Avian Monitoring in Support of the Estuaries Vital Sign in Puget Sound: Inventory and Assessment

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EXECUTIVE SUMMARY

Estuarine habitat, including shallow bays, mudflats, and marshes provide critical habitat for a wide diversity of bird taxa, especially as wintering and migratory stopover habitat. In Puget Sound, many estuarine sites have undergone extensive habitat alteration, although the past few decades have seen large-scale tidal reconnection projects to improve habitat conditions. While the conservation objectives of these estuarine restoration projects largely focus on native salmon recovery, little is known about the cumulative impacts of estuary restoration on migratory and resident birds.

This knowledge gap has consequences for advancing bird conservation. Habitat restoration is a main conservation strategy in national and regional avian management plans, but with salmon recovery as the primary objective for estuary restoration in Puget Sound, our ability to measure how restoration is meeting local, regional and national bird conservation objectives is limited. Furthermore, considering a broader monitoring framework that is inclusive of other fish and wildlife species is required to evaluate the true costs and benefits of coastal restoration, especially as new threats, such as climate change, become an important driver for restoration in Pacific Northwest coastal estuaries.

In recognition of this information need, members of the Puget Sound Ecosystem Monitoring Program, Ecostudies Institute, Washington Audubon and Puget Sound Partnership, proposed a multi-step project aimed at compiling the state of knowledge about the effects of estuary restoration on birds in the Pacific Northwest region, with the ultimate goal of facilitating the development of a more strategic and aligned regional approach to future monitoring efforts. The project included four main components:

1. Inventory and summarize bird monitoring projects associated with estuarine restoration in Puget Sound;
2. Inventory and summarize bird monitoring projects associated with estuarine restoration in other regions of the Pacific Flyway, including Washington outer coast, Oregon, northern California, and British Columbia;
3. Conduct a regional workshop on the effects of estuarine restoration on birds in the Pacific Flyway with the goal of identifying information needs and recommendations for standardized monitoring;
4. Develop an outreach plan to grow and connect the community of scientists and restoration managers involved with bird monitoring at estuarine restoration sites throughout the Pacific Flyway.

In this report, project partners took the first step in this project by investigating the state of knowledge of the effects of estuary restoration on birds in the Pacific Northwest by summarizing attributes of 14 completed and ongoing bird monitoring projects on estuary restoration sites in Puget Sound between 1994 and 2016. Attributes considered in our analysis include methodology, monitoring objectives, data analysis, results, funding and lessons learned. Other areas of the US, such as the Gulf of Maine, Gulf of Mexico and San Francisco Bay, have likewise adopted regional bird monitoring programs to track trends on a broader geographic scale.

PRIMARY OUTCOMES:

- 14 out of 21 large-scale (greater than 20 acres) estuary restoration projects included some form of bird monitoring, indicating strong interest in the question.
- Monitoring projects varied widely in analytical approach, objectives, and funding. These factors complicated comparisons of bird trends beyond single monitoring sites.
- Few projects tracked before/after effects of restoration on bird populations. Projects that included abundance and density results did not include measurement error to show strength in signal detected.
- Waterfowl tended to increase on monitoring sites post-restoration, while shorebird response was variable. However, these results were not tested for significance.
- Limited funding for monitoring and nonuniform monitoring objectives were two key limiting factors in our ability to assess trends on a regional scale.

Based on our findings, we believe a key factor in enhancing our understanding of the effects of estuary restoration on birds is outlining priority avian conservation objectives during the restoration planning phase, which can guide bird monitoring objectives pre- and post-restoration, inform progress towards population and habitat targets, and allow for adaptive management should those goals fall short. Existing documents such as the Pacific Coast Joint Venture for North Puget Sound Lowlands provide guidance on regional avian conservation objectives.

PROJECT RECOMMENDATIONS:

This project is the first step in assessing the effect of estuarine restoration on bird communities and developing a regional monitoring approach for birds in Puget Sound. We propose the following recommendations for the next phases in this project:

- Regional partners convene to establish a set of common avian monitoring objectives based on conservation benchmarks.
- Based on our inventory, the following topics should be considered a high priority in future discussions towards developing a regional monitoring program: data access and storage; tide influences on site accessibility after dike breach; and seasonality, survey frequency, and duration of monitoring.
- Partners will also need to consider the value of monitoring a comprehensive list of taxa (shorebirds, waterfowl, raptors and passerines) versus a more focused approach (i.e., shorebirds). Comprehensive monitoring could help improve community support for estuarine restoration by informing and engaging a wider diversity of stakeholders (e.g., birdwatchers and waterfowl hunters), while a shorebird focus could help monitoring projects amplify existing efforts such as the Pacific Flyway Shorebird Survey and further our understanding of the regional value of Puget Sound estuaries on shorebirds. This report offers a preliminary assessment of the respective value of each approach.

INTRODUCTION

Tidally-influenced estuarine habitats in the Pacific Northwest, such as shallow bays, mudflats and marshes, serve as places of vital importance for many bird taxa at various stages of their annual cycle within the Pacific Flyway. Estuaries along the coast of Washington and in Puget Sound have been identified as particularly important for shorebirds, waterfowl, and other marine birds, especially as wintering and migratory stop-over habitat. For example, the Western Hemisphere Shorebird Reserve Network identifies six estuaries in this region as sites of regional, hemispheric, or international importance (WHSRN 2017). Estuarine emergent marsh habitats also support a unique group of passerines and secretive marshbirds, contributing to the region's biodiversity. Overall, estuarine habitats function as roosting, foraging, and nesting habitat for over 92 species of birds and they are an important driver for productivity in the marine food web (Petrie 2013).

Like many other coastal regions of the United States, the loss and degradation of coastal estuaries in the Pacific Northwest has been significant, affecting ecosystem function and populations of aquatic and terrestrial animals (Mitsch and Gosselink 2000). Losses in Puget Sound are especially notable, as approximately 80% of Puget Sound's 16 major river delta tidal wetlands have been lost (Collins and Sheikh 2005). In Puget Sound, the loss and degradation of wetlands has had a significant negative impact on many important fisheries, most notably salmon (Simenstad and Cordell 2000). In particular, extensive diking along tidally-influenced wetlands reduces channel sinuosity and extent, and restricts recruitment of large woody debris landward and seaward of dikes (Hood 2004), thus reducing habitat complexity vital for vulnerable salmon populations. The consequences of such expansive habitat alterations also extend to birds, especially waterbirds such as shorebirds and waterfowl, because intertidal and transitional foraging grounds are significantly altered or lost. Although little is known about the historic population size, composition, and distribution of wetland associated bird species, it is generally accepted that present-day populations are significantly reduced (Ball et al. 1989; Drut and Buchanan 2002).

Significant investments in restoration of tidal habitats are underway in Puget Sound, with major projects completed or underway at all 16 large river deltas. Between 2006 and 2016, approximately 2,791 acres of estuarine river delta wetlands were restored (Puget Sound Partnership 2017) and nearly $80 million USD spent (RCO 2017). Tidal restoration typically aims to return physical and biological attributes to conditions similar to those historically present, acknowledging modern constraints, most notably human

modifications to the watershed, its habitats, and fish and wildlife populations. In Puget Sound, most estuary restoration projects have been initiated in support of salmon recovery, particularly the federally listed Chinook Salmon (*Oncorhynchus tshawytscha*). During the last decade these projects have developed effective monitoring protocols and management techniques designed to track and inform salmon restoration effectiveness.

However, monitoring of other fish, wildlife, and habitat values have been limited, and thus the effects of salmon-focused estuarine restoration on other important ecosystem attributes, such as birds, remain relatively unknown. Consequently, we lack a clear understanding of the spectrum of benefits, or costs, of salmon-focused restoration on overall ecosystem function. This lack of understanding has consequences for advancing bird conservation because habitat restoration is a main conservation strategy in national and regional waterfowl and shorebird management plans (Brown et al. 2001, Drut and Buchanan 2002, NAWMPC 2012, Petrie 2013). Because standardized bird monitoring has not been a priority in Puget Sound restoration, we have limited information from which to evaluate tidal restoration and to quantify how these projects may help address national, regional, or local conservation objectives. Embracing a broader monitoring framework that is inclusive of other fish and wildlife species is required to evaluate the true costs and benefits of coastal restoration, especially as new threats, such as climate change, become an important driver for restoration in Pacific Northwest coastal estuaries.

