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1 **Using citizen-science data to identify local hotspots of species occurrence**

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42 **Abstract**

43 Seabirds have been identified and used as indicators of ecosystem processes such as
44 climate change, and anthropogenic activity in nearshore ecosystems around the globe. Temporal
45 and spatial trends have been documented at large spatial scales, but few studies have examined
46 fine scale spatial patterns, by species or functional group. In this paper, we apply spatial
47 occupancy models to assess the spatial patchiness and interannual trends of 18 seabird species in
48 the Puget Sound region (Washington state, USA). Our dataset, the Puget Sound Seabird Survey,
49 is unique in that represents a seven year study, collected in winter months (October – April), and
50 is collected at an extremely fine spatial scale (62 sites in the current analysis). Despite historic
51 declines of seabirds in the region over the last 50 years, results from our study are optimistic,
52 suggesting increases in probabilities of occurrence for 14 of the 18 species included. We found
53 support for declines in occurrence for white-winged scoters, brants, and 2 species of grebes. The
54 declines of Western grebes in particular are troubling, but in agreement with other recent studies
55 that have shown support for a range shift south in recent years, to the California Current.

56

57 **Introduction**

58 Ecologists and conservation practitioners have long focused on describing species
59 distribution and estimating changes in abundance (Holmes 2001) or occurrence through time
60 (MacKenzie et al. 2006). Identifying hotspots of a species' distribution has multiple implications
61 for science and management. From a conservation perspective, incorporating spatial variation in
62 models may assist in selecting areas to protect or where species are likely to persist (Cabeza &
63 Moilanen 2001; Naujokaitis-Lewis et al. 2009). From a theoretical ecology perspective, null or
64 neutral models of species' occurrence may be useful in predicting species diversity or
65 community assembly (Gotelli 2000; Gotelli & McGill 2006). Finally, the inclusion of spatial
66 variation may help in forecasting how species may respond to future environmental conditions,
67 such as climate change (Jetz et al. 2007).

68 Trends in occurrence through time may be spatially structured as well. Habitat
69 conditions, behavior, or prey availability all contribute to spatial structure (Ward et al. 2010).
70 Anthropogenic drivers of change in species distribution may also exhibit spatial variability (e.g.
71 wildfires, oil spills, climate change, urbanization). Ignoring underlying spatial variation when it
72 exists may lead to poor estimation of trends through time (Hoeting et al. 2008).

73 Models that incorporate both spatial and temporal variation represent a rapidly evolving
74 field in ecology (Hooten & Wikle 2008; Latimer et al. 2006; Shelton et al. 2014). While many of
75 these methods have been in the statistical literature for decades (Banerjee et al. 2005; Cressie &
76 Wikle 2011), ecological data often present a unique set of challenges relative to data from other
77 fields, and the computational advances necessary to run these models have only occurred very
78 recently. Compared to other disciplines, ecological data on species abundance is often corrupted
79 by observation error, representing uncertainty arising from taking measurements or sampling a

80 fraction of the population (Holmes 2001). Similarly, in conducting studies of species presence-
81 absence, detections may be missed, resulting in false-negatives (MacKenzie et al. 2006).

82 Declining budgets for monitoring programs in recent years have increased the need for
83 cost efficient survey techniques. In the face of recent reductions, one potentially underutilized
84 resource is citizen-science. Participation in these volunteer based programs appears to have
85 increased in recent years (Silvertown 2009), and some of the longest running citizen-science
86 programs in North America are related to bird-watching. Large-scale volunteer programs like the
87 Audubon Christmas Bird Count and the North American Breeding Bird Survey (BBS) have been
88 effective at collecting vast amounts of survey data on commonly occurring bird species (Sauer et
89 al. 2014). The strength of these programs is their duration, large spatial extent, and consistent
90 methodologies over time, enabling them to be useful in monitoring species assemblages and
91 distribution shifts in response to changing climate (Hitch & Leberg 2007). Regional-scale
92 citizen-science programs, such as the Coastal Observation and Seabird Survey Team (COASST;
93 Hamel et al. 2009; Litle et al. 2007; Parrish et al. 2007), or the British Columbia Coastal
94 Waterbird Survey (Crewe et al. 2012) have also been developed to address conservation
95 questions and establish baseline monitoring. A collective limitation of some of these surveys is
96 that few have any consistent measures of survey effort.

97 Citizen science may be a useful tool for conducting baseline environmental monitoring,
98 or helping to inform management actions or restoration activities (Cooper et al. 2007). One of
99 the areas in in the USA that has been prioritized for restoration actions is in the Puget Sound
100 (Washington state), where one of the largest ecosystem restoration programs in the nation is
101 underway (Puget Sound Partnership 2014). The Puget Sound ecosystem is part of the Salish Sea
102 (which also includes the Strait of Juan de Fuca and the Strait of Georgia), and it has been

103 affected by widespread environmental degradation largely associated with increased urbanization
104 (effects summarized in Puget Sound Partnership 2009; Ruckelshaus & McClure 2007). The
105 Puget Sound consists of over 4,000 km of coastline with a suite of high-value ecosystem
106 services, including commercial fisheries and various recreation opportunities (e.g. Tallis &
107 Polasky 2009). A portfolio of ecosystem indicators have been developed and implemented in
108 restoration goals for the Puget Sound region to monitor ecological condition, including seabirds
109 (Kershner et al. 2011; Puget Sound Partnership 2013).

