Sea Duck Joint Venture
Final Report
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Project Title:

Distribution of Sea Ducks in Southeast Alaska: Geographic Patterns and Relationships to Coastal Habitats. SDJV Project # 86.

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Project Description:

Southeast Alaska (Figure 1) provides winter habitat for at least 10 species of sea ducks totaling >300,000 individuals, making the region one of the most important sea duck wintering areas in the Pacific Flyway. In summer the region provides molting habitat for large numbers of scoters, mergansers, and harlequin ducks. The U.S. Fish and Wildlife Service (USFWS) conducted winter surveys of sea duck abundance in Southeast Alaska in 1996 (Anonymous 1996). Hodges et al. (2008) provided estimates of summer and winter sea duck distribution and abundance based on aerial surveys of most shorelines and adjacent nearshore waters in Southeast Alaska from 1997-2002. We summarized aerial survey data collected by the USFWS between 1996 and 2002 using a Geographic Information System (GIS) to evaluate regional patterns of sea duck diversity and abundance, consistency in use of sites between years and seasons, and habitat attributes associated with sea duck presence in Southeast Alaska.

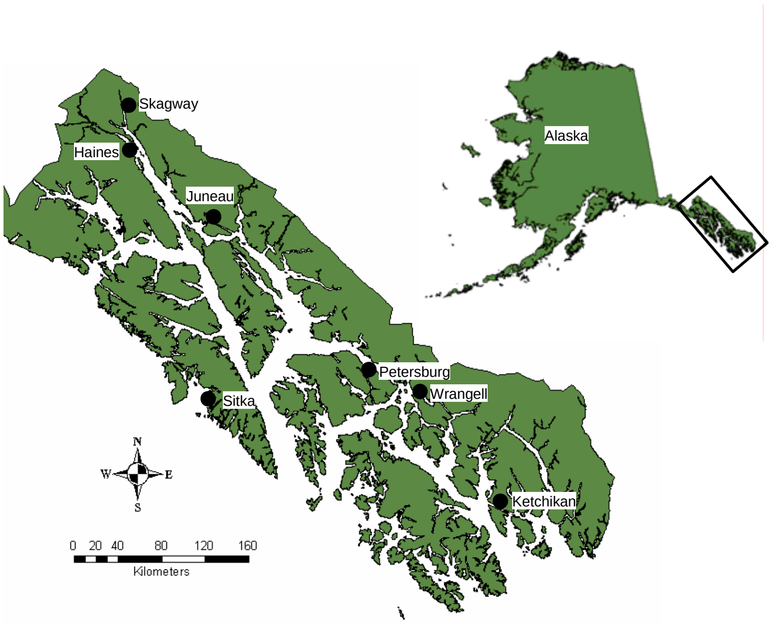


Figure 1. Location of the Southeast Alaska study area.

Objectives:

1. Document and map regional patterns of species diversity among sea ducks that occur in Southeast Alaska.

2. Compare regional distributions of scoters, harlequin ducks, goldeneye, bufflehead, long-tailed ducks, and mergansers in Southeast Alaska.

3. For each species or species group of sea ducks, assess consistency in distributions across years, and similarities between summer and winter distributions.

4. For each species or species group, develop and test models describing seasonal relationships between characteristics of shoreline or nearshore environments and numbers of sea ducks.

Methods:

Aerial Surveys

The FWS conducted aerial surveys in 130 randomly selected quadrats in marine habitats throughout Southeast Alaska from February 13 – March 1, 1996 (Anonymous 1996). Each quadrat was approximately 172 km^2 and was ¼ of a 1:63,000 topographic map. Three experienced air crews conducted the surveys with two observers/aircraft. Within each quadrat all waterbirds were identified and group sizes estimated on both sides of the aircraft as it was flown approximately 30 m above ground level 0.2 km from the shoreline, resulting in a 0.4 km wide survey area. Large intertidal areas were circled so they were surveyed completely. Areas of open water in the random plot that were >0.4 km from shore were surveyed via transects that were centered on each 1 minute of latitude. Observations in each plot were separately recorded according to whether they occurred along shorelines or open-water transects. Scoters, goldeneye, and mergansers were identified to species when possible, but for analysis they were simply classified to species group.

From 1997-2002, the FWS conducted aerial surveys of waterbird abundance along nearly all shorelines in Southeast Alaska during winter (late February – early March), and in 1997-2001 the same surveys were conducted in summer (late July – mid August). Details of the surveys are provided in Hodges et al. (2008). Different areas of Southeast Alaska were surveyed each year, with no area surveyed more than once within a season. These surveys were similar to the shoreline component of the random plot surveys conducted in 1996 in that the flight path was parallel (although closer) to the shoreline, and all waterbirds within approximately 0.4 km of shore were identified and group size enumerated. However, unlike the 1996 surveys, a modification of the flight tracking program described by Butler et al. (1995) that linked a GPS receiver to a laptop computer was used to monitor the flight route and to record latitude and longitude of all observations. Most sea ducks were only counted if they were $\leq$0.4 km from the shoreline, although scoters were counted so long as they were within view of the observer. In addition, during both seasons boat surveys were conducted concurrently with aerial shoreline surveys in some areas to derive visibility correction ratios and to determine species composition of scoters, mergansers, and goldeneye. Those results are in Hodges et al. (2008).

GIS Analysis

Patterns of species diversity and abundance. – We based patterns of species diversity and abundance on shoreline surveys conducted from 1997-2002. We randomly selected 5190 points from a shoreline GIS coverage (Albert and Schoen 2007) of Southeast Alaska and created an 800 m radius (2 km^2) circle around each point in ArcGIS 9.1. We set a minimum inter-point distance of 1800m. We excluded random plots where the centroid was >600 m from the survey flight lines, because most sea ducks in those plots would not have been observed during the surveys. This resulted in samples of 4051 and 4576 random plots for the summer and winter shoreline surveys, respectively. We superimposed the random circular plots on GIS coverages of sea duck distributions in winter and summer derived from the shoreline surveys. Within each plot for both seasons, we summed (1) the number of sea duck species groups, (2) total number of sea ducks, and (3) total individuals of each species group. We computed sea duck density as numbers of sea ducks/km^2 of area surveyed within a random plot. We computed the survey area in a plot based on a 400 m buffer of the flight line recorded via GPS during shoreline surveys, subtracting any area in the buffer that was on the inland side of the shoreline. From those data we also computed a Simpson's diversity index for each plot (Simpson 1949). We then extrapolated the data to areas within 5 km of random plots using an inverse distance weighted approach (Burrough and McDonnell 1998) to create regional maps of sea duck diversity and abundance. We broadly summarized regional patterns of diversity and abundance by dividing Southeast Alaska into three zones (1) Outer Coast, (2) North Inside shorelines, and (3) South Inside shorelines (Figure 2). The Outer Coast included shorelines classified as "highly exposed" by Albert and Schoen (2007), as well as adjacent bays and islets, along the open-ocean edge of the outer islands. Sumner Strait divided northern from southern inside shorelines. We computed mean sea duck abundance and diversity based on random plots in each zone.