In recognition of this information need, members of the Puget Sound Ecosystem Monitoring Program Marine Birds Work Group proposed a multi-step project aimed at compiling the state of knowledge about the effects of estuary restoration on birds in the Pacific Northwest region, with the ultimate goal of facilitating the development of a more strategic and aligned regional approach to future monitoring efforts. A secondary goal is to promote inclusion of avian conservation objectives in large-scale estuary restoration projects that develop a deeper understanding of avian population trends, habitat needs, and responses to restoration efforts.

The project included four main components: 1) Inventory and summarize bird monitoring projects associated with estuarine restoration in Puget Sound; 2) Inventory and summarize bird monitoring projects associated with estuarine restoration in other regions of the Pacific Flyway, including Washington outer coast, Oregon, northern California, and British Columbia; 3) Conduct a regional workshop on the effects of estuarine restoration on birds in the Pacific Flyway with the goal of

identifying information needs and recommendations for standardized monitoring; and 4) Develop an outreach plan to grow and connect the community of scientists and restoration managers involved with bird monitoring at estuarine restoration sites throughout the Pacific Flyway.

In this study, collaborators from Ecostudies Institute, Audubon WA and the Puget Sound Partnership take the first step in this multi-step project by assessing completed or ongoing bird monitoring projects at estuary restoration sites in Puget Sound (Component 1). To complement this review, we also summarized information from a restoration site in Oregon, and reviewed literature from other regions of the country where large-scale estuarine restoration efforts have resulted in more developed regional bird monitoring programs, such as the Gulf of Maine, Gulf of Mexico, and, San Francisco Bay. We included these areas because we had prior knowledge about bird monitoring efforts at these locations, and thus believed they could help play a role in helping guide the development of a Puget Sound monitoring framework. We then identified knowledge gaps and limiting factors in Puget Sound monitoring projects. Finally, we offer some preliminary suggestions for standardized monitoring that can be used as a starting point for a regional workshop (Component 3).

METHODS

We compiled a list of estuary restoration projects associated with 16 major river deltas in Puget Sound between 2006 and 2016 from the Washington State Recreation and Conservation Office (RCO) Project Information System (PRISM) database. PRISM is a comprehensive database that provides geographic and descriptive information for recreation and habitat projects funded through RCO in Washington State. Because RCO grant programs include state estuary restoration funding programs such as the Salmon Recovery Funding Board (SRFB), Puget Sound Acquisition and Restoration Program (PSAR), and Estuary and Salmon Restoration Program (ESRP), we consider PRISM a comprehensive list of estuary restoration projects in Puget Sound. However, to ensure we included federally-funded projects not covered in part by state grants, we made targeted inquiries to organizations such as Ducks Unlimited (DU), Washington State Department of Transportation (WSDOT), and the Pacific Birds Habitat Joint Venture.

Projects were prioritized by size (acres) of area restored. Projects under 20 acres were not actively investigated given time constraints and perceived diminishing returns on smaller projects. Exceptions were made for small projects that came to our attention through other inquiries. Finally, projects were also gleaned from Puget Sound Partnership outreach materials. For projects in the Snohomish River

Delta, the summary report, "An overview of projects in the Snohomish River Delta to restore tidal wetlands and support young salmon" 2015, provided a list of three projects included in this inventory. All three projects were compensatory mitigation projects with 10-year monitoring requirements.

Information on bird monitoring efforts associated with these projects was gathered through a variety of means. We contacted restoration project lead entities by email and phone and reviewed reports provided by lead entities or that were available online. When reports were unavailable, lead monitoring entities were given a questionnaire concerning monitoring protocols, results and recommendations. In addition, all project managers were given a brief questionnaire on project funding sources, costs, and coverage of monitoring goals. Overall, we collected information on 36 attributes related to the restoration project and bird monitoring. For the purposes of this report, we focus our comparison and summary of monitoring projects in Puget Sound on a subset of the 36 project attributes.

Monitoring projects were characterized according to general information about the project, bird sampling methodology, and analytical approach (Table 1). These categories provide an illustration of the range of monitoring objectives, methods, and outcomes to help us evaluate their contribution to understanding the effects of restoration on bird communities in Puget Sound.

TABLE 1 FIELDS USED TO CHARACTERIZE BIRD MONITORING PROJECTS AT RESTORATION SITES IN PUGET SOUND

General information	***Sampling methodology***	***Analysis***
Study site	Survey type	Taxa
Bird monitoring objectives	Timing and frequency	Metrics
Surrounding landscape	Duration of monitoring project	Analytical approach
Reference sites	Habitat sampled	Monitoring results
Crew type		Recommendations
Other data collected		
Project funding		

RESULTS

GENERAL INFORMATION

Study sites

We found 21 berm and/or dike removal projects that were initiated in Puget Sound between 1994 and 2016, of which 16 came from PRISM and 5 came from other sources. Of those 21 restoration projects,

14 incorporated bird monitoring. Nine of the monitoring projects are complete, three are ongoing, one has not yet begun data analysis, and one was discontinued after pre-restoration monitoring.

All results discussed hereafter refer to the 14 projects with associated bird monitoring. Bird monitoring project summaries are included in Appendix B and the full inventory is compiled in an Excel file available from the authors. We catalogued bird monitoring information from projects on seven different estuaries, including the Skokomish, Puyallup, Snohomish, Nisqually, Skagit, Stillaguamish river estuaries and the JimmyComeLately River estuary on Sequim Bay. One project, Red Salmon Slough restoration, is located adjacent to the Nisqually site. For assessment purposes, the Nisqually and Red Salmon Slough sites are considered a single project. Projects listed in the PRISM database multiple times due to phased restoration activities were treated as a single project for our inventory. Five of the 14 bird monitoring projects we assessed were not listed on the PRISM database list because they either fell outside the originally-defined time frame for PRISM (Marysville Mitigation, Port of Everett's Union Slough, Deepwater Slough and Gog-Le-Hi-Ti) or were located on a minor river delta (JimmyComeLately). Restoration sites ranged from 14 to 762 acres, with a median acreage of 150.

Bird Monitoring Objectives

Objectives fell into three main categories: establish a baseline to assess future effects of restoration (3 of 14 projects), determine before/after effects (4 of 14 projects), and track changes from beginning of restoration over time (7 of 14 projects). Additional objectives included investigating habitat associations and modelling response trajectory.

Surrounding Landscape

Restoration project locations ranged from rural, agricultural, suburban, urban and industrial areas, but were predominantly located in agricultural settings (10 projects).

Reference sites

Reference sites were included for comparison on nine of the 14 restoration projects. In some instances, former restoration sites served as reference sites, such as the Marysville mitigation site and Wiley Slough.

Crew type

Five projects utilized volunteers. Eight used paid staff only, and one employed a volunteer biologist.

Other data collected

Eleven of the 14 projects sampled additional biophysical measures (e.g. water quality, macroinvertebrates, vegetation, sediment characteristics), and nine included some measure of fish performance. Commonly, projects collected and analyzed these data independently of bird response. The Nisqually refuge and Port Susan Bay were the exceptions. At the Nisqually refuge, macroinvertebrate surveys examined the functional response of waterbirds to prey abundance. That site revealed a positive correlation between bird abundance and macroinvertebrate density during the winter. Authors suggested that the increase in invertebrate habitat throughout the restoration site could theoretically support substantial increases in shorebird populations (Takekawa et al. 2013). Port Susan Bay is similarly looking at macroinvertebrate abundance as prey availability for waterbirds, but those results are not yet available.

Funding

An estimated minimum of $220,000 was spent on estuary restoration bird monitoring between 1996 and 2017, based on data from the ten restoration projects that reported funding information. Project managers were asked to estimate total cost of monitoring project based on the following categories: less than $2000, $2-5000, $5-10,000, $10-20,000, $20-50,000, or over $50,000. Total funding per project ranged from $2-5,000 to over $50,000, not adjusted per year or per site.

