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Research Article

Stopover Habitats of Spring Migrating Surf Scoters in Southeast Alaska

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ABSTRACT Habitat conditions and nutrient reserve levels during spring migration have been suggested as important factors affecting population declines in waterfowl, emphasizing the need to identify key sites used during spring and understand habitat features and resource availability at stopover sites. We used satellite telemetry to identify stopover sites used by surf scoters migrating through southeast Alaska during spring. We then contrasted habitat features of these sites to those of random sites to determine habitat attributes corresponding to use by migrating scoters. We identified 14 stopover sites based on use by satellite tagged surf scoters from several wintering sites. We identified Lynn Canal as a particularly important stopover site for surf scoters originating throughout the Pacific winter range; approximately half of tagged coastally migrating surf scoters used this site, many for extended periods. Stopover sites were farther from the mainland coast and closer to herring spawn sites than random sites, whereas physical shoreline habitat attributes were generally poor predictors of site use. The geography and resource availability within southeast Alaska provides unique and potentially critical stopover habitat for spring migrating surf scoters. Our work identifies specific sites and habitat resources that deserve conservation and management consideration. Aggregations of birds are vulnerable to human activity impacts such as contaminant spills and resource management decisions. This information is of value to agencies and organizations responsible for emergency response planning, herring fisheries management, and bird and ecosystem conservation.

KEY WORDS habitat, *Melanitta perspicillata*, satellite telemetry, southeast Alaska, spring migration, stopover, surf scoter.

Many migratory birds acquire energy and nutrient reserves at spring stopover sites, and the availability and quality of resources at these sites may have implications for success during subsequent stages of the annual cycle (Ankney and MacInnes 1978, Alisauskas and Ankney 1992, Warnock and Bishop 1998, Smith and Moore 2003, Morrison and Hobson 2004). Several studies have described cross-seasonal effects of spring habitats on reproductive performance by migratory waterfowl (Lovvorn et al. 2003, Reed et al. 2004, Schmutz et al. 2006). Because spring stopover sites often provide the energy and nutrients required for reproduction, it follows that population dynamics may be influenced by habitat quality at these sites.

Recent reviews and commentaries have highlighted the need for research addressing habitat use and resource availability along migration routes (Webster et al. 2002, Mehlman et al. 2005, Arzel et al. 2006, Drent et al. 2006), which requires identification of key sites used during spring migration, as well as an understanding of the habitat features that make these sites attractive to migrants. The importance of stopover sites has been defined by a number of criteria, often including the duration of stay (e.g., a brief stopover compared to longer term staging) or the relative value of a site for energy acquisition (Skagen and Knopf 1994, Farmer and Parent 1997, Warnock and Bishop 1998).

Surf scoters (*Melanitta perspicillata*) are sea ducks that winter along the Pacific and Atlantic coasts of North America and breed in low densities across the boreal forests of Alaska and Canada (Savard et al. 1998, Takekawa et al. 2011). Recent work by De La Cruz et al. (2009) provides a thorough synthesis of Pacific surf scoter migration patterns, routes, and chronology. In general, most marked scoters follow 2 major routes to the breeding area: either a southern inland route involving staging in Puget Sound and the Strait of Georgia and direct migration inland or a northern coastal route characterized by smaller movements along the Pacific coast of British Columbia and Southeast Alaska followed by inland migration from southeast Alaska. However, little is known about the specific stopover sites used by surf scoters during spring migration along the Pacific coast. Identification of discrete areas used during spring migration has been previously limited by the large geographic scale involved, the remoteness of areas used, the continuous nature of potential stopover habitat along the Pacific coast, and the lack of information about scoter distributions during spring. Habitat conditions and nutrient reserve levels during spring migration have been suggested as important factors affecting broad-scale and long-term population declines in other waterfowl (Anteau and Afton 2004). Scoter populations have been declining continent-wide (Nysewander et al. 2003) and

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this phenomenon could be similarly related to changes in spring stopover habitats. Hence, identification of key stopover sites and their associated habitat attributes are important for population management.

Satellite telemetry provides a useful and unbiased tool for describing migration routes and identifying stopover sites over a large geographic range. We integrated satellite telemetry data from studies conducted at 4 major Pacific coast wintering areas to track surf scoters using spring stopover sites in southeast Alaska. Specifically, our objectives were to 1) identify stopover sites in southeast Alaska and 2) identify habitat attributes of stopover sites that differ from random sites, to provide insight into features that influence use of stopover sites.