110 To date, the largest seabird-monitoring effort in Puget Sound has been an annual winter
111 aerial survey conducted by the Washington Department of Fish and Wildlife (WDFW)
112 (Anderson et al. 2009). These annual transects occur in 13-18% of the nearshore (<20m depth)
113 and 3-6% of the offshore (>20m depth) marine waters seabird habitat in Puget Sound, ranging
114 from southern Puget Sound to the Canadian border. Results from the WDFW aerial seabird
115 surveys suggested that the density of some species, including Western Grebes (*Aechmophorus*
116 *occidentalis*), have declined over the last two decades (Bower 2009; Evenson 2010; Vilchis et al.
117 2014). However, the cause(s) of these declines and the effects of environmental drivers on
118 seabird density remain largely unknown.

119 To complement the WDFW seabird survey both spatially and temporally, and to establish
120 baseline monitoring of local seabird species occurrence and abundance in winter months
121 (October - April), Seattle Audubon initiated the shore-based Puget Sound Seabird Survey (PSSS)
122 in 2007. This program is unique in Puget Sound, in that it is the only one that monitors seabirds
123 repeatedly throughout the winter months in nearshore habitat. This survey also represents one of
124 the more scientifically rigorous citizen-science efforts, because survey effort is quantified and
125 volunteers are trained annually (and the subject of ongoing validation studies to quantify biases).

126 Recent research has demonstrated that rigorous statistical models can be applied to
127 volunteer based surveys, yielding a relatively large impact, particularly when agency or
128 industry-led data collection efforts are limited (Thorson et al. 2014a). The primary
129 objective of our analysis was to apply spatiotemporal models to data from the Puget Sound
130 seabird surveys to evaluate relative hotspots of occurrence. Using output from these
131 models, a second objective was to evaluate species-specific trends in occurrence over time.
132 These estimates may be useful to refine the list of indicator species to include spatial as
133 well as temporal components.

135 **Methods**

136 *Data Collection*

137 Beginning in October 2007, pairs of volunteer birdwatchers were trained by Seattle
138 Audubon staff to collect data on birds in the nearshore environment of Puget Sound. Though the
139 species encountered includes waterfowl, we collectively refer to all species as 'seabirds'. Each
140 observer team was responsible for monthly surveys (October – April) at selected sites. Many of
141 the seabird species in the region overwinter in Puget Sound, and are of highest abundance from
142 late fall – early spring. The PSSS survey sites were selected non-randomly due to dependence on
143 public access (parks, beach access), but they were selected to be spaced at least 1.6 km apart.
144 Observer teams recorded all species present out to 300m for a minimum of 15 minutes, but some
145 site visits lasted up to 60 minutes. To minimize the variability of weather conditions, tidal stage,
146 and the risk of double counting birds at multiple survey sites, volunteer teams completed their
147 monthly surveys on the same date within a specific four-hour window (two hours on either side
148 of high tide) on the first Saturday of each month. In each subsequent year of surveys, we added

149 sites to cover parts of northern and southern Puget Sound. For this study, we limited our analysis
150 to 62 sites with at least 15 visits (Table 1).

151 *Species Selection*

152 Over the first seven years of the PSSS (the most recent ending in spring 2014), observer
153 teams recorded 75 unique seabird species. While many of these species may be useful as
154 indicators of various ecosystem processes or anthropogenic impacts, we focused our analysis on
155 18 species that have previously been identified as useful seabird indicator species in the region
156 (Table 2; Pearson & Hamel 2013). These species can be aggregated into five distinct groups:
157 alcids, cormorants, grebes, loons, and waterfowl. Some of the species breed locally in Puget
158 Sound, while others are transient in the Sound, breeding elsewhere (Table 2). Similarly, the
159 species represent a range of diets and behaviors (Pearson & Hamel 2013), from piscivores
160 (alcids, loons and grebes) to omnivores (cormorants, waterfowl).

161 *Statistical Modeling*

162 For each species, we constructed matrices of presence-absence, dimensioned by the
163 number of unique month-year combinations ($t = 49$) and sites ($n = 62$). Sites that were not visited
164 during a given month were treated as NA values. We constructed a spatial occupancy model
165 separately for each species, to incorporate spatial patchiness, as well as annual and seasonal
166 variation. The model describing the probability of species presence can be represented as
167 $z_{i,j} \sim \text{Ber}(\phi_{i,j})$, where $z_{i,j}$ represents the unobserved presence-absence (1, 0), and $\text{logit}(\phi_i) =$
168 $BX_i + ET_i + \varepsilon$, where ϕ_i represents the site-specific occupancy probabilities at time i , X_i
169 represents a matrix of covariates (Intercept, Month, Month², Year, Year²), B represents a vector
170 of estimated coefficients (shared across sites and time periods), E represents a linear offset
171 coefficient for sampling effort (T_i), and ε represents a vector of spatially correlated random

172 effects. We included time spent (T_i in minutes, ranging from 15 – 60) as a measure of effort to
173 account for the higher chance of recording a species present during longer visits. The spatially
174 correlated random effects are assumed to have the distribution $\varepsilon \sim MVN(0, \Sigma)$. For simplicity,
175 we modeled the covariance matrix Σ as an exponential covariance function, $\Sigma_{i,j} = \sigma^2 \cdot I_{i,j} + \tau \cdot$
176 $\exp(-d_{i,j}/\gamma)$, where I represents an identity matrix, $d_{i,j}$ is the Euclidian distance between sites i
177 and j , and the scaling parameters (τ, γ) control how quickly covariance decays as a function of
178 distance (Banerjee et al. 2005; Ward et al. 2012). Our model could be modified to include more
179 complex covariance functions (Cressie & Wikle 2011) or spatial random effects that also vary
180 temporally (Shelton et al. 2014). Because our model also includes an observation error
181 component, however, we chose to make these spatial deviations temporally constant. The
182 observation model, linking latent unobserved states ($z_{i,j}$) to data ($y_{i,j}$) can be written as
183 $y_{i,j}|z_{i,j} \sim Ber(p \cdot z_{i,j})$ (Royle & Kery 2007), where p represents the probability of detection
184 when a species is present.