When asked how funds covered monitoring goals, respondents reported that four projects were fully funded, four were moderately funded, and two were minimally funded.

BIRD SAMPLING METHODOLOGY

Survey method

Projects used a range of survey methods (Appendix A, Table 3). Projects most commonly employed point counts alone (4 projects) or in combination with other survey methods (eight projects). Transect surveys were used alone (2 projects) or in combination at seven projects. Area searches were used alone (3 projects) or in combination on six projects.

Timing and Frequency of monitoring

All 14 projects conducted spring season surveys. Four projects surveyed during all four seasons, and three surveyed only fall and spring. When specified in reports, timing of surveys was based on breeding vs. non-breeding seasons or migration periods. Most projects surveyed at both high and low tides (8

projects). Survey tide conditions were reported in a variety of ways, including: 3 m and receding low tide or 3 m and higher high tide; tidal minimum or maximum to the midpoint of ebb and flood tides; or intermediate tides between high and low. Frequency of monitoring was highly variable among projects. Most commonly, sites were surveyed monthly or bi-weekly (4 projects). The highest frequency of surveys were conducted on a weekly basis during a survey season, while the lowest frequency were those conducted 2 days each fall and spring. All projects recorded both migratory and resident birds.

Duration

Of the 11 completed projects, monitoring duration spanned 2 - 16 years (median = 7 years). Three projects are ongoing and have thus far spanned 2 - 5 years. This time span does not include projects that incorporated historical data gathered through alternative survey methods and used the data as a baseline for comparison. Three projects had a 10-year monitoring program, but conducted quantitative surveys only on select years within that timeframe. Eight of the 14 projects initiated monitoring prior to restoration. However, only five projects surveyed pre- and post-restoration periods. Two projects conducted pre-restoration monitoring only; one project was designed and funded as a baseline-only monitoring project before restoration occurred, and the other was discontinued due to lack of funding. Another project has ongoing pre-restoration monitoring with the intention of conducting post-restoration monitoring upon project completion.

Types of habitat sampled

Ten projects recorded bird observations by habitat type. Habitat categories varied by project, but each generally included the following habitats: open water/flooded, marsh plain/marsh vegetation, ditch or pond, natural slough/channel, and levee. One project divided point count locations by habitat type (forested saltmarsh, riparian saltmarsh, forest, open water, wetland), but noted these habitats were expected to change with the influence of tidal processes over time. One project discussed bird use of a newly constructed channel, but observations were not recorded by habitat type. Among the five completed projects that recorded observations by habitat type, the type of habitat analysis varied. Two projects compared taxa abundance by habitat type, two projects analyzed taxonomic group abundance by habitat type, tide, and time of year without cross-taxa comparisons, while another looked at overall bird density by habitat type, but not by taxa.

ANALYSIS

Taxa

The most common taxa analyzed were shorebirds (eight projects), waterfowl (eight projects), and passerines (six projects). Of the eight projects that analyzed waterfowl, three projects further delineated the group to Anatidae ducks (two projects) or dabbling and diving ducks (one project). Other taxa monitored include secretive marsh birds (four projects), raptors (two projects), geese and swans (two projects), and waterbirds (defined as gulls and terns; two projects).

Metric for analysis

Most projects summarized data by multiple metrics. Total bird abundance was the most common metric (nine projects), followed by occurrence (seven projects), species density (six projects), species richness (four projects), and species diversity (one project). No project analyzed demographic metrics.

Analytical approach

No project in this inventory used a statistical analysis (e.g., *t*-test, ANOVA) for comparing differences in mean abundance or density for before/after restoration, sub-habitat, or seasonal comparisons in the reports we reviewed. For these types of summaries most projects reported means, although none reported measures of error (e.g., SD or SE). Projects did include the following statistics: analysis of similarity (ANOSIM) to test differences in community composition between reference and restoration sites, and a discriminating species analysis (SIMPER) to test for the species most responsible for dissimilarities in assemblages among sites (two projects); regression analysis to test correlation between bird abundance and macroinvertebrate density (one project); and Spearman's rank correlation to determine the relationship between duck density and percent standing water (two projects). Five monitoring projects used distance sampling survey methods. However, two projects just started and have thus not completed an analysis, two projects did not include those data in their final analysis, and one reportedly used distance sampling, but did not report those results. One project published a peer-reviewed report (Gog-Le-Hi-Ti wetland; Simenstad and Thom 1996), one published results for a conference proceedings (Port of Everett's Union Slough; Houghton and Uhlig 2003), and another expects to publish results in the coming year (Nisqually Refuge; Isa Woo, personal communication).

Monitoring Results

Two projects have completed before/after effect analysis, three projects have completed post-restoration trend analysis, and four projects have reported results from preliminary analyses (Appendix A, Table 2). Three projects were excluded from results table because they were descriptive surveys that did not provide data to evaluate effects of restoration. Projects that completed post-restoration monitoring reported mixed effects relating to bird use of the restoration area immediately after restoration, community structure and increased food production. Port Susan Bay Preserve reported changes in community composition (before/after effects), with a shift from passerines and dabbling ducks as the dominant taxa groups to dabbling ducks, shorebirds and geese. JimmyComeLately Creek Estuary reported a decrease in overall abundance and no change in species richness, but an increase in some groups of waterbirds, such as dabbling ducks. Similarly, Nisqually Refuge compared waterbird abundances with historic aerial surveys and found an increase in abundance post restoration. Monitoring in Wiley and Deepwater slough found that waterfowl and shorebirds used large, well-drained channels at low tide, while avoiding large channels that did not drain. Overall, this inventory revealed a mix of patterns in bird response to estuary restoration.

Recommendations

Recommendations from each project varied, but included topics such as the ideal frequency and duration of monitoring, habitat associations, cost-effectiveness, survey methods, data storage and access, and study variables. We did not encounter recommendations relating to specific estuary restoration practices to impacts on bird populations, but one monitoring project, covering Deepwater and Wiley sloughs, recommended that conservation efforts for waterbirds include non-tidal wetlands, and stressed the role of agricultural fields in augmenting the habitat needs of waterbirds in the wake of limited natural coastal wetlands (Slater 2004).

DISCUSSION

BIRD MONITORING IN PUGET SOUND

Overview

Bird monitoring was prevalent among the large-scale estuary restoration projects occurring between 1994 and 2017. The fact that 14 of 21 (67%) restoration projects included some form of bird monitoring

indicates that there is a strong interest in understanding how estuarine restoration influences bird composition and abundance. Although bird monitoring at estuarine restoration sites was common, justification for incorporating bird monitoring was not tied to large-scale bird conservation goals. Notably, only one restoration project in our inventory (JimmyComeLately) had explicit objectives related to bird population metrics or desired response to habitat modification. The lack of explicit avian objectives makes it difficult to assess the effectiveness of these projects from a bird conservation lens. The contribution of these projects towards creating habitat for species of local, flyway or national conservation concern (e.g., red knot [*Calidris canutus*], dunlin [*Calidris alpina*]) is similarly unclear.

Even though many restoration projects incorporated bird monitoring, we found objectives, study design, survey methods, monitoring duration, and funding levels highly variable across projects. Not surprisingly, results from this review did not lead to strong, consistent patterns. However, some basic patterns of bird response were identified. Overall, waterfowl abundance appeared to increase after restoration, as indicated by results from JimmyComeLately, Nisqually Slough and Port Susan Bay Preserve. At Deepwater Slough, waterfowl density was similar to reference marsh densities 3-4 years after restoration, indicating a quick response by this taxon even though the site became dominated by reed canary grass after tidal reconnection. Shorebird response was more variable. Of the two projects that analyzed before/after effects, one found a decrease in shorebirds (JimmyComeLately) and one found an increase in shorebirds (Port Susan Bay Preserve) post-restoration. It should be noted that Port Susan Bay is one of four sites in North Puget Sound that account for 52-93% of all non-breeding shorebird numbers in Puget Sound, whereas Sequim Bay, which includes JimmyComeLately, supports relatively few shorebirds (Evenson and Buchanan 1997). In general, we might expect stronger, positive effects of shorebirds from restoration projects in North Puget Sound. Likewise, at the Gog-Le-Hi-Ti wetland in the southern Puget Sound Puyallup estuary, Simenstad and Thom (1996) reported an increase in waterfowl abundance and a decrease in shorebirds after the first year of restoration. We caution strong interpretation of these results, however, because they were descriptive in nature. For example, JimmyComeLately conclusions were based on relatively small differences (10 individuals) between pre- and post-restoration surveys. In general, many of the reports we reviewed only provided descriptive statistics. None of the projects that reported abundance or density results included measurement error (SD, SE) to evaluate the strength of the signal detected.

