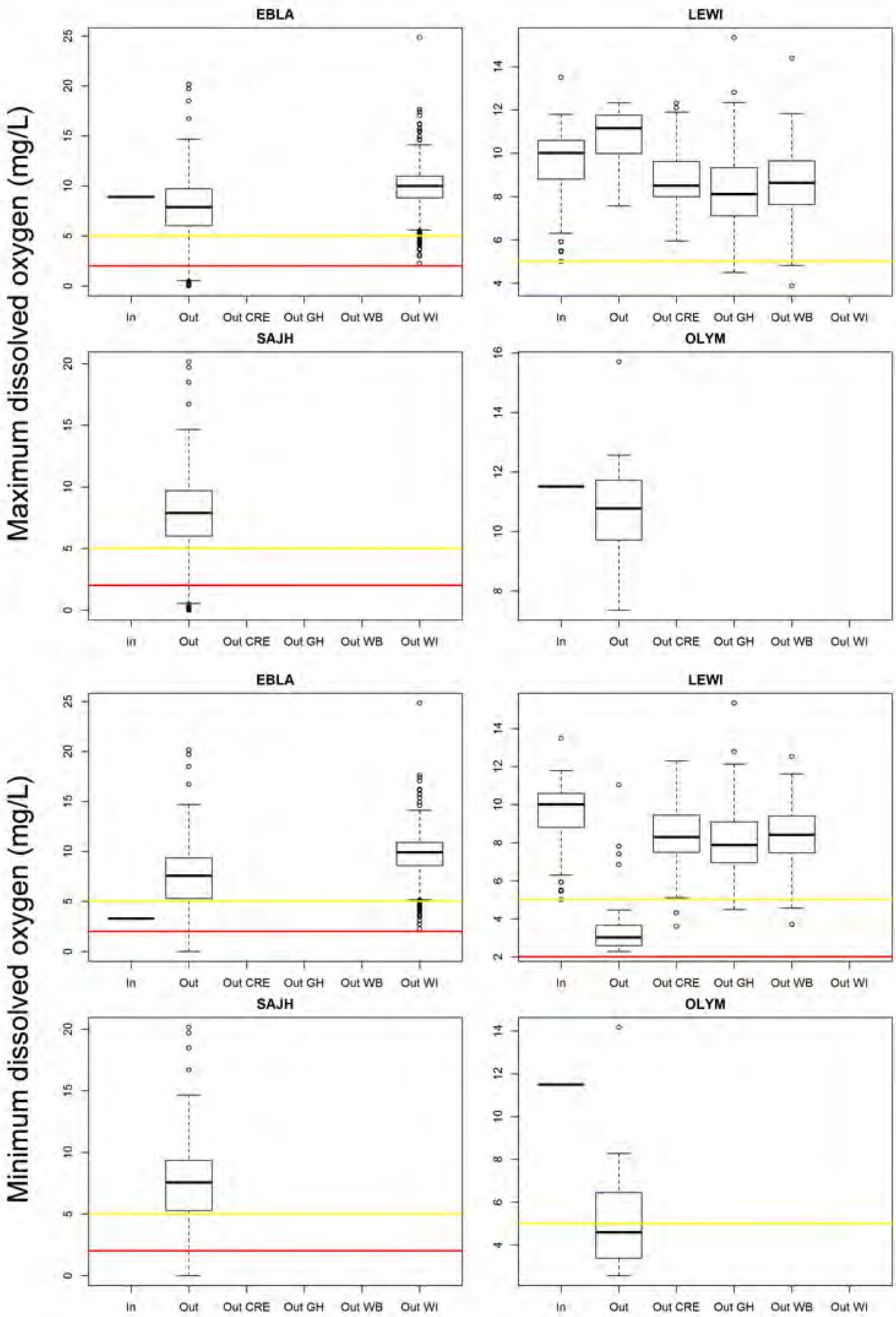


Figure 13. Boxplots of maximum and minimum water dissolved oxygen (mg/L) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow and red lines represent EPA criteria (EPA 2012).

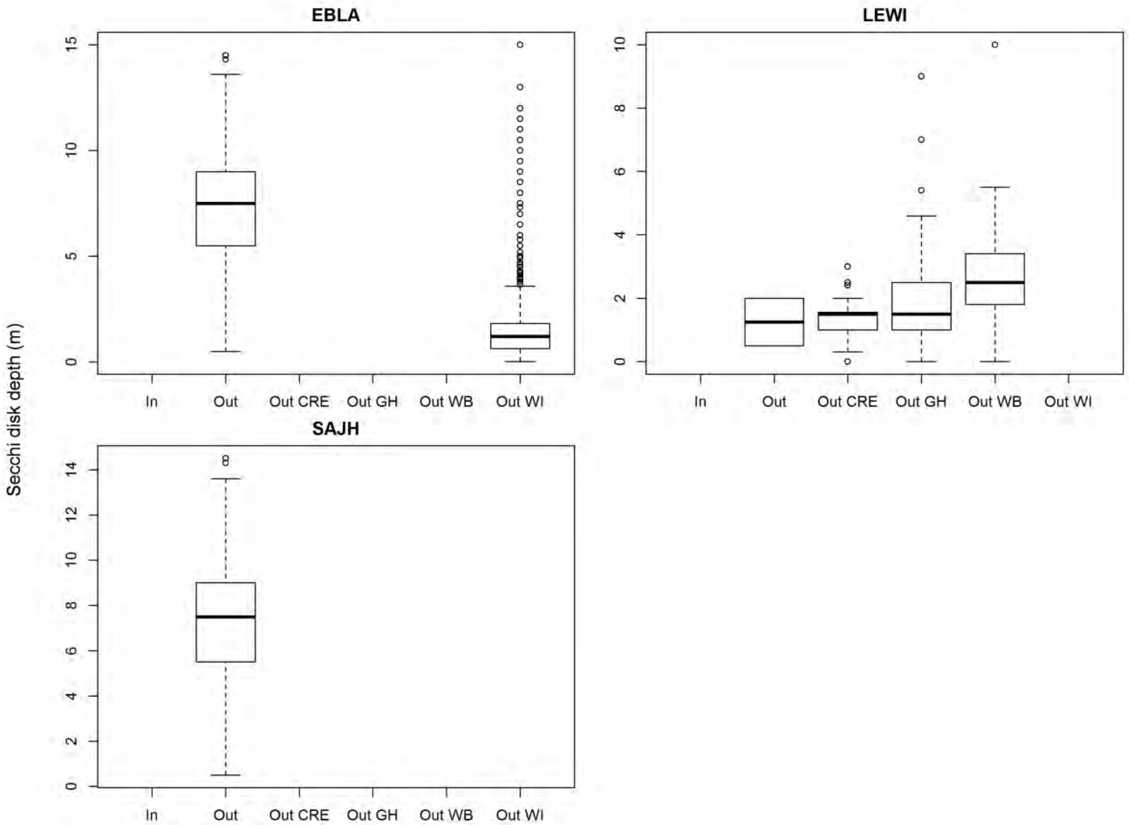


Figure 14. Boxplots of Secchi disk depth (m) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance.

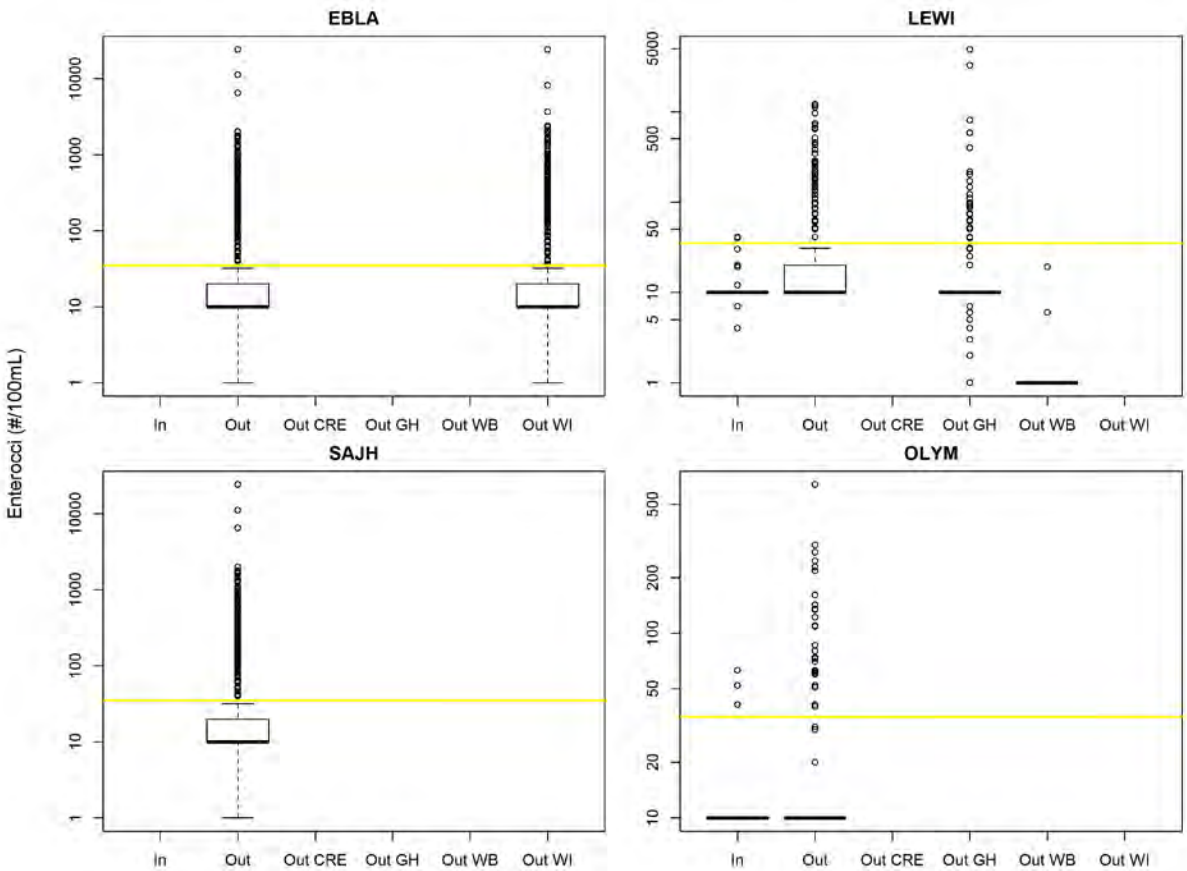


Figure 15. Boxplots of Enterococci (#/100ml) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent recommended EPA levels for recreational beaches (EPA 1986). Note log scale on y axis.

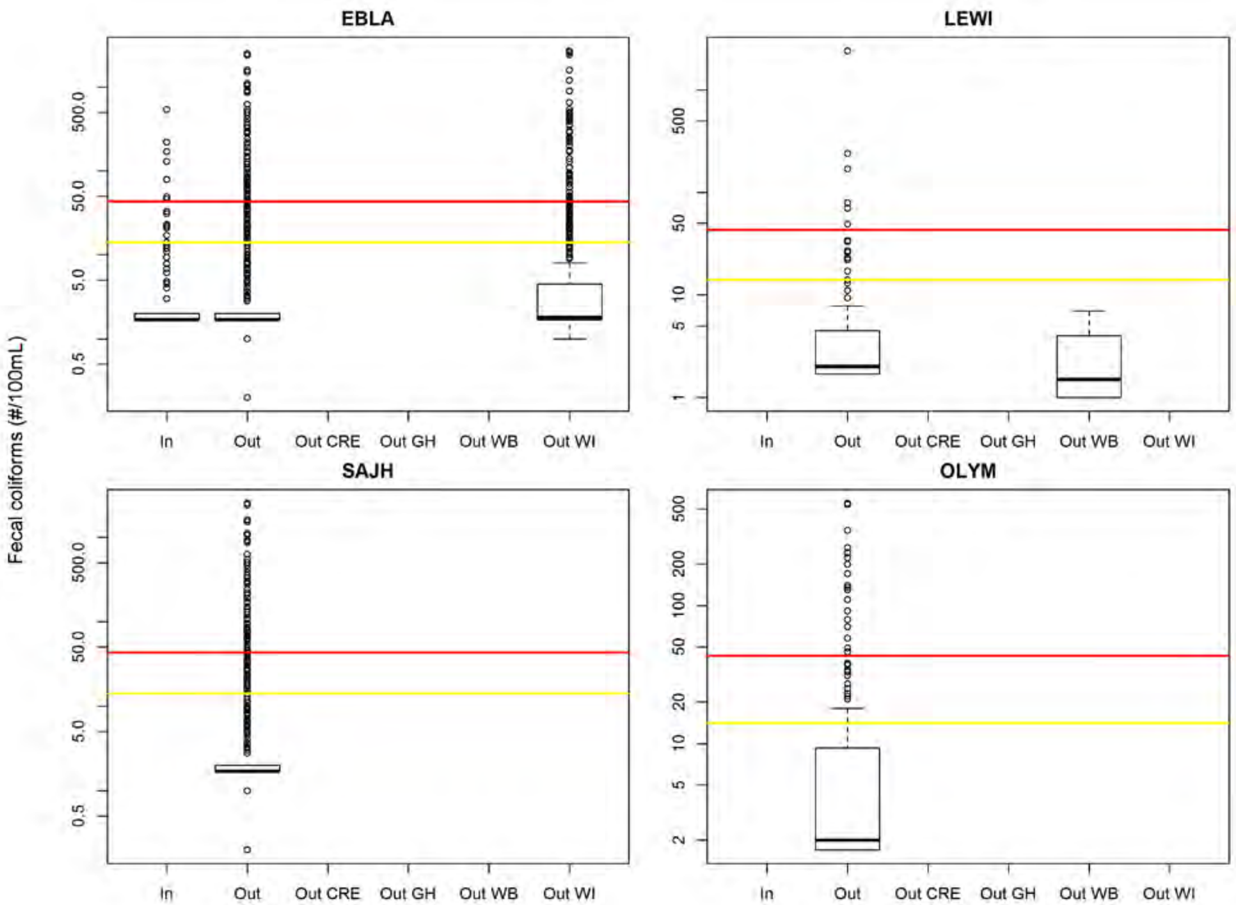


Figure 16. Boxplots of fecal coliforms (#/100ml) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow and red lines represent guidelines for shellfish harvesting (NSSP, Woolrich 2012). Note log scale on y axis.

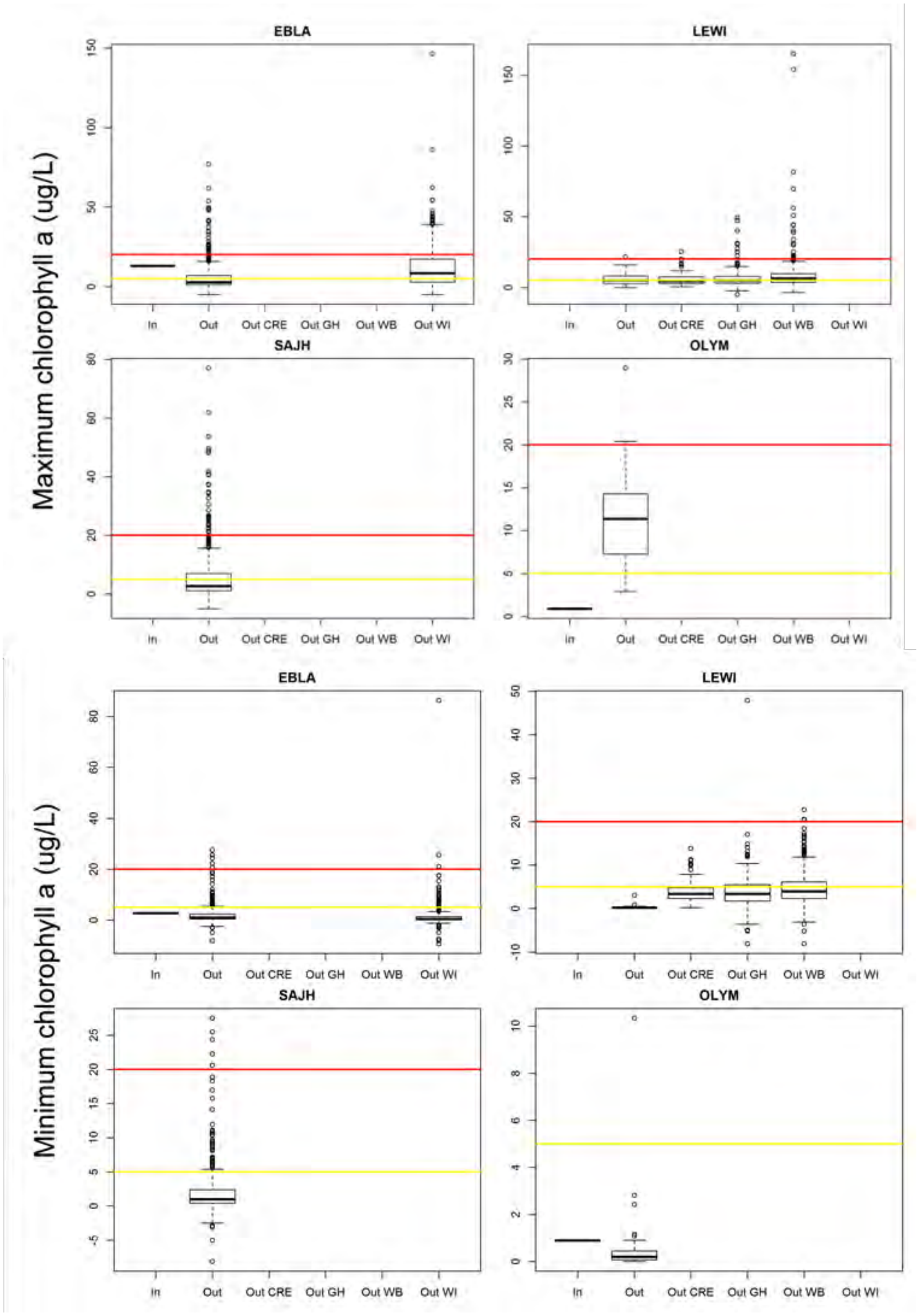


Figure 17. Boxplots of chlorophyll a (ug/L) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow and red lines represent EPA criteria (EPA 2012).

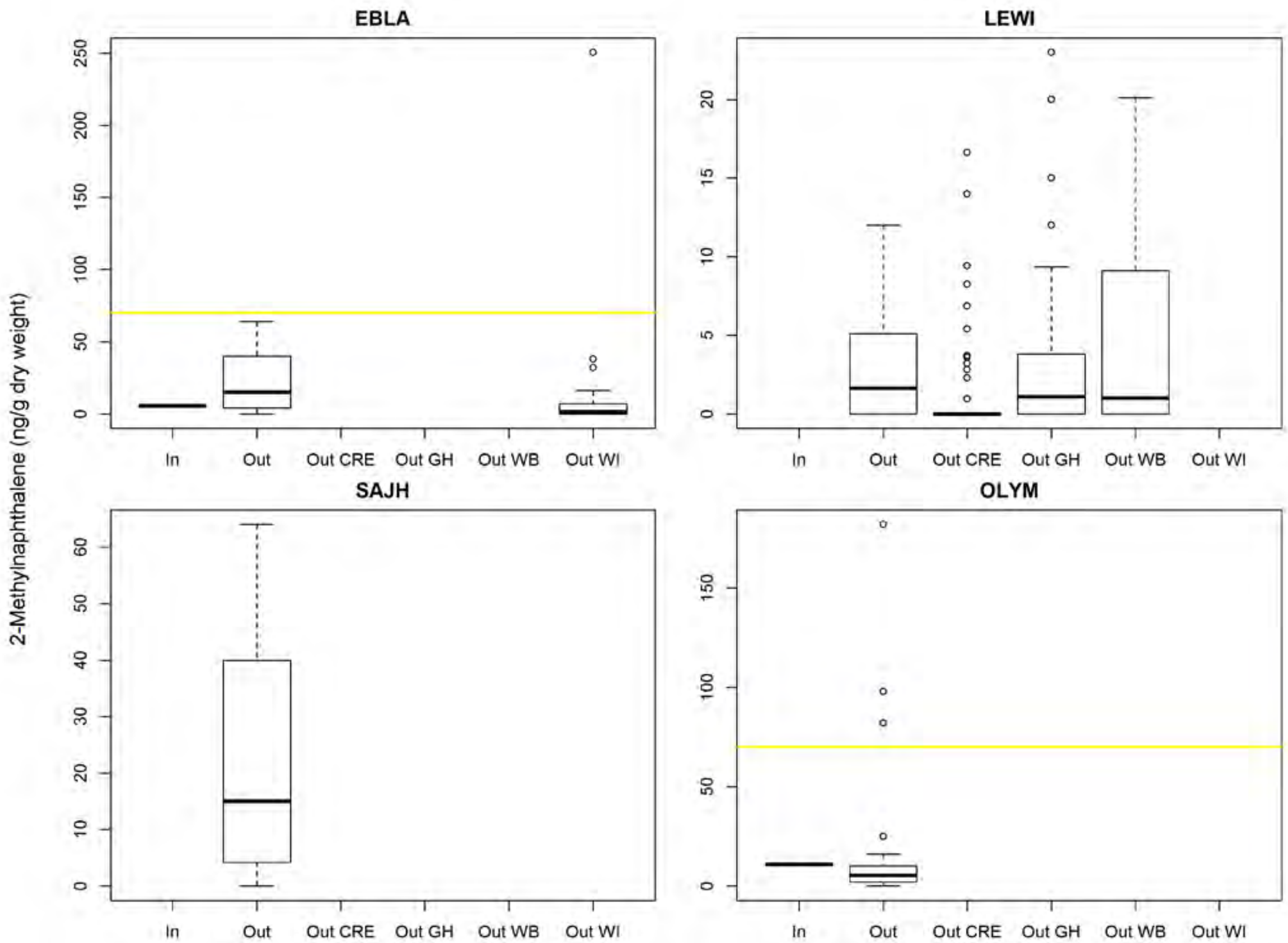


Figure 18. Boxplots of 2-Methylnaphthalene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25^{th} and 75^{th} quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

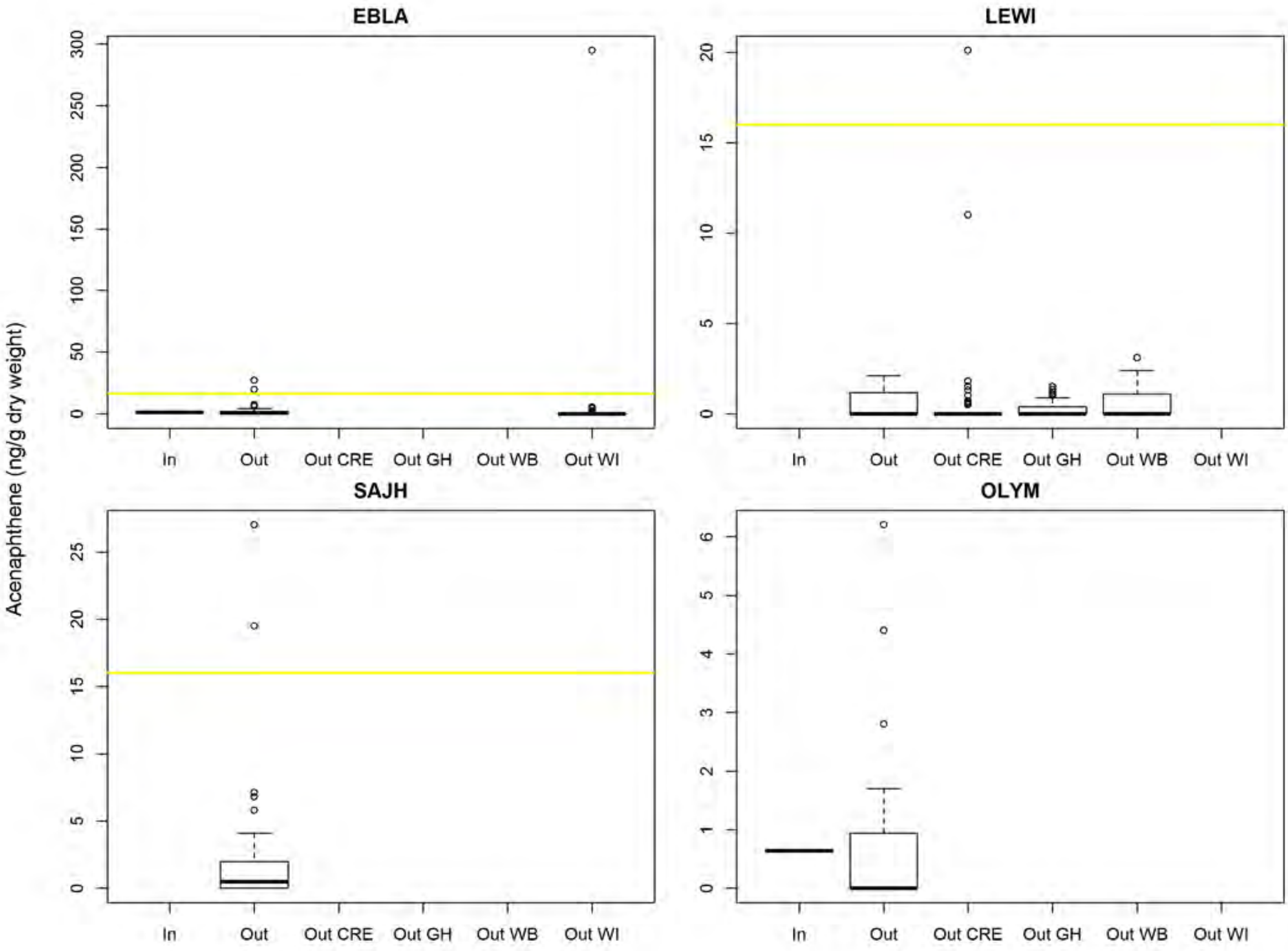


Figure 19. Boxplots of Acenapthene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

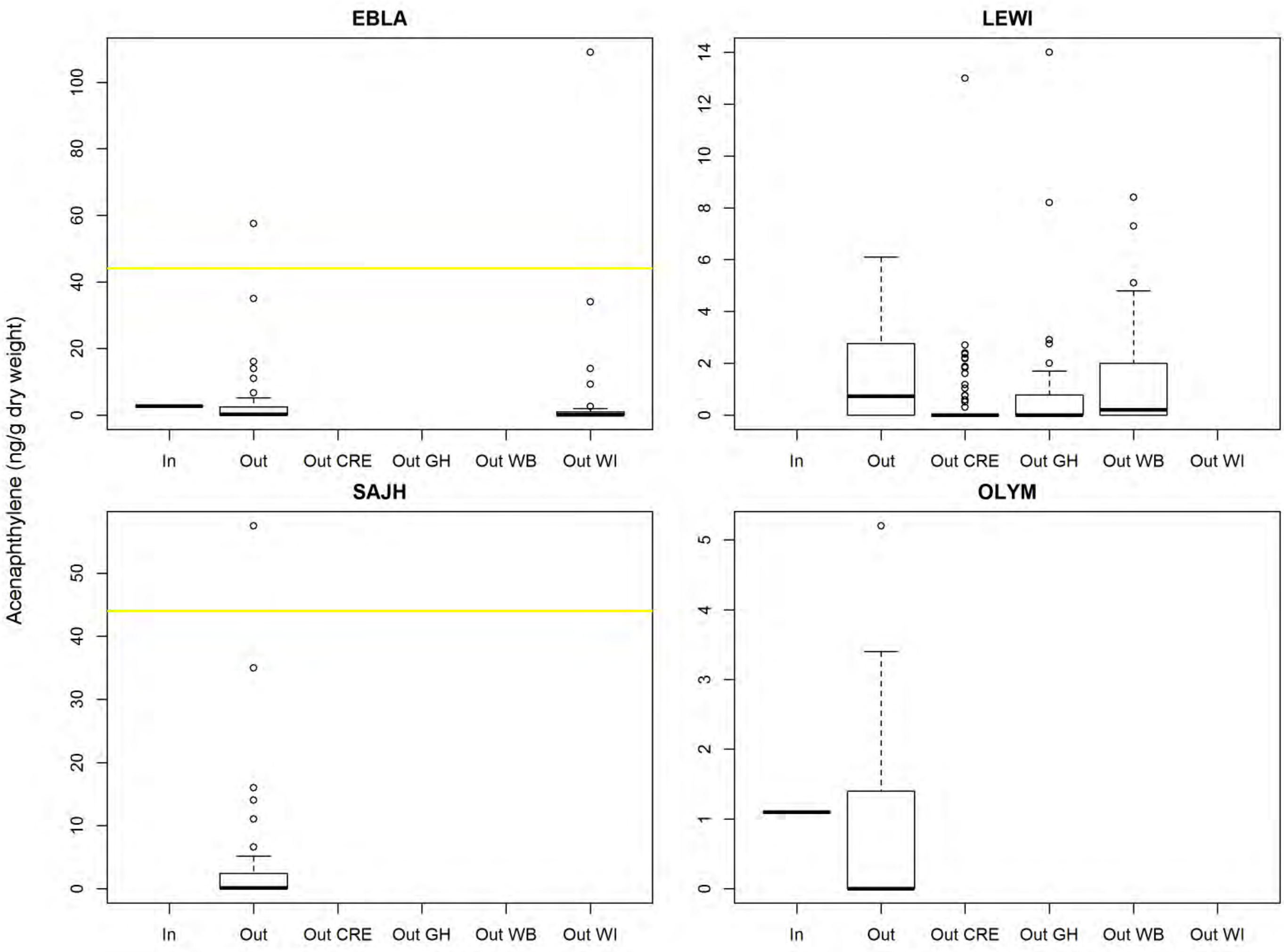


Figure 20. Boxplots of Acenaphthylene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25^{th} and 75^{th} quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