185 All Markov Chain Monte Carlo (MCMC) estimation was conducted in R and JAGS
186 (Plummer 2003; R Core Team 2014), using the R2jags package (Su & Yajima 2014). We ran
187 five parallel MCMC chains for each species, with a burn-in of 100,000 draws and additional
188 sampling of 50,000 MCMC draws. Trace plots were used to visually assess convergence, and the
189 Gelman-Rubin statistic (Gelman & Rubin 1992) was used to quantify successful convergence.
190 Not surprisingly, the only parameters that did not successfully converge (potential scale
191 reduction factor > 1.05) were several latent states (z) at sites that were not visited by observers in
192 certain months. For the purposes of visualizing predicted hotspots of occupancy in Puget Sound,
193 we used our model output to generate predictions (spatial maps, temporal trends) of species
194 occupancy for a standardized 15-minute survey. In addition to making these predictions for each

195 of the 18 species included in our analysis, we generated specific occupancy probabilities for the
196 five seabird groups: alcids, cormorants, loons, grebes, and waterfowl. For each group, the
197 probability of occupancy for a group (corresponding to any species from that group being
198 present) was calculated as $1 - \prod_{i=1}^{sp} (1 - \phi_i)$.

200 Results

201 Our species occupancy maps reveal some localized hotspots of occurrence in Puget
202 Sound for some alcid and cormorant species (rhinoceros auklet, pelagic cormorant, Brandt's
203 cormorant (Fig. 1) as well as loons and some waterfowl spp. like harlequin ducks (Fig. 2). The
204 individual species maps show that some species are ubiquitous in all nearshore habitat (horned
205 grebes, goldeneyes, scoters), while others have a much more patchy distribution of occurrence
206 (loons, rhinoceros auklets, pigeon guillemots). Some maps of very rare or very common species
207 may not be informative, but areas of high bird density become more apparent when our estimated
208 occupancy probabilities are calculated by group (Fig. 3). For example, each loon species in the
209 surveys is relatively rare (Fig. 2), but the aggregated spatial distribution of all loons shows
210 several patches of high and low occurrence, with the highest density of occurrence in the
211 central-south Puget Sound (Fig. 3).

212 The 18 species included in our analysis showed a range of seasonal variation, with
213 waterfowl species (bufflehead, common goldeneye, surf scoter) and grebes varying the most and
214 peaking in December – January (Fig. 4). Several species exhibited monotonic increases
215 throughout the winter (pelagic cormorant, pigeon guillemot), however most of the 18 species had
216 relatively small variation over the 7-month survey. Of the 18 seabird species, the probabilities of
217 trends in occurrence being positive over the 7-year survey were greater than 80% for 14 species

218 (Fig. 5). Western grebes, white-winged scoters, and brants showed relatively strong negative
219 trends in occurrence (probabilities of negative trends > 99%, 84%, 79%, respectively).

220 The 18 species in our analysis represent a gradient of both occurrence probabilities and
221 trends over space. Several species from each group were relatively rare in central and south
222 Puget Sound; the most rare species included two of the alcids (common murre, marbled
223 murrelet), western grebes, all three loon species, and three of the waterfowl species (brant,
224 harlequin duck, white-winged scoter; Fig. 5). In contrast, horned grebes and three different
225 waterfowl species (bufflehead, common goldeneye, surf scoter) were the most widely occurring
226 (Fig. 5).

227

228 **Discussion**

229 Analyses that incorporate both spatial and temporal variation are becoming increasingly
230 common in ecology. These types of analyses are widely applicable to virtually any type of
231 observed data, from presence-absence to continuous observation measurements (Johnson et al.
232 2013; Shelton et al. 2014). Incorporating spatially structured random effects introduces a layer of
233 statistical complexity, however in many cases, this complexity is warranted, because predicted
234 density estimates (both in space and time) are more precise (Thorson et al. 2014b).

235 Spatially-structured citizen-science datasets have been used at a large spatial scale,
236 particularly in quantifying shifts in phenology linked to climate. One of the most frequently
237 documented changes by citizen-science efforts have been shifts in breeding seasons (Hitch &
238 Leberg 2007; Hurlbert & Liang 2012; Mayer 2010). Spatially-structured statistical models have
239 been fit to these types of datasets to improve estimates of trends (Hurlbert & Liang 2012;
240 Thorson et al. 2014a), but few analyses have applied spatiotemporal models to data from citizen-

241 science efforts to identify hotspots or areas of conservation concern at a fine spatial scale.
242 Citizen-science programs, such as the Puget Sound Seabird Survey data analyzed here, offer a
243 unique opportunity, because both the temporal and spatial scales of data collection are much
244 finer than national (Breeding Bird Survey) or regional (WA Department of Fish and Wildlife)
245 efforts. If volunteer-driven science can result in relative indices of occurrence or abundance, it
246 provides an extremely cost effective approach for identifying local areas of risk (Hass et al.
247 2012) or potential hotspots of diversity that may be useful in conservation planning (e.g.,
248 establishing reserves) or permitting activities.

249 Utilizing citizen-science data – either by including it to complement existing datasets or
250 to fill in data gaps when other surveys are absent – is particularly important for areas or habitats
251 at risk. The PSSS may be a good model for adopting similar citizen science efforts, either in
252 other regions or for other species, as there are a number of risk factors to the food web that
253 initially motivated the development of the citizen-science effort behind the PSSS. In addition to
254 the historic decline of many seabird species (Bower 2009), there are a number of additional
255 human impacts that have caused shifts or reorganization in the prey base (Rice et al. 2012) or
256 competitors of seabirds (Harvey et al. 2012). These impacts could include effects of overfishing
257 (and associated impacts of derelict fishing gear; Good et al. 2009), climate change, toxins,
258 habitat loss (Raphael et al. 2014), altered freshwater flow regimes, and the recovery of many top
259 predators to historic levels (pinnipeds, harbor porpoise, bald eagles).