STUDY AREA

The wintering range of surf scoters along the Pacific coast extends from Alaska to Baja California, Mexico (Savard et al. 1998). We compiled information from studies of surf scoters captured and marked at wintering areas throughout this range. These wintering areas included San Quintin Bay, Baja California, Mexico (116.0°W, 30.4°N); San Francisco Bay, California, USA (122.4°W, 37.8°N); Puget Sound, Washington, USA (122.4°W, 47.5°N); and the Strait of Georgia, British Columbia, Canada (122.4°W, 49.3°N). In spring, surf scoters migrate along the Pacific coast from these wintering areas to northern breeding areas throughout the inland boreal forest of western Canada and Alaska (Savard et al. 1998).

We considered all of southeast Alaska as our study area and examined stopover site use within this region (Fig. 1). Southeast Alaska is comprised of a large, complex archipelago adjacent to a mountainous mainland. These landforms create an extensive network of protected waterways and nearshore marine areas that provide a wide variety of habitat types, and the region is a major migration route for many bird species in the Pacific Flyway.

METHODS

Capture and Marking

We captured surf scoters on their wintering grounds between November and March, 2002–2006, using a floating mistnet (Kaiser et al. 1995, Lewis et al. 2005) or a netgun (Mechlin and Shaiffer 1980). We banded, weighed, and implanted 75 adult surf scoters (63 F, 12 M) with coelomic platform-transmitter-terminal (PTT) satellite-transmitters following standard procedures (Mulcahy and Esler 1999; Table 1). This transmitter implantation method has been shown to perform well for scoters relative to other attachment methods (Iverson et al. 2006). We released marked birds after a recovery period of $\geq$1 hr. We programmed PTT transmitters with duty cycles to transmit location data for 6–8 hr and turn off for 48–96 hr.

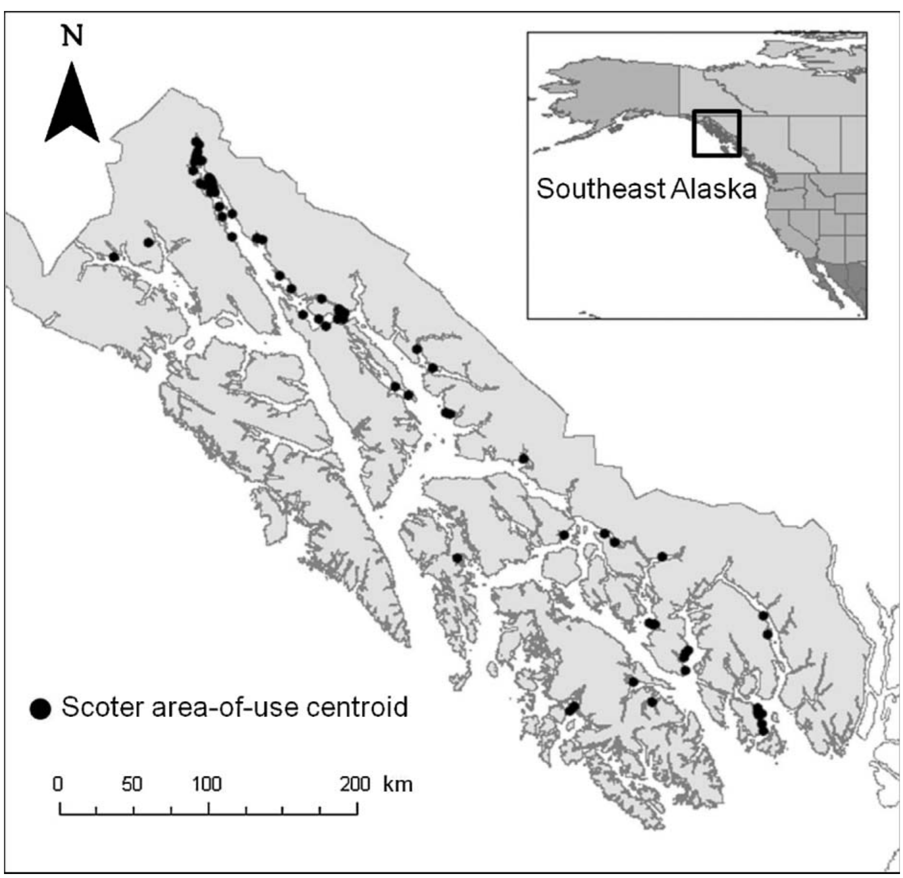

Figure 1. Centroids of stopover areas of use ($n = 72$) of 37 satellite-marked spring migrating surf scoters in southeast Alaska, 2003–2006. We defined an area of use as a series of $\geq$2 consecutive selected locations (representing a location on 1 day) within 22 km of each other.