Summary of study results: habitat trends

Habitat trends were also difficult to decipher due to the limited number of completed studies that looked at bird responses by habitat type and the variation in how that data was analyzed. Not accounting for changes in particular species, bird density by habitat type changed over time at the Gog-Le-Hi-Ti wetland, where the highest density of birds shifted from cattail marsh in the first year post-restoration to open water, intertidal and dike areas by the third year. Monitoring at Wiley and Deepwater sloughs indicate that shorebirds and waterfowl prefer large, draining channels to non-draining distributary channels.

A further confounding factor when interpreting results about habitat trends from this inventory stems from the fact that most monitoring projects ended before vegetation communities reached a climax condition or equilibrium. This is evidenced by the mitigation monitoring projects that documented dramatic but continuous changes from mud flat- or reed-canary grass/scrub shrub-dominated habitats to low and high marsh vegetation communities from the first to tenth year after restoration (ICF International 2016; Jones and Stoke 2003), and the similar lack of equilibrium observed through seven years of post-restoration monitoring at Gog-Le-Hi-Ti (Simenstad and Thom 1996). Excluding mitigation projects, the average post-restoration monitoring projects lasted 5 years. In order to evaluate restoration effects on birds adequately, projects will likely need to plan for studies with substantially longer time horizons (> 10 years).

Focal Taxa – method consideration and recommendation

All but one study in our inventory recorded all bird species that were observed on restoration sites, but data analysis focused on major taxa. In most cases, data analyses focused on shorebirds, waterfowl, or, more specifically, dabbling ducks. Four projects surveyed secretive marsh birds, although those projects have not completed data analysis. Considering the large-scale changes in habitat structure and composition expected with estuarine restoration, monitoring a wide range of taxa likely allows projects to better detect the shifts in abundance and habitat use after restoration sites. Indeed, Takekawa et al (2013) suggest that as time progresses post-restoration, different signals emerge from species that respond in different timeframes, such as the quick responses observed by waterbird generalists and the slower response of marsh specialists. Incorporating taxa diversity to monitor for estuary response will help detect a diversity of signals (Shriver and Greenberg 2012).

Given the wide-range of taxa monitored, it is not surprising that point counts and transect surveys were frequently used to monitor restoration projects. The advantage of these methods is that they are useful for sampling a wide array of species, including waterbirds and landbirds. Furthermore, these methods can be modified to allow for estimates of bird detectability; for example, distance sampling can be used with point counts or line transects. Bird detectability can vary for a number of reasons, in particular due to changing habitat structure and composition as would be expected to occur with estuary restoration (Thompson 2002). Without taking detectability into account, spatial or temporal comparisons of bird metrics are likely to be inappropriate. Area searches were also used regularly. Although this technique yields values for species richness, community composition, or relative abundance in a defined area, one cannot incorporate detectability, making comparisons of before and after restoration (or any type of management) difficult. Curiously, no projects adopted a study design that incorporated occupancy modeling (MacKenzie et al. 2006). This approach, which uses presence/absence data, would appear to offer promise for monitoring objectives related to investigating the effects of restoration. Further, it could be used with a wide array of survey methods.

Factors limiting understanding about effects of estuarine restoration on birds

Based on our review, we found two main factors that hindered the ability to understand the effects of restoration on birds at the project or landscape scale. These include monitoring objectives and funding. The objectives represented in our inventory review indicated most projects focused on tracking changes of birds over time since restoration, with a smaller fraction looking at before/after effects, or establishing a baseline for which to compare abundance, richness or other metrics following implementation of restoration actions. Eleven projects in this inventory included either baseline monitoring, reference sites, or both, but only two projects had complete before/after comparison monitoring projects. Reference sites were commonly used, but only the Qwuloolt and Smith Island projects tested for significant differences in bird community composition between restoration and reference sites. Wishnek (2014) recommends multiple reference sites to avoid problems with pseudoreplication. The lack of uniformity in bird monitoring objectives inhibits cross-site comparisons and provides minimal information to understand avian response to restoration. Standard objectives for Puget Sound monitoring could, for example, promote inclusion of pre-restoration monitoring or, at minimum, reference sites for comparison. Increased communication between restoration practitioners and scientists early in the planning phase of restoration projects could help anticipate the need for

monitoring and allow the development of rigorous approaches to answering questions about the effects of estuarine restoration on birds.

Out of ten projects that provided funding information, six responded that funding covered minimum to moderate monitoring goals, while only four reported their goals were fully funded. Funding coverage did not seem to impact project duration as much as project elements such as monitoring frequency or reference sites. Fully-funded projects spanned 2-7 years, with one ongoing project currently in the 5th year of monitoring. One respondent, qualified that while their seven-year project could be considered fully-funded, its scope was minimal (qualitative analysis with no reference sites or pre-restoration monitoring). Post-restoration monitoring at the 326-acre Smith Island site was cancelled due to lack of funds, and while the JimmyComeLately project recorded bird data for 16 years, project managers noted that the scope of monitoring was extremely limited due to lack of funding (Shreffler 2012). Projects often relied on volunteers to conduct bird monitoring to offset costs and in at least one case, made monitoring projects possible.

MOVING TOWARDS A REGIONAL MONITORING PROGRAM

A future goal of this inventory project is to develop a standardized avian monitoring approach for the Pacific coastal region north of San Francisco Bay. To inform future discussions of how this might take shape, we reviewed large-scale bird monitoring efforts from other estuarine regions around the U.S. that use standardized protocols to inform bird population assessments on regional scales. These avian-focused collaborations are driven by a variety of objectives, including endangered species monitoring, oil spill impact mitigation, and forecasted habitat loss due to sea level rise.

Examples of how we might best pursue a coordinated approach exist in other parts of the United States. Restoration practitioners in the Gulf of Maine addressed the need for a consistent, standardized saltmarsh restoration monitoring program to strengthen adaptive management of individual projects and provide performance standards for the widespread restoration occurring in the region (Neckles et al. 2002). Regional restoration partners developed a salt marsh monitoring protocol based on 16 monitoring variables, including bird sampling metrics, methods and frequency. As a result, Konisky et al. (2006) were able to conduct a regional analysis of restoration monitoring data to detect regional trends related to management practices and ecosystem response indicators. However, this study did note that inconsistent adherence to the monitoring protocol caused difficulties in analyzing response indicators beyond specific sites (Konisky et al. 2006). This revelation prompted a call to reinforce the need for

broader adoption of a standardized protocol, and the authors noted a heightened interest and cooperation from regional practitioners following a discussion of the study's preliminary results.

Other comprehensive monitoring programs are underway in San Francisco and the Gulf of Mexico. The US Fish and Wildlife Service (USFWS) and Point Blue (formerly PRBO) have finalized a site-specific marsh bird monitoring protocol to understand aquatic bird population trends on wildlife refuges in San Francisco Bay, targeting the federally listed California Ridgeway's rail (*Rallus obsoletus*) and state listed California black rail (*Laterallus jamaicensis coturniculus*) (Wood et al. 2017). The Gulf of Mexico Avian Monitoring Network (GoMAMN) was formed after a lack of data at appropriate scales constrained efforts to assess pre-spill baseline bird population and habitat conditions after the Deepwater Horizon oil spill in 2010. This network of over 35 agencies focuses on creating a coordinated monitoring effort across the Gulf and establishing a set of high-level objectives to guide future avian monitoring (GoMAMN 2017).