260 Although many seabird species in the Puget Sound region are thought to be depleted
261 relative to abundances in the 1960s-1970s (Bower 2009), our results present a more optimistic
262 picture for many seabird species in the region over the last decade. Of the 18 species included in
263 our analysis, we found strong support for 14 becoming more common, and these results are in

264 agreement with recent studies in the region (for example, nesting surveys suggest Rhinoceros
265 auklets are also increasing; Pearson et al. 2013). Many of the species that are occurring more
266 frequently are those that breed in the region (Table 2). In the list of indicator species compiled by
267 Pearson et al. (2013), some of these species (scoters, murrelets) were declining significantly
268 when considering trends based on total abundance, so it is possible that, for species in decline,
269 the spatial distribution increases at low densities (making them detected more frequently). Of
270 the species not declining, one species provided weak support for declining occurrence (white-
271 winged scoter), and three species provided strong support for continued declines in occurrence
272 (brant, western grebe, red-necked grebe). These three species in decline are also concerning
273 because they are already rarely seen species in the PSSS data (Fig. 5).

274 There is no obvious mechanism for why the three declining species in our analysis
275 exhibit a declining trend in occupancy, but some of these declines may be related to shifts in prey
276 abundance. Some recent evidence suggests that there have been changes in forage fish in the
277 region (Rice et al. 2012), and over-wintering seabird species that rely on forage-fish are
278 declining (Vilchis et al. 2014). Another mechanism that may also be related to shifts in the
279 spatial distribution of prey are large-scale shifts in seabird species' ranges. For example, Wilson
280 et al. (2013) used citizen-science data to show that western grebes appear to have shifted out of
281 the Puget Sound region to the southern California Current. Our estimated declines in occupancy
282 over the last seven years are largely in agreement with a continued decline in the occurrence of
283 western grebes in the region. Like western grebes, brants and white-winged scoters over-winter
284 in Puget Sound, but breed elsewhere, and thus may be affected by threats in other ecosystems.
285 Though the exact mechanisms responsible for these trends are not known, our trend estimates

286 may be useful in prioritizing monitoring efforts or refining existing marine bird or ecosystem
287 indicators in the region (Kershner et al. 2011; Pearson & Hamel 2013).

288 Though the focus of our volunteer-driven surveys in the Puget Sound region are focused
289 on identifying spatial hotspots and improving estimates of annual trends, citizen-science efforts
290 like the Puget Sound Seabird Survey may provide additional valuable baseline monitoring. For
291 example, in the event of an oil spill in the region, PSSS data could provide 7+ years of baseline
292 information on seabird distribution and abundance before the spill for comparison. Such citizen-
293 science efforts may also be scalable to different types of data collection that also involve
294 spatially structured threats to marine ecosystems (harmful algal blooms, ocean acidification, etc).

295
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300 observers who braved wind and rain to collect bird data; this work would not be possible without
301 their dedication. Thanks to Chris Jordan and Tom Good for providing helpful reviews of earlier
302 drafts of this manuscript.

303

Table 1. Name, latitude, and longitude of the 62 sites included in our analysis

Site	Lat (N)	Lon (W)	Site	Lat (N)	Lon (W)
60th St Viewpoint	47.6723	122.4062	Mee Kwa Mooks	47.5637	122.4070
Alki Beach	47.5784	122.4144	Mukilteo State Park	47.9478	122.3071
Boston Harbor	47.1396	122.9029	Myrtle Edwards Park	47.6268	122.3775
Brace Point	47.5152	122.3964	Narrows Park	47.2671	122.5641
Brown's Point	47.3058	122.4443	Normandy Beach Park	47.4116	122.3401
Burfoot County Park	47.1310	122.9046	North Redondo Boardwalk	47.3507	122.3238
Carkeek Park	47.7125	122.3796	Olympia waterfront	47.0582	122.9020
Cromwell East	47.2709	122.6110	Owens Beach Pt Defiance	47.3128	122.5280
Cromwell West	47.2714	122.6191	Penn Cove Pier	48.2228	122.6883
Dash Pt State Park	47.3204	122.4141	Penrose State Park	47.2601	122.7450
DeMolay Boys Camp (E)	47.2777	122.6662	Pier 57	47.6062	122.3429
DeMolay Boys Camp (W)	47.2775	122.6668	Pier 70	47.6149	122.3573
Discovery Park West	47.6674	122.4227	Point No Point	47.9122	122.5265
Dumas Bay Park	47.3263	122.3853	Pt Wilson	48.1441	122.7538
Duwamish Head	47.5954	122.3876	Purdy Spit South	47.3817	122.6348
Edmonds north	47.8114	122.3891	Raft Island north	47.3318	122.6700
Edmonds south	47.8033	122.3947	Raft Island south	47.3261	122.6675
Elliott Bay Water Taxi Pier	47.5898	122.3800	Richmond Beach	47.7636	122.3858
Fox Island Fishing Pier	47.2287	122.5898	Ruston Way	47.2948	122.4990
Frye Cove County Park	47.1152	122.9643	Saltwater State Park	47.3728	122.3249
Golden Gardens	47.6928	122.4056	Seahurst Park	47.4781	122.3638
Howarth State Park	47.9642	122.2407	Sinclair Inlet	47.5398	122.6621
Jack Hyde Park	47.2758	122.4622	South Redondo Boardwalk	47.3434	122.3328
Kayak Point State Park	48.1373	122.3668	The Cove	47.4428	122.3563
Kopachuck	47.3101	122.6874	Thea's Park	47.2620	122.4398
Les Davis Pier	47.2836	122.4813	Three Tree Point	47.4522	122.3792
Libbey Beach County Park	48.2322	122.7668	Titlow Beach	47.2469	122.5536
Lincoln Park	47.5263	122.3949	Tolmie State Park	47.1209	122.7761
Lowman Park	47.5403	122.3974	Totten Inlet	47.1540	122.9645
Luhr Beach	47.1008	122.7272	West Point north	47.6624	122.4335
Magnolia Bluff	47.6313	122.3954	West Point south	47.6610	122.4330