Temporal consistency in sea duck abundance. – To compare consistency in abundance of sea ducks at sites between years, we superimposed the 1996 aerial survey plot boundaries on the GIS coverage of winter distributions of sea ducks derived from the 1997-2002 shoreline surveys. We tallied the total number of birds observed in each species group along the shoreline component of the 1996 random quadrats, and compared that to numbers of birds seen in the same area during the 1997-2002 shoreline surveys. We only included random quadrats from the 1996 survey if the shorelines within the plot were fully surveyed in one year during the subsequent shoreline surveys. For scoters, we included birds observed along the shoreline and offshore during the 1996 surveys, because in later surveys scoters were counted even if they were >0.4 km from the shoreline. For each species group we conducted a linear regression analysis to determine if there was a relationship between numbers of ducks observed in 1996 and numbers observed in the same area 1-6 years later.

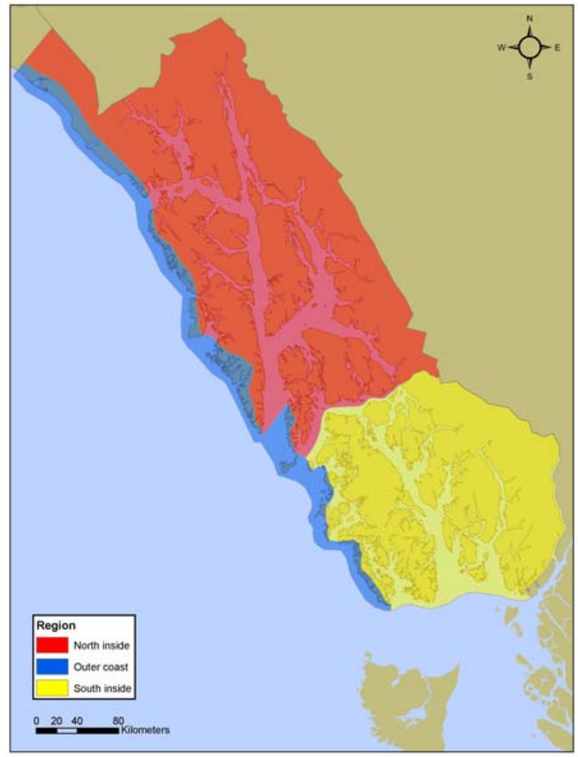


Figure 2. Regional boundaries used to summarize sea duck density and diversity in Southeast Alaska.

To examine consistency in use of shorelines between seasons, we computed mean abundance for a species group across all random plots in winter and compared that to mean abundance in summer, based on the 1997-2002 surveys. We compared seasonal consistency between the three regions of Southeast Alaska.

Sea duck distribution and shoreline attributes. – We examined whether sea duck presence along a shoreline in winter was influenced by (1) shoreline exposure to high energy waves, (2) distance to the outer coast, (3) distance to a large stream (>5km in length), (4) number of islets (<1ha in size), (5) shoreline substrate, or (6) width of the intertidal area. Based on the 1997-2002 winter shoreline surveys, we determined whether a particular sea duck species group was present in the 2-km^2 random plots described above. We classified shoreline attributes within each random plot from GIS data sets developed by The Nature Conservancy (Albert & Schoen 2007). Some random plots lacked data on shoreline features and were excluded, resulting in a final sample of 4060 plots. We modeled the relationships between habitat attributes and sea duck presence using logistic regression with separate analyses for each species group. We included an offset in the models calculated as log(area surveyed), so that the probability of sea duck presence was proportional to the area in the plot that was surveyed. To mitigate the consequences of spatial autocorrelation in sea duck abundance, we included an autocovariate in our models:

$$autocov_i = \frac{\sum_{j=1}^{k_i} w_{ij} y_j}{\sum_{j=1}^{k_i} w_{ij}}$$

where k_i is the number of neighboring plots of plot i that are considered in the analysis, w_{ij} is the weight of an individual neighbor, and y_j is the value of that neighbor (1 for sea duck presence, 0 for absence). The weight of an individual neighbor j is $w_{ij} = 1/h_{ij}$, where h_{ij} is the Euclidean distance between the center of plots i and j. (Augustin et al. 1996).

For each species group, we created a set of candidate models that included all additive combinations of the explanatory variables, and used Akaike's Information Criterion (AIC) to identify the most parsimonious models (Burnham and Anderson 2002). We calculated model averaged parameter estimates, standard errors, and odds ratio (odds ratio = $e^{|\text{parameter estimate}|}$).

We evaluated the best models for each species against a second set of 890 random 2-km^2 plots created from the same original datasets. We compared the model's predictions to actual observations using "receiver operating characteristic" (ROC) curves for the logistic models (Hanley ad McNeil 1982, Fielding and Bell 1997). The area under the ROC curve (AUC) provides a single measure of accuracy that is threshold independent. An AUC value of 1.0 indicates a perfect prediction, whereas values <0.5 indicate random predictions

Results*:*

Patterns of Species Diversity and Abundance

Summer and winter densities and diversity of all sea ducks tended to be highest in the North Inside region and lowest on the Outer Coast (Figures 3 and 4, Table 1). Among individual species groups, mean winter densities of scoters, goldeneye, harlequin ducks, and bufflehead were highest in the North Inside region (Figure 5 and 6). Highest winter densities of mergansers were in the South Inside region. Long-tailed ducks were the least abundant species in winter, although their densities were highest in the North Inside region. Winter densities of all sea ducks were low on the Outer Coast.