Guideposts for a Puget Sound approach

We believe a regional approach would similarly improve Puget Sound monitoring efforts and regional understanding of bird populations, particularly in response to large-scale restoration projects. A first step in developing a program for Puget Sound is establishing avian conservation benchmarks and monitoring objectives. Several guiding documents can inform how those objectives take shape. The Pacific Coast Joint Venture for North Puget Sound Lowlands advises that conservation efforts should focus on habitats associated with target shorebird and waterbird species (Petrie 2013). Further, the diversity of habitat requirements, including foraging, nesting and roosting habitats, by individual species should be taken into consideration when setting conservation strategies (Petrie 2013). Puget Sound estuarine environments have high regional value for shorebird conservation planning. While the North Pacific Coast Regional Shorebird Management Plan (Drut and Buchanan 2000) recognizes the regional-scale importance of at least three sites in Puget Sound (including Port Susan Bay, one of the large-scale restoration sites in this report) and the Hemispheric importance of the Fraser River estuary in the greater Salish Sea—they emphasize that dozens of smaller estuaries (some less than one km^2) contribute to what should *collectively* be considered an area of international significance. Post-restoration monitoring programs that track habitat associations also would help inform broader efforts to understand the diverse habitat needs of shorebirds, waterfowl and other waterbirds, and more

importantly how to predict how habitat use and availability might change over time in response to sea level rise.

Conservation objectives

Despite the identified need for estuarine conservation efforts for shorebirds and waterfowl, large-scale estuary restoration goals and objectives in Puget Sound have primarily focused on improving populations of listed salmon; specific conservation objectives for birds are largely absent. In fact, in our inventory only the JimmyComeLately project established specific waterbird conservation objectives. And even so, with such limited funding for monitoring, the project had insufficient data to assess whether this objective was met (Shreffler 2012). Setting conservation objectives that address habitat limitations for migratory shorebird and waterfowl in the restoration phase will help guide bird monitoring and inform progress towards habitat and population targets (Petrie 2013), allowing for adaptive management should those objectives fall short. If habitat conditions are not meeting needs of birds, or results fall outside expectations, the monitoring program provides an opportunity to evaluate the restoration and make alterations if necessary.

In other areas along the Pacific Flyway, conservation objectives for shorebird habitat guided estuary restoration and monitoring (National Audubon Society 2017). The Ni-les'tun wetland in the Bandon Marsh National Wildlife Refuge, an important migratory stopover for shorebirds along the Pacific Flyway, was considered undersized for the density of migratory shorebirds utilizing the area, and so the 400-acre restoration project was spurred by the need to expand tidal habitat by lowering dikes and creating tide channels (Bridgeland 2014). A primary goal of the monitoring program was "to document the accomplishment of bird conservation goals of the restoration project" (Wishnek 2014).

Moving forward, it is important to consider impacts of sea level rise (SLR) to the diverse habitat needs of priority species in Puget Sound. A USGS SLR model for tidal marshes in Oregon and Washington predicted that under a mid-SLR scenario (a gain of 63 cm per 100 years), most tidal marsh habitat would convert from high marsh to low marsh vegetation zones by 2100, despite modeled resilience to SLR up to 2050 - 2090. Other sites may experience sediment accretion and expand high marsh vegetation zone (Thorne et al. 2015). In the case of Port Susan, Bandon, and Skokomish, the model predicts a transition to mudflat habitat by 2100 under mid-SLR conditions. Monitoring migratory bird use of estuarine habitats will be an important part of understanding habitat changes over time and the poorly understood projected effects of SLR on avian communities (Thorne et al. 2015).

CONSIDERATIONS FOR DEVELOPING A REGIONAL MONITORING PROGRAM

Based on our inventory, we highlight several topics that need to be considered as part of future efforts to develop a regional monitoring program for Puget Sound. These points include data access and storage; tide influences on site accessibility after dike breach; and seasonality, survey frequency, and duration of monitoring. We also provide discussion and preliminary recommendations about which bird taxa should be the focus of monitoring based on our knowledge of the issues driving bird conservation in the Puget Sound regions.

1. **Data access**. Access to data from Puget Sound bird monitoring efforts can be improved by contributing monitoring data to shared databases, such as the Avian Knowledge Network (AKN), which operates a regional sub-database for the northwest region of the US. The JimmyComeLately project noted that a shared database containing maps, protocols and survey data accessible to the restoration project team was essential to the monitoring project, and recommended this practice for other practitioners (Shreffler 2012). This project also noted that their database would become available to the public. Managers for the Bandon Marsh restoration project also noted their desire to add bird monitoring data to the AKN (Bill Bridgeland, Refuge Manager, personal communication), and integrated databases have been used in San Francisco Bay for region-wide monitoring (Julian Wood, PRBO, personal communication).

2. **Site accessibility**. Future monitoring projects may need to address problems associated with changes in site accessibility after tidal reconnection when designing survey methods. Virzi et al (2017) and ICE International (2016) reported that transects and point count stations can be difficult or impossible to access at high tide on restoration sites after inundation, or on reference marshes. At Bandon Marsh, survey timing was altered from pre-restoration methods after breaching the dike made surveys possible only at low tide (Bridgeland 2014). The Nisqually project adapted to access issues on the restored area by conducting surveys only at tides high enough to operate a boat (Isa Woo, USGS biologist, personal communication). Unfortunately, variation in habitat use by birds in estuaries is largely driven by tidal height because most waterbirds, especially shorebirds and waterfowl, follow tidelines when foraging (Slater 2004). Consequently, limiting bird monitoring to a narrow tide window, such as low tide, may lead to

incomplete characterization of habitat use. Researches may need to modify research questions about the effects of estuarine restoration if access is limited to specific tide heights.

3. **Monitoring duration.** Monitoring projects should be of sufficient duration to detect changes in bird communities as they respond to the dynamic habitat changes expected at restoration sites. Restoration sites on formerly diked agricultural or reed-canary grass-dominated fields undergo extensive habitat alterations post tidal reconnection as they develop into a tidal marsh and associated network of tidal channels. Projects in this inventory alluded to the limited ability of short-term projects to detect such changes, noting that even 10 years post-restoration may not be sufficient time to document the effects of such habitat changes (Simenstad and Thom 1996; Konisky et al. 2006). Further, projects should incorporate baseline monitoring prior to restoration, or at minimum monitor reference sites, to adequately categorize the effects of restoration on bird communities.

4. **Timing and frequency of surveys.** Monitoring frequency and seasonality of surveys should be designed to 1) effectively capture trends in bird abundance and 2) build on existing Puget Sound monitoring data. In this inventory, all projects conducted spring surveys, suggesting that future project should consider spring surveys to build upon this foundation. However, it is also important to recognize that community composition can vary dramatically by season, and monitoring in only one season may not capture the full variation in species use or distribution. From a sampling methodology perspective, sampling is more problematic in the spring and fall because populations are open, with ingress and egress from the sampling areas. For most bird sampling techniques, a primary assumption is that the sample population is closed, which for birds in Puget Sound is likely limited to breeding and wintering seasons. Projects also noted that survey frequency should exceed two times per monitoring season. Monitoring at Smith Island/Union Slough revealed that increasing survey days from 2 to 4 per season yielded a 30% increase in number of species detected (ICF International 2016).

Results from this inventory, which outlines our current knowledge about the effects of restoration on birds in Puget Sound, and information on the bird-related issues surrounding estuarine restoration, leads us to some preliminary recommendations on focal taxa to monitor at estuarine restoration sites. Considering we lack a clear understanding of the spectrum of benefits, or costs, of salmon-focused restoration on bird conservation objectives, there is support for a comprehensive approach. At a

minimum, this would include waterfowl, shorebirds, and passerines, which were the most surveyed taxa at projects included in the inventory. One justification for this recommendation is that variability in species distribution and temporal response to restoration by taxa and guilds are likely highly variable across Puget Sound. For example, shorebird abundance in Puget Sound is highly concentrated in estuaries of North Puget Sound. Another justification for a comprehensive approach is that estuarine restoration will likely lead to clear winners (e.g., waterbirds) and losers (e.g., landbirds) following conversion of upland habitats to wetland habitats. Understanding the quantitative response in bird numbers will be needed to place estuarine restoration among large scale bird conservation goals. Fortunately, we believe a comprehensive approach is feasible because most of the survey methods used to monitor birds in the estuarine environment can be used across taxa, and therefore comprehensive monitoring does not have to translate to increased costs.