307 Table 2. The 18 species included in our analysis of the Puget Sound Seabird Survey. Rows in
 308 bold represent species that breed locally (in Puget Sound).

309

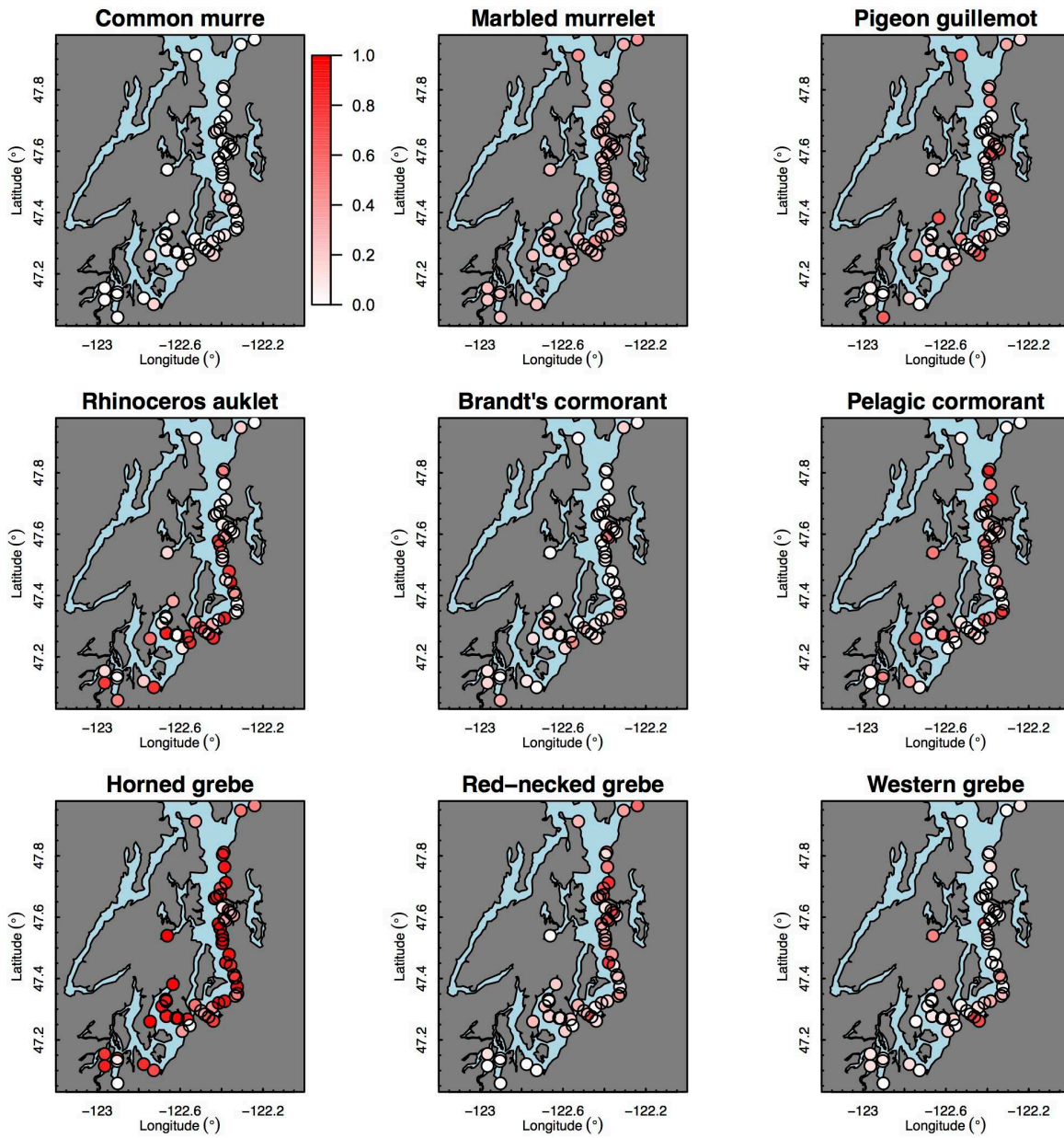
<u>Common name</u>	<u>Scientific name</u>	<u>Group</u>
Common murre	<i>Uria aalge</i>	Alcids
Marbled murrelet	<i>Brachyramphus marmoratus</i>	Alcids
Pigeon guillemot	<i>Cepphus columba</i>	Alcids
Rhinoceros auklet	<i>Cerorhinca monocerata</i>	Alcids
Brandt's cormorant	<i>Phalacrocorax penicillatus</i>	Cormorants
Pelagic cormorant	<i>Phalacrocorax pelagicus</i>	Cormorants
Horned grebe	<i>Podiceps auritus</i>	Grebes
Red-necked grebe	<i>Podiceps grisegena</i>	Grebes
Western grebe	<i>Aechmophorus occidentalis</i>	Grebes
Common loon	<i>Gavia immer</i>	Loons
Pacific loon	<i>Gavia pacifica</i>	Loons
Red-throated loon	<i>Gavia stellata</i>	Loons
Brant	<i>Branta bernicla</i>	Waterfowl
Bufflehead	<i>Bucephala albeola</i>	Waterfowl
Common goldeneye	<i>Bucephala clangula</i>	Waterfowl
Harlequin duck	<i>Histrionicus histrionicus</i>	Waterfowl
Surf scoter	<i>Melanitta perspicillata</i>	Waterfowl
White-winged scoter	<i>Melanitta deglandi</i>	Waterfowl