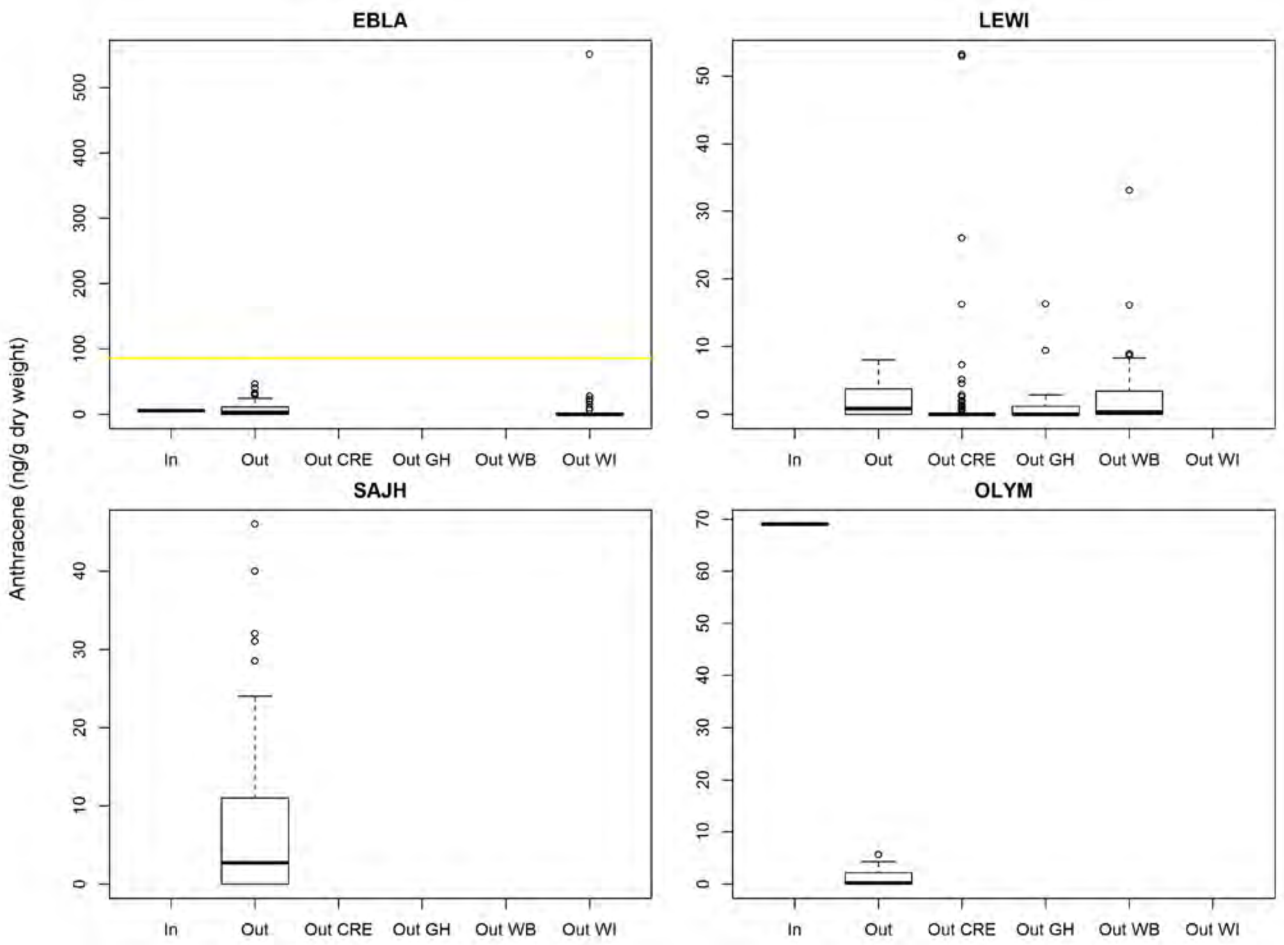


Figure 21. Boxplots of Anthracene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

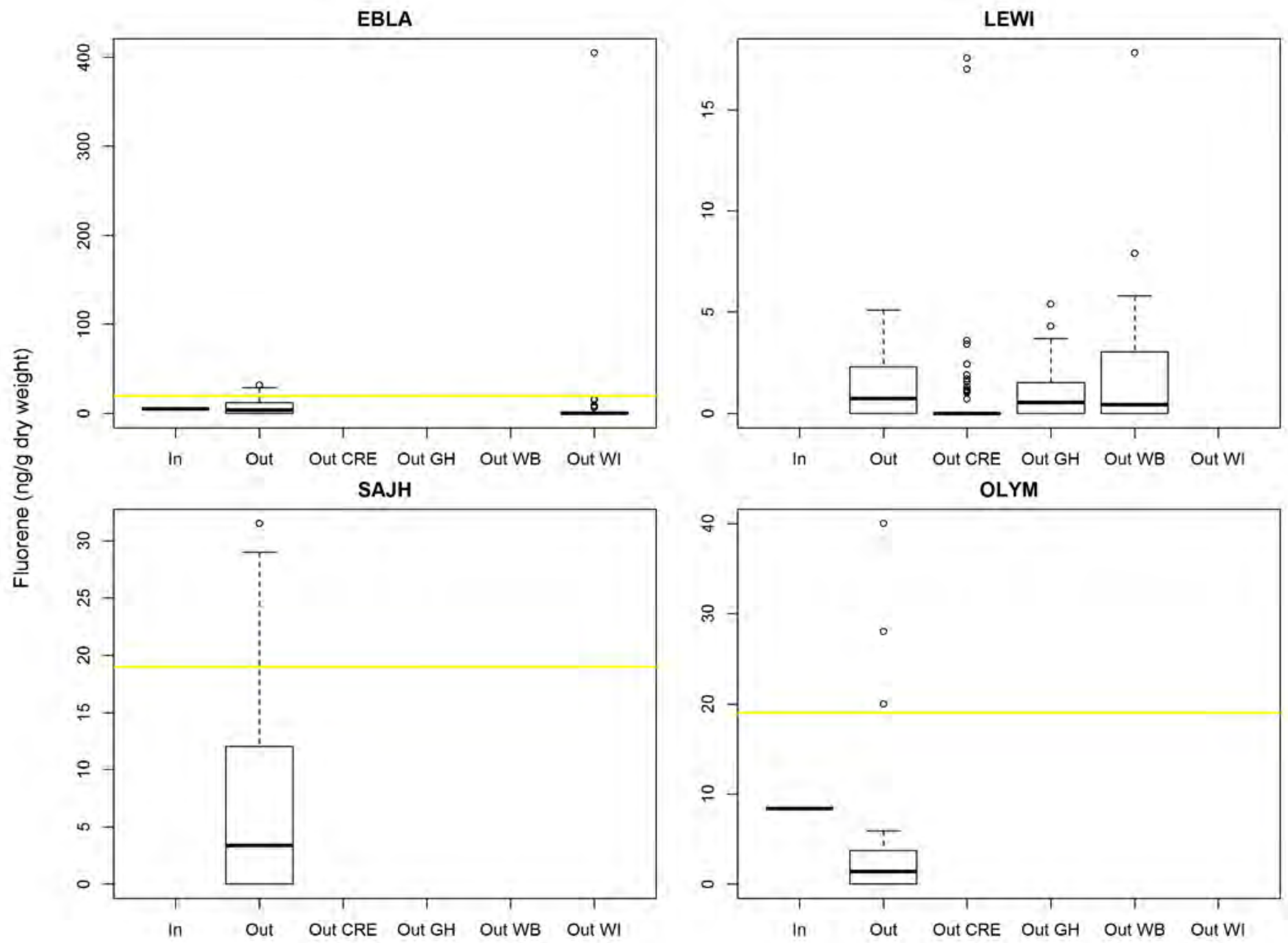


Figure 22. Boxplots of Fluorene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25^{th} and 75^{th} quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

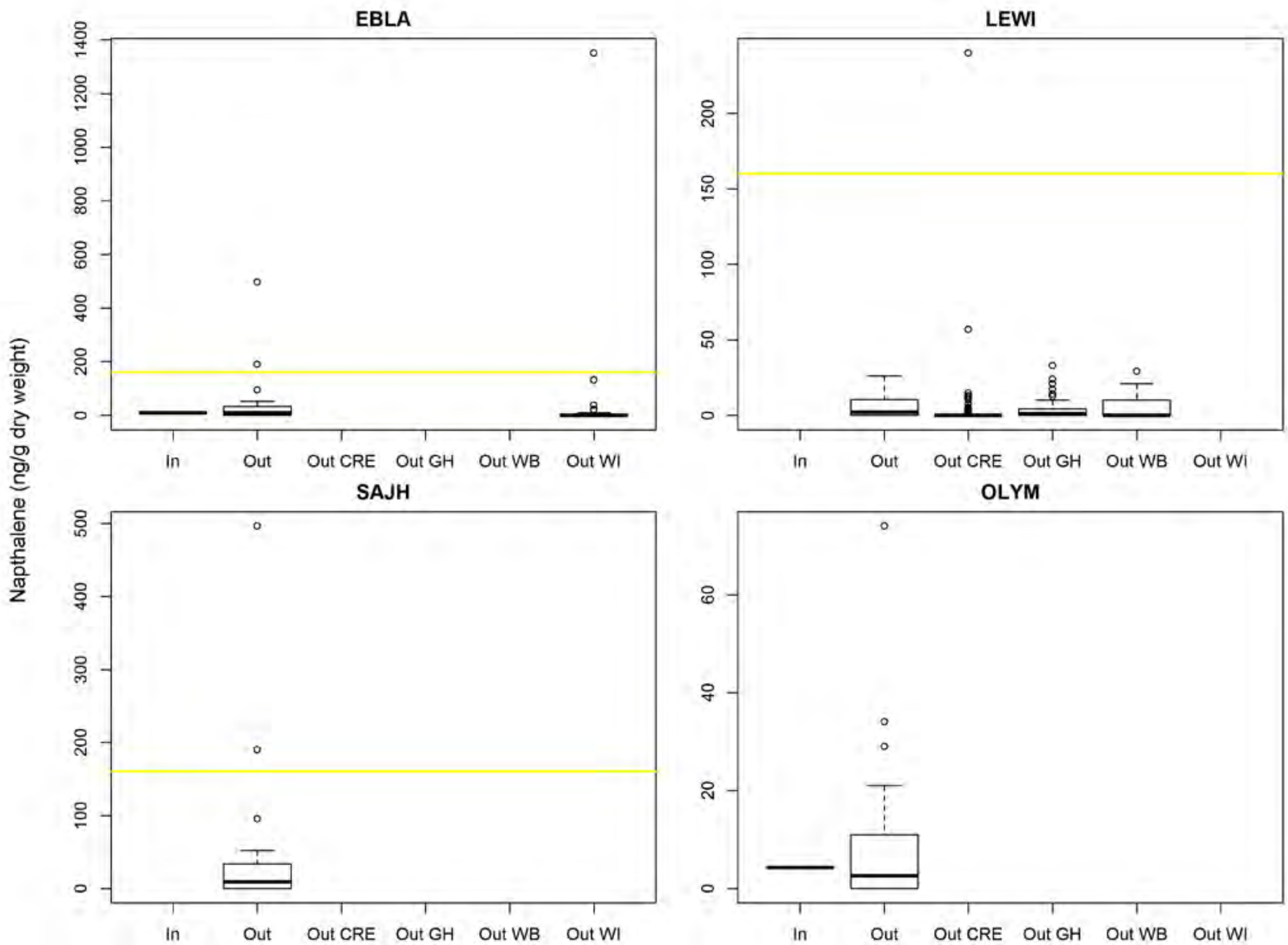


Figure 23. Boxplots of Napthalene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

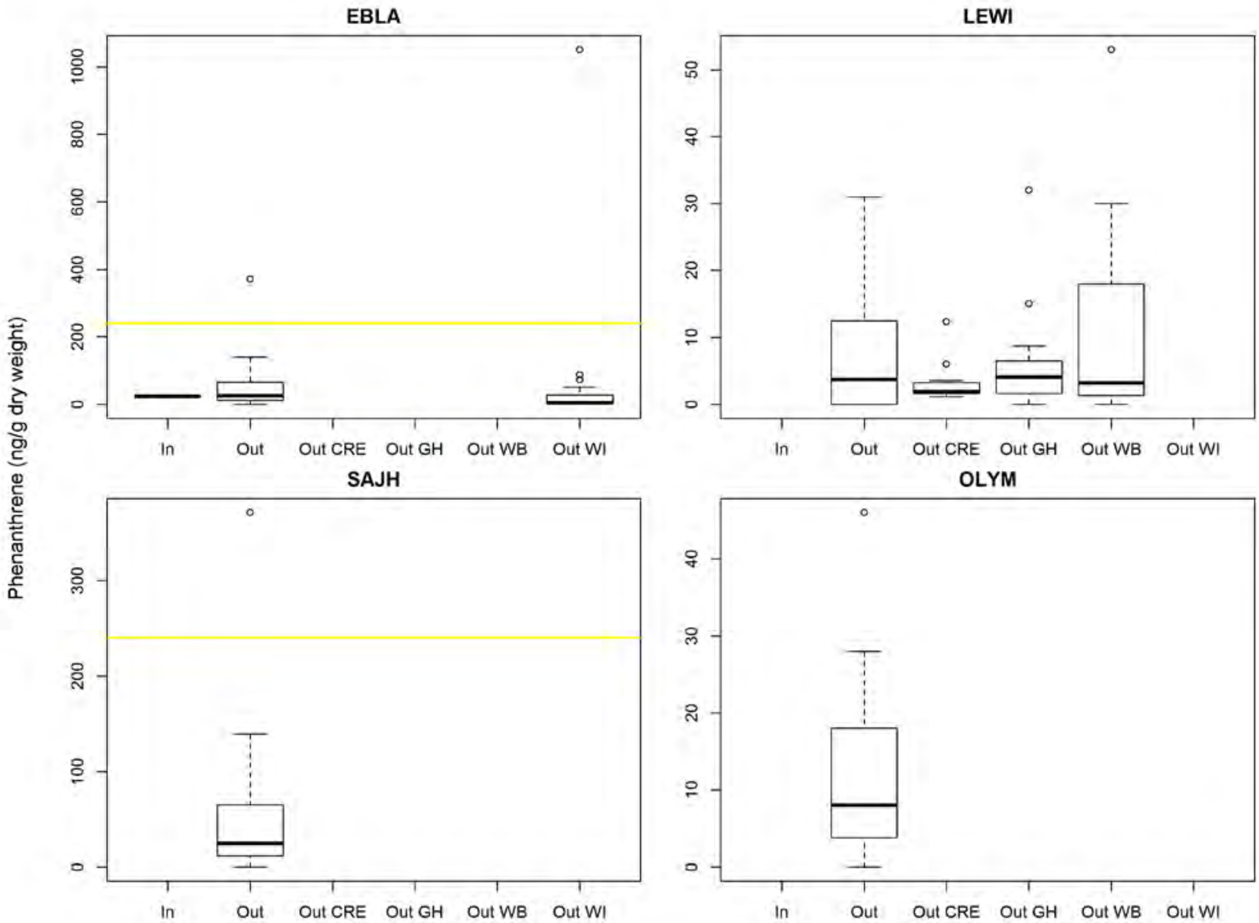


Figure 24. Boxplots of Phenanthrene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

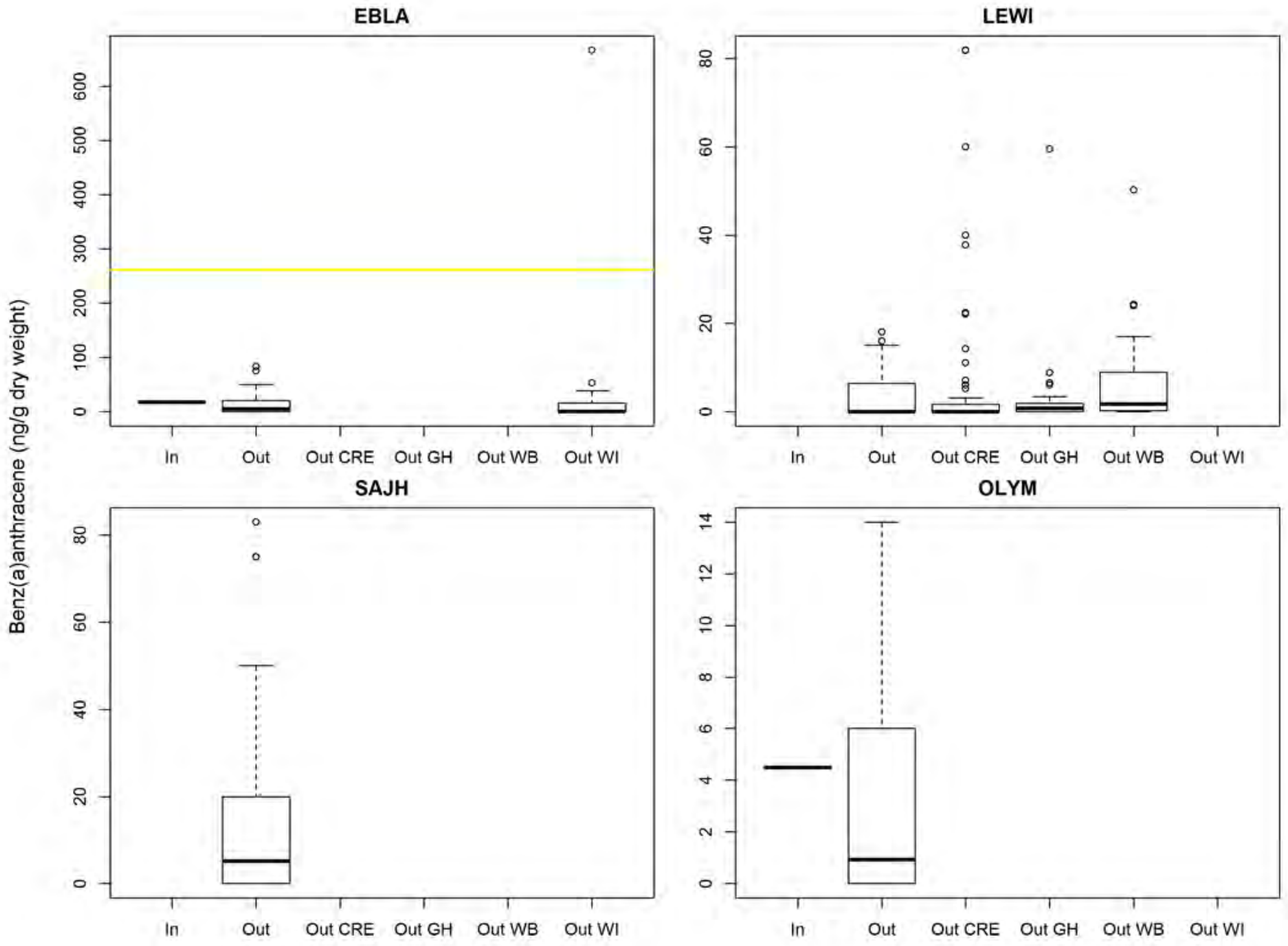


Figure 25. Boxplots of Benz(a)anthracene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

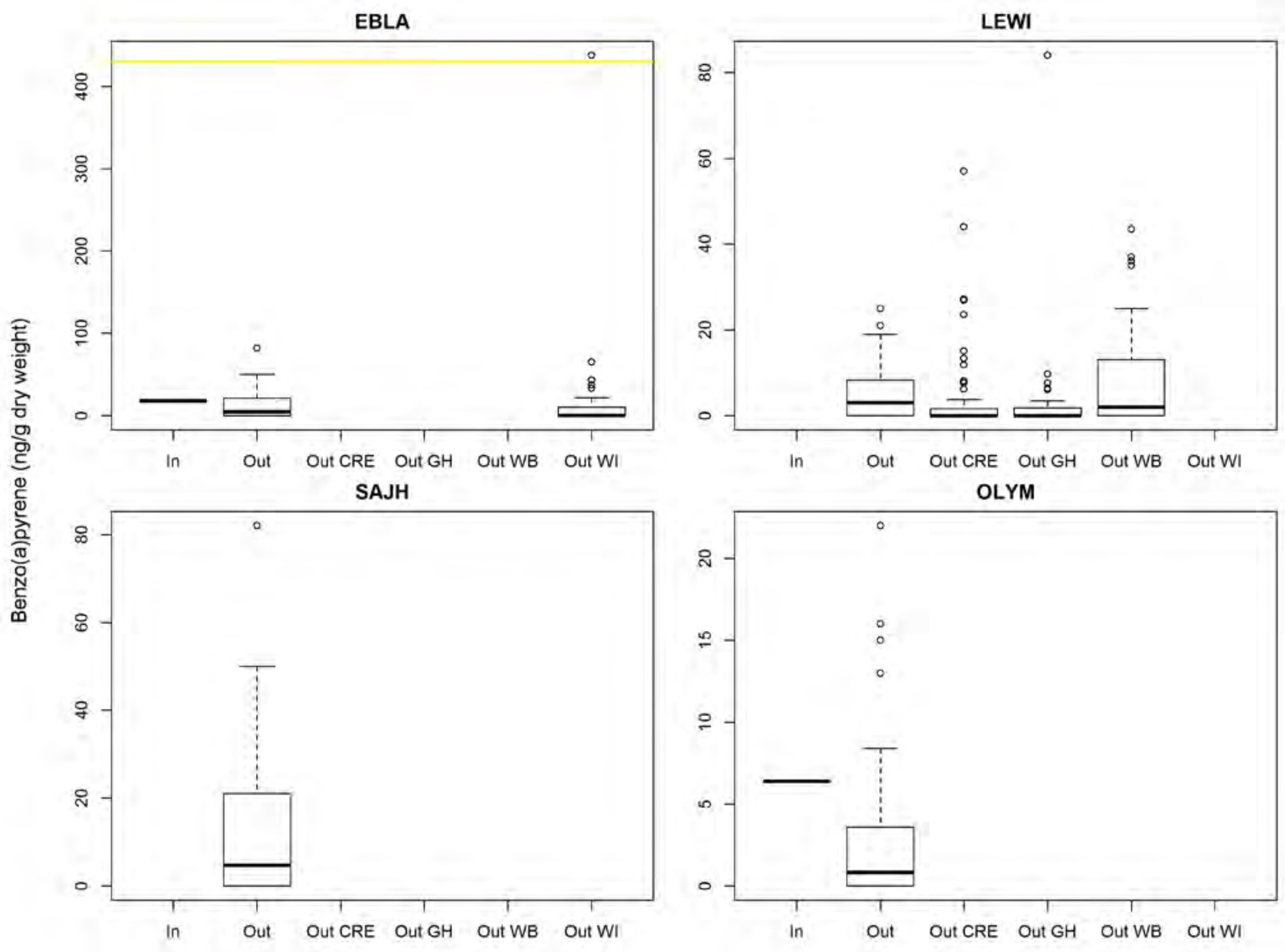


Figure 26. Boxplots of Benzo(a)pyrene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

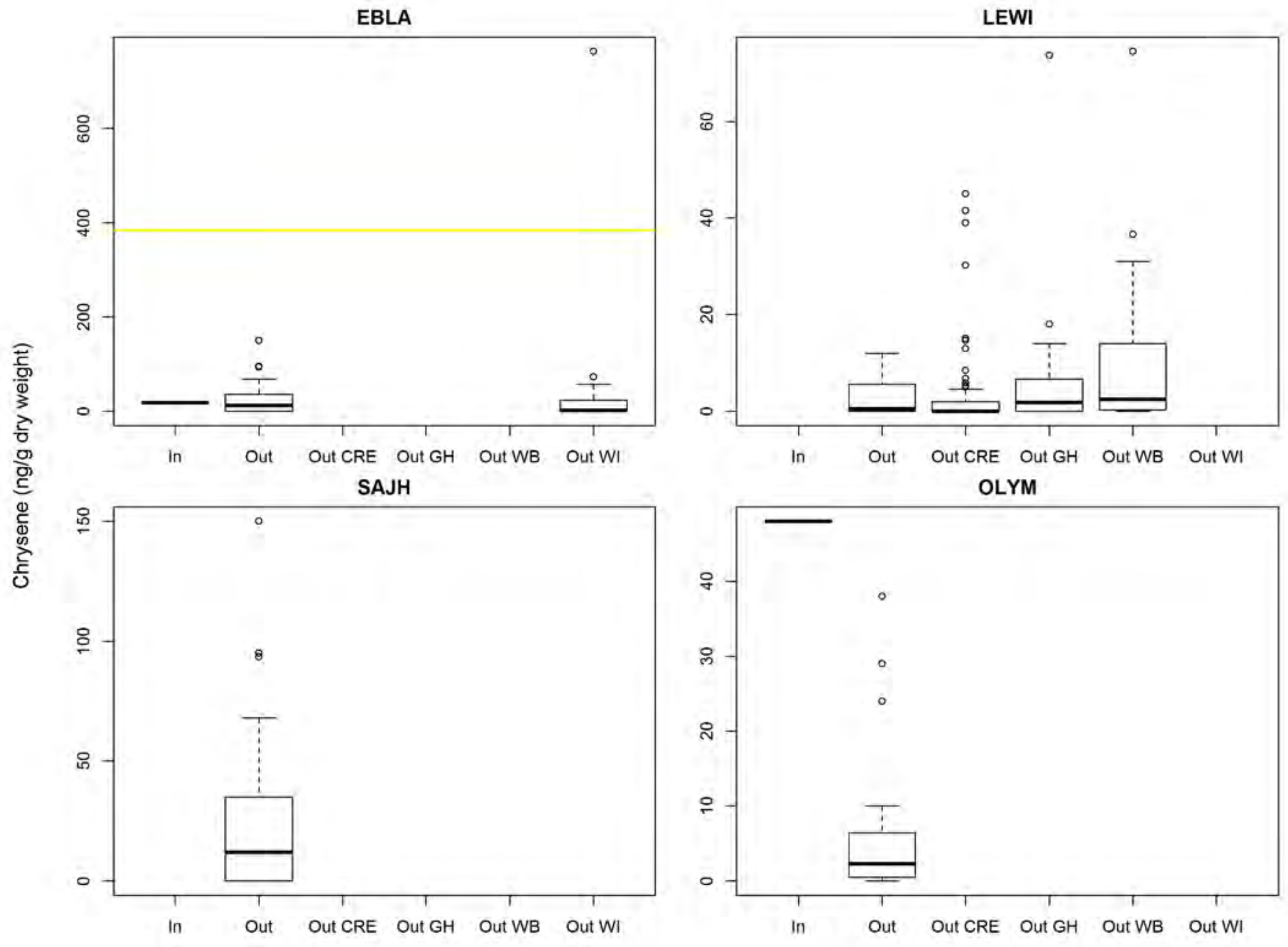


Figure 27. Boxplots of Chrysene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25^{th} and 75^{th} quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

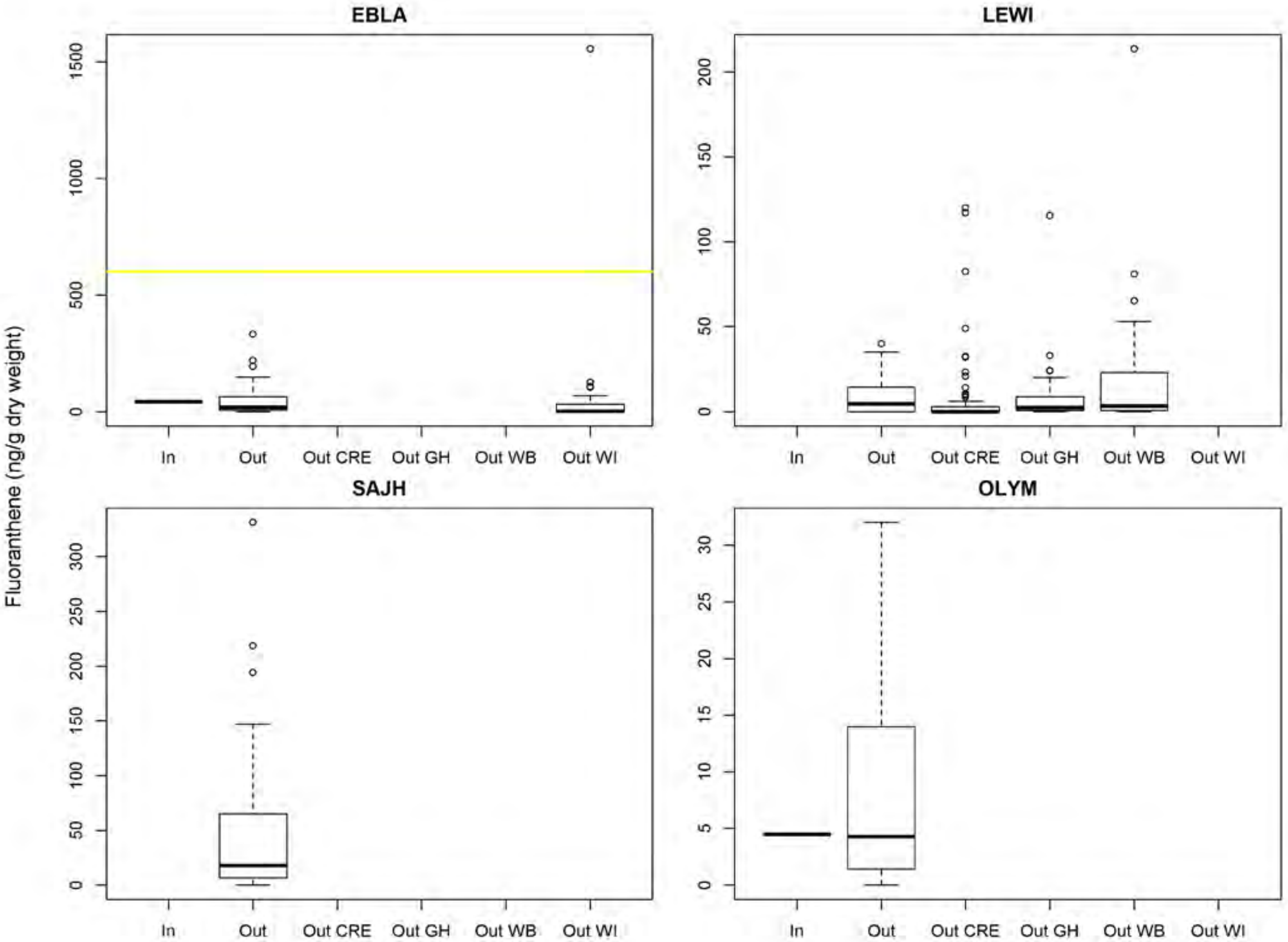


Figure 28. Boxplots of Fluoranthene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