In summer, the sea duck community consisted mainly of scoters, mergansers, and harlequin ducks, many of which were molting. Densities of each species were highest in the North Inside region (Figures 6 and 7), especially near Admiralty Island and in Glacier Bay National Park, resulting in highest summer diversity in those areas.

Table 1. Mean values for Simpson's diversity index for sea ducks present in random plots located in three regions of Southeast Alaska during summer and winter aerial surveys of shorelines, 1997-2002.

Region	Summer diversity	Winter diversity
North inside	0.019	0.252
Outer coast	0.000	0.119
South inside	0.004	0.175

Temporal Consistency in Sea Duck Abundance

For all species and total sea ducks, the numbers of birds present during the 1997-2002 winter shoreline surveys were positively related to numbers present in the same areas in 1996 (Table 2). Thus, areas that had large numbers of sea ducks in 1996 were still likely to have large numbers in later years. The relationship was strongest for goldeneye and weakest for long-tailed ducks. For all species and total ducks the slope of the relationship was <1.0 indicating that fewer birds were observed during the 1997-2002 shoreline surveys, compared to the shoreline component of the 1996 surveys.

The Outer Coast and South Inside regions had higher densities of most sea ducks in winter than in summer (Figure 8). In contrast the North Inside region supported high densities of goldeneye in the winter and large numbers of molting scoters in summer.

Table 2. Linear regression analysis comparing numbers of sea ducks observed in 107[a] randomly located 172-km^2 plots in Southeast Alaska during winter aerial surveys in 1996 with numbers of sea ducks in the areas during winter shoreline surveys from 1997-2002.

Species	Slope	SE	r^2	p
Bufflehead	0.499	0.092	0.219	<.0001
Goldeneye	0.590	0.056	0.513	<.0001
Harlequin duck	0.617	0.101	0.263	<.0001
Long-tailed duck	0.311	0.068	0.167	<.0001
Merganser	0.373	0.056	0.294	<.0001
Scoter	0.299	0.059	0.198	<.0001
Total ducks	0.494	0.053	0.453	<.0001

[a]Some plots from the 1996 data set were excluded because they lacked shoreline habitat or subsequent shoreline surveys of that plot were not completed in one year.

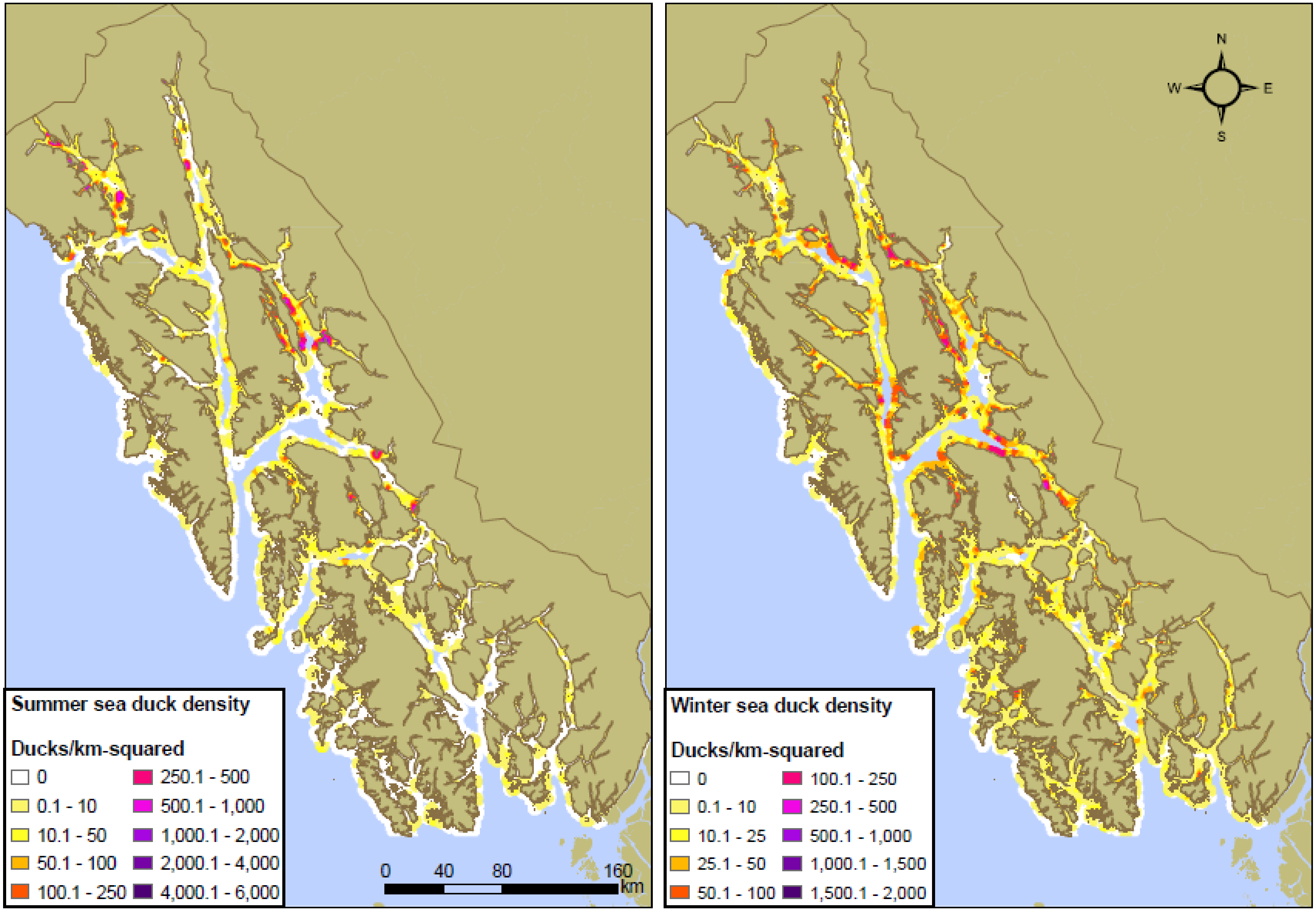


Figure 3. Densities of all sea duck species in Southeast Alaska during summer and winter shoreline surveys, 1997-2002. Sea duck density was measured in 4501 and 4576 randomly located 2-km^2 plots in summer and winter respectively, and extrapolated to areas within 5 km of plots.