A comprehensive approach would also go a long way in addressing controversy among various bird stakeholder and user groups associated with estuarine restoration, thereby improving community support. In some regions of Puget Sound, proposed and ongoing restoration projects have been met with trepidation, primarily from duck hunters and birdwatchers, due to concerns about how tidal reclamation will impact high use areas for waterfowl, and passerines and raptors. Without comprehensive data to document how such projects impact taxonomic groups of public concern, addressing these stakeholder concerns can take significantly more hours of negotiation and outreach. For example, several proposed restoration efforts in the Skagit-Stillaguamish Delta have resulted in 100's of hours of agency staff and stakeholder time devoted to trying to reach agreement on whether bay front sites should be restored to estuary condition (R. Milner, WDFW, personal communication). Hunters and birdwatchers have expressed frustration that their interests have been ignored in these negotiations, as avian responses to estuary restoration projects remain largely unknown. Comprehensive monitoring will help dispel speculation and increase informed decision making surrounding estuarine restoration in Puget Sound. Ideally, it will ultimately result in community support and formal agreements such as that reached in the Skagit Delta Tidegates and Fish Initiative (Johnson *et al.* 2008), thereby reducing the costs of implementing new restoration projects.

Shorebirds, in particular, deserve attention as a focal taxon, and in the long-term may represent the best taxa to monitor for a variety of reasons. This inventory revealed that there is already a high prevalence of shorebird monitoring among the projects, providing a foundation from which to build from. A focus on shorebirds is also recommended in light of the recognized decline in many shorebird species and the

threats of habitat loss due to sea level rise and coastal squeeze along the Pacific Flyway. Recent support by the Pacific Flyway Council may help maintain monitoring efforts such as the Pacific Flyway Shorebird Survey organized by Point Blue, ensuring that flyway-wide monitoring continues for this unique group of birds.

Shorebird monitoring would also help examine the regional value that Puget Sound estuarine habitat has for supporting conservation planning and targets for several shorebird species across the Pacific Flyway. Many sites in the Puget Sound and the Salish Sea are nationally recognized as site of importance by WHSRN. During the development of this inventory report, the Pacific Americas Shorebird Conservation Strategy was released by USFWS and National Audubon (Senner et al 2016). This Conservation Strategy, along with the 2013 Pacific Flyway Shorebird Business Plan highlighted the need for shorebird monitoring to provide marketing opportunities to mobilize funding and emphasized the indicator value of Western Sandpipers due to their ubiquity and population targets. Finally, as more information is gathered at the regional or flyway-wide scale, there may be to opportunities to further streamline monitoring to one (or a few) species (and seasons) that coincide with flyway priorities for monitoring.

SUMMARY OF FINDINGS

Projects in this inventory did not illuminate the effect of restoration on birds on a regional scale. The common limiting factor involved across programs is a gap in our ability to understand bird population and habitat trends on a scale beyond the survey site, and the need to coordinate data collection to establish regional (even transcontinental) trends. Our study suggests that limited funding, wide variation in monitoring objectives and lack of bird conservation objectives are significant contributing factors in this shortcoming. Given the variety of objectives summarized in our Puget Sound inventory, we suggest that regional partners convene to establish a set of common avian monitoring objectives. Finally, we propose that avian monitoring of estuarine restoration efforts in Puget Sound build upon the existing foundation of monitoring efforts and ultimately seek to further streamline their focus to one (or a few) species (and seasons) that coincide with flyway priorities for monitoring.

CONCLUSION

The Pacific Northwest is an ecologically important region for migratory birds, especially shorebirds and waterfowl, and a high degree of uncertainty exists over how these taxa will respond to continued

habitat modifications, sea level rise, and even restoration projects on critical habitats like river deltas, saltmarshes and mudflats. Several large-scale restoration projects are slated for Puget Sound estuaries in the coming years. These include: Smith Island, Leque Island, Milltown Island, Three Crabs Restoration, Steamboat Slough, and Zis a ba, and account for approximately 600 restored acres. Leque and Zis a ba have proposed bird monitoring projects contingent on securing funding. Bird monitoring was cancelled at Smith Island due to lack of funding. It is unfortunate that during the current phase of large scale restoration in North Puget Sound, so many planned bird monitoring projects may be abandoned due to funding limitations or uncertainty.

This inventory and assessment is the first step in building a regional bird monitoring program that will help inform and advance the diverse habitat needs of migratory birds. While our study revealed key details regarding the state of bird monitoring in Puget Sound, an important next step is to stimulate dialogue with regional practitioners and researchers to work towards a monitoring framework that propels our understanding and conservation of migratory birds as vital signs and components of estuarine health.

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APPENDIX A TABLES

TABLE 2 SUMMARY OF MONITORING SITES AND METHODS IN PUGET SOUND. PROJECTS ARRANGED CLOCKWISE FROM NORTH PUGET SOUND

Reference	Estuary	Restoration type	Name of survey areas and size (acres)	Timing of survey	Methods
Slater 2004	Skagit	Levee/dike removal	Wiley Slough (157) Deepwater Slough (200)	Wintering and spring migration periods	1 low and 1 high tide road, dike and transect surveys during each survey window
Virzi, et al. 2017	Skagit Stillaguamish	Levee/dike removal	Fir Island Farms (131) Leque Island (294)	Spring, fall, winter migration periods	Line transects 250 x 125 m (ag) & >400 x 125 m (marsh). PCs 5 min listening w/4 min playback of secretive marsh birds. Area searches 250 x 250
Randi Shaw & Isa Woo, pers. Comm	Stillaguamish	Levee/dike removal	Port Susan Bay Preserve (150)	Fall, winter, spring	Monthly areas searches @ high, intermediate, and low tide
Molly Alves, Tulalip Tribe, Pers comm., Rice, et al. 2014	Snohomish	Levee/dike removal	Qwuloolt Estuary (354) Smith Island (326)	Breeding (May 5-June 30) & Non-Breeding (July 1-May 14)	Bimonthly low and high tides point counts
Houghton and Uhlig 2003	Snohomish	Levee/dike removal (mitigation)	Union Slough (24)	March, April, September	Qualitative observations recorded

Reference	Estuary	Restoration type	Name of survey areas and size (acres)	Timing of survey	Methods
Jones & Stokes 2003	Snohomish	Levee/dike removal (mitigation)	Marysville mitigation (14)	Fall and Spring	3 surveys each season, 1 hr point count (1 station) plus transects
Armbrust, et al. 2010; ICF International 2016	Snohomish	Levee/dike removal (mitigation)	Smith Island/Union Slough	Fall and Spring	30 min PCs before 10 AM @ 2 stations 2 days/seasons; plus transect surveys but not consistent from year to year due to accessibility
Simenstad & Thom 1996	Puyallup	Levee/dike removal	Gog-Le-Hi-Te Wetland (9.6)	April-September	Weekly to monthly counts
Takekawa, et al., 2013; Isa Woo, USGS, pers. Comm.	Nisqually	Levee/dike removal	Nisqually (762) Red Salmon Slough (140)	Spring, fall, winter. June excluded.	Weekly boardwalk counts under 3m receding tide, monthly, and bimonthly high tide area searches
Bethany Ackerman, Skokomish Tribe, pers comm	Skokomish	Levee/dike removal	Skokomish Estuary Island (256)	Year-round	High tide transect surveys, 1 hr/survey 2x/month
Shreffler (ed) 2012	Sequim	Levee/dike removal	JimmyComeLately (29)	Year-round	2-hr area searches at intermediate tide, irregular frequency