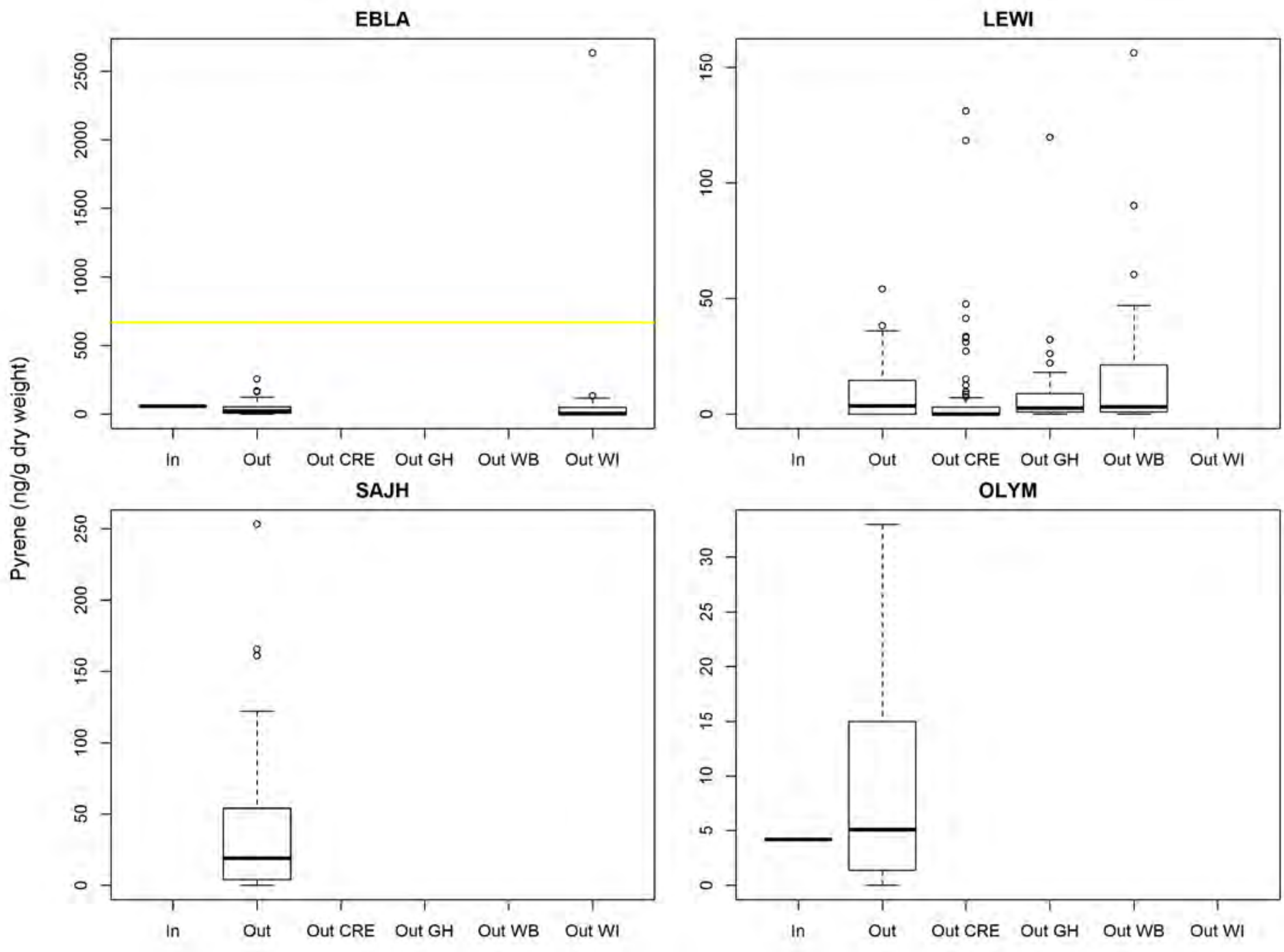


Figure 29. Boxplots of Pyrene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

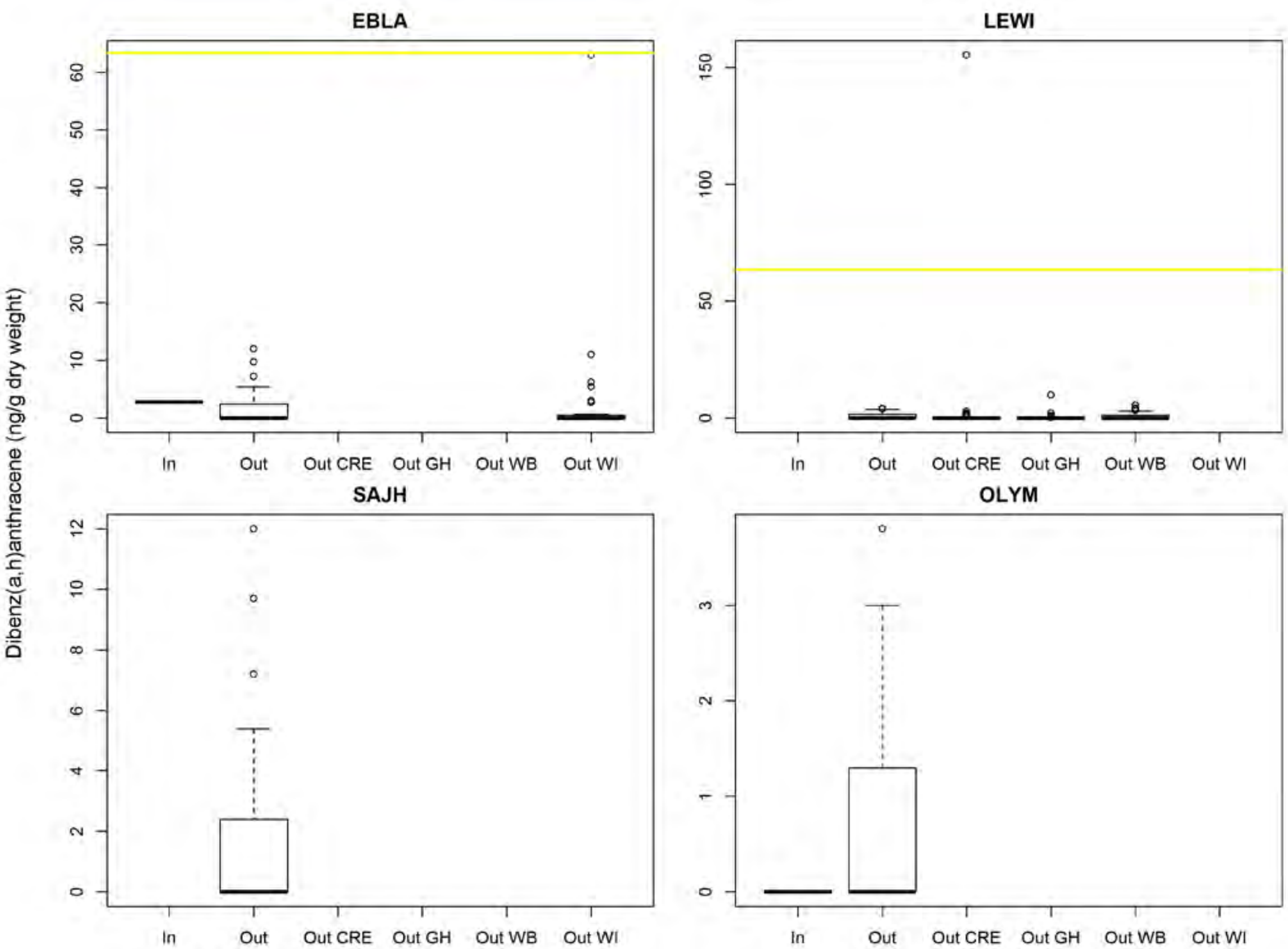


Figure 30. Boxplots of Dibenz(a,h)anthracene (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

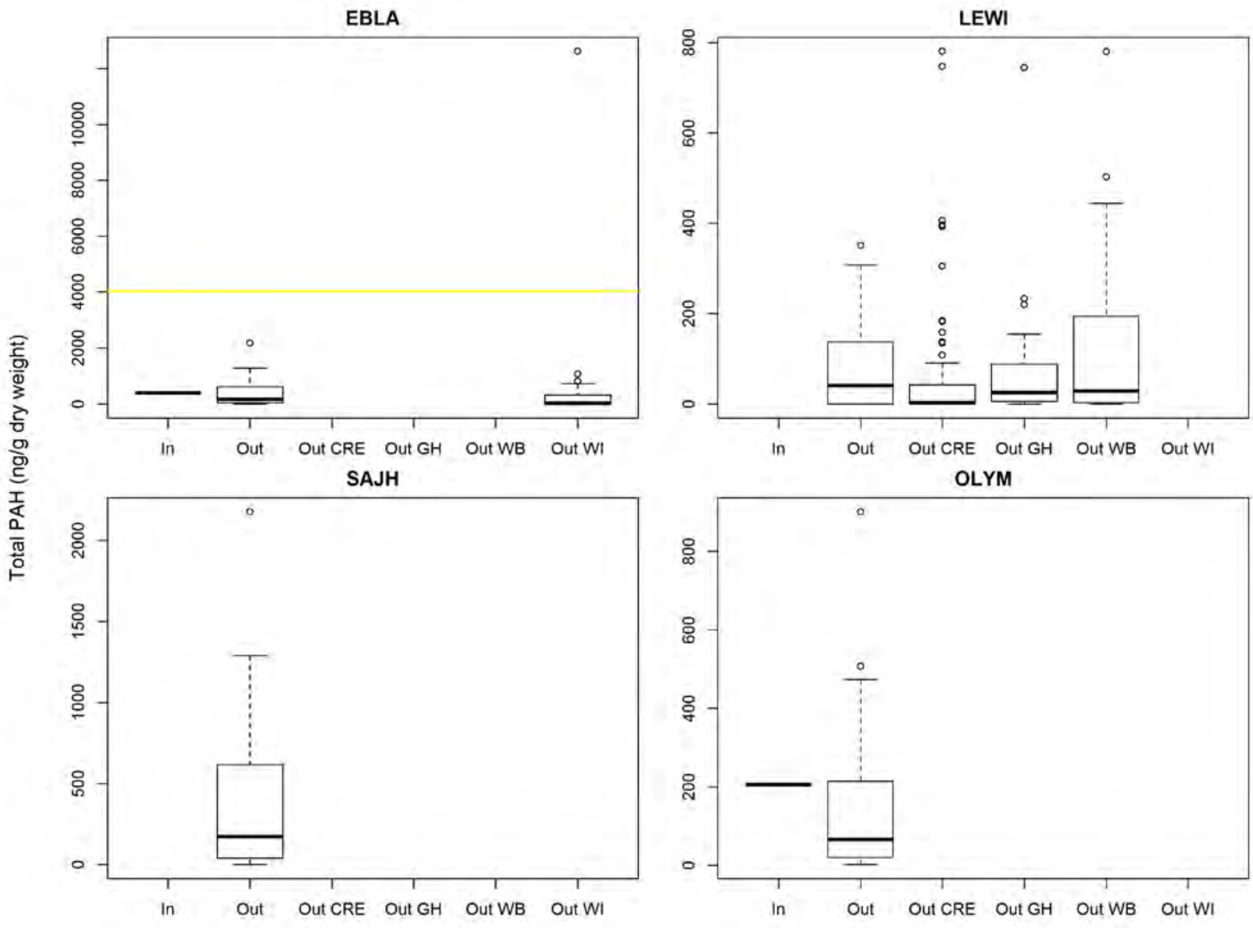


Figure 31. Boxplots of Total PAH (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

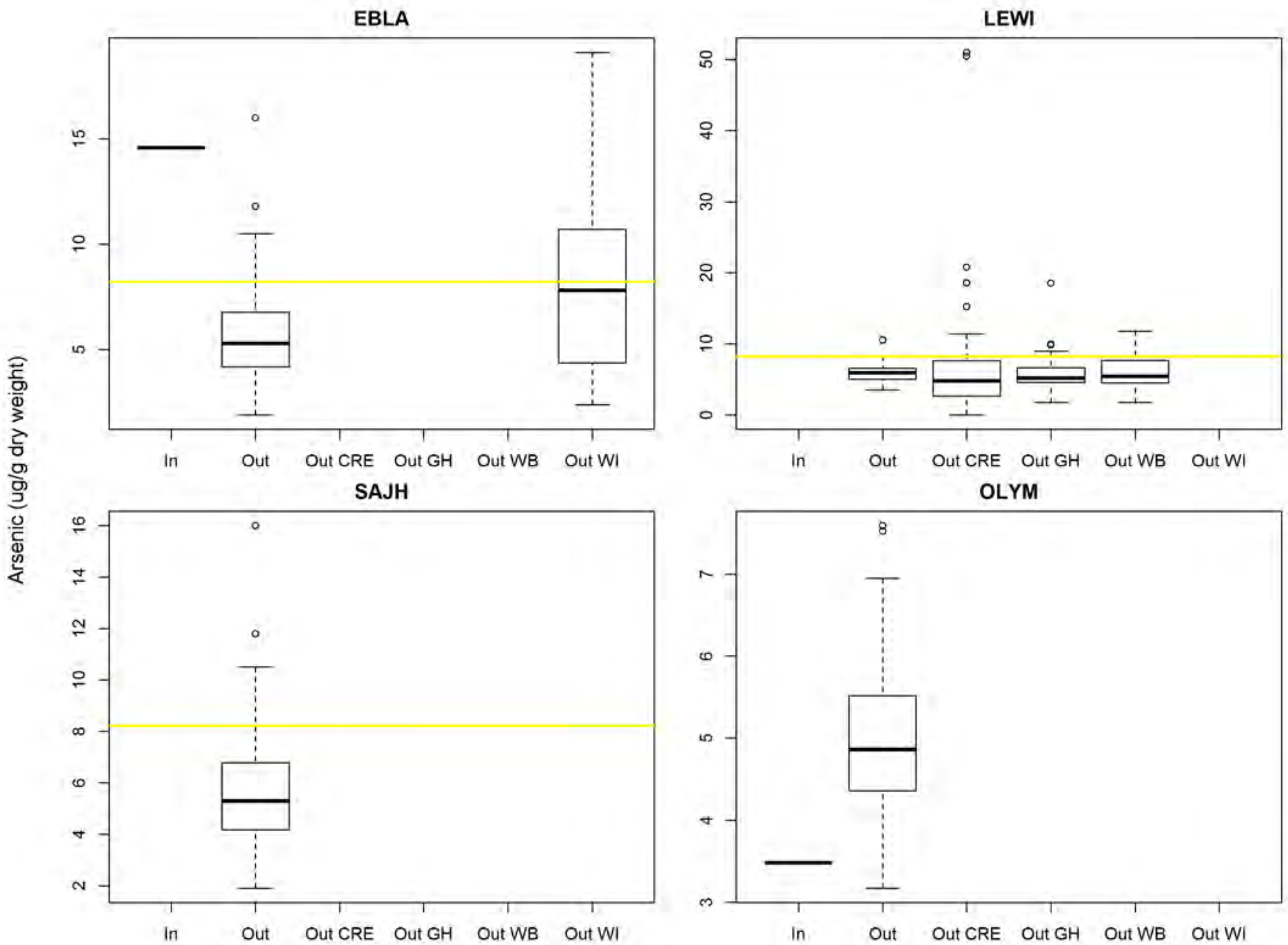


Figure 32. Boxplots of arsenic (ug/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

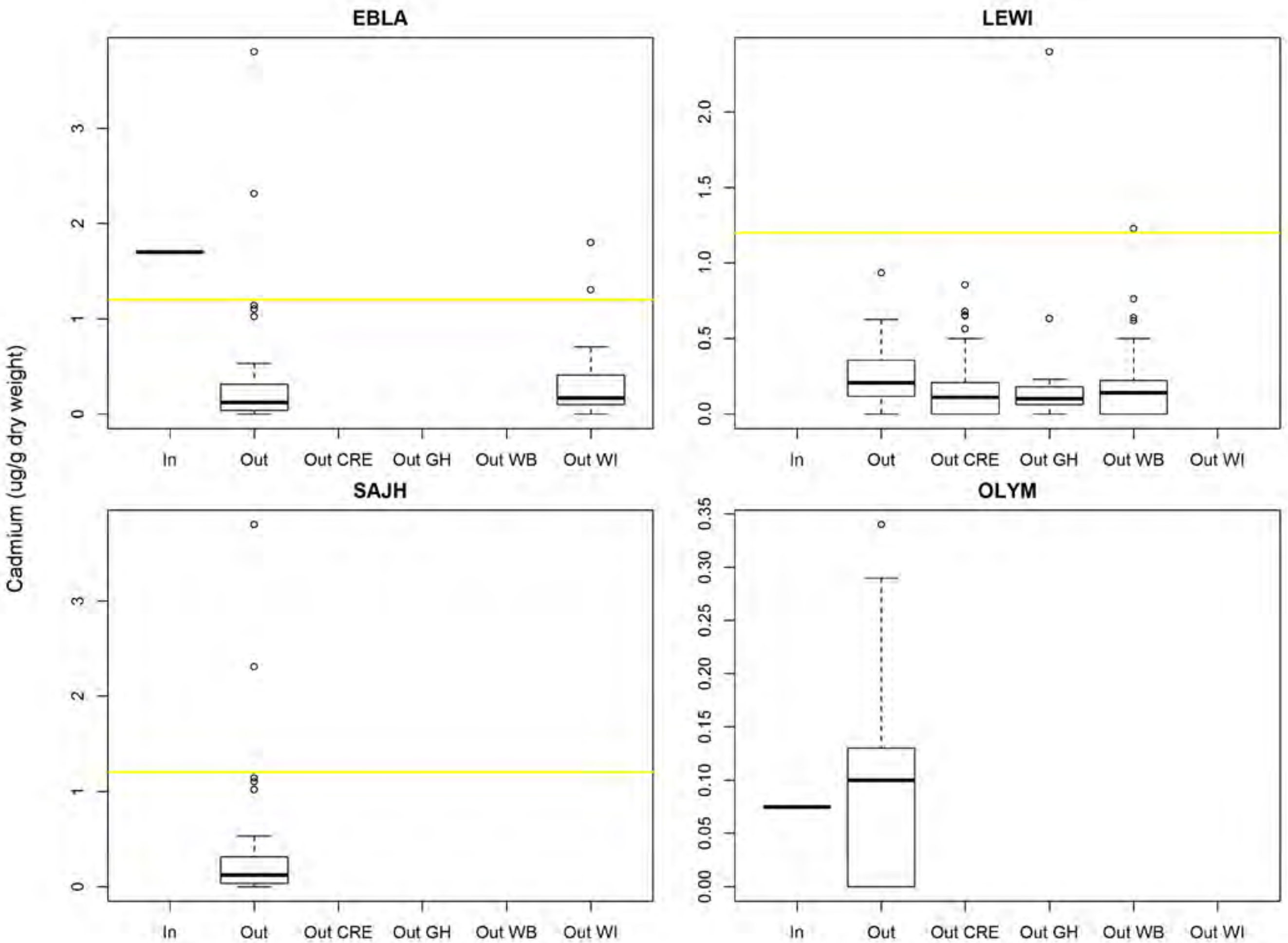


Figure 33. Boxplots of cadmium (ug/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

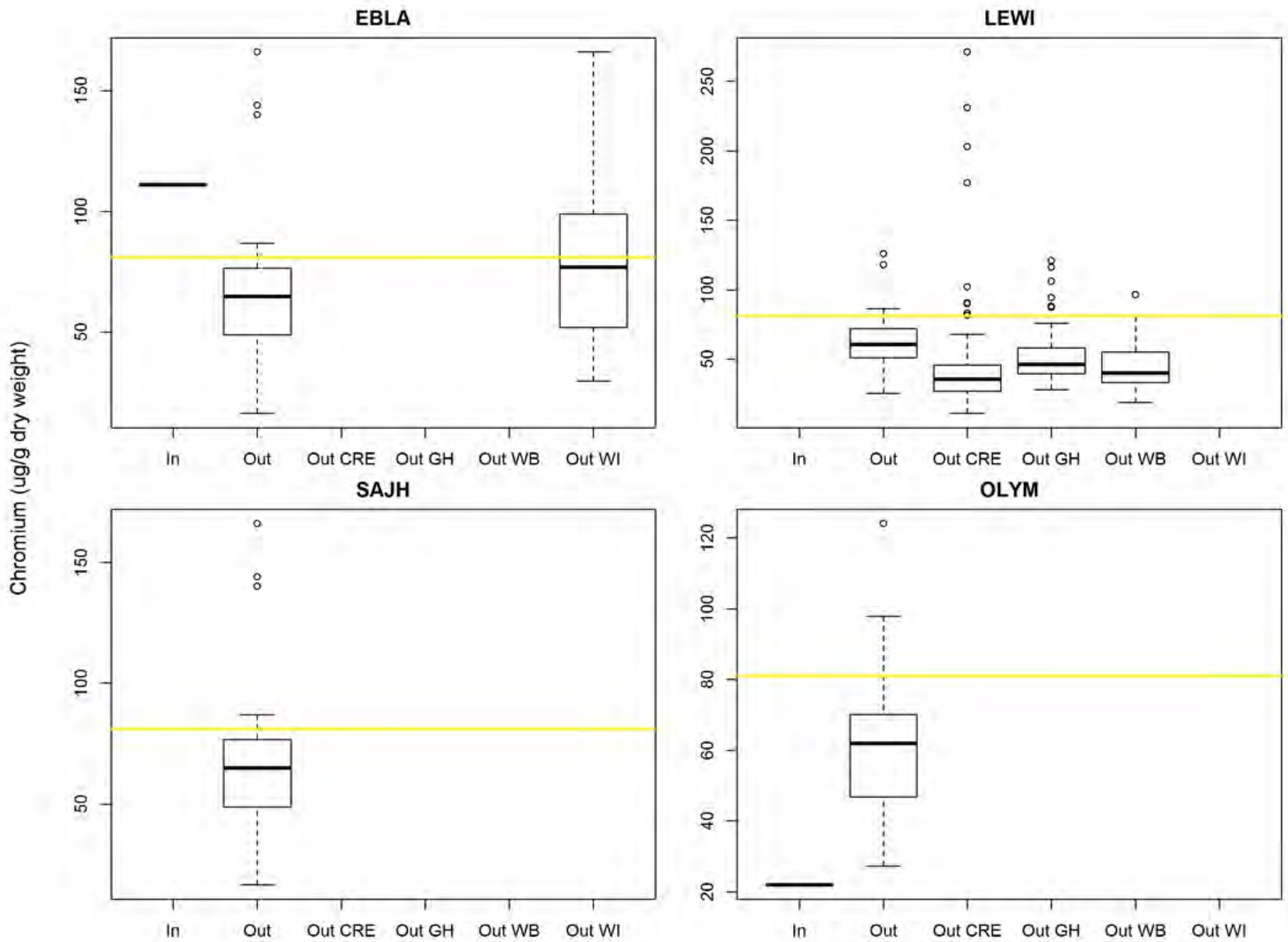


Figure 34. Boxplots of chromium (ug/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

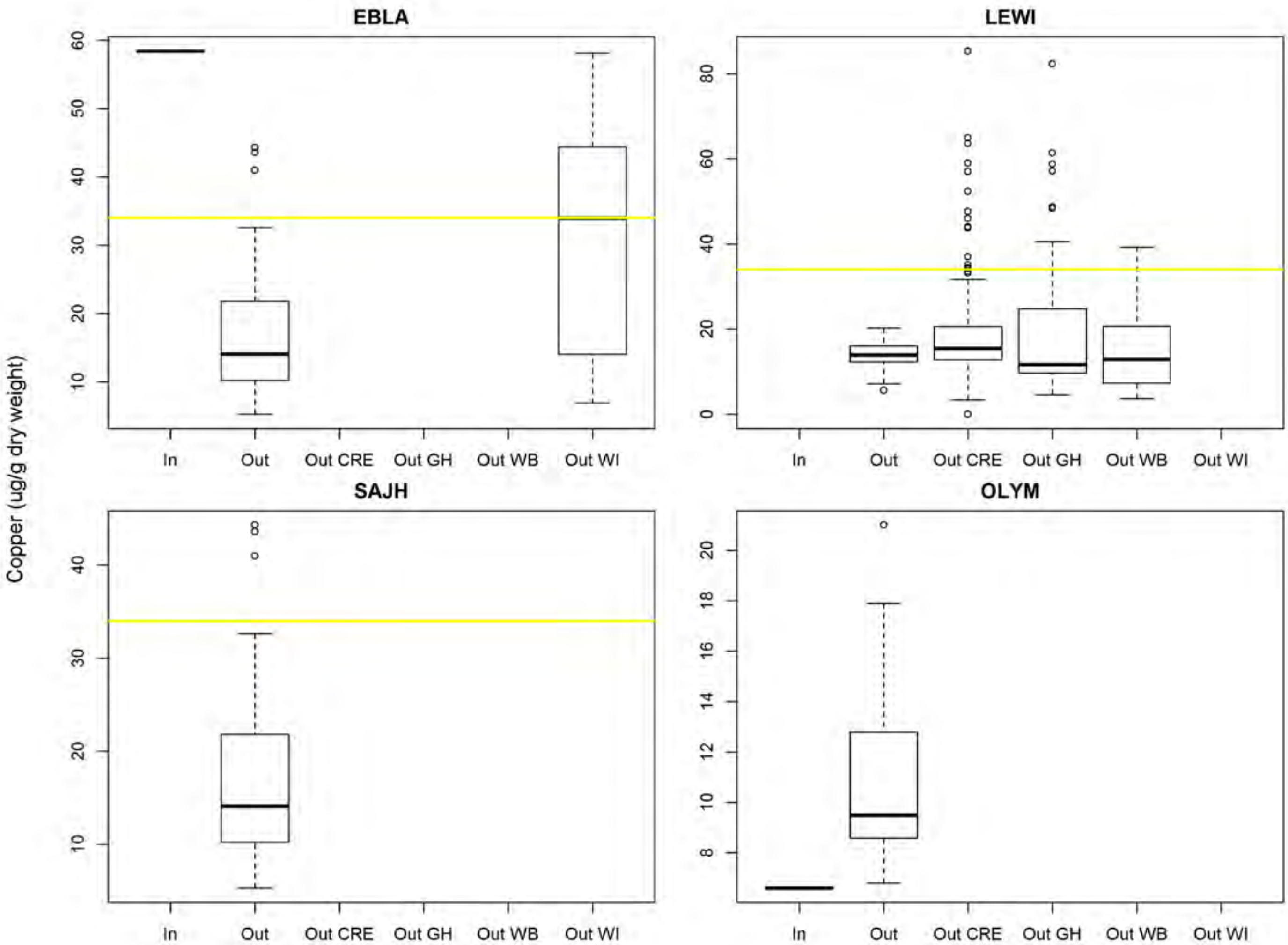


Figure 35. Boxplots of copper (ug/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