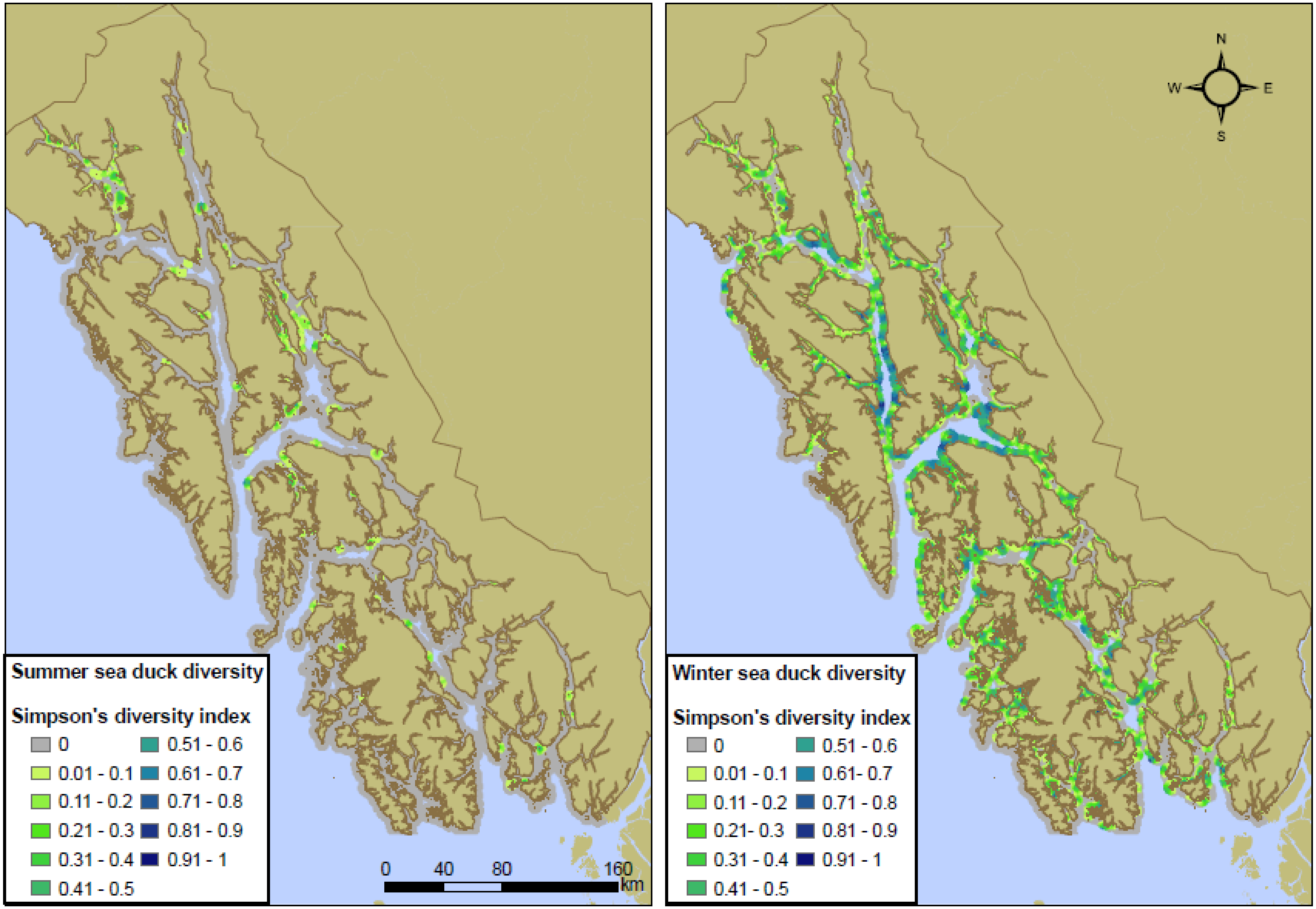


Figure 4. Diversity of sea ducks in Southeast Alaska during summer and winter aerial surveys of shorelines, 1997-2002. Simpson's diversity index was computed in each of 4501 and 4576 randomly located 2-km^2 plots in summer and winter respectively, and extrapolated to areas within 5 km of plots.