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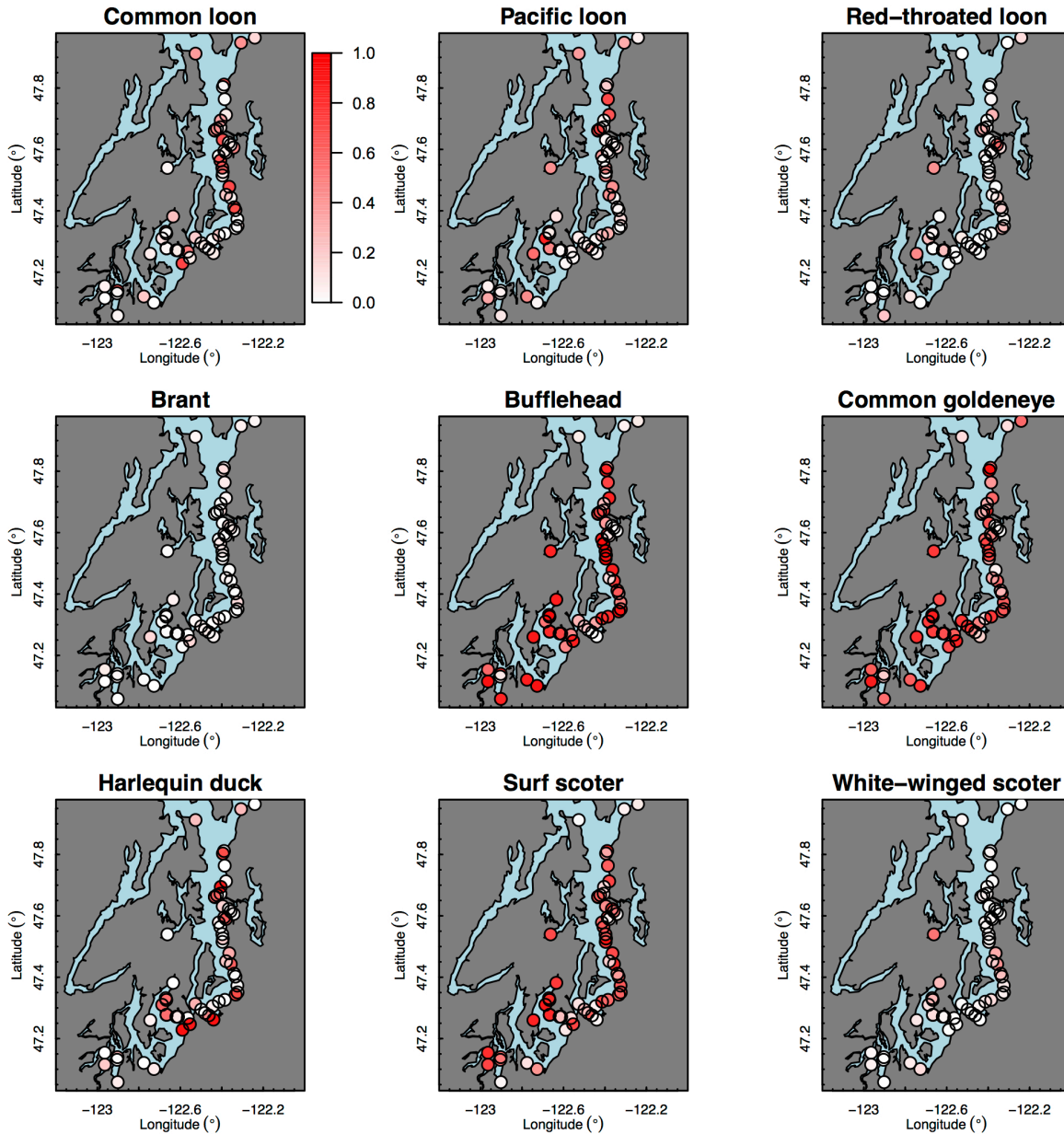
313 Figure 1. Estimated probability of occurrence for the 62 sites included in our analysis. Presented
314 estimates are for alcids, cormorants, and grebes in December 2013.