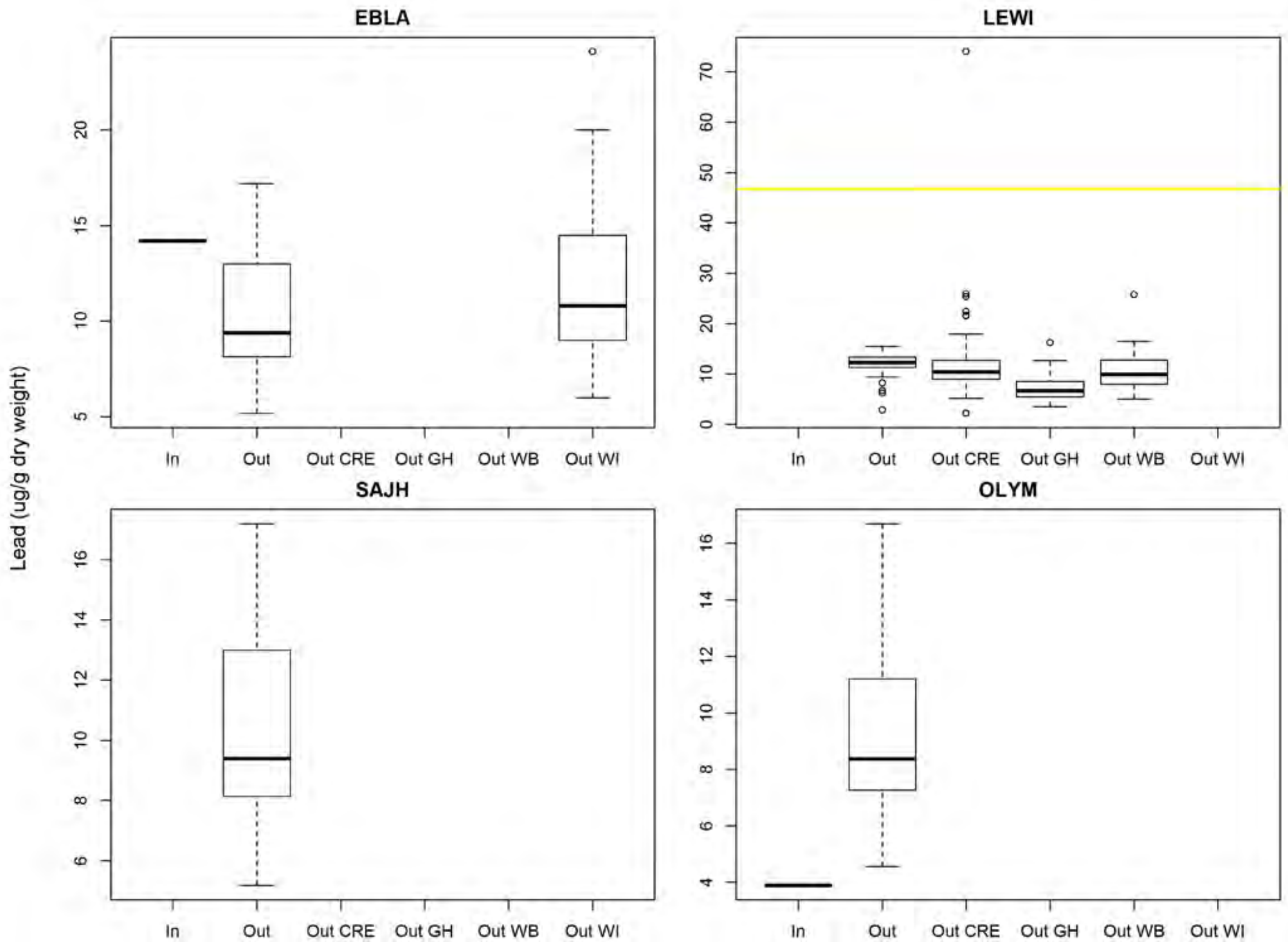


Figure 36. Boxplots of lead (ug/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

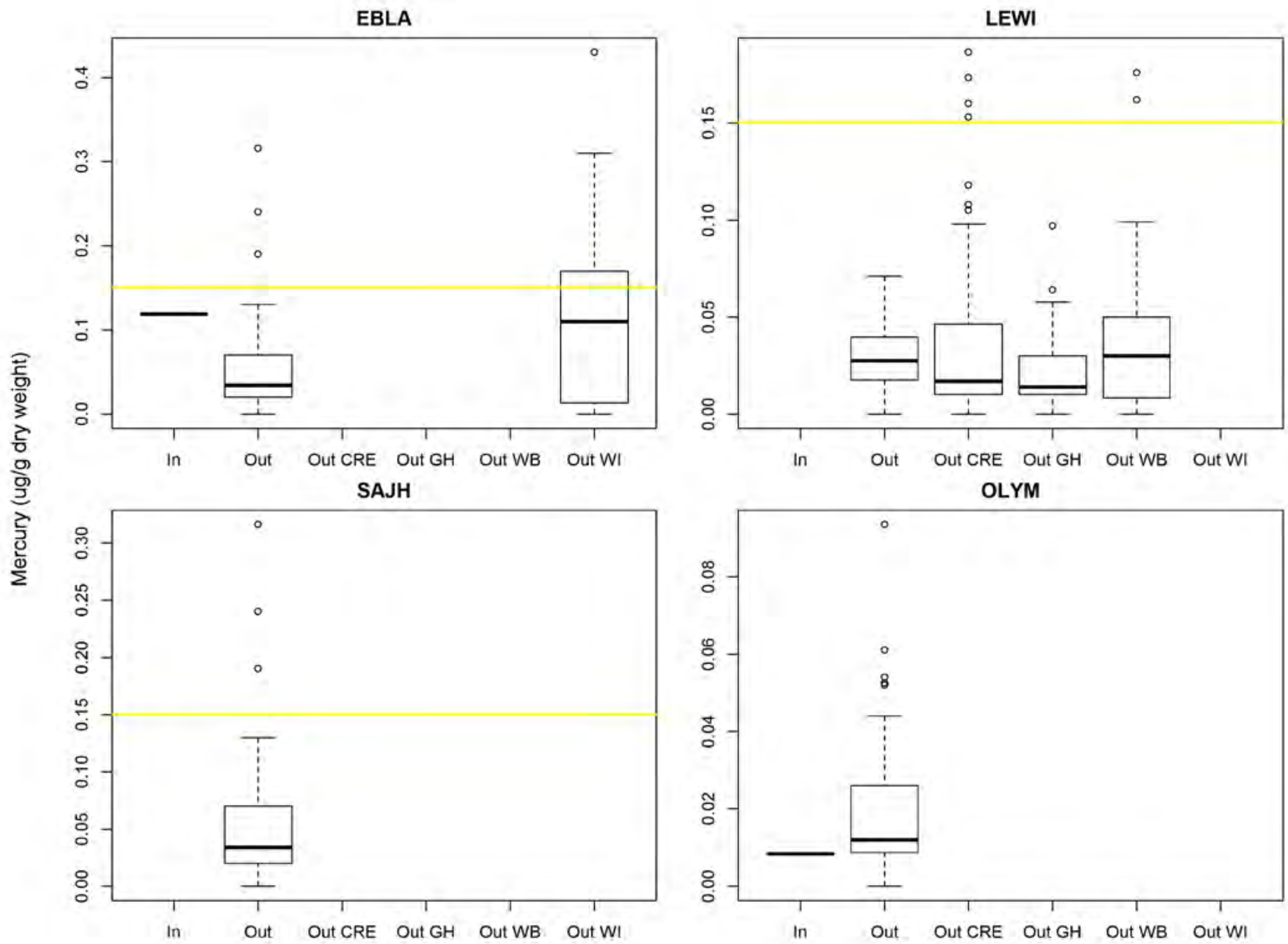


Figure 37. Boxplots of mercury (ug/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

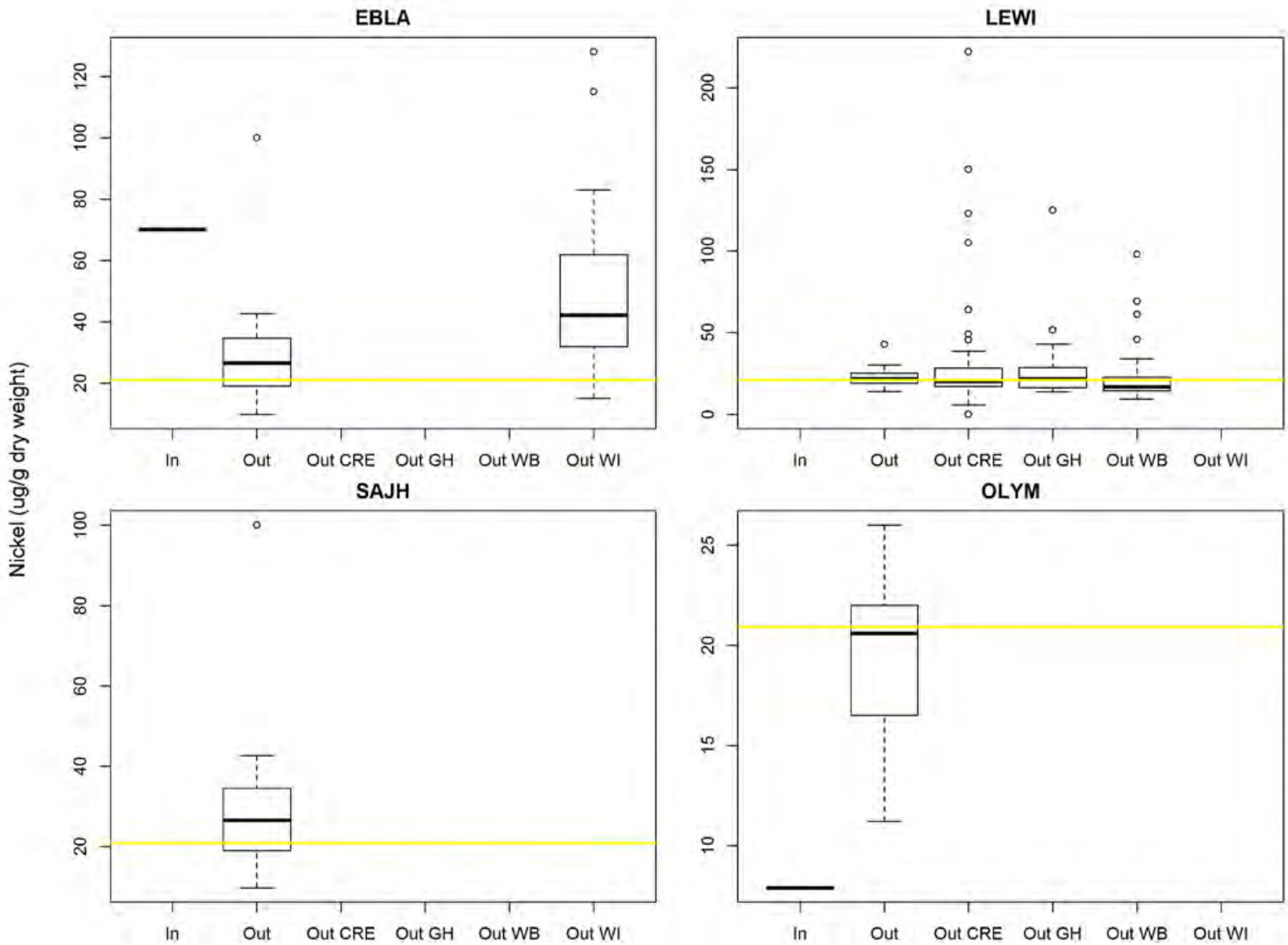


Figure 38. Boxplots of nickel (ug/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

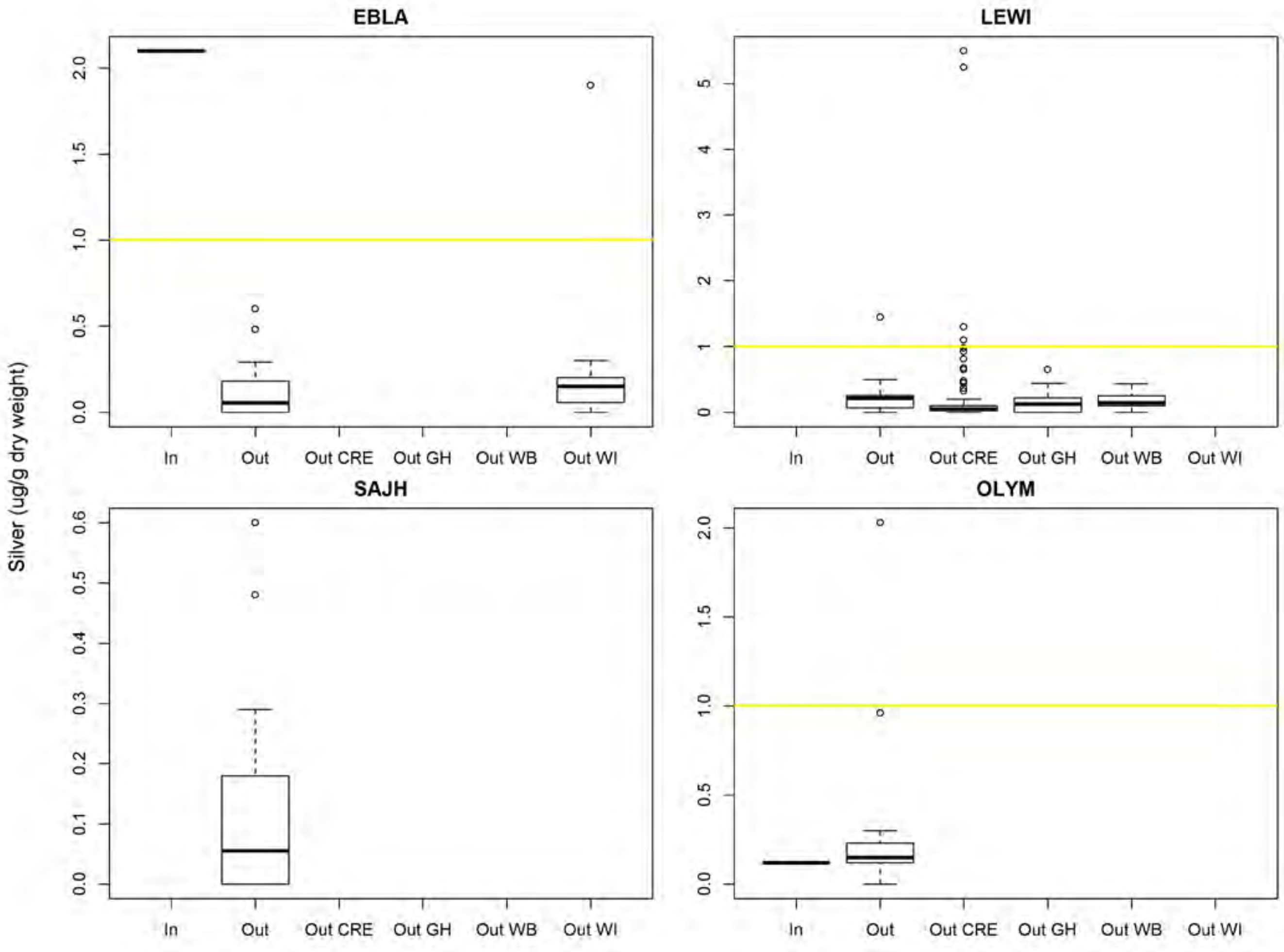


Figure 39. Boxplots of silver (ug/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

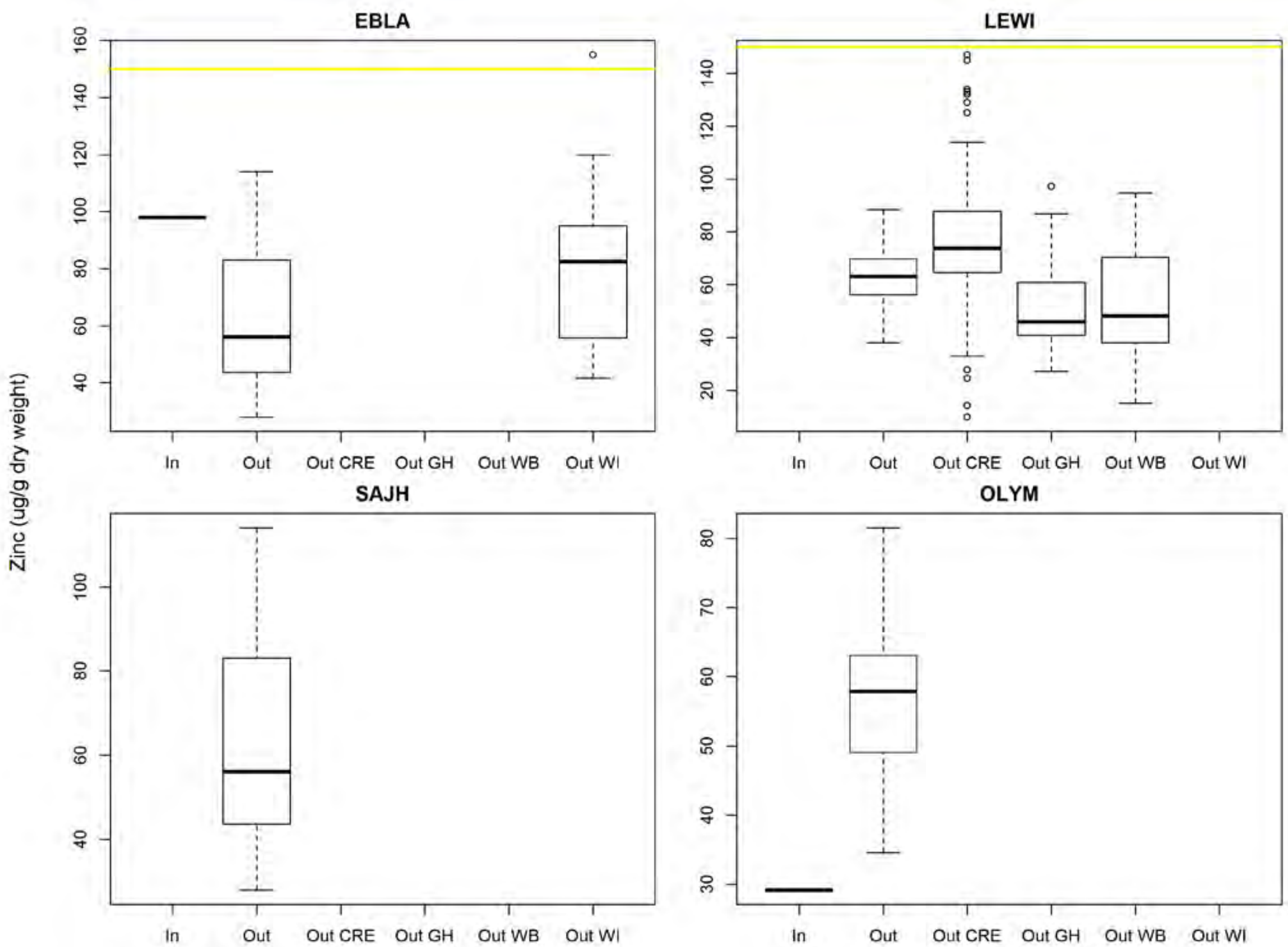


Figure 40. Boxplots of zinc (ug/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

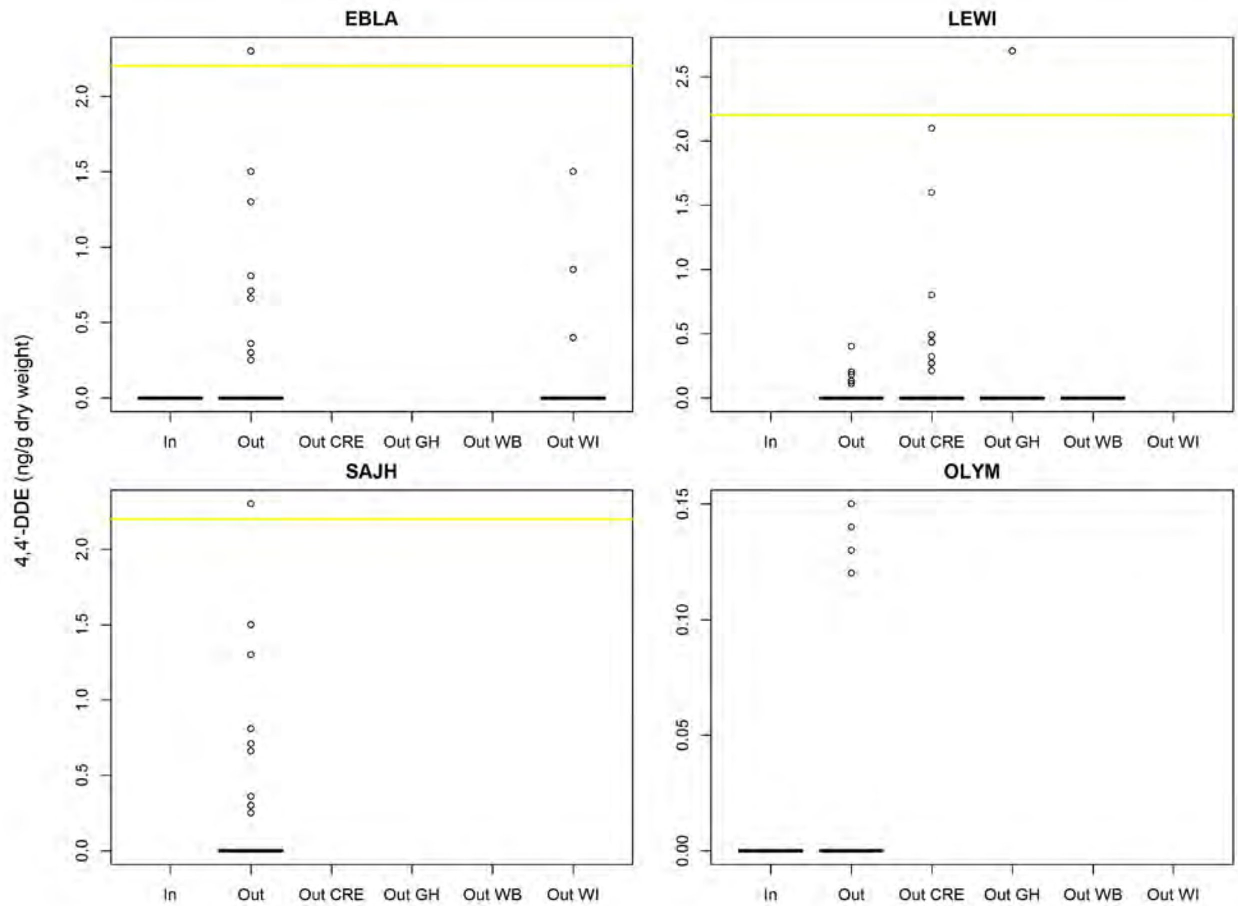


Figure 41. Boxplots of 4,4-DDE (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

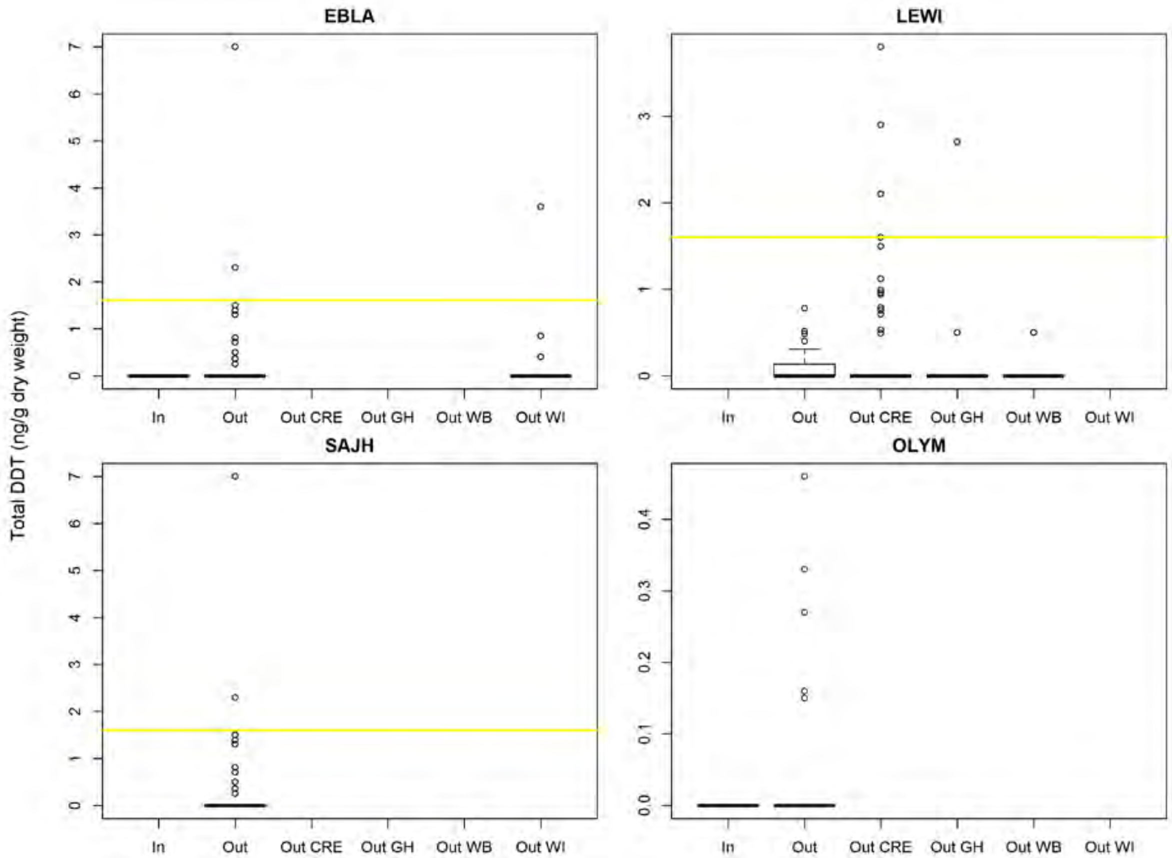


Figure 42. Boxplots of total DDTs (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians, 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

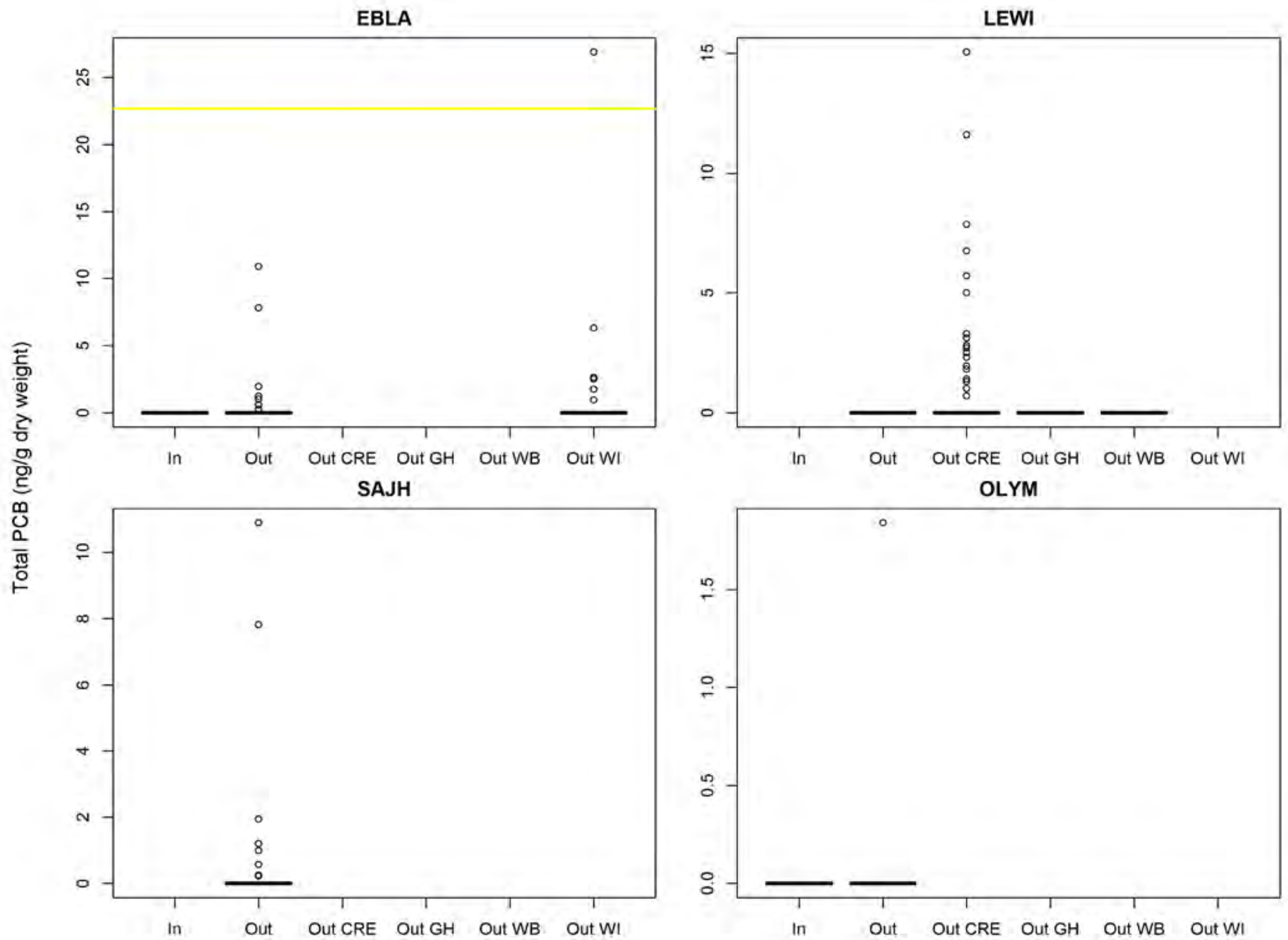
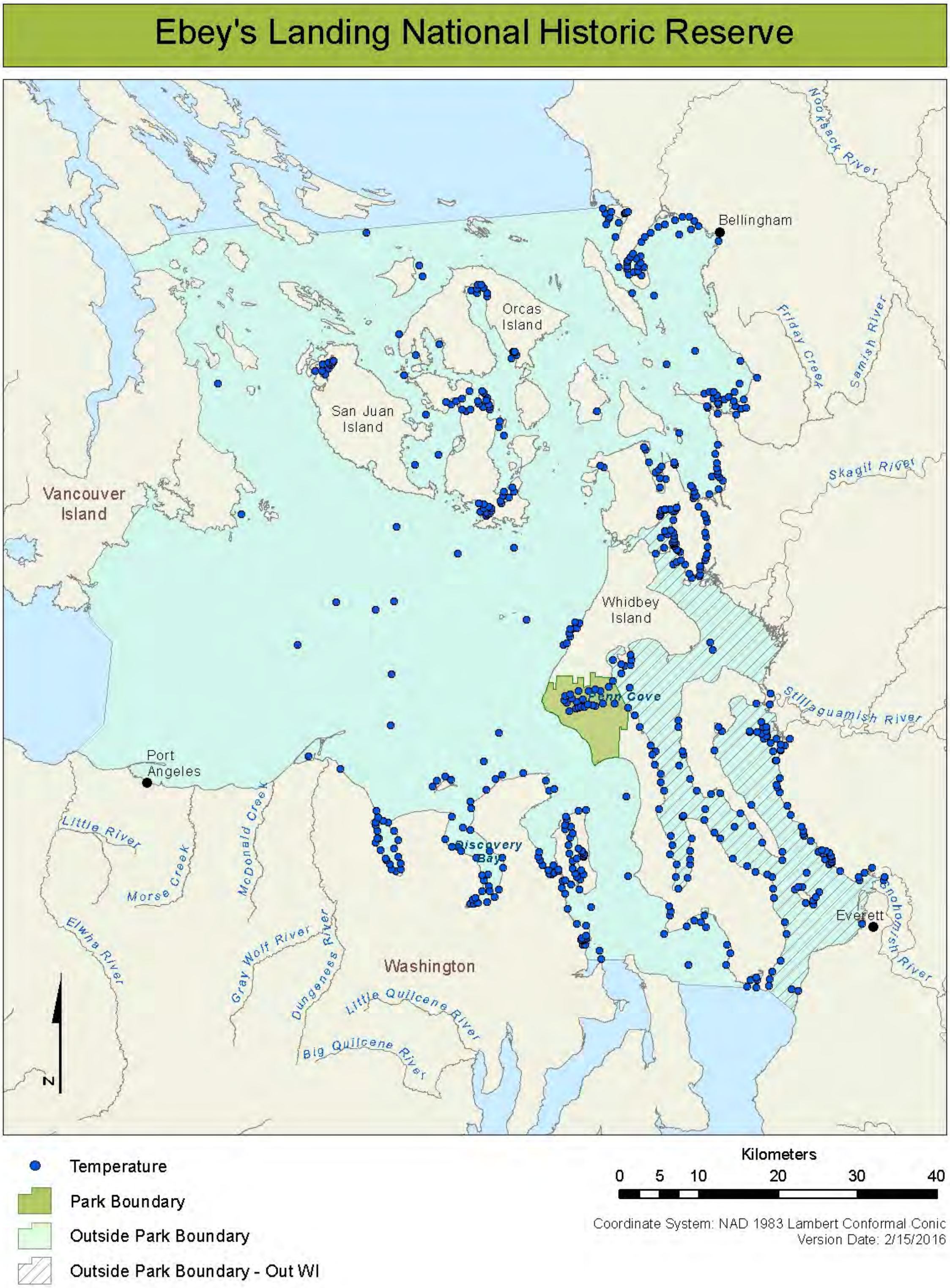