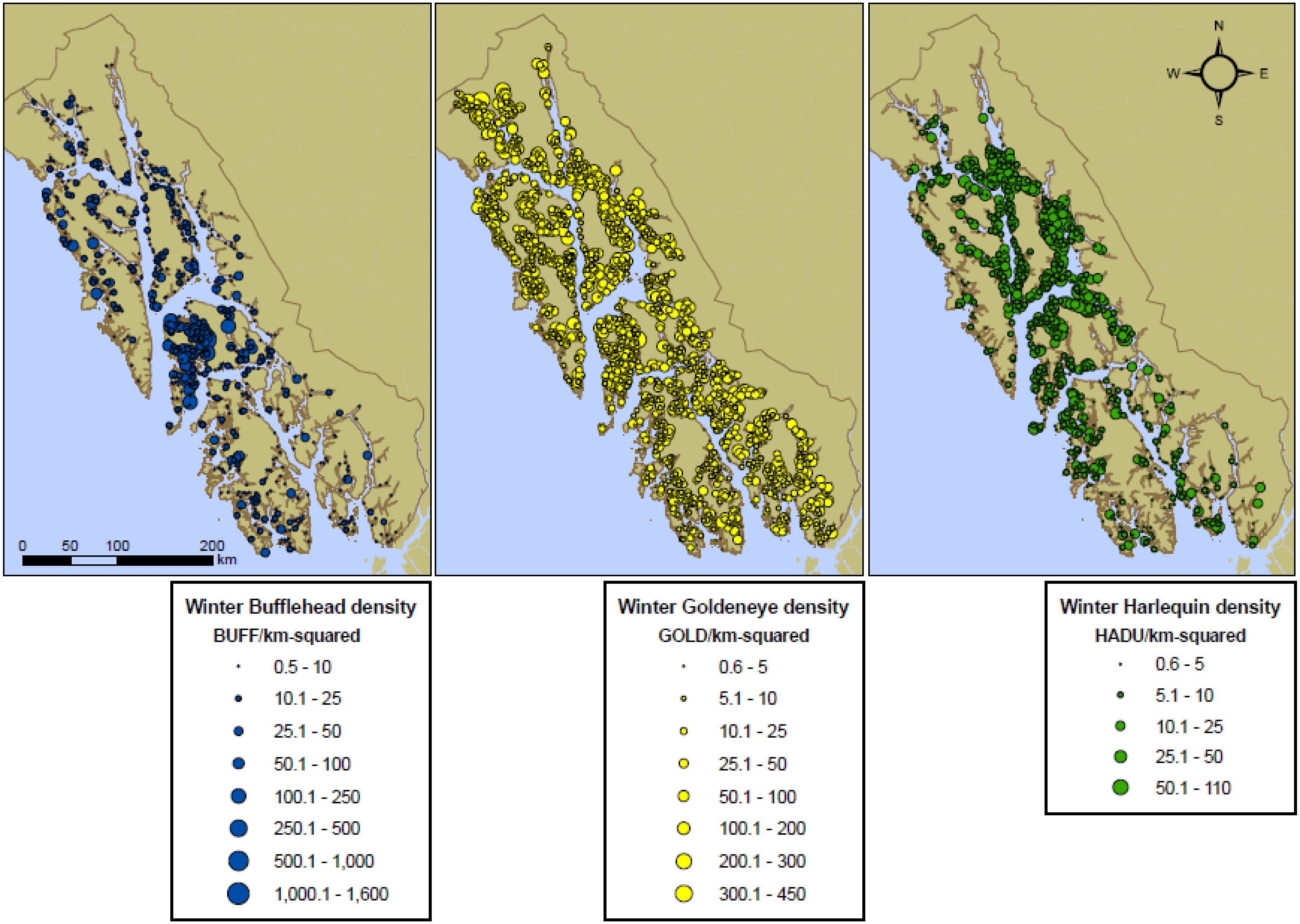


Figure 5. Densities of species groups of sea ducks in 4576 randomly located 2-km^2 plots during winter aerial surveys of shorelines in Southeast Alaska, 1997-2002.

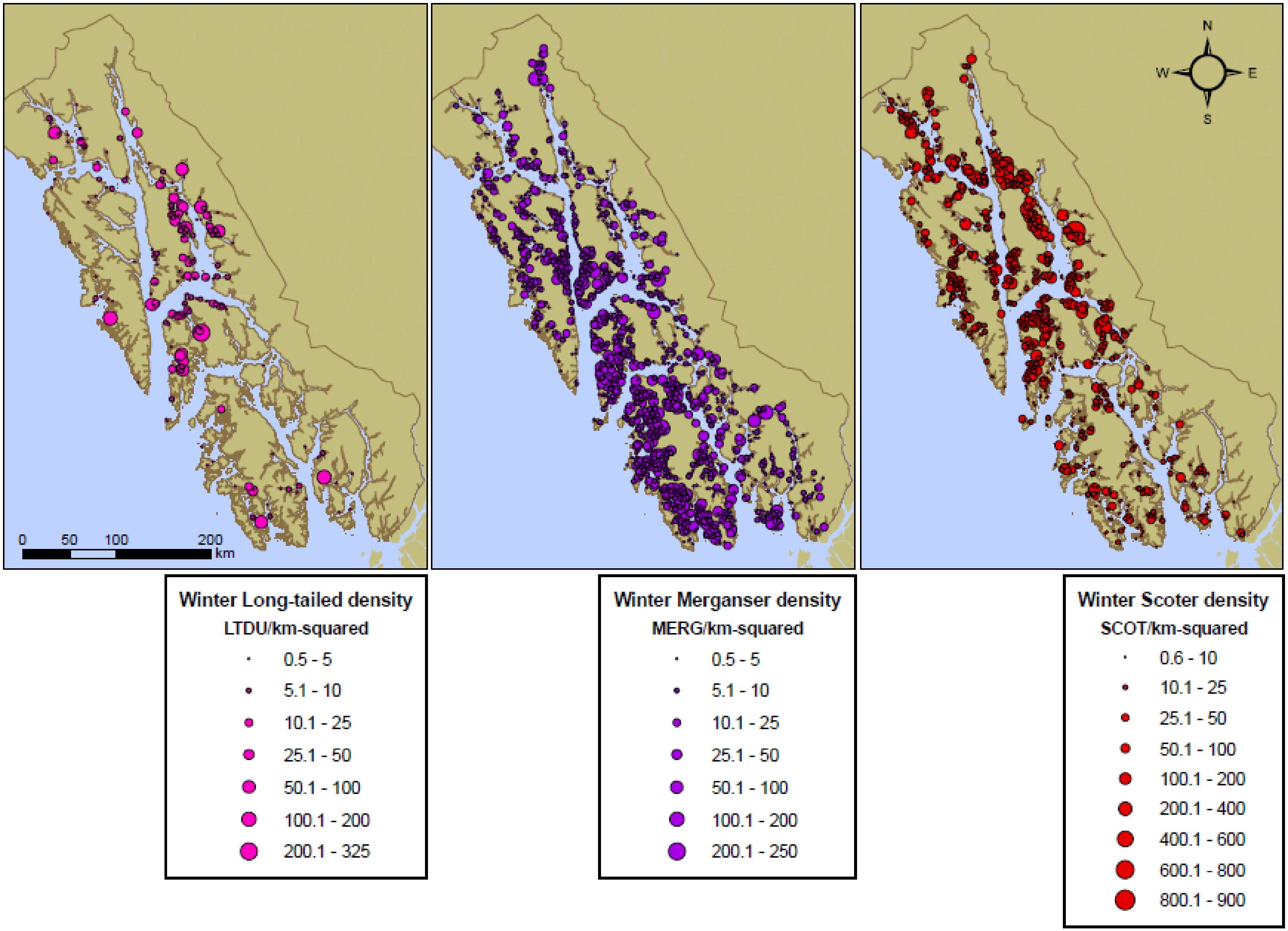


Figure 5. Continued.