TABLE 3 MONITORING RESULTS FROM COMPLETED OR ONGOING BIRD MONITORING PROJECTS ON PUGET SOUND ESTUARY RESTORATION SITES. LIST DOES NOT INCLUDE QUALITATIVE MONITORING RESULTS FROM THE THREE MITIGATION PROJECTS OR THE BASELINE STUDY FROM WILEY SLOUGH

	Before/After comparison monitoring projects
Survey site and years monitored	Monitoring Results: Main finding and habitat results
Port Susan Bay Preserve Pre-restoration: 2012 Post-restoration: 2014-2015	**Main findings:** Results descriptive only. No tests for significance or measurement error. • 68 species recorded post-restoration (between 2014-2015) • Higher diversity on reference marsh, largely driven by flyover observations • More birds using restoration site for foraging and roosting (67% of observations) than on reference site (14%) Seasonal abundance of birds changed following restoration • In spring, dabbling ducks were more abundant post-restoration, but in winter dabbling ducks were more abundant during the pre-restoration period Community composition changed following restoration • Total abundance of passerines and freshwater-preferring dabbling ducks were higher in pre-restoration period • Total abundance of dabbling ducks, geese and shorebirds increased after restoration. **Bird response by habitat:** Project did not provide pre-restoration habitat use comparisons. Dominant post restoration bird communities by habitat were provided: • Tide marsh: swans and geese (winter), and passerines • Mud flat: shorebirds, namely dunlin and sandpipers, and diving ducks • Restoration area: dabbling ducks, snow geese, and Canada geese

JimmyComeLately Creek Estuary Pre-restoration: 1996-2004 Post-restoration: 2004-2011	**Main findings:** Results descriptive only. No tests for significance or measurement error. • Mean number of waterbird species recorded per survey (n=14) equal before and after restoration • Total bird abundance lower post-restoration, but species richness was similar • Dabbling duck abundance was higher post-restoration • Shorebird abundance lower post-restoration, driven by decrease in dunlin • Most abundant species: Dunlin (max count 3,900), western sandpiper (2,400), and widgeon (1,700) **Habitat results:** Project did not collect habitat use data, but did note birds using newly restored channel.

Post-restoration trend analysis projects

Survey site and years monitored	Monitoring Results: Main finding and habitat results
Deepwater Slough* Post Restoration: 2003-2004	**Main findings:** Duck density on restoration site similar to reference marsh, but more variable. **Habitat results:** Project did not provide pre-restoration habitat use comparisons. • Duck density similar between restoration and reference sites, despite high reed canary grass cover at post-restoration site • Waterfowl and shorebirds used large, well-drained channels at low tide but avoided non-draining distributary channels
Nisqually Refuge** Post-restoration: 2009-2015	**Main findings:** Results descriptive only. No tests for significance or measurement error for taxa abundance. • Over 160 species recorded • Dabbling ducks most common taxonomic group overall, and most abundant during winter • Post-restoration habitat used by large numbers of dunlin and western sandpiper. Shorebird abundance peaked in fall 2011 (n=1,514) and winter 2012 (933)

	• Increased food capacity can support up to 33,800 more western sandpipers **Habitat results:** Project did not provide pre-restoration habitat use comparisons. Dominant post-restoration communities by habitat: • Mudflat: shorebirds, gulls/terns, waders and non-waterfowl divers ("other") • Open water: waterfowl • Marsh plain minimally used by shorebirds or waterfowl, but used by "other" group
Gog-Le-Hi-Te Wetland Post-restoration: 1986-1993	**Main findings:** Results descriptive only. No tests for significance or measurement error. • 112 species recorded • Species evenness higher in Year 1 after restoration than later years. After Year 1, waterfowl most abundant (40-85% of total abundance), shorebird less abundant. • During period from 1986 to 1990, number of species on restored wetland increased. **Habitat results:** Bird density changed from 1st year of restoration: • In Year 1, bird density highest in cattail marsh, but little pattern in overall distribution. • By Year 3, highest density in open water, intertidal and dike habitats within restoration area.
	Preliminary results from ongoing monitoring projects
Survey site and years monitored	Monitoring Results: Main finding and habitat results
Qwuloolt and Smith Island*** Estuaries Pre-restoration: 2012-2013 Post-restoration: 2013-present	Used analysis of similarities (ANOSIM) to test for differences in bird species composition among three reference and two restoration sites *prior to* restoration. Species composition differed among reference and treatment sites: • Qwuloolt did not have clearly defined species compositions compared to other sites, but small, significant difference between Qwuloolt and undisturbed estuarine wetland. Dominant vegetation at Qwuloolt is reed canary grass. • Smith Island most distinct from a marsh sedge reference site.

Leque Island and Fir Island Farm Pre-restoration Leque: Winter 2016- Spring 2017 Fir Island Farm: winter-summer 2016 Post-restoration Fir Island Farm: Fall 2016-present	Survey results are preliminary, descriptive, and have not been adjusted for pre/post restoration or detectability. Only trends in abundance by season are presented. Abundance varied by season, but was similar on transect surveys at Leque and Fir Island Farm: • Winter: highest abundance of dunlin, American wigeon and mallard • Spring: highest diversity of species • Fall: lowest species diversity and abundance of most species

*Bird response to estuary restoration was not primary objective of this study
**Preliminary results provided from 2009-2012 surveys. Analysis of 2013-2015 survey data not yet complete. ***Smith Island estuary was only surveyed pre-restoration.

APPENDIX B PROJECT SUMMARIES

Nisqually Refuge Restoration
Estuary: Nisqually River
Duration of Restoration: 2009-2010
Duration of monitoring: 1975-2008 (historic data from aerial surveys), Sept. 2009 single pre-survey "snapshot", 2009 - 2015 (post-restoration surveys)
Acres restored: 762

Project summary
Monitoring objectives: 1. Determine the numerical response of waterbirds to tidal marsh restoration at the Nisqually Delta. 2. Examine the potential for functional response of waterbirds to changing prey abundance.

Results: Waterbirds used newly open tide flats, and respond to increases in food production. Example finding, increased food production could support over 30,000 additional western sandpipers per season. Development of marsh plain from open tideflat to vegetated marsh is expected to alter waterbird use over time. Some observed species may decrease, but site may favor species associated with tide marsh vegetation. Waterbird abundance higher post-restoration compared to historic counts.

Recommendations: Waterbirds good early restoration indicators, marsh specialists good longer term restoration indicators as habitat changes over time (Takekawa, 2013). Important to take time to analyze data, look at trends when doing long-term monitoring. Results can be confounded by external forces or geographic context-interpreting results can be challenging so important to consider extenuating factors. Extent of monitoring should be determined by objectives. It's not cost effective to look at all variables in question every year, so you could tier your approach. Ex. Look at habitat associations during subset of monitoring period.

Red Salmon Slough Ph II
Estuary: Nisqually River
Duration of Restoration: 2006
Duration of monitoring: 2009-2015
Acres restored: 140

This site was monitored as part of the Nisqually bird monitoring, thus all protocols and results are as reported for Nisqually.

Gog-Le-Hi-Te Estuary Restoration

Estuary: Puyallup
Duration of Restoration: 1985-1987
Duration of monitoring: 1986-1993
Acres restored: 9.6

Project summary
This was a mitigation project by Port of Tacoma

Monitoring objective: To determine whether, and which, wetland attributes would follow linear, asymptotic, logistic, or other development patterns to predict functional equivalency and contribute extensively to the future predictive power of wetland restoration.

Results: Birds responded immediately to restoration. Intertidal, open water and dike were most common habitats for birds by 1990, compared to cattails, aerial and upland habitats. Waterfowl were most abundant taxonomic group after first year of restoration except in summer, and shorebirds represented less than 10% of all species until August, when abundances reached waterfowl numbers. Authors found that trajectory of restoration site compared to reference site were highly variable; some variables approached reference site conditions, indicating a restored site, while others indicated the restored area was still in very early stages of development.

Recommendations: Authors recommend longer monitoring periods (beyond 10 years), and to consider functional measures in restoration monitoring, such as trophic linkages, to get a better understanding of the dynamic nature of the progression of a restored wetland.