Figure 43. Boxplots of total PCBs (ng/g dry weight) inside and outside Ebey's Landing (EBLA), Lewis and Clark (LEWI), San Juan (SAJH) and Olympic (OLYM) National Parks. For EBLA, data are shown for inside the park (In), outside the park (Out), and waters between the mainland and Whidbey Island (Out WI). For LEWI, data are shown inside the park (In), outside (Out), Columbia River estuary (OUT CRE), Grays Harbor (Out GH) and Willapa Bay (Out WB). Boxes show medians , 25th and 75th quartiles. Dots represent values falling outside 1.5x the interquartile distance. Yellow lines represent Effects Range Minimum levels (Long 1995).

Appendix A: Maps of individual parameter collection locations



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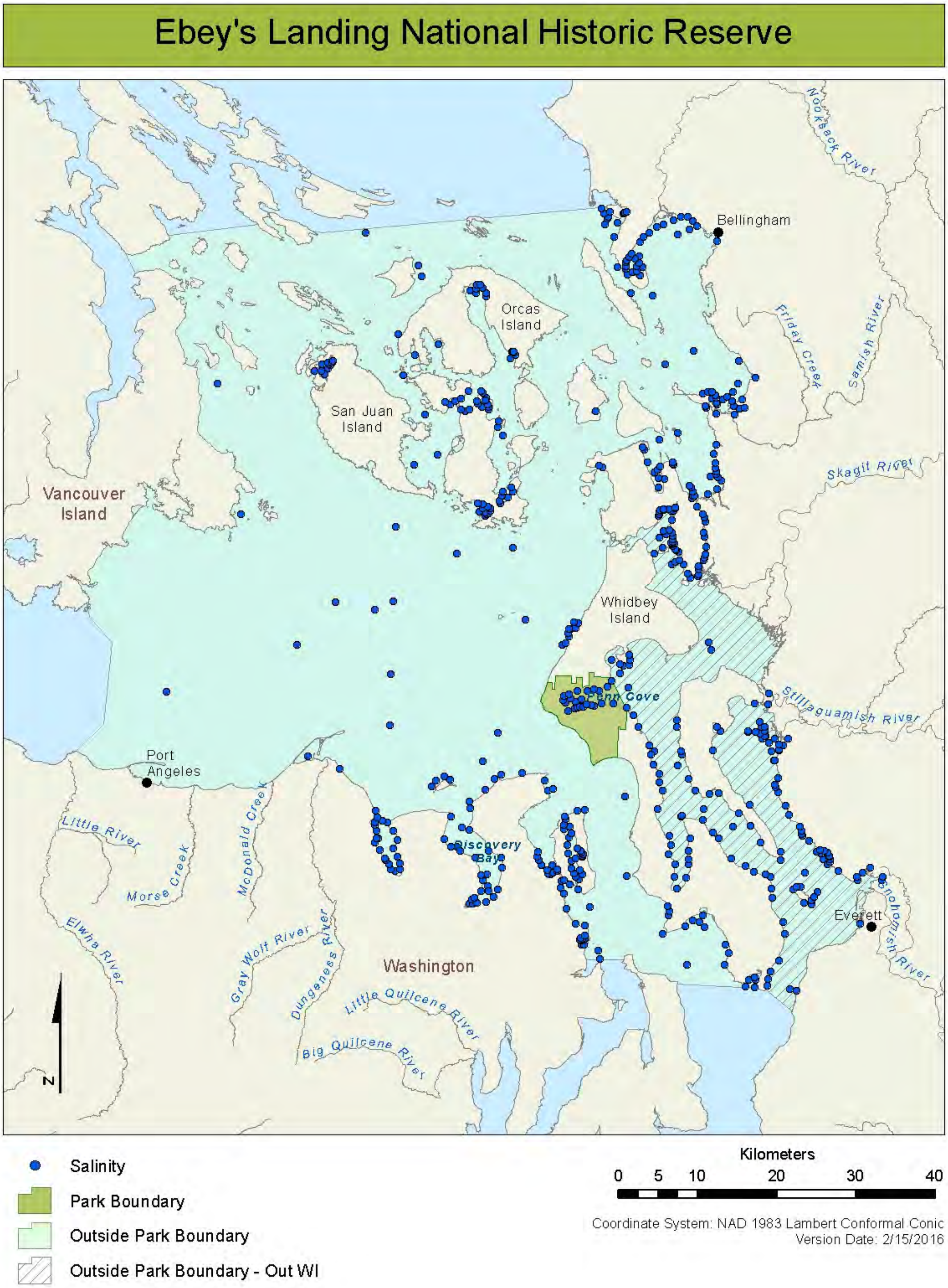

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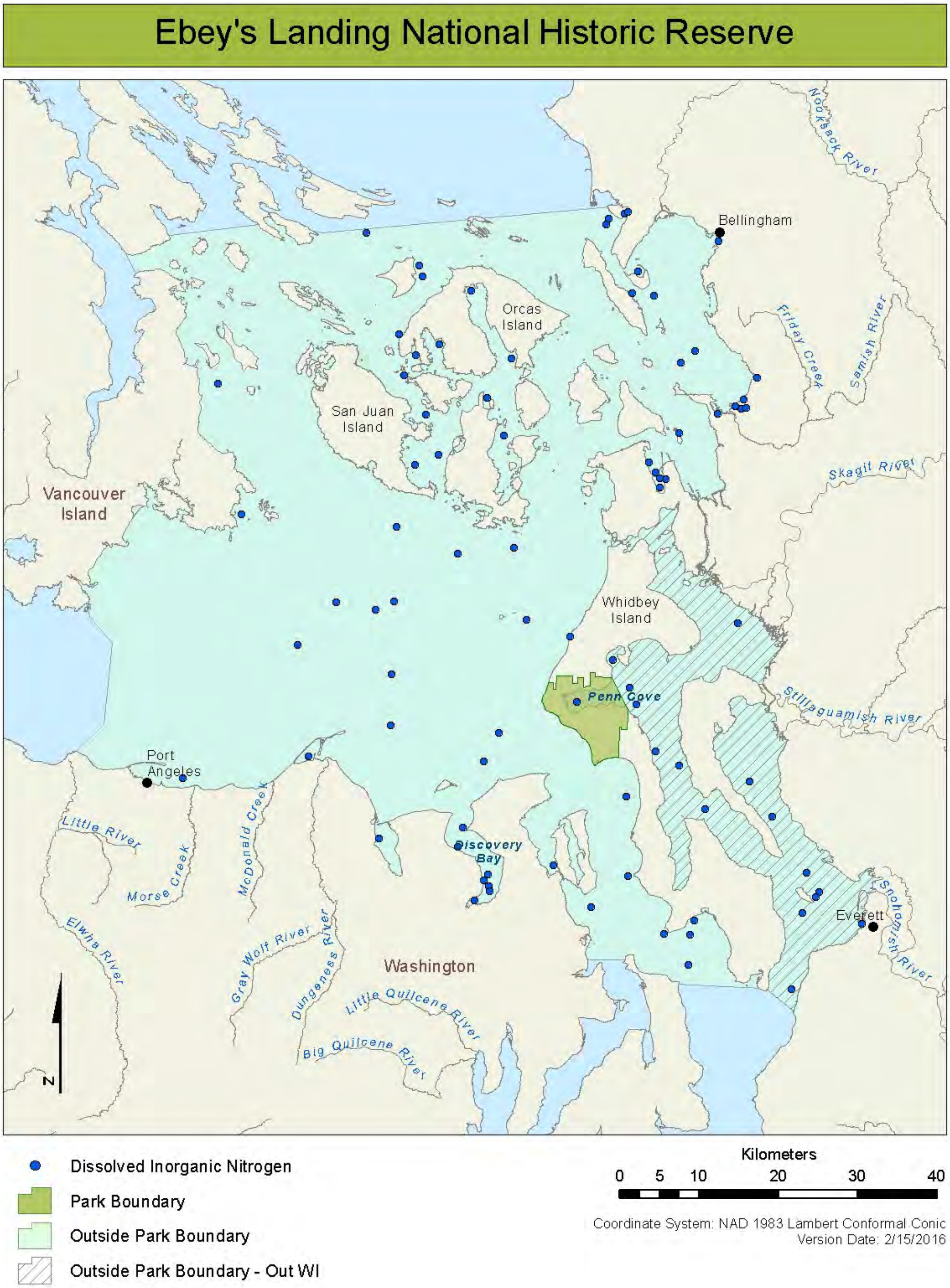

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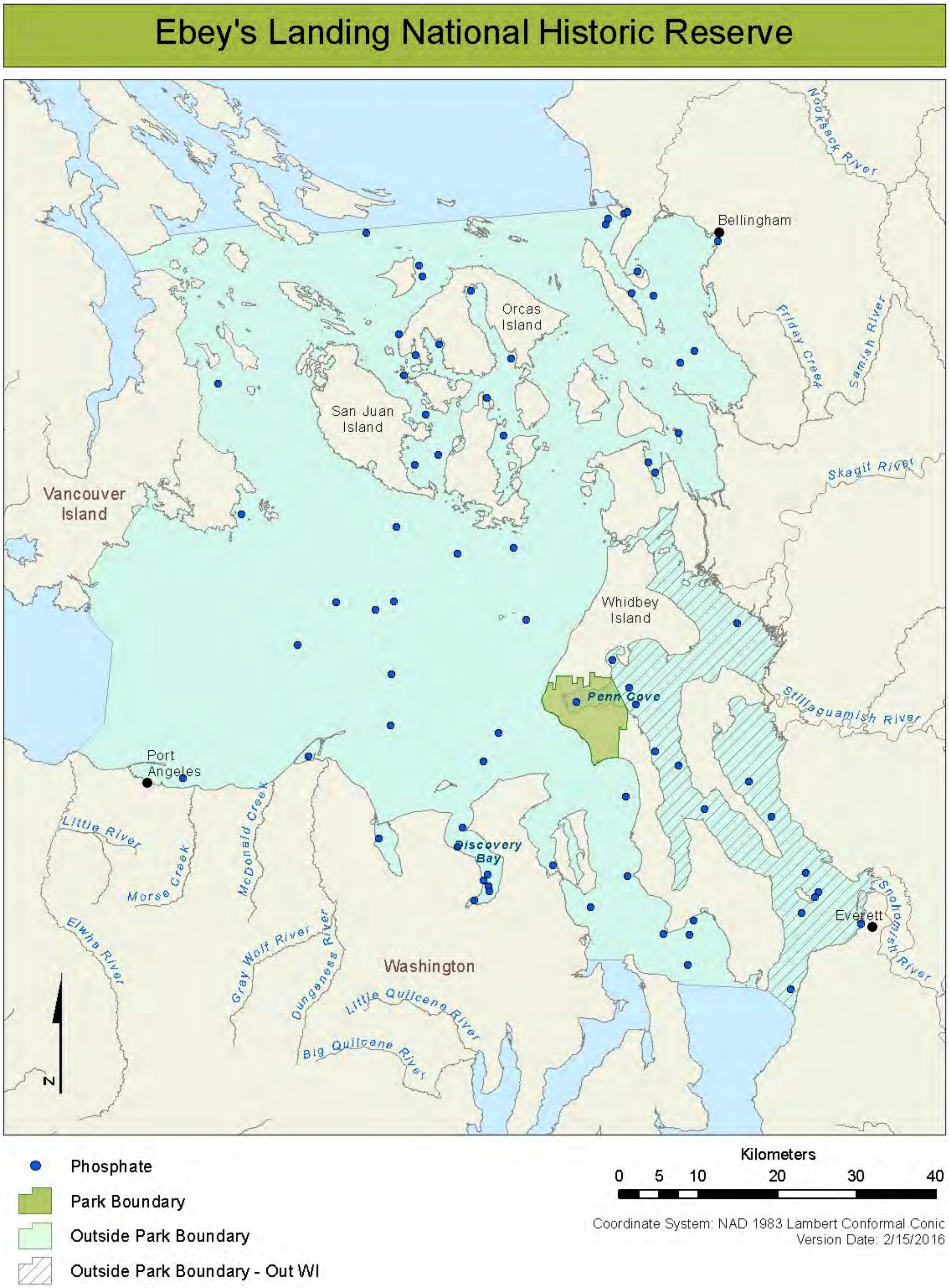

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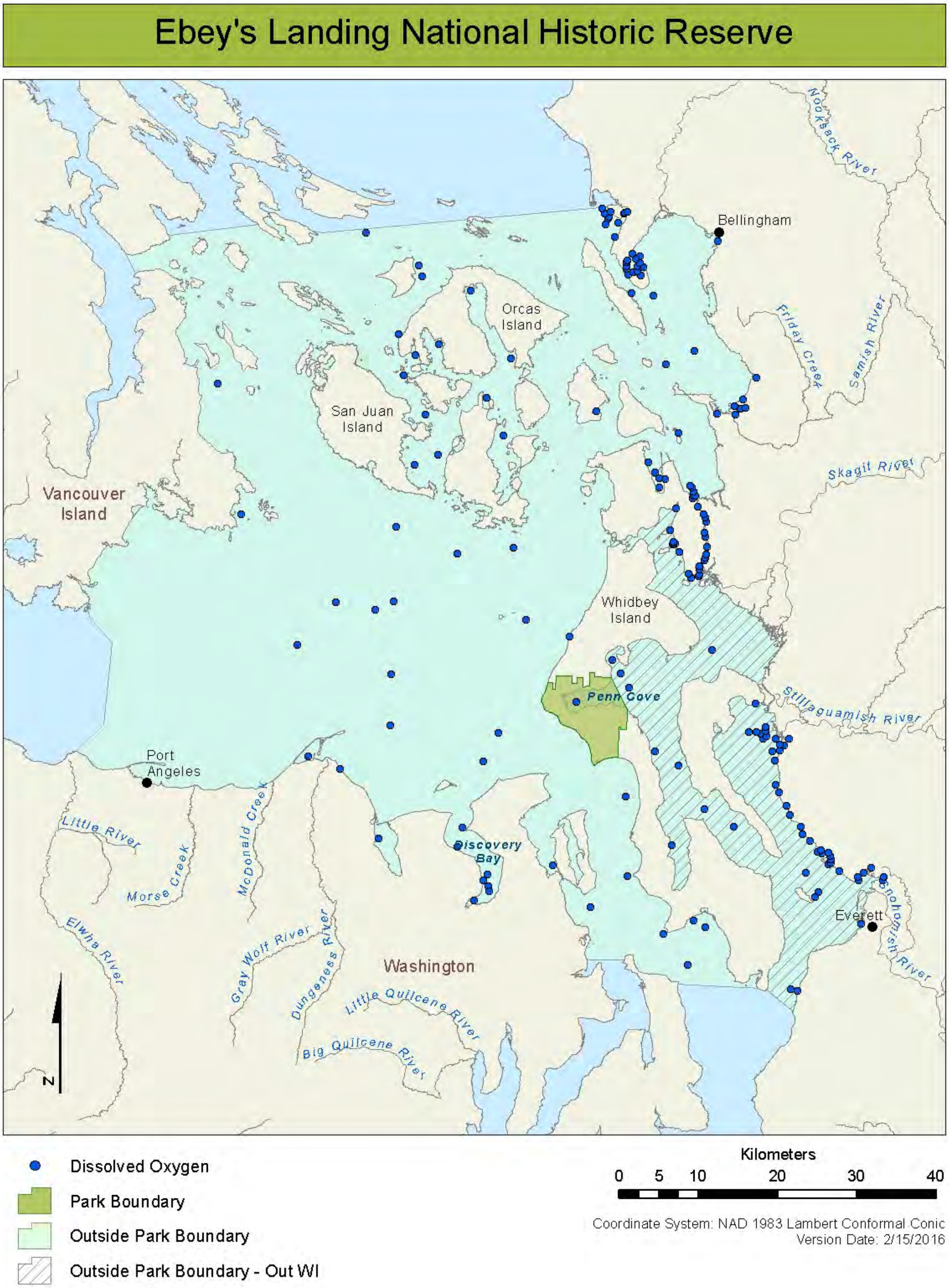

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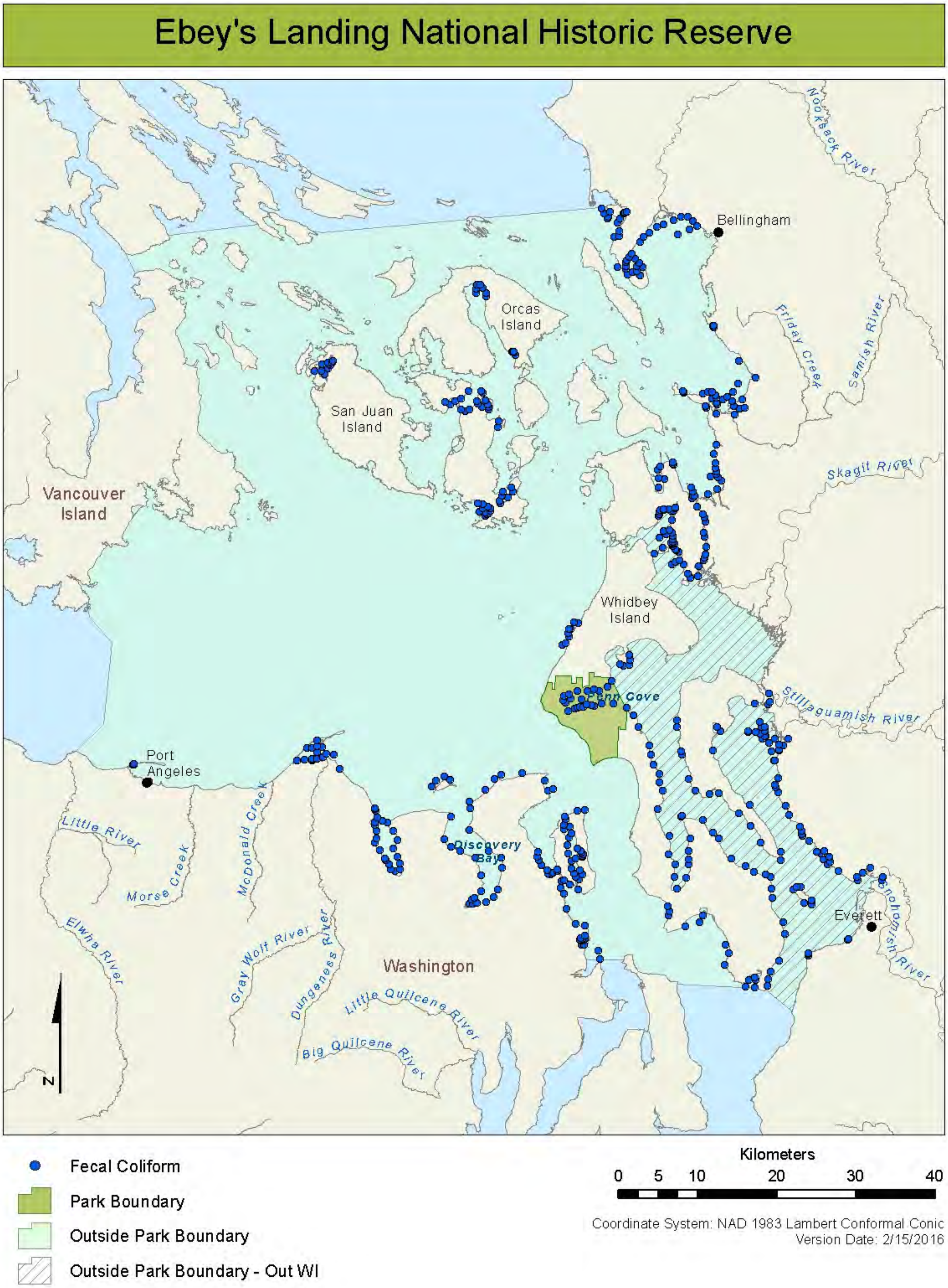

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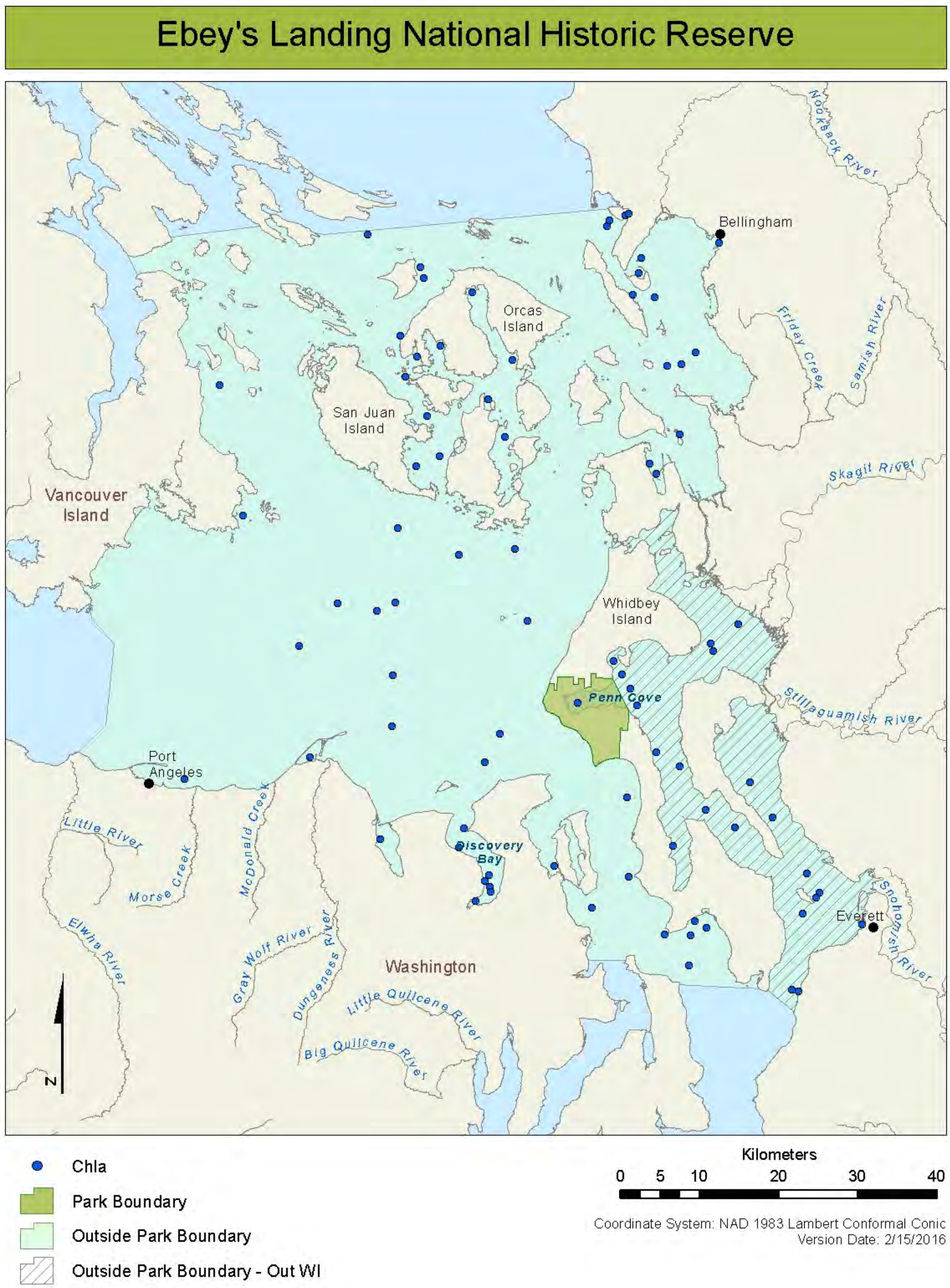

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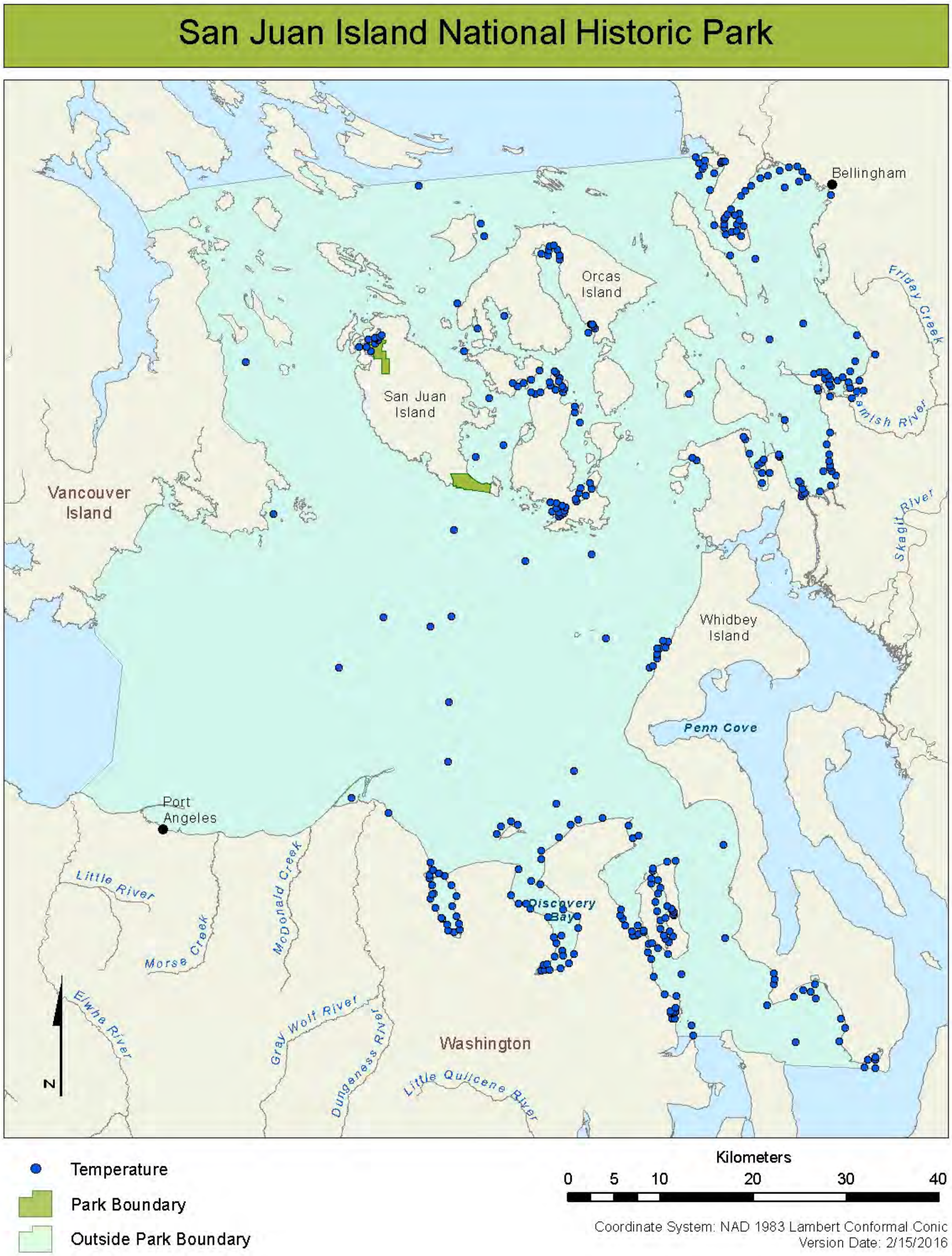