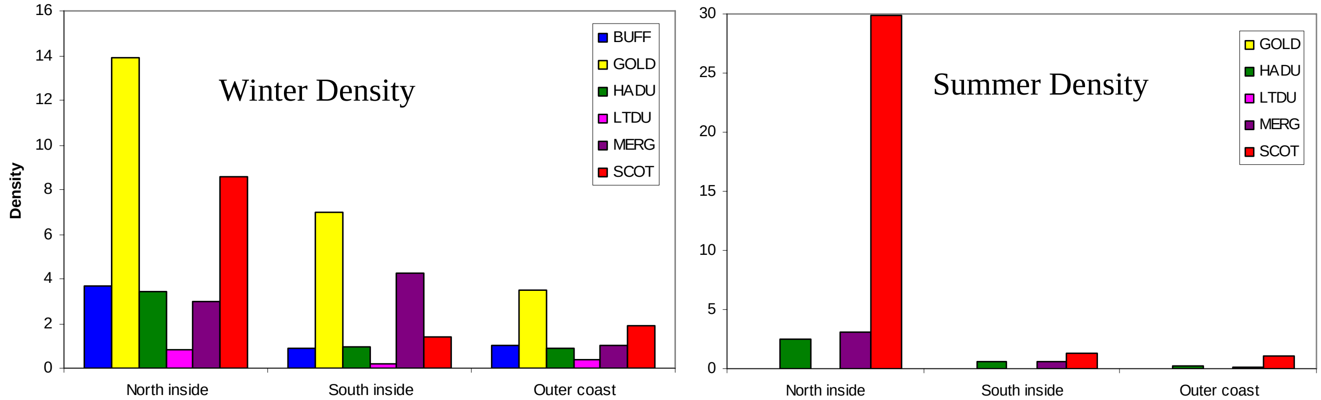


Figure 6. Average density (birds/km^2) of sea duck species groups in randomly located plots in three regions of Southeast Alaska during aerial surveys of shorelines in winter and summer, 1997-2002.

Sea Duck Distribution and Shoreline Attributes

We modeled the relationship between the presence of six groups of sea ducks in winter and selected shoreline habitat variables using logistic regression. Moran's I correlograms indicated spatial autocorrelation in all duck observation data, and habitat data. To account for spatial autocorrelation in our models, we included an autocovariate term that was based on the presence of ducks in neighboring plots. This reduced the degree of spatial autocorrelation in all species groups.

For five of the six species groups, inclusion of the habitat variables improved model fit (Table 3). The exception was long-tailed ducks, where only the autocovariate term was strongly supported. There was some model uncertainty in each species group, therefore we report model-averaged parameter estimates.

Based on model averaged parameters that had weights >0.5 and estimates that were >2 SE (Table 4), harlequin ducks were most likely to be present near narrow, rocky shorelines, and were less likely to use wide shorelines that had a sediment substrate. Mergansers were most likely to occur near rocky shorelines that were protected from high energy waves and were near large streams. Bufflehead and goldeneye were more likely to occur near shorelines that were protected from high energy waves and close to large streams. Bufflehead were also more likely to be present near wide shorelines and where there were small offshore islets. Scoter presence increased near shorelines that were protected from high energy waves and with increased numbers of offshore islets. There were no habitat features strongly associated with the presence of long-tailed ducks. The best predictive model for bufflehead had a good discriminatory level (ROC = 0.8) when applied to the test data set, whereas the best models for harlequin ducks, long-tailed ducks, and scoters had fair discriminatory capabilities ($0.6 < \text{ROC} \leq 0.7$). Best models for mergansers and goldeneye had poor discriminatory abilities ($0.5 < \text{ROC} < 0.6$)