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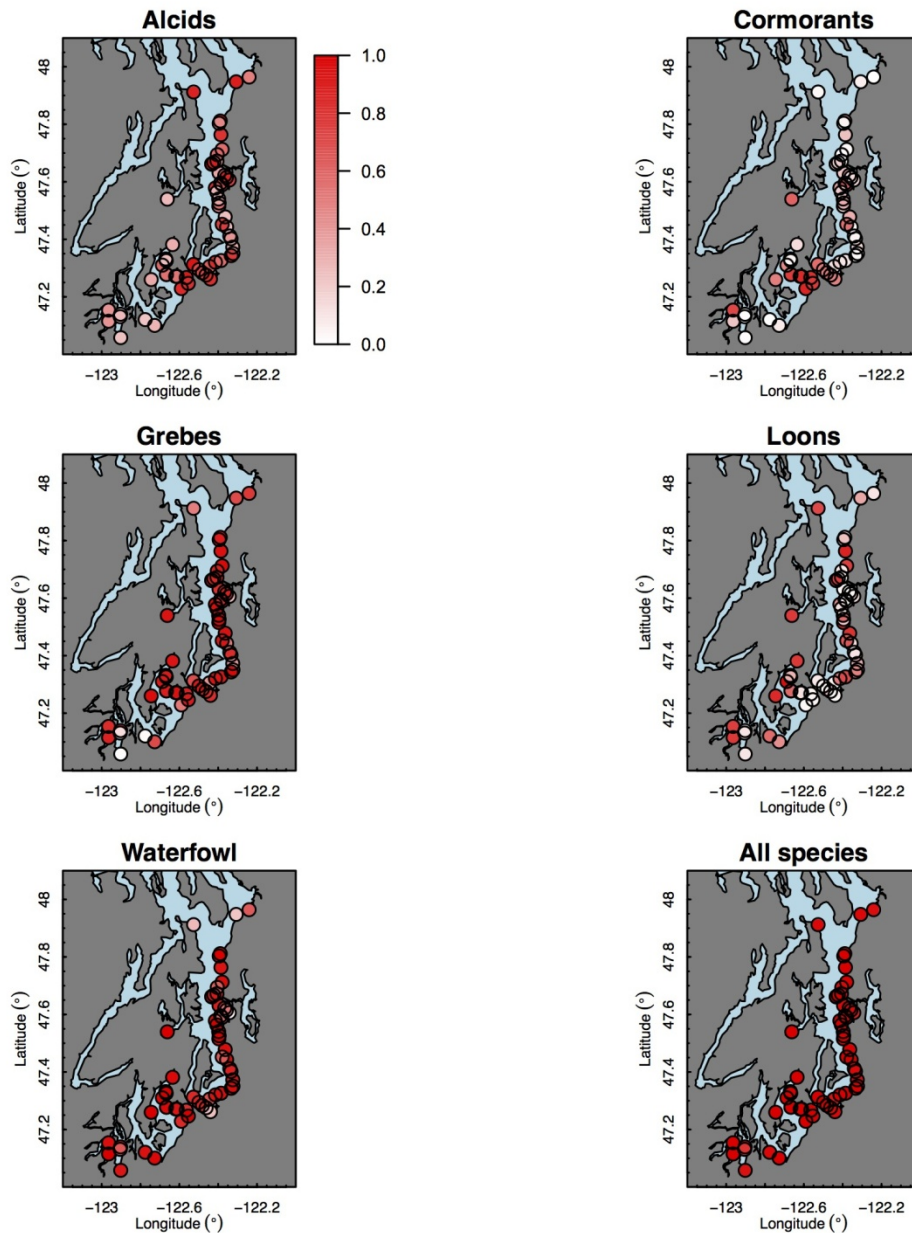
317 Figure 2. Estimated probability of occurrence for the 62 sites included in our analysis. Presented
318 estimates are for loons and waterfowl in December 2013.

319



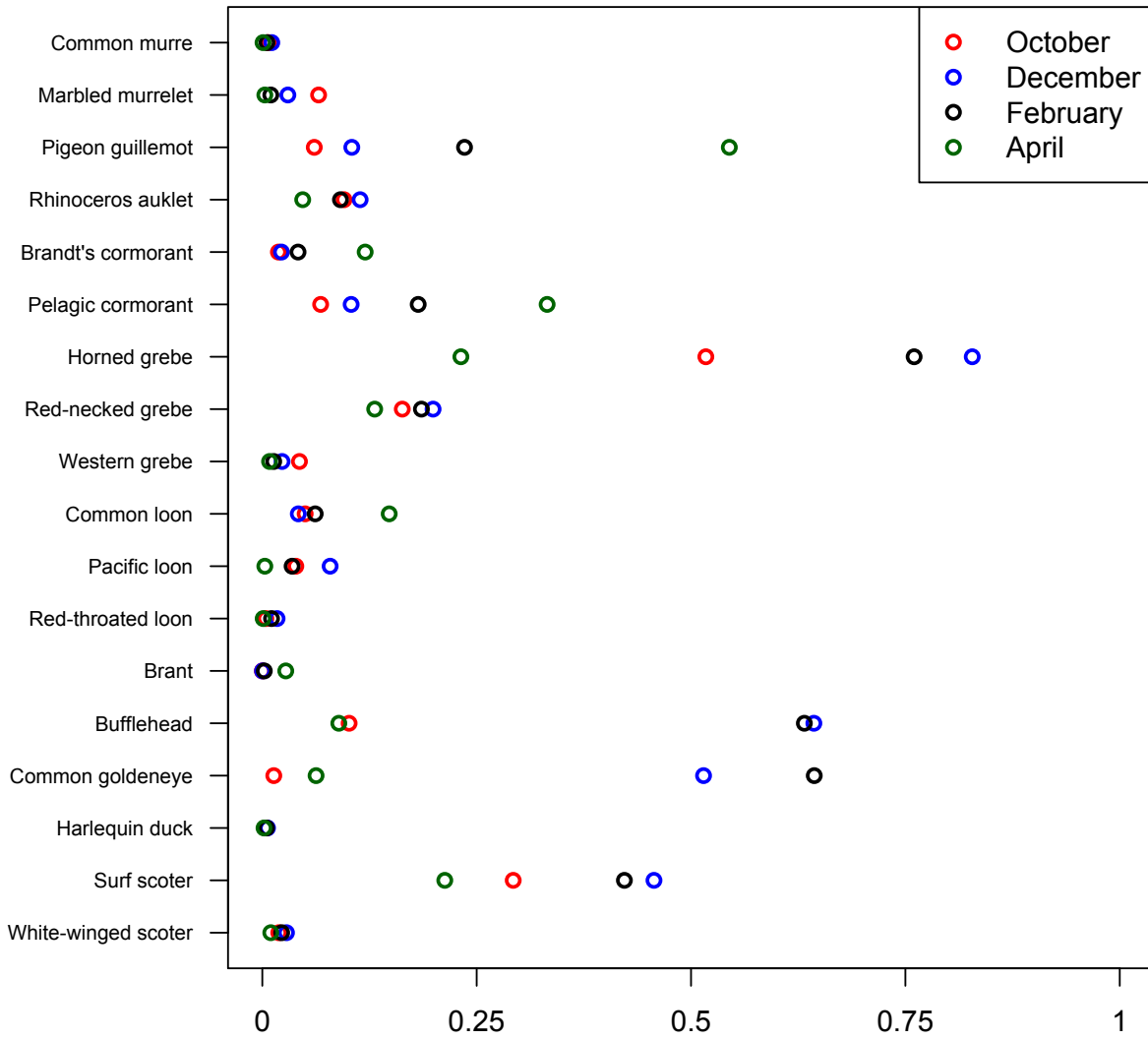
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322 Figure 3. Aggregated probabilities of occurrence for each of the 5 groups in our analysis, as well
323 as for all species. For groups, these represent the probability of seeing any bird that is a member
324 of that group; for all species, these represent the probability of seeing at least 1 bird (of the 18
325 species in our analysis). Estimates are shown for December 2013.