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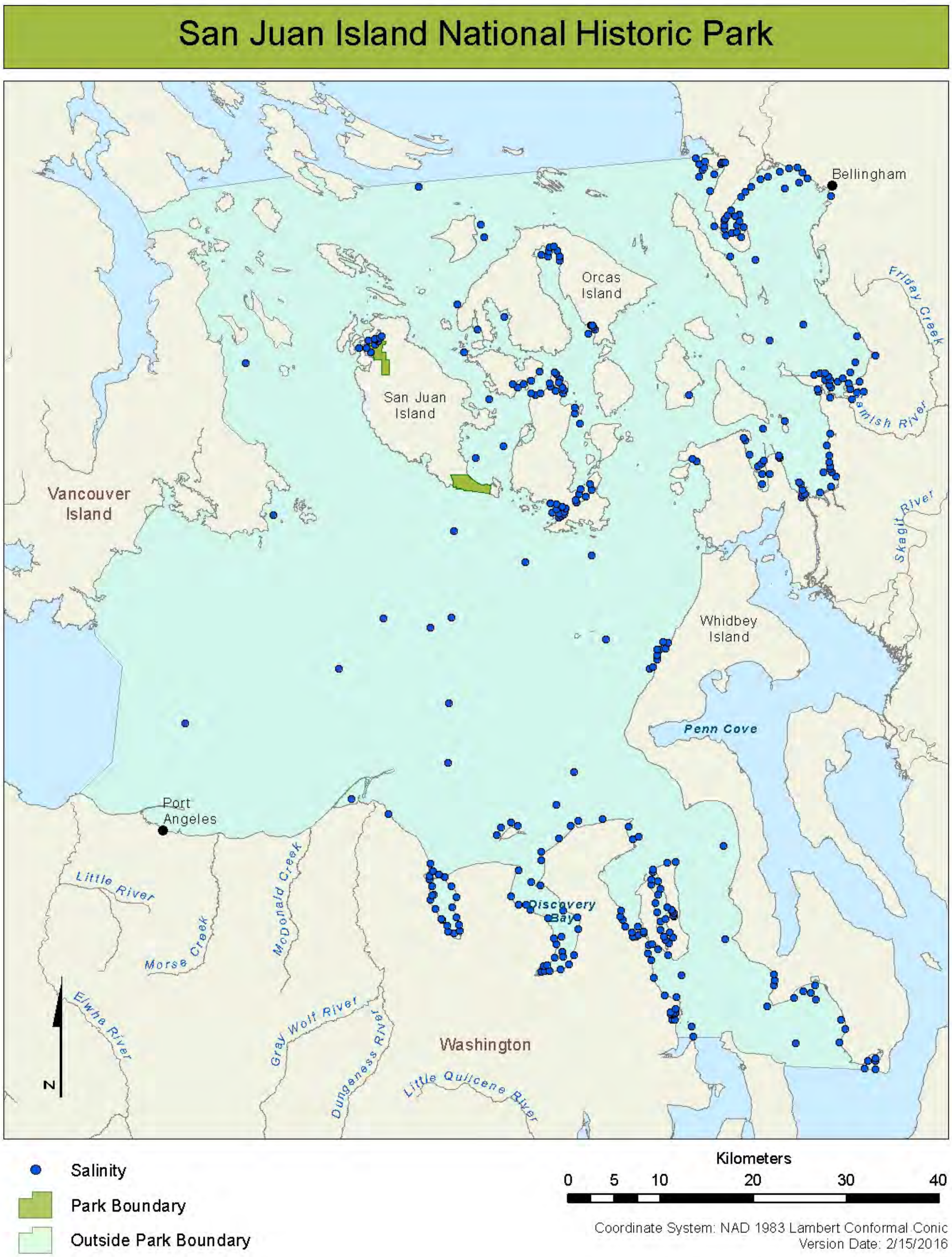

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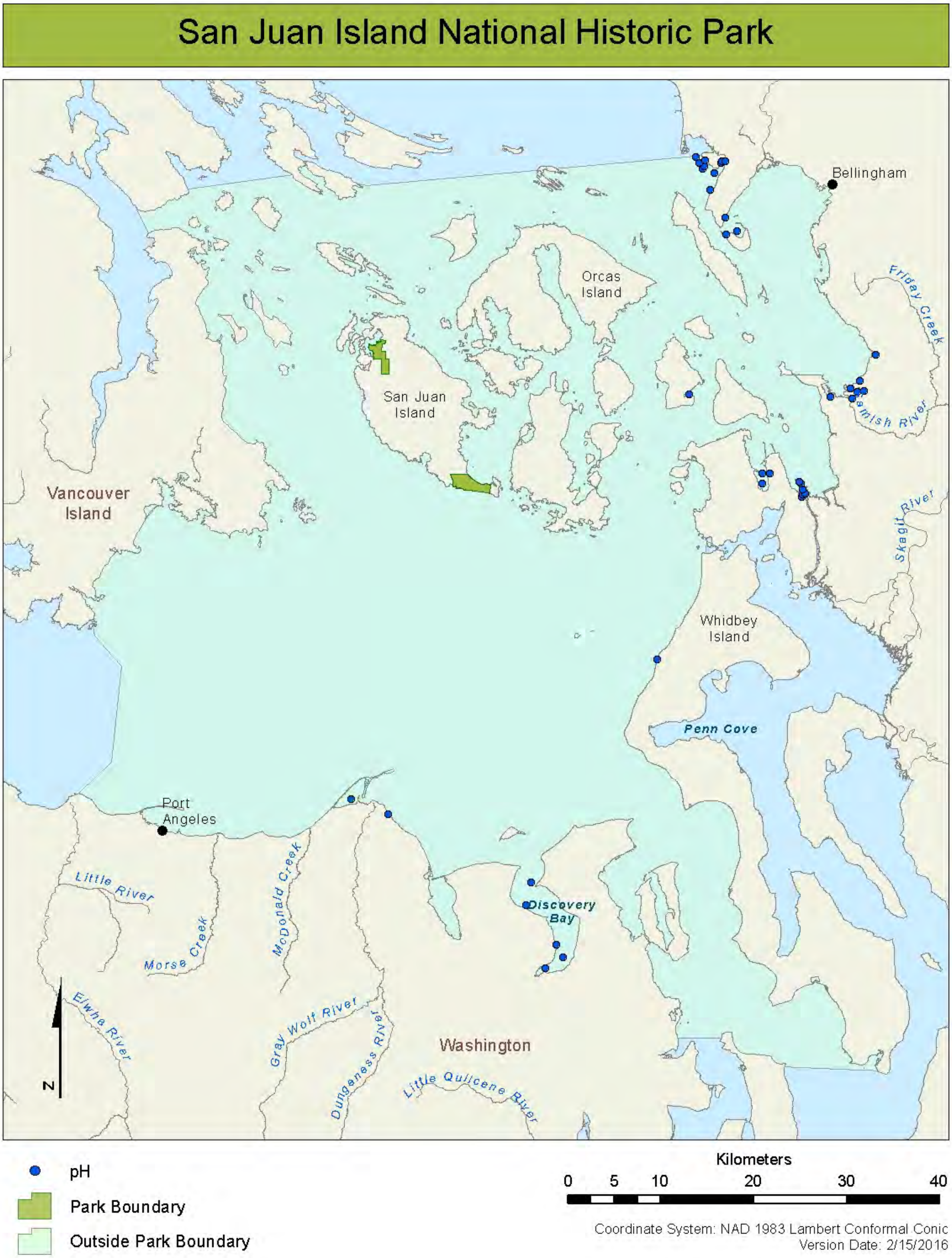

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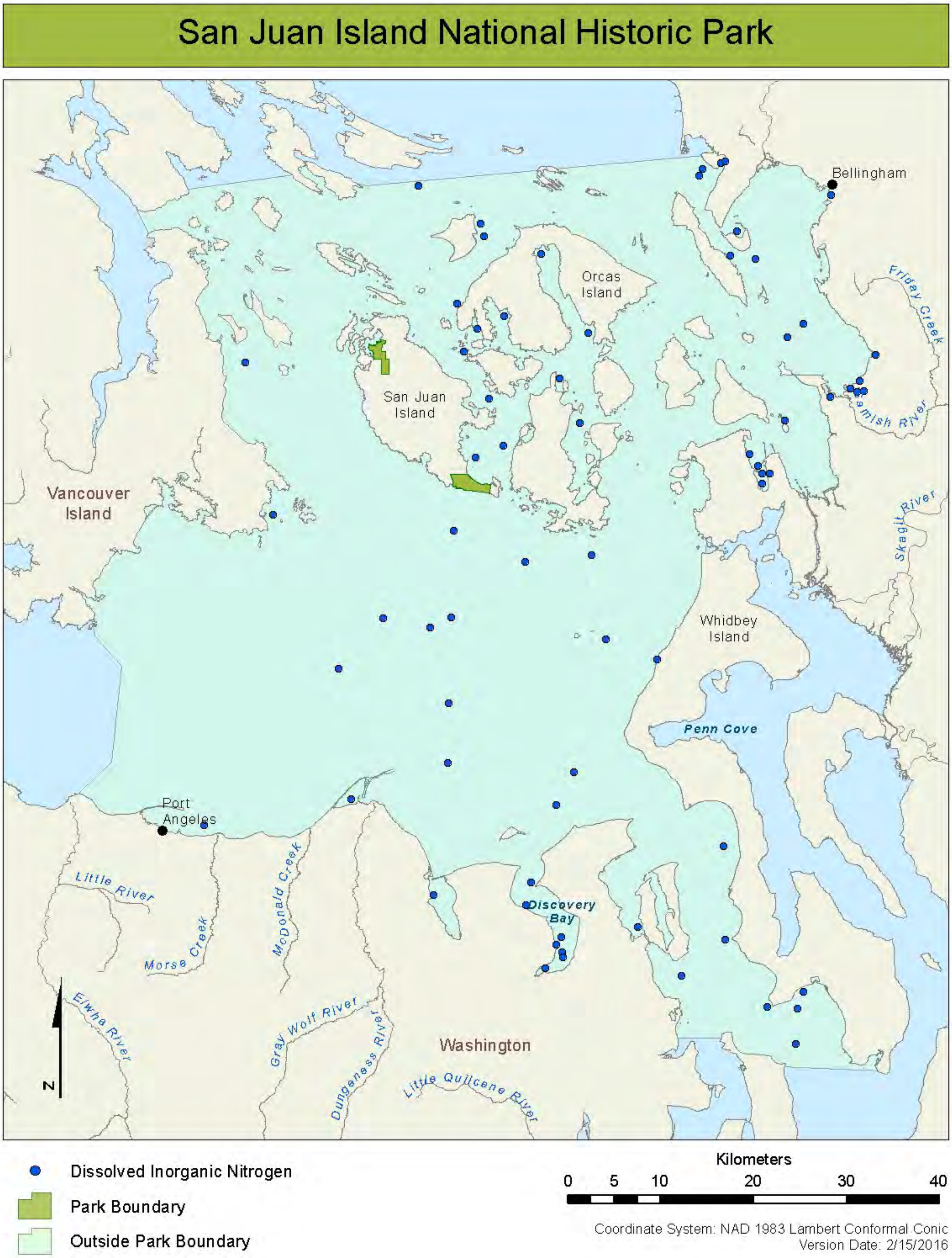

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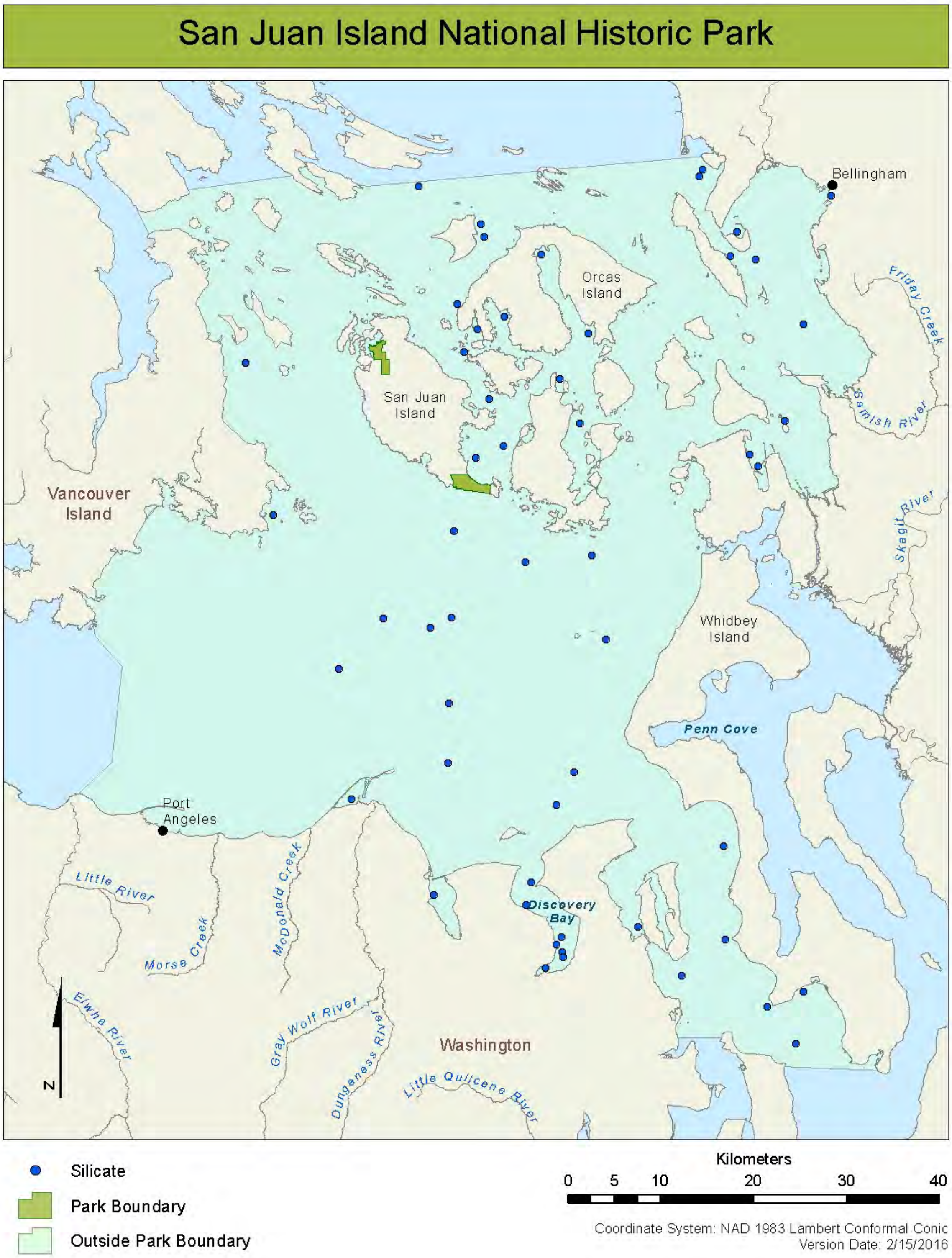

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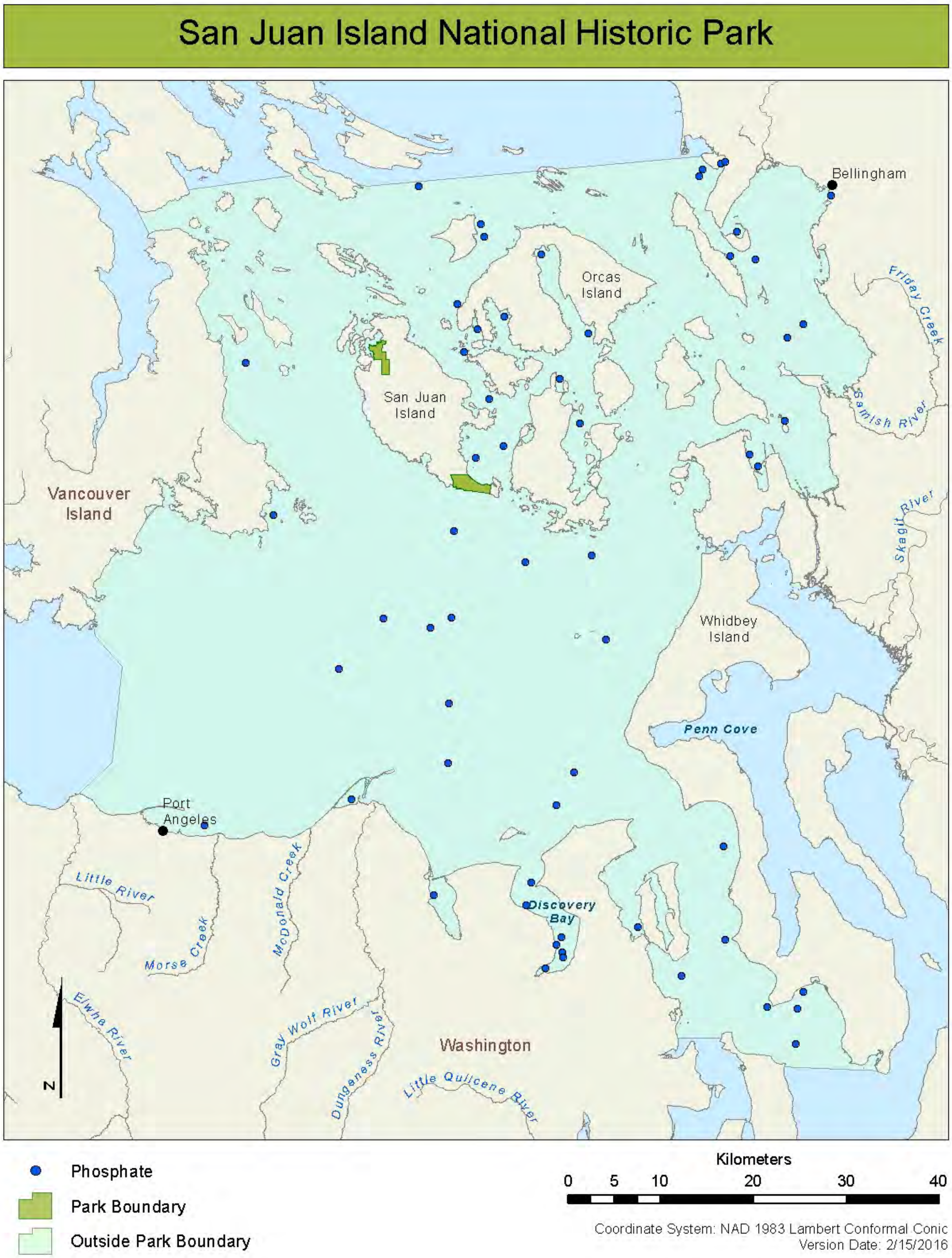

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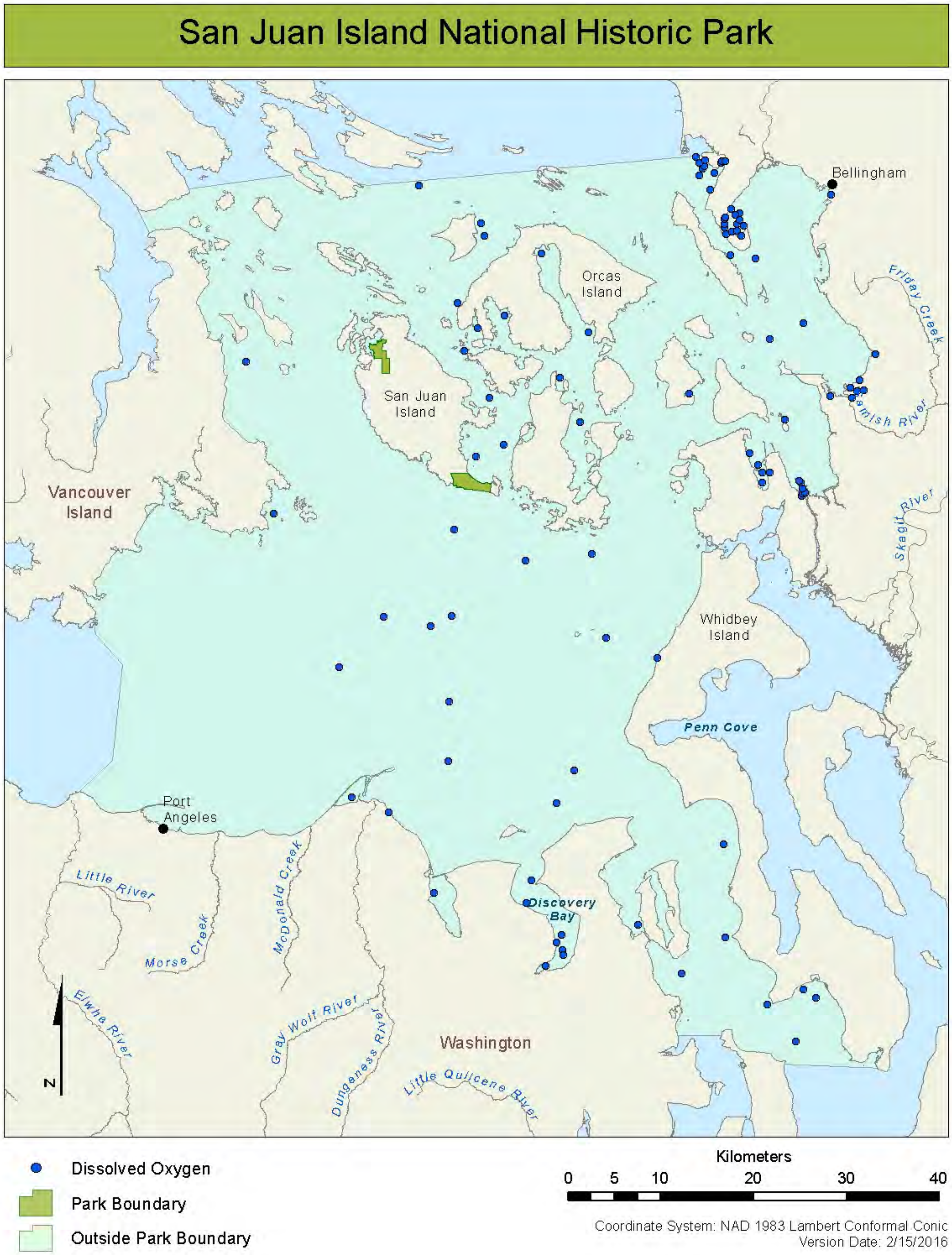

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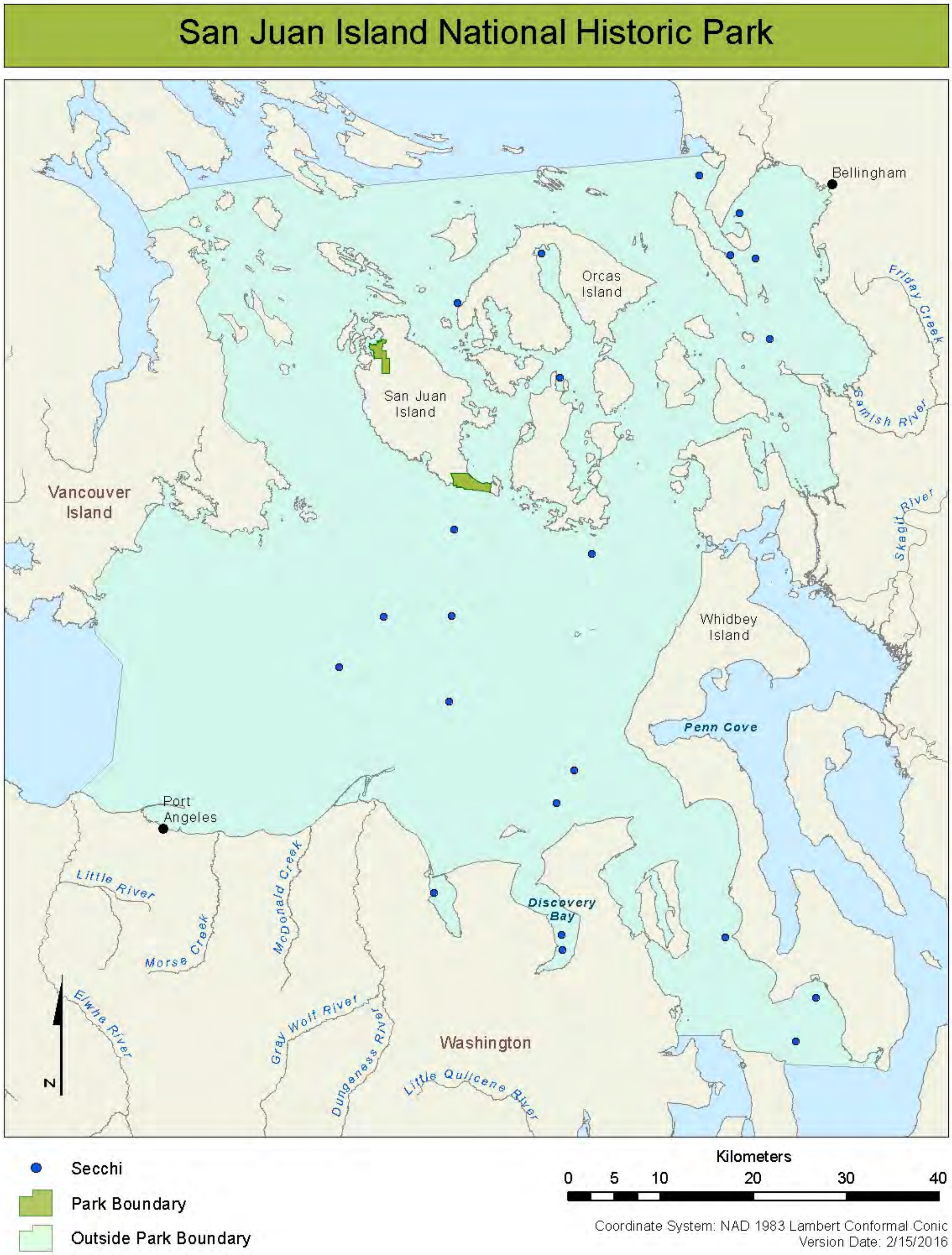