JimmyComeLately Ecosystem Restoration
Estuary: Sequim
Duration of Restoration: 2002-2005
Duration of monitoring: 1996-2011
Acres restored: 29

Project summary
Monitoring Objective: To compare bird usage prior to restoration to post-restoration abundance and richness.

Results: Shorebirds decreased after restoration driven by decrease in dunlin; Western sandpiper abundance increased. Waterfowl abundance decreased overall after restoration, but dabbling ducks increased. Overall average species richness unchanged after restoration.

Recommendations: A centralized, openly accessible database essential to project. Funding limiting factor for project reach and success, but project pooled from multiple funding sources to achieve moderate monitoring goals. Relied on volunteer biologist for bird monitoring.

Deepwater Slough
Estuary: Skagit River
Duration of Restoration: 1999-2000
Duration of monitoring: 2003-2004
Acres restored: 200

Project summary
Monitoring objectives: Compare waterbird abundance between restored and natural marsh sites as a preliminary assessment of the success of the restoration with regards to waterbirds

Results: Successfully created waterfowl habitat, used extensively by ducks. Duck density was similar to natural marsh sites, although it was more variable, which is likely due to small sample size. Channel density positively correlated to duck density.

Recommendations: Conservation efforts should include entire integrated set of wetland habitats, such as freshwater non-tidal wetlands, which were heavily used by ducks and shorebirds as roosts and foraging grounds during high tides and flood events. Agricultural lands play an important role for waterfowl and shorebirds, and restored coastal estuaries may not be vast enough on their own to support these groups. Conservation plans should thus account for Ag lands as support habitat for waterfowl and shorebirds.
Project also recommends that bird monitoring examine the effects of restoration on abundance and habitat use by waterbirds.

Wiley Slough Dike Removal
Estuary: Skagit River
Duration of Restoration: 2008-2010
Duration of monitoring: 2003-2004
Acres restored: 157

Project summary
This is a descriptive project to provide baseline information that could be used to assess effect of future restoration on waterbird abundance.

Monitoring objectives: 1. Quantify the abundance of waterbirds with respect to habitat and tide; 2. Examine the relationship between habitat characteristics and waterbird use.

Results: Ducks selected flooded habitat on ag fields disproportionate to availability. Ducks responded to tide on estuarine habitat but not on agricultural fields. Duck density higher on emergent marsh than ag fields. Marsh areas denuded by geese had higher abundance of shorebirds than vegetated areas. Shorebirds and waterfowl preferred large channels that drained over non-draining distributary channels. Shorebird use of ag fields low, but may use as roosting during high tide/flood events.

Fir Island Farm Estuary Restoration

Estuary: Skagit River
Duration of Restoration: 2015-2016
Duration of monitoring: 2016-present
Acres restored: 131

Project summary
Monitoring objectives: 1. Quantify the numerical response in species abundance of migrating (spring and fall) and wintering shorebirds and waterfowl, including snow geese, with restoration. 2. Quantify the numerical response in species abundance of breeding and wintering land birds (passerines and raptors) and secretive marsh birds with restoration. 3. Investigate changes in shorebird abundance and distribution across the Skagit/Stillaguamish estuary.

Project ongoing. No results to report.

Leque Island

Estuary: Stillaguamish River
Duration of Restoration: 2017 (anticipated)
Duration of monitoring: 2016-present (ongoing)
Acres restored: 294

Project summary
Only pre-restoration monitoring has occurred thus far.

Monitoring objectives (same as Fir Island Farm): 1) Quantify the numerical response in species abundance of migrating (spring and fall) and wintering shorebirds and waterfowl, including snow geese, with restoration. 2) Quantify the numerical response in species abundance of breeding and wintering land birds (passerines and raptors) and secretive marsh birds with restoration. 3) Investigate changes in shorebird abundance and distribution across the Skagit/Stillaguamish estuary.

Project ongoing. No results to report.

Recommendations: Access to transects difficult at high tide, may need to consider alternative survey methods to account for access

Skokomish Estuary Island Restoration

Estuary: Skokomish River
Duration of Restoration: 2007 - 2017, Multi-phase - Dike removal began in 2007.
Duration of monitoring: 2010-2017
Acres restored: 256

Project summary
Monitoring objectives: Monitor richness, abundance, and diversity over time

Monitoring project just completed (as of April 2017). No results or recommendations to report.

Qwuloolt

Estuary: Snohomish River
Duration of Restoration: 2008-2015 (Breach in 2015)
Duration of monitoring: 2012-present
Acres restored: 354

Project summary
Monitoring objectives: Establish a baseline by which to measure the effect of restoration on birds by assessing the composition of avian assemblages at two restoration sites (Qwuloolt Estuary and Smith Island) and reference stands before tidal inundation.

Project is now conducting post-restoration monitoring. No results or recommendations to report.

Smith Island

Estuary: Snohomish River
Duration of Restoration: 2015-present (ongoing)
Duration of monitoring: 2012-2013
Acres restored: 326

Project summary
Monitoring objectives: Establish a baseline by which to measure the effect of restoration on birds by assessing the composition of avian assemblages at two restoration sites (Qwuloolt Estuary and Smith Island) and reference stands before tidal inundation.

Monitoring ended in 2013 due to limited funding. Post-restoration monitoring will not occur at this site.

Port of Everett Union Slough Restoration

Estuary: Snohomish River
Duration of Restoration: 2000-2001
Duration of monitoring: 2001-2010
Acres restored: 24

Project summary
Compensatory mitigation project with 10-year monitoring plan.

Monitoring objectives: No specific objectives listed relating to bird monitoring. Overall objective "provide estuarine habitat and ecological functions to replace those lost to unavoidable impacts" of filling littoral marine habitat.

Qualitative bird monitoring most years. Monitoring report mentioned that a quantitative bird survey should have taken place in 2003, but unable to locate those results. Report for qualitative survey says birds used restoration area immediately after dike breach.

Marysville Mitigation
Estuary: Snohomish River
Duration of Restoration: 1993-1994
Duration of monitoring: 1994-2003 (7 total years of monitoring within that span)
Restoration Area (acres): 14

Project summary
Compensatory mitigation project with 10-year monitoring plan.

Monitoring objectives: To determine the development of wildlife habitat values at the site; to qualitatively compare wildlife use at treatment and reference sites to see how use has changed at the mitigation site since project implementation.

Results: Compared average number of birds encountered per hour year to year between restoration and reference site. No statistical analysis, but noted that benchmarks set for wildlife numbers achieved for restoration site.

City of Everett Smith Island/Union Slough
Estuary: Snohomish River
Duration of Restoration: 2003-2007
Duration of monitoring: 2007-2017 (Years 1-3, 5, 8 & 10 after restoration)
Acres restored: 93

Project summary
Compensatory mitigation project with 10-year monitoring plan.

Monitoring objectives: To document changes in species composition and use of the site over time, as a result of the ecological changes anticipated by the dike breaching.

Results: Mitigation site supports a wide variety of birds, including ducks, shorebirds, wading birds, raptors, woodpeckers, and songbirds. The differences in species observed from year to year are more a factor of the number of survey days than a quantification of presence and absence each year. Bird species observed increased 30% when survey days increased from 2 to 4 per season. Project concluded that the diversity of birds observed overall years indicates that this site provides excellent habitat for a variety of breeding, wintering, and migratory birds.

Recommendations: Two surveys days per season doesn't adequately capture shorebird migration numbers, more frequent monitoring recommended. Dike breaches were not low enough to fully drain site, recs to improve drainage by creating new and lengthening existing channels on site.

Port Susan Bay Preserve

Estuary: Stillaguamish River
Duration of Restoration: 2012
Duration of monitoring: 2004-2005 (ESI protocol) 2012, 2014-2015
Acres restored: 150

Project summary

Monitoring objectives: Pre and post-restoration monitoring of abundance and species, following protocol that allowed comparison to pre-restoration survey in 2012 and historical surveys

Results: Change in bird community composition post-restoration (changed from passerine and fresh water dabbling ducks to dabbling ducks, shorebirds and geese)

Recommendations: Consider restoration in larger geographic context. If it's a small project, but providing habitat connectivity, especially within Pacific flyway, may still serve important ecological role.