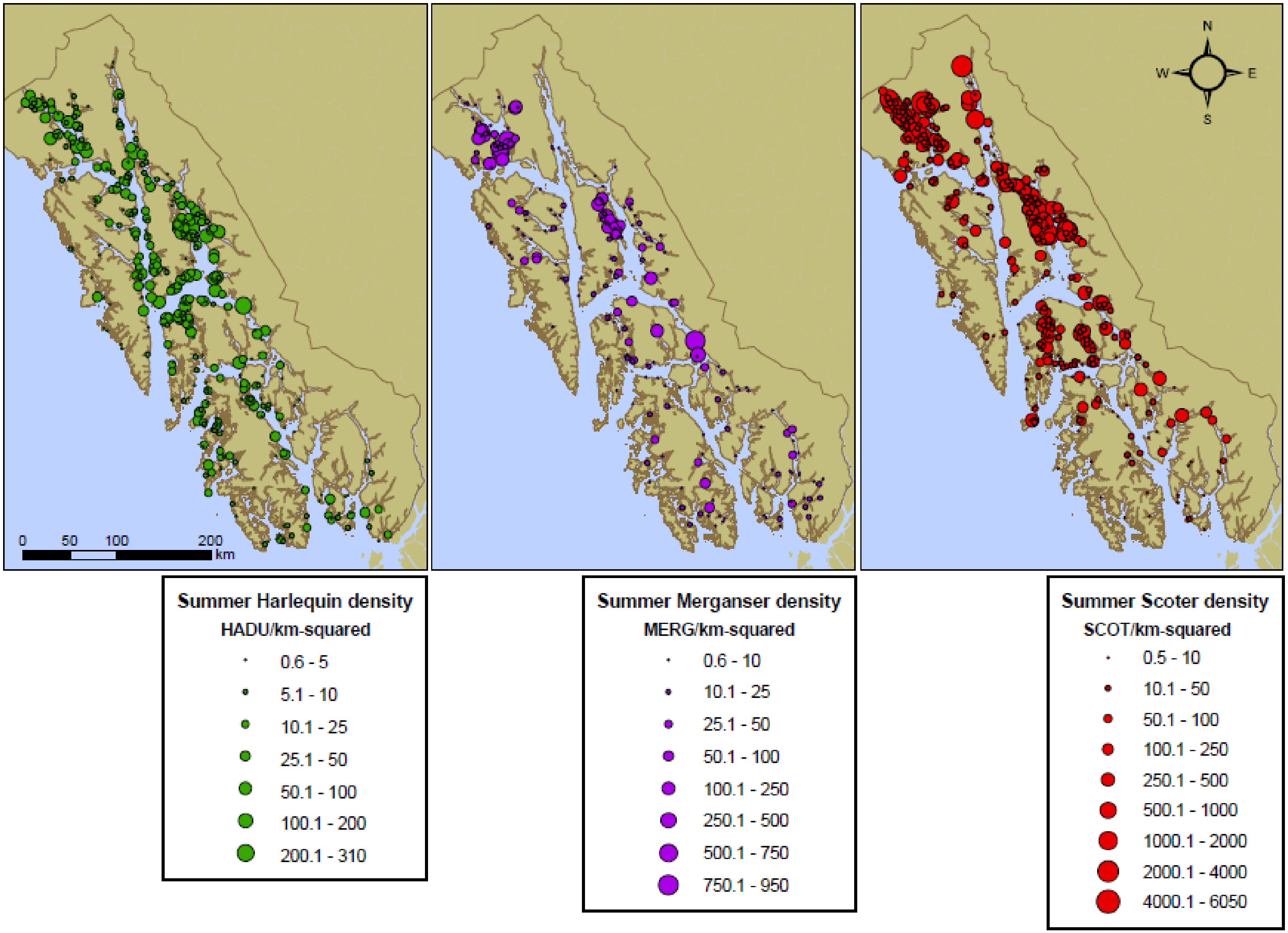
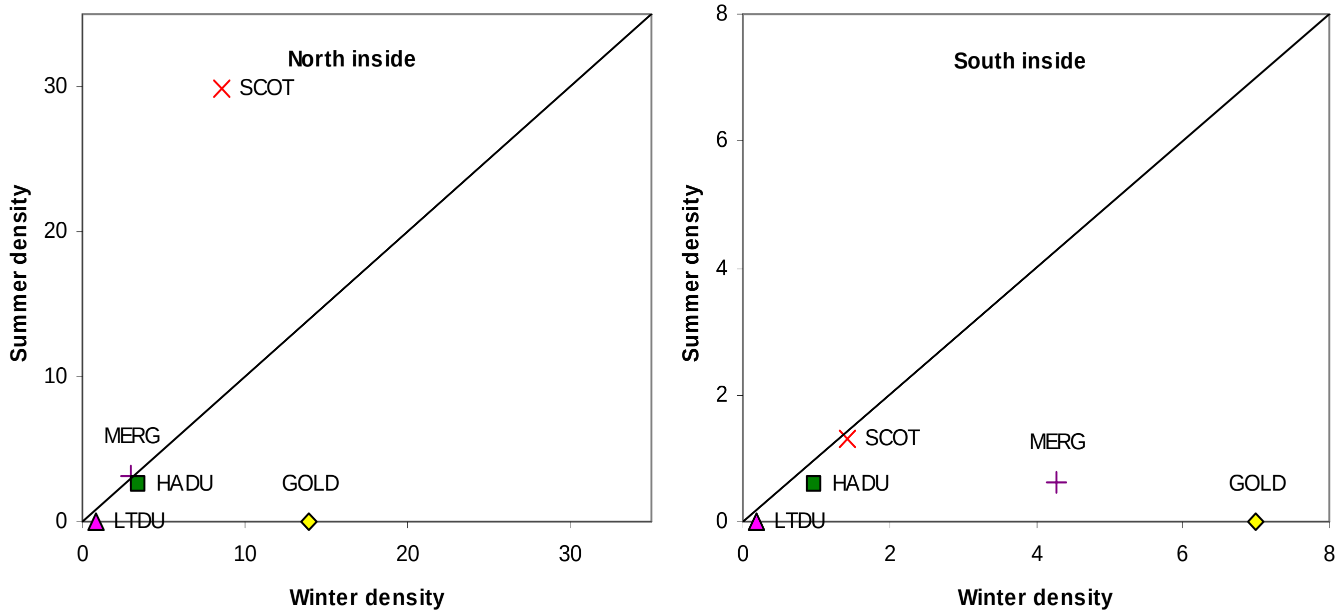


Figure 7. Densities of sea duck species groups in 4501 randomly located 2-km^2 plots during summer aerial surveys of shorelines in Southeast Alaska, 1997-2001.



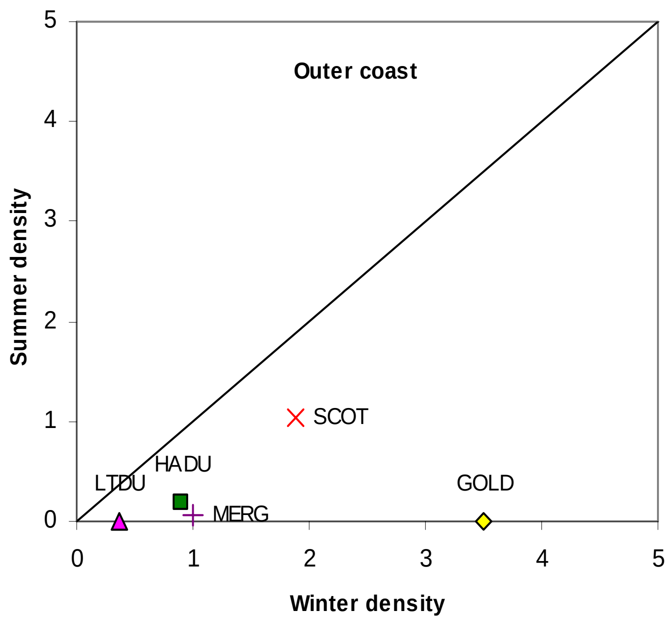


Figure 8. Comparison of mean summer and winter sea duck densities (ducks/km^2) by species for each of three regions in Southeast Alaska. Based on aerial surveys of shoreline habitats from 1997-2002. Higher densities were observed in winter than in summer for species below the diagonal reference line.

Conclusions

Aerial surveys by the USFWS have demonstrated that Southeast Alaska is a globally important region for sea ducks. It supports significant proportions of the world populations of Barrow's goldeneye and harlequin ducks, and provides critical winter and molting habitat for surf and white-winged scoters. There is substantial regional variation in sea duck abundance and diversity. The inner shorelines and near shore waters of northern Southeast Alaska appear to be especially important for sea ducks during both summer and winter. Glacier Bay and waters surrounding the Glass Peninsula on Admiralty Island support particularly large numbers of scoters, mergansers, and harlequin ducks during molt. Waters near Admiralty Island and the north end of Kupreanof Island are also important to wintering scoters, harlequin ducks, and goldeneye. The positive correlations between numbers of sea ducks in an area in different years suggest that individuals show fidelity to winter sites and/or that some shorelines consistently attract sea ducks. Sea duck winter presence in Southeast Alaska was correlated with shoreline habitat features. Four of the six species groups of sea ducks were more likely to be near shorelines that were protected from high energy waves, and three species groups were found in closer proximity to large streams. Thus, we predict that shorelines that are protected from high energy waves and are close to streams that are >5 km long will support the greatest diversity of sea ducks in Southeast Alaska.