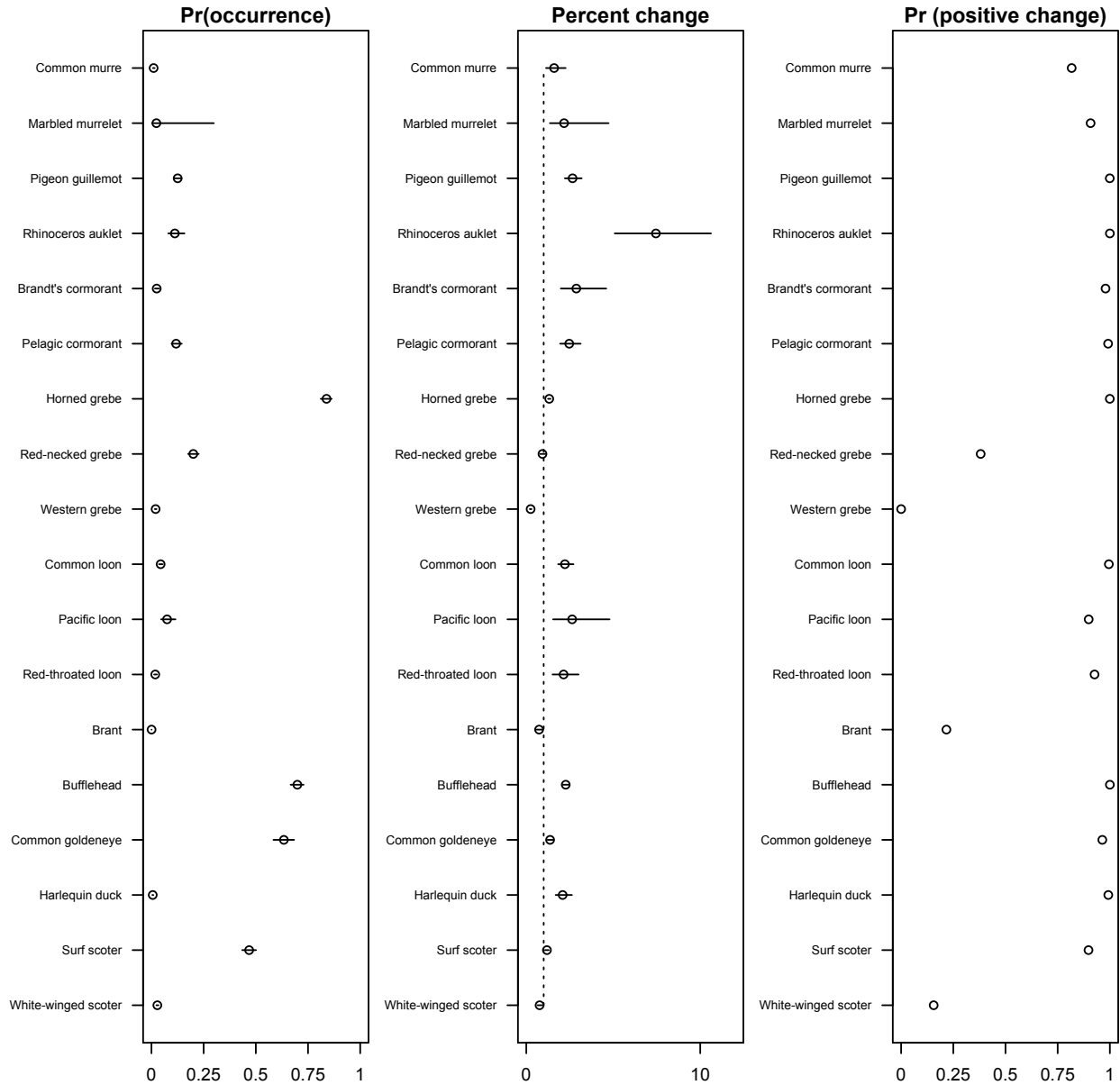
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328 Figure 4. Estimated median probabilities of occurrence by month. Estimates are shown for the
 329 most recent year (October 2013- April 2014). Estimates for November, January, and March are
 330 not shown.



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334 Figure 5. Estimated probability of occurrence in the 2013-2014 seabird survey (with 25%, 50%,
 335 75% intervals), percent change in the probability of occurrence from 2007-2013 (25%, 50%,
 336 75% intervals), and the probability of the annual rate of change from 2007-2013 has been
 337 positive. All data (2007-2013) are used to estimate intra- and inter-annual trends.
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