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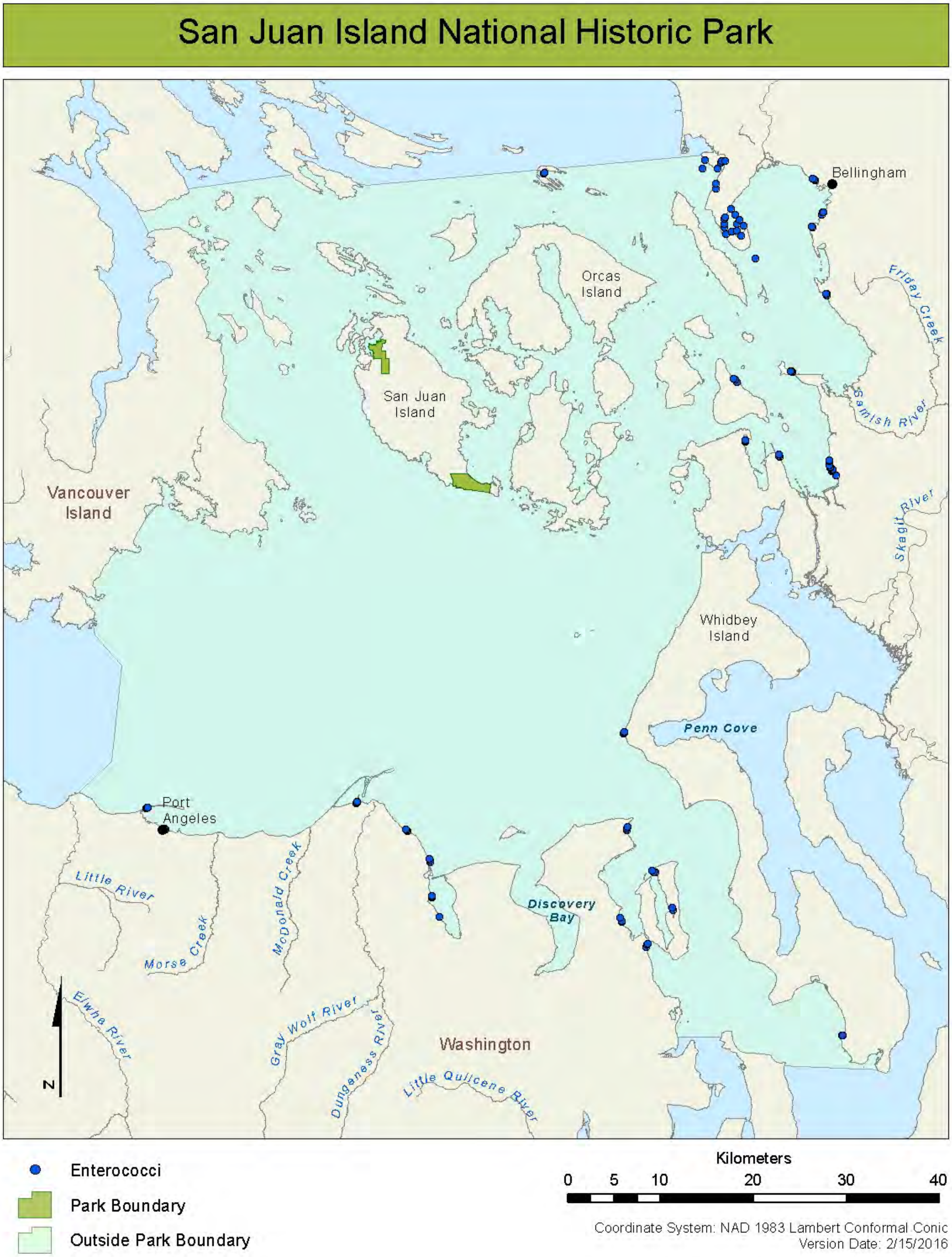

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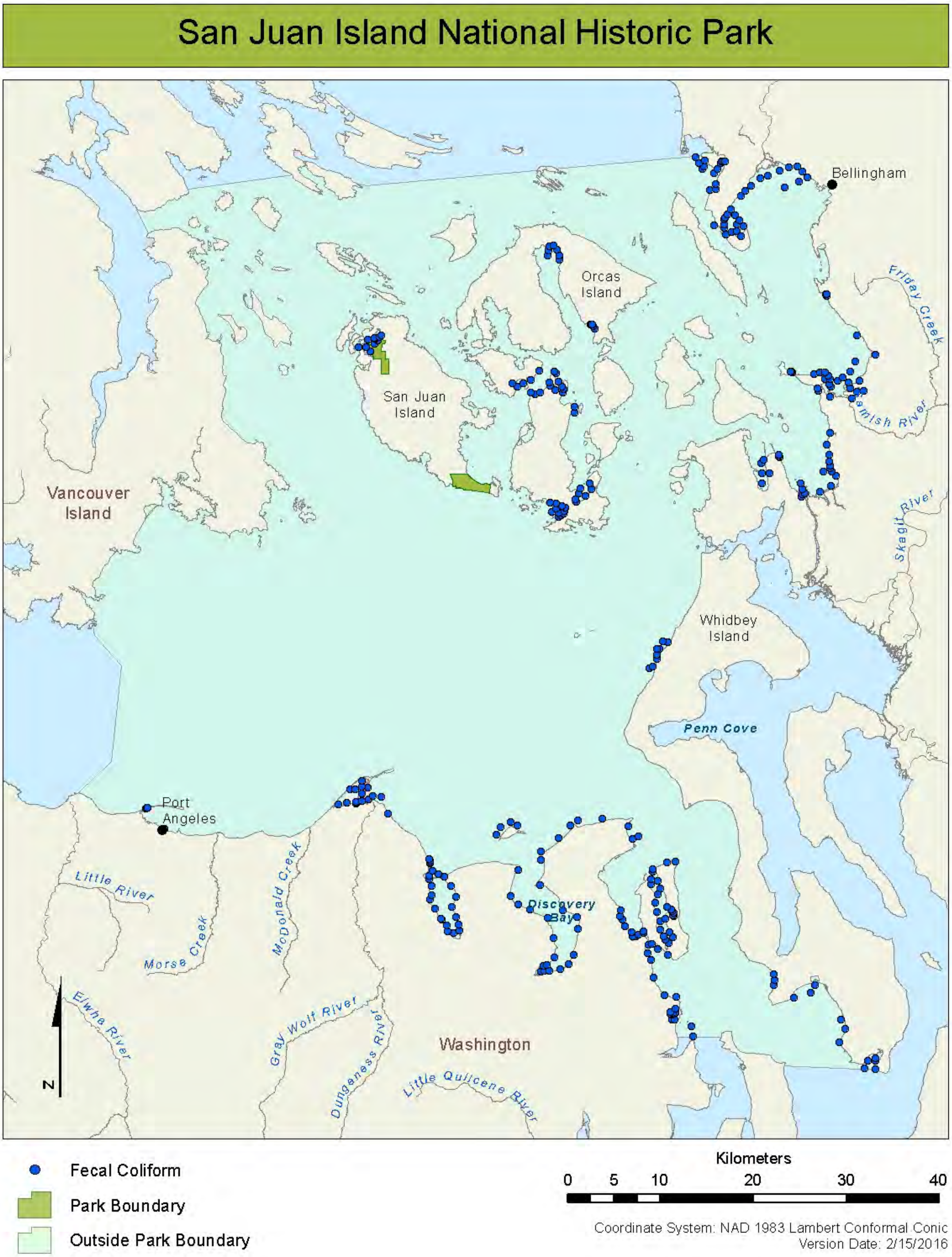

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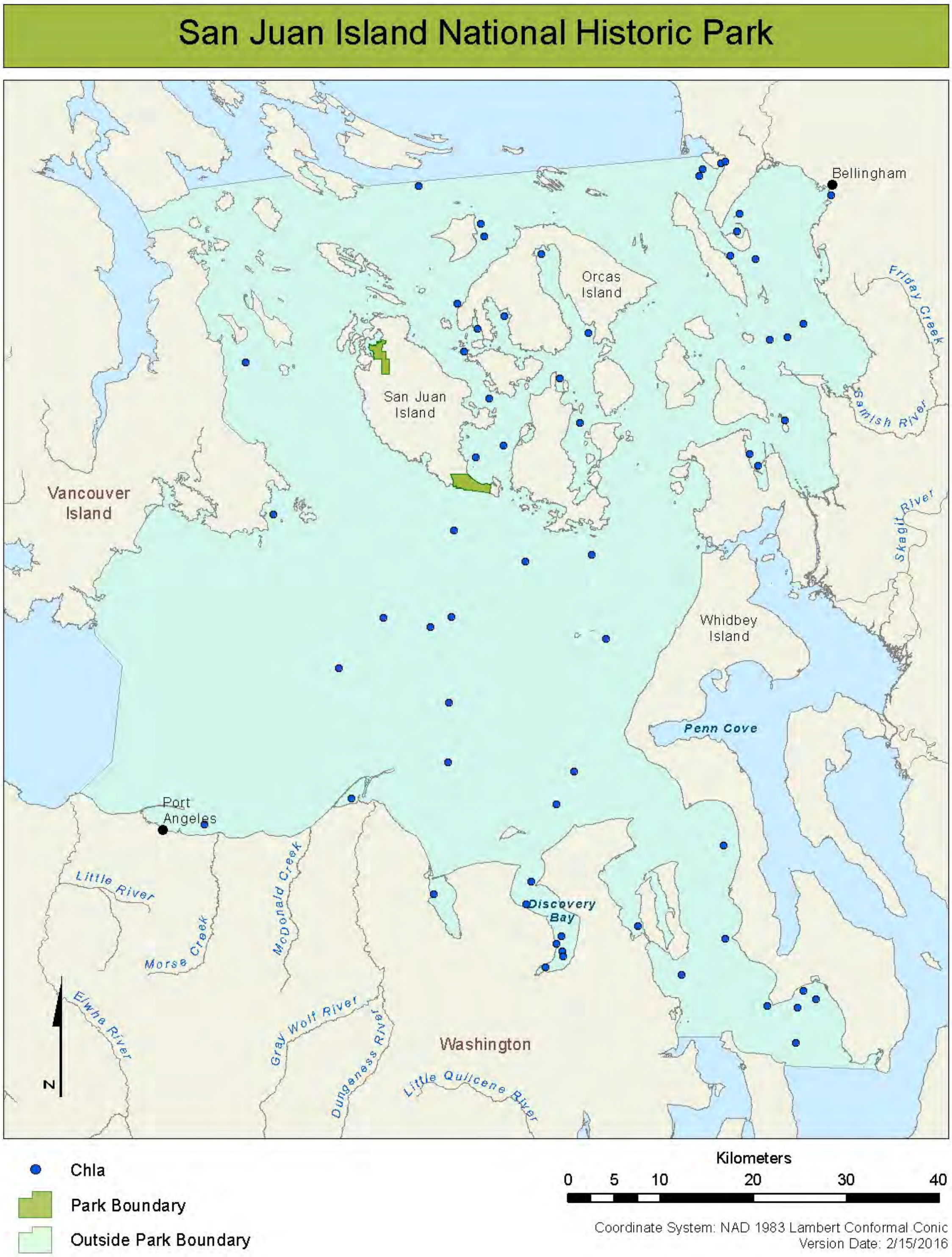

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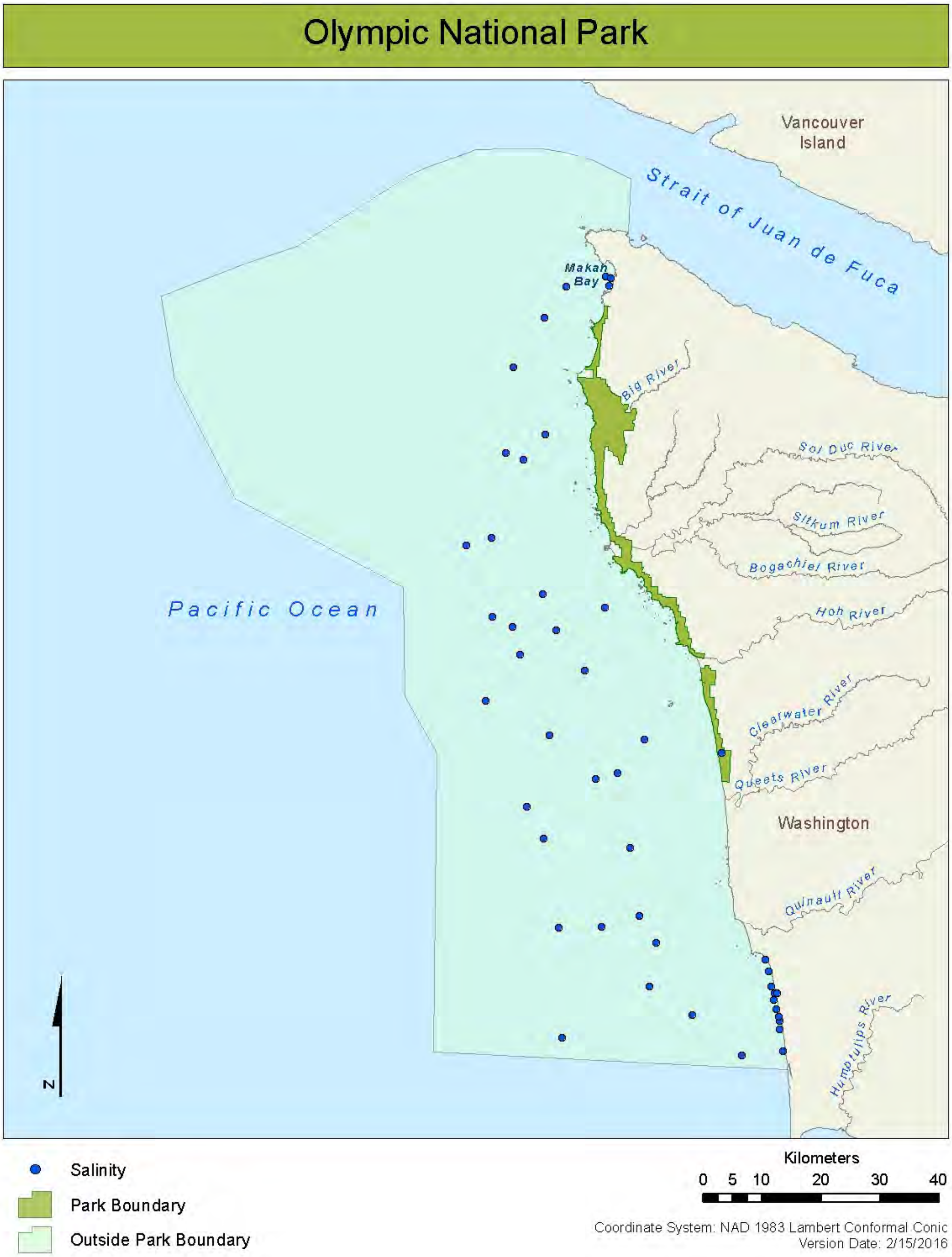

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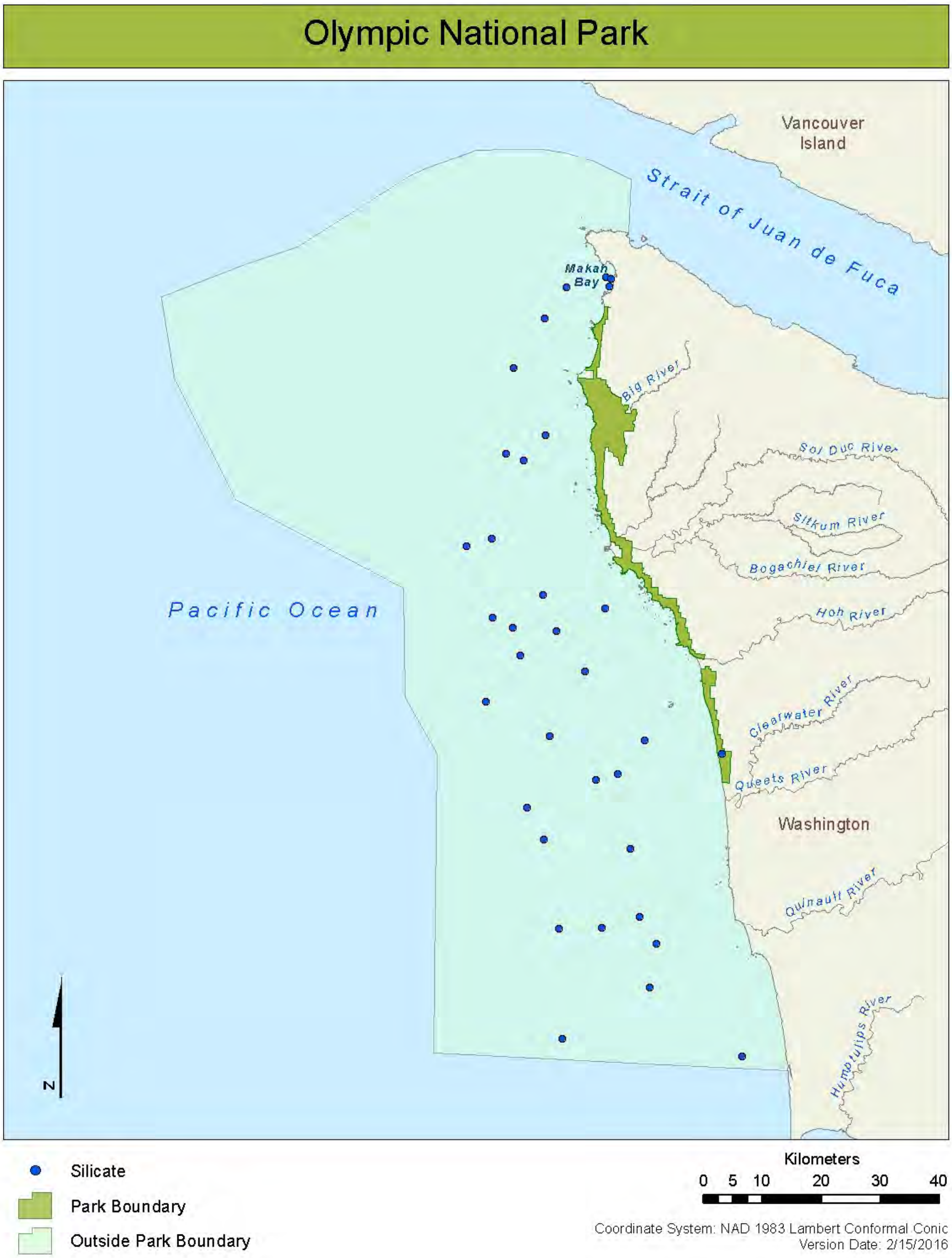

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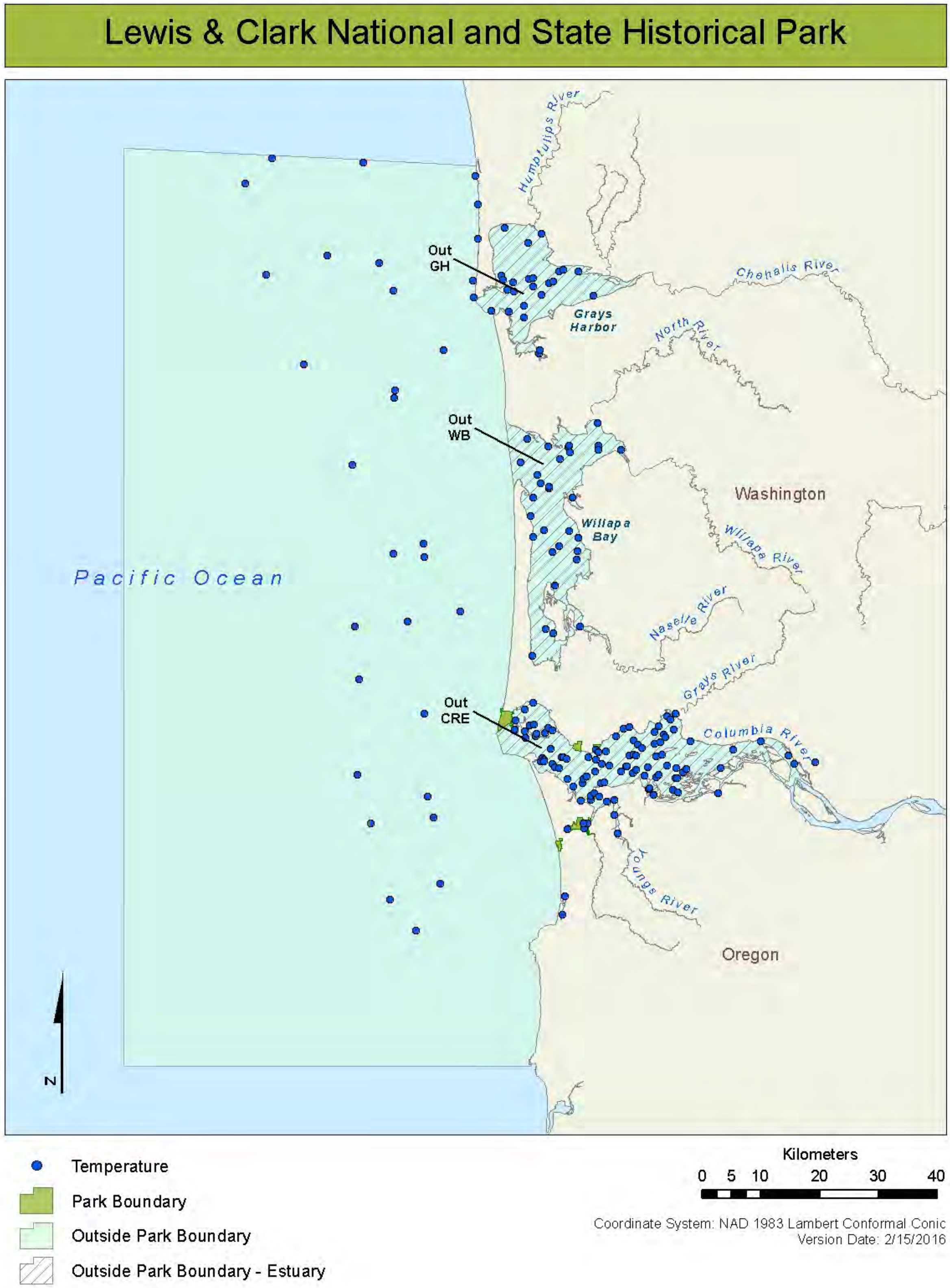

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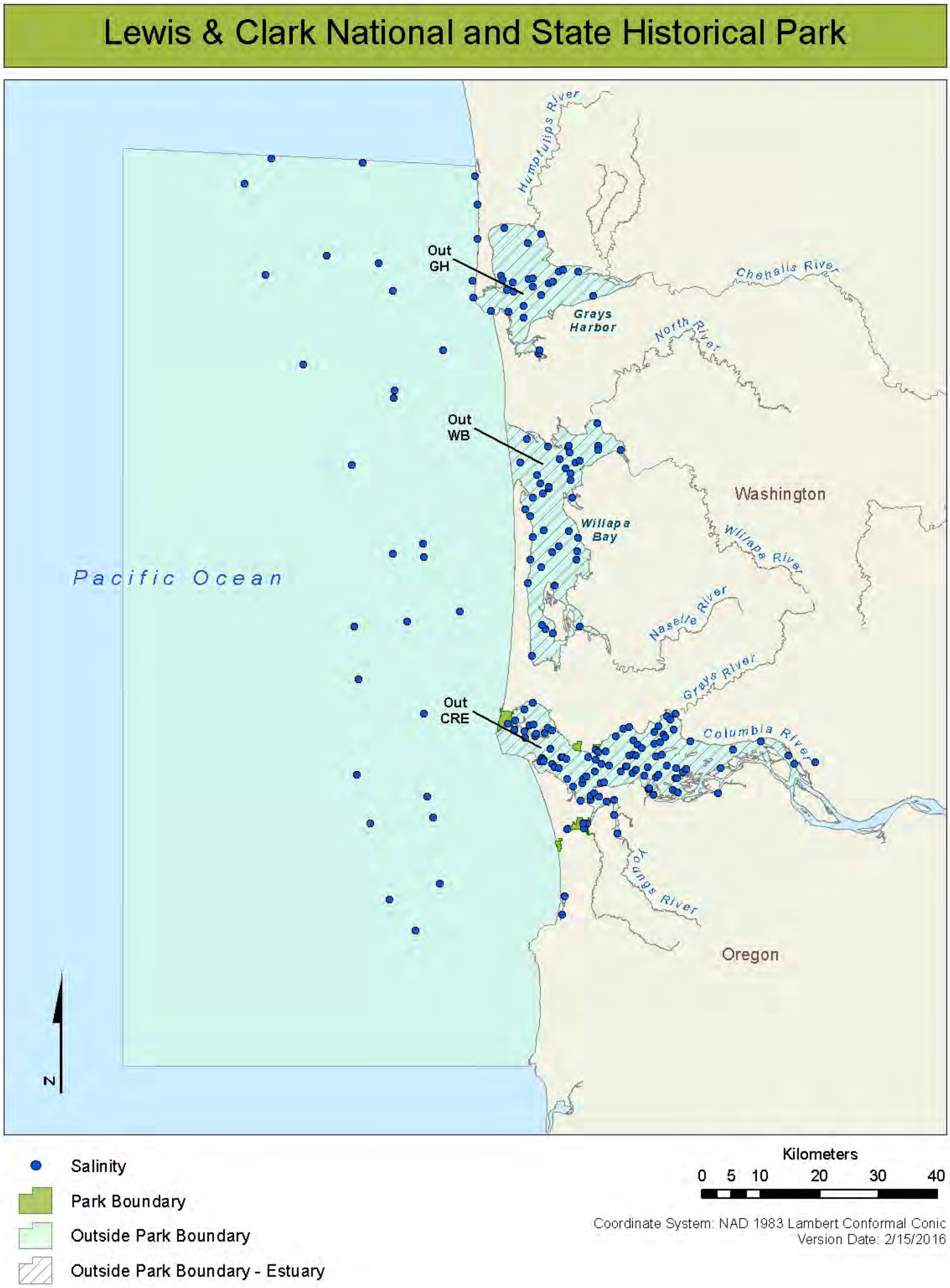

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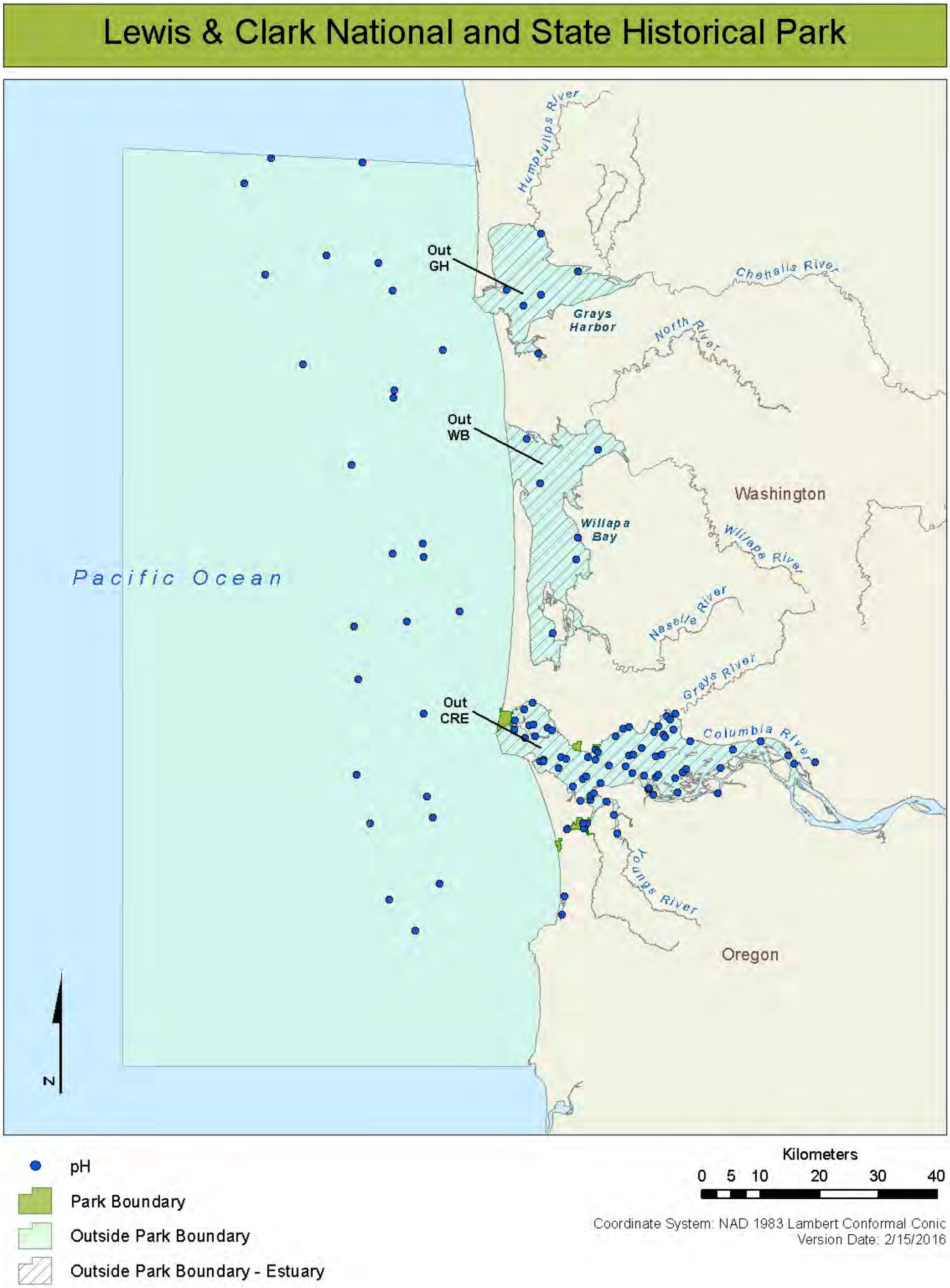