Project Status

Most data analysis associated with this project has been completed and manuscript preparation is ongoing with projected submission of a manuscript on habitat associations of sea ducks early in 2009. Preparation of additional manuscripts on spatial and temporal patterns of sea duck diversity and abundance in Southeast Alaska is ongoing. GIS coverages of sea duck diversity and abundance in Southeast Alaska will be posted on a web site at Simon Fraser University with links to the Southeast Alaska GIS Library maintained by the University of Alaska.

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Table 3. Model selection results for logistic models of sea duck presence in randomly selected plots during winter shoreline surveys in southeast Alaska 1997-2002. Only models within 2 AIC of the best-supported model are indicated.

Model by Species	Delta AIC	Weight	Parameters
Harlequin Duck			
Width[a] + Islets + Rock + HAutocov	0.00	0.183	5
Width + Exp + Islets + Rock + HAutocov	0.66	0.132	6
Width + Exp + Islets + Rock + DtoStream + HAutocov	1.05	0.109	7
Width + Islets + Rock + DtoStream + HAutocov	1.11	0.105	6
Width + Rock + HAutocov	1.98	0.068	4
Mergansers			
Exp + Islets + Rock + DtoStream + MAutocov	0.00	0.332	7
Width + Exp + Islets + Rock + DtoExp + DtoStream + MAutocov	1.22	0.181	8
Width + Exp + Rock + DtoStream + MAutocov	1.63	0.147	6
Width + Exp + Rock + DtoExp + DtoStream + MAutocov	1.76	0.138	7
Bufflehead			
Width + Exp + Islets + DtoStream + BAutocov	0.00	0.488	6
Width + Exp + Islets + DtoExp + DtoStream + BAutocov	1.68	0.211	7
Width + Exp + Islets + Rock + DtoStream + BAutocov	1.74	0.204	7
Goldeneyes			
Exp + DtoStream + GAutocov	0.00	0.164	4
Exp + Rock + DtoStream + GAutocov	0.09	0.156	5
Width + Exp + DtoStream + GAutocov	0.86	0.106	5
Width + Exp + Rock + DtoStream + GAutocov	1.13	0.093	6
Exp + Islets + Rock + DtoStream + GAutocov	1.82	0.066	6
Exp + Islets + DtoStream + GAutocov	1.92	0.063	5
Exp + DtoExp + DtoStream + GAutocov	1.97	0.061	5
Long Tailed Duck			
LAtuocov	0.00	0.076	2
Rock + LAutocov	0.18	0.069	3
Exposure + LAutocov	0.94	0.047	3
Width + Rock + LAutocov	1.10	0.044	4
Width + LAutocov	1.33	0.039	3
Islets + Rock + LAutocov	1.33	0.039	4
Islets + LAutocov	1.58	0.035	3
DtoExp + LAutocov	1.90	0.029	3
DtoStream + LAutocov	1.92	0.029	3
Width + Exp + LAutocov	1.94	0.029	4
Scoters			
Exp + Islets + SAutocov	0.00	0.206	4
Exp + Islets + DtoStream + SAutocov	1.49	0.098	5
Width + Exp + Islets + SAutocov	1.53	0.096	5
Exp + Islets + DtoExp + SAutocov	1.89	0.080	5
Exp + Islets + Rock + SAutocov	1.99	0.076	5

[a]Width = width of intertidal area; Islets = number of islets; Rock = percentage of shoreline that was rocky, Autocov = the spatial autocorrelation term for a species; DtoStream = distance to a stream; DtoExp = distance to the outer coast.

Table 4. Model averaged parameter weights and estimates for sea ducks by species group in southeast Alaska 1997-2002. W = parameter weight, E = weighted parameter estimate, se = standard error of the weighted parameter estimate, and OR = odds ratio. Items in bold are parameter weights > 0.50, and parameter estimates ≥ 2*SE

	Harlequin Ducks				Mergansers				Buffleheads			
covariate	W	E	se	OR	W	E	se	OR	W	E	se	OR
Intercept		-2.595	0.010			-0.754	0.152			-1.714	0.155	
Autocov	**0.977**	**4.248**	0.179	70.00	**0.857**	**3.521**	0.175	33.83	**1.000**	**4.844**	0.273	127.027
Exp	0.445	0.004	0.006	1.004	**1.000**	**-0.056**	0.006	1.058	**1.000**	**-0.05**	0.007	1.051
DtoExp	0.285	-0.000	0.000	1.000	0.391	-0.001	0.001	1.000	0.302	0.000	0.001	1.000
DtoStream	0.356	-0.002	0.003	1.002	**0.911**	**-0.010**	0.005	1.010	**0.992**	**-0.020**	0.006	1.020
Islets	**0.749**	0.013	0.010	1.013	0.636	0.009	0.009	1.009	**0.999**	**0.038**	0.009	1.039
Rock	**0.997**	**0.589**	0.151	1.802	**0.953**	**0.391**	0.148	1.479	0.296	-0.029	0.080	1.029
Width	**0.971**	**-0.004**	0.002	1.004	**0.892**	**-0.002**	0.001	1.002	**1.000**	**0.008**	0.001	1.008

	Goldeneyes				Long Tailed Ducks				Scoters			
covariate	W	E	Se	OR	W	E	se	OR	W	E	Se	OR
Intercept		-0.388	0.153			-3.653	0.203			-2.132	0.144	
Autocov	**0.907**	**3.452**	0.177	31.57	**0.979**	**8.342**	0.488	4197	**0.996**	**5.169**	0.219	175.6
Exp	**1.000**	**-0.060**	0.006	1.062	0.342	0.003	0.007	1.000	**1.000**	**-0.029**	0.006	1.029
DtoExp	0.273	0.000	0.000	1.000	0.277	0.000	0.001	1.000	0.292	0.000	0.001	1.000
DtoStream	**1.000**	**-0.022**	0.005	1.022	0.257	0.000	0.002	1.000	0.328	0.001	0.002	1.001
Islets	0.287	0.001	0.003	1.001	0.342	0.005	0.010	1.005	**0.839**	0.018	0.011	1.018
Rock	0.486	-0.090	0.127	1.095	0.462	-0.152	0.226	1.164	0.274	0.007	0.050	1.007
Width	0.383	0.000	0.001	1.000	0.371	-0.001	0.001	1.000	0.314	0.000	0.001	1.000