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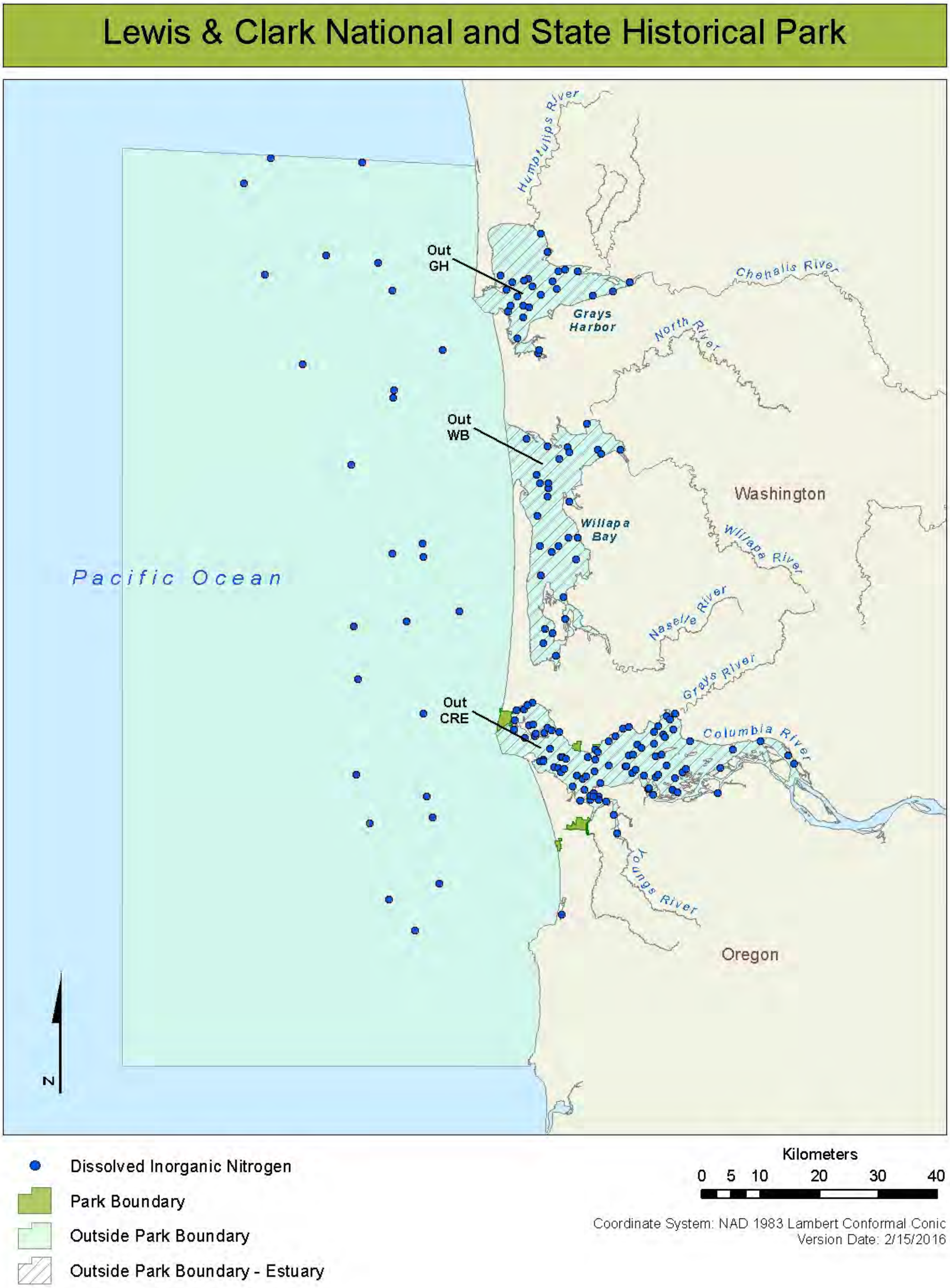

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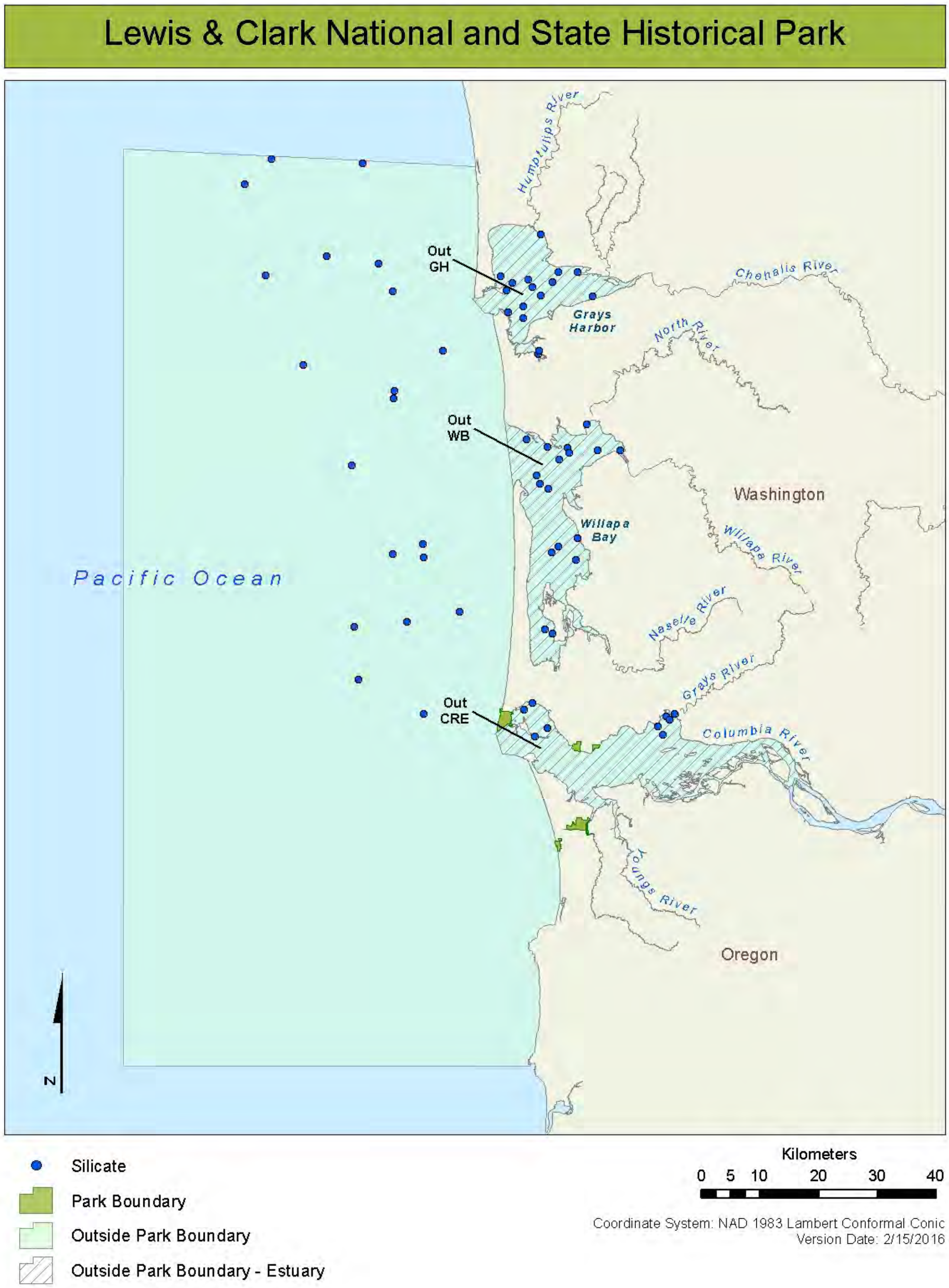

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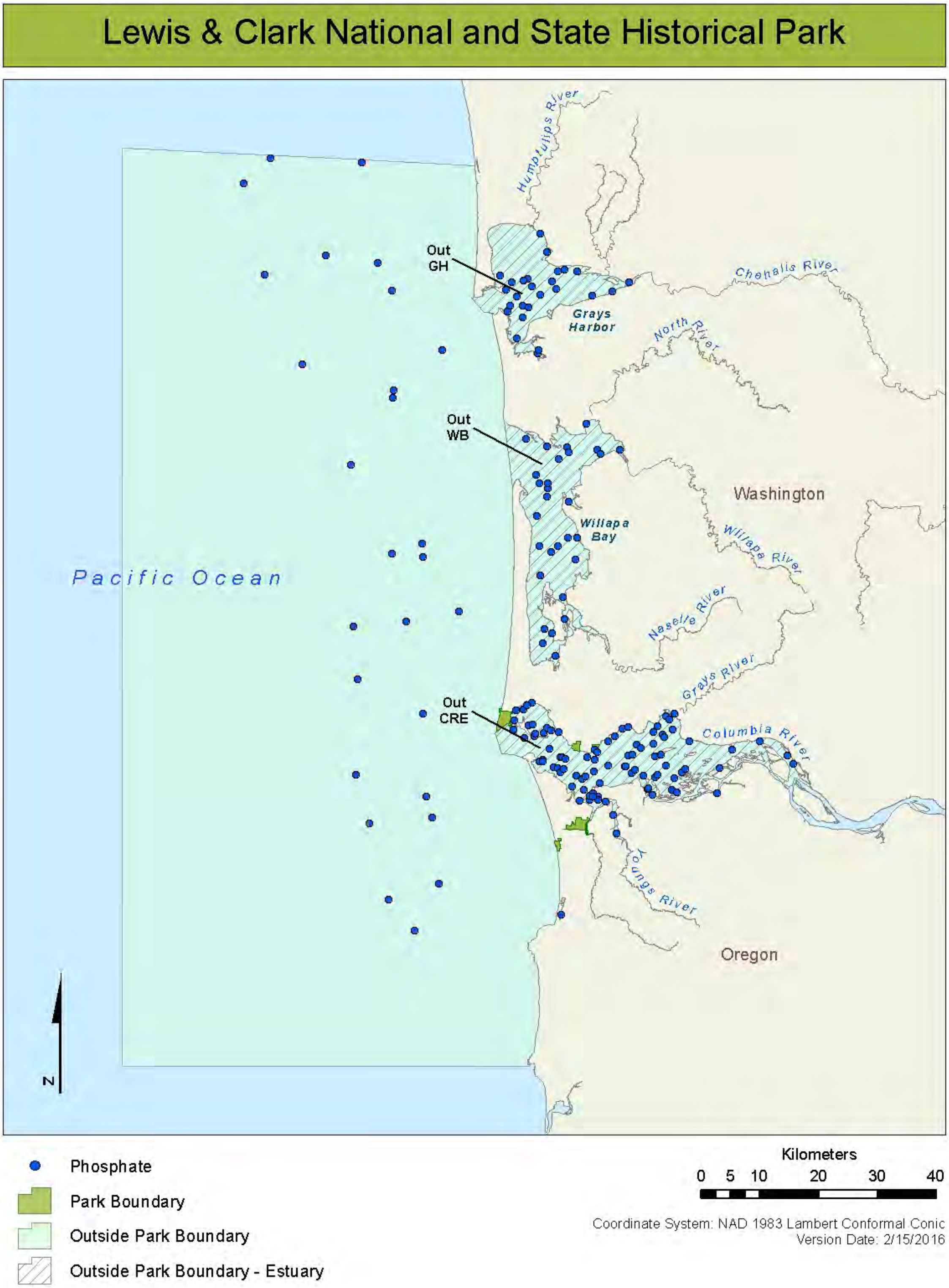

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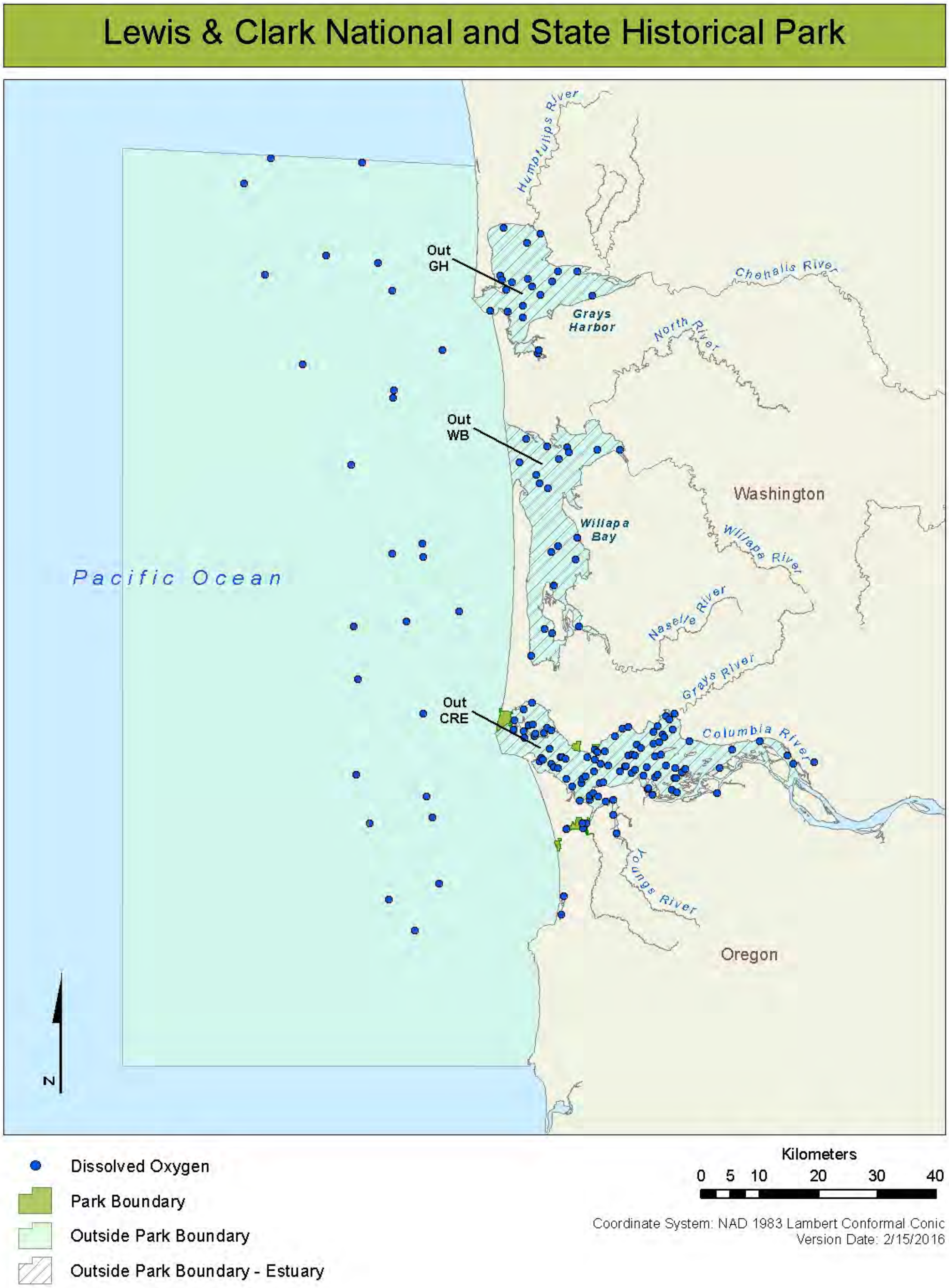

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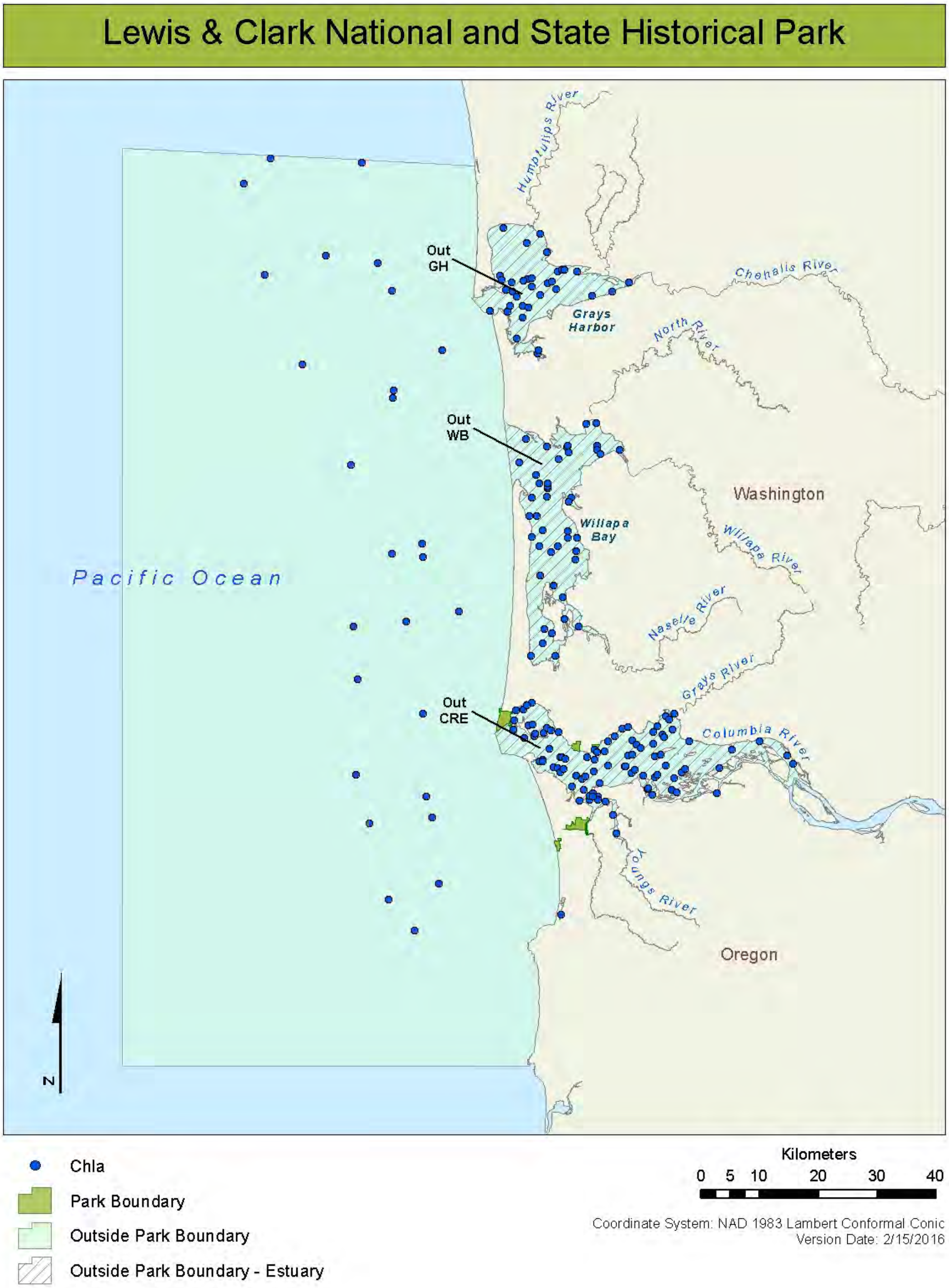

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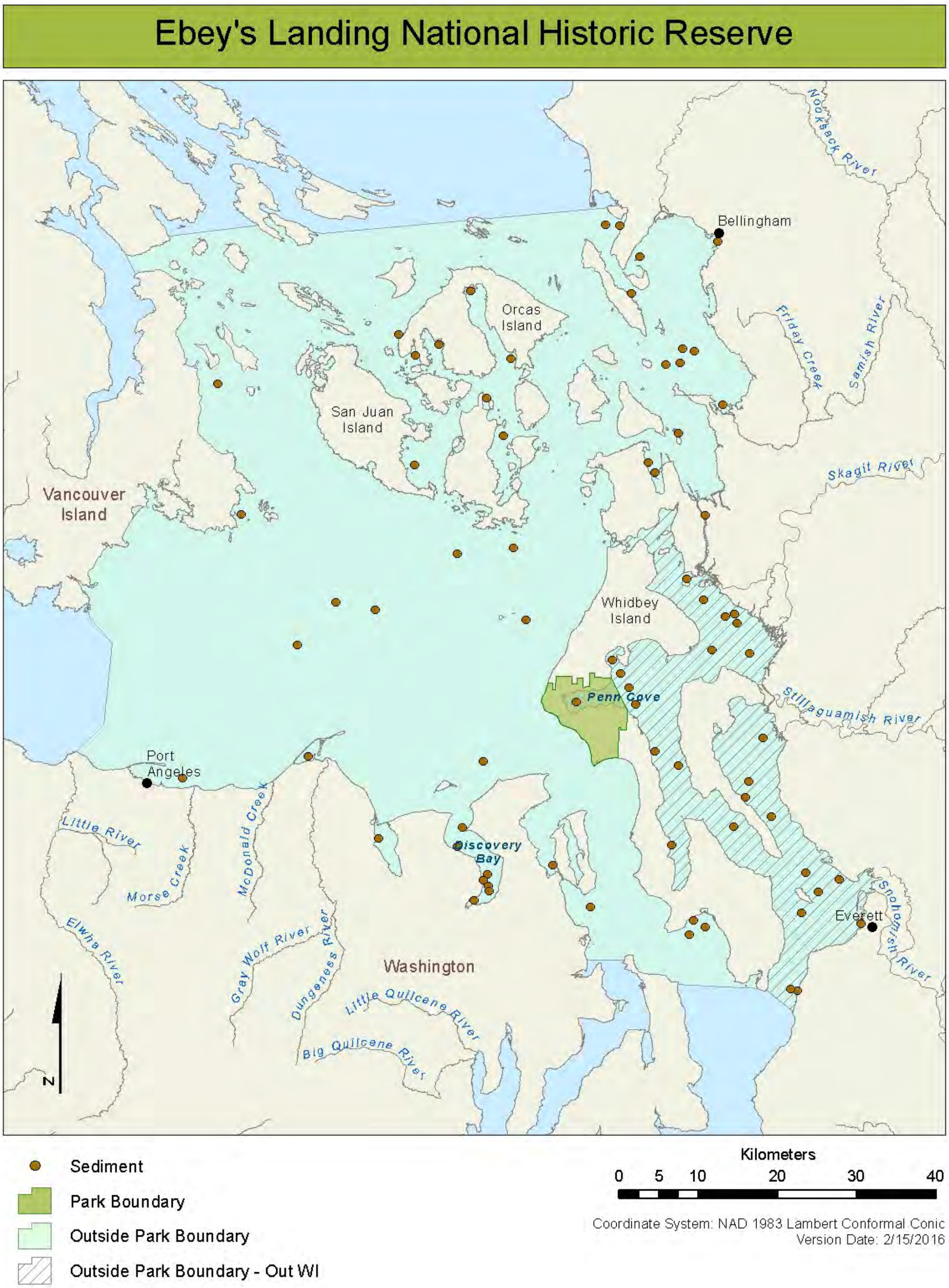

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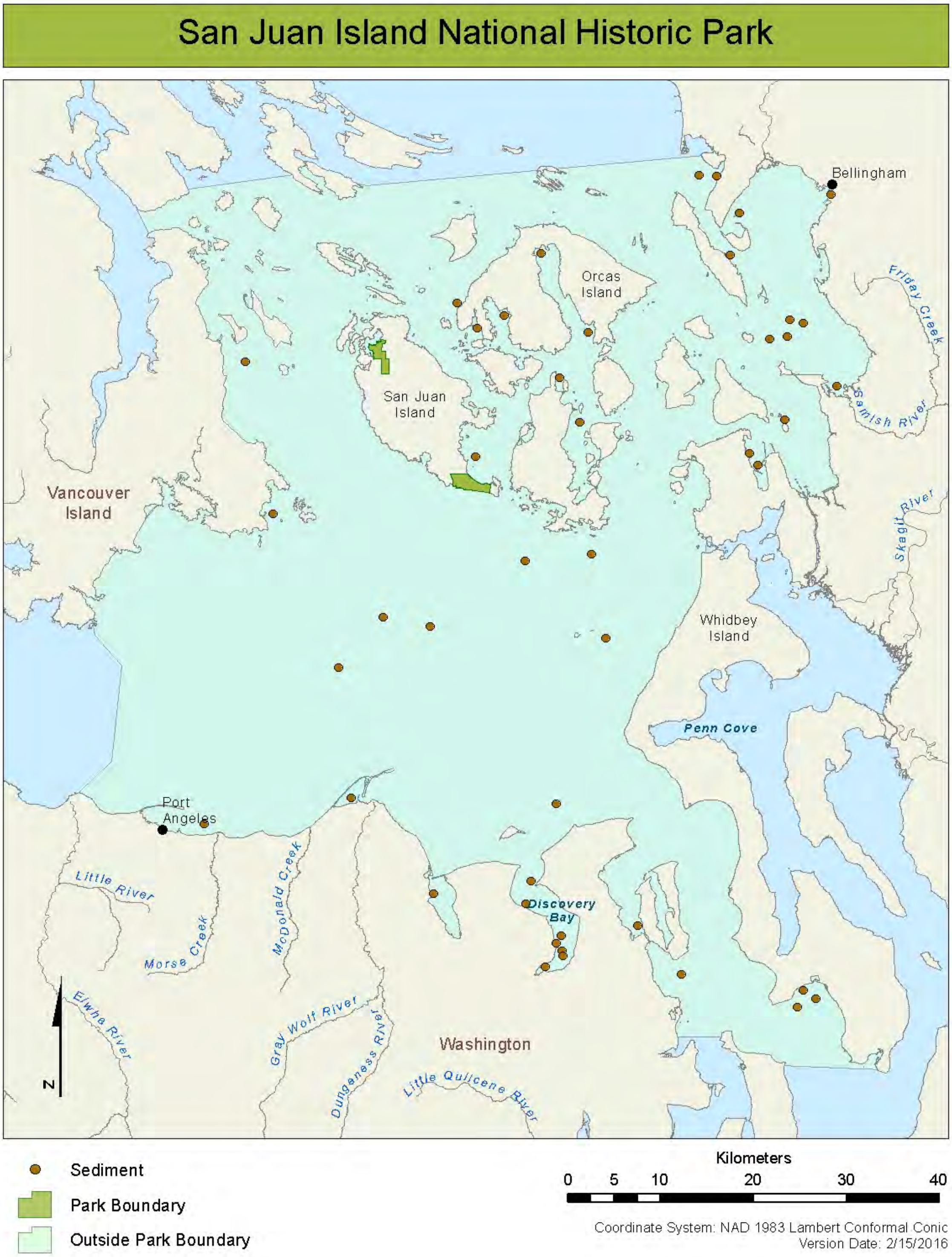

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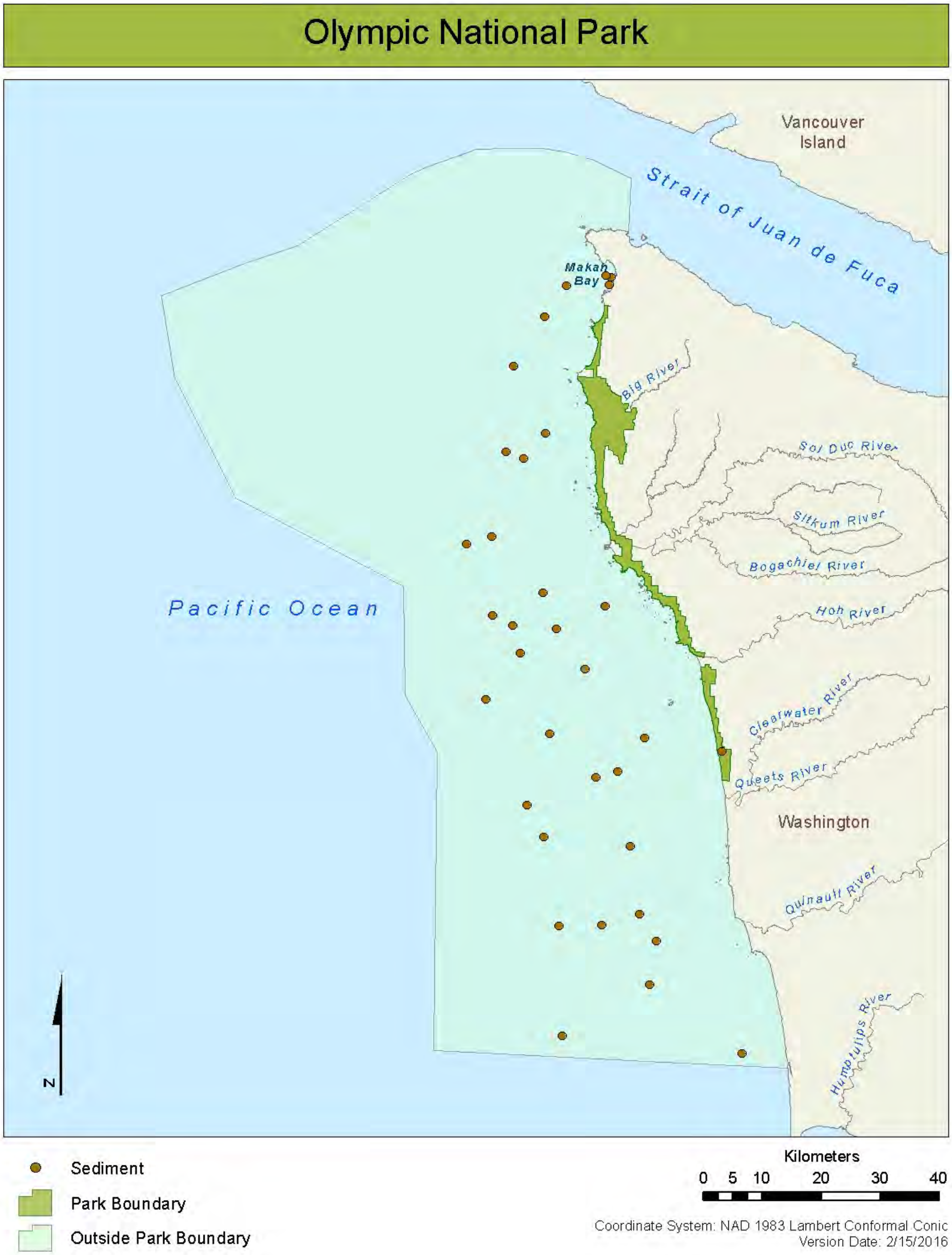

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