Table 1. Surf scoters marked with platform transmitter terminal (PTT) satellite transmitters in 2003–2006 from 4 wintering areas: San Quintin Bay, Baja California, Mexico (SQ), San Francisco Bay, California, USA (SF), Puget Sound, Washington, USA (PS), and Strait of Georgia, British Columbia (SG).

	Wintering area							
	SQ		SF		PS		SG	
Yr	Marked[a]	Stopover[b]	Marked[a]	Stopover[b]	Marked[a]	Stopover[b]	Marked[a]	Stopover[b]
2003	0	0	8	5	0	0	0	0
2004	0	0	0	0	7	2	0	0
2005	2	0	9	2	16	5	8	5
2006	3	3	11	8	11	7	0	0
Total	5	3	28	15	34	14	8	5

[a] Total no. of transmitter-marked scoters that left wintering areas and were active through spring migration.
[b] Total no. of transmitter-marked scoters that were used in stopover analyses, not including birds that migrated using other inland migratory routes, died, or experienced transmitter failure.

All capture and marking work followed guidance from Animal Care and Use Committees and with permits from California Department of Fish and Game (Takekawa: SC-004857, De La Cruz: SC-003855), Canadian Wildlife Service (EC Scientific Permit 59-02-0761, 59-03-0430, and 59-04-0272), United States Fish and Wildlife Service (MB102896-1), USGS Federal Banding Permit (22911), Simon Fraser University (Animal Care and Use Protocol 731B-04), Washington Department of Fish and Wildlife United States Department of Interior master banding permit 06508, and Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) through Ducks Unlimited de Mexico and Permit 7232.

We obtained satellite transmitter locations from the Argos data system, which estimated positions by calculating the Doppler-effect shift with receivers on National Oceanic and Atmospheric Administration (NOAA) weather satellites. We compiled location data from all PTT-marked surf scoters and filtered the data spatially and temporally to select only coastal spring migration locations in southeast Alaska (Fig. 1). We classified PTT locations by estimated accuracy and number of signals. For Location Classes (LC) 3, 2, 1, and 0, in which $\geq$4 messages are received by the satellite, Argos rates accuracy as <150 m, 150–350 m, 350–1,000 m, and >1,000 m, respectively. Accuracy was not provided for LC A (3 messages), B (2 messages), and Z (latitude and longitude often provided if >1 message received). Location data usually included >1 useable location per bird in a transmission day; we chose one Selected Location for each bird per transmission day according to criteria described in Miller et al. (2005), which favor locations with LC 3, 2, and 1 but recognize that accurate locations are obtained for a large proportion of detections within all Argos location quality classes. Although less conservative than filtering locations of lower location quality classes, accepting more location classes allowed us to maximize the number of Selected Locations during the short migration period, and 91% of Selected Locations were of LC 1 or higher.

Habitat Data

We assembled Geographic Information System (GIS) data from existing data sources on habitat features of southeast Alaska that we considered potentially important predictors of surf scoter stopover habitat use. We assumed that use of stopover sites was related to the habitat attributes of those sites and that attributes of used sites are related to habitat quality and profitability. We used habitat attributes to represent environmental variables related to general resource availability throughout southeast Alaska. In addition to resource availability, we considered geographical context, such as the proximity to natural breaks and migration routes (Mehlman et al. 2005).

Habitat use by surf scoters during winter is well documented and strongly related to physical habitat attributes and associated bivalve prey distribution and densities (Žydelis et al. 2006). We obtained physical habitat attribute data from a shoreline ecosystem database compiled by Audubon Alaska and The Nature Conservancy (Albert and Schoen 2007). This dataset characterizes physical habitat within southeast Alaska using information from multiple sources and integrates information about the physical attributes, wave exposure, and bathymetry of the study area shoreline (Albert and Schoen 2007). The habitat attributes summarized for each shoreline segment included the maximum depth within 1 km of shore (depth), shoreline segment length (length), maximum shoreline width between high tide and low tide (width), dominant substrate type (substrate), and an exposure index (exposure). We divided substrate into 12 categories, including rocky shore and cliff, rock platform, rock with gravel beach, rock with sand and gravel, rock with sand beach, gravel beach, sand and gravel beach, sand and gravel flat, sand beach, tide flat, salt marsh, and no data. Because scoter habitat use is related to bivalve prey distribution, the shoreline habitat database did not include data on this important variable, and we could not obtain continuous bivalve distribution data for all of southeast Alaska for the years of our study, we developed a proxy for distribution and availability of blue mussels (*Mytilus edulis*). We considered the 5 categories containing rock as "rocky substrate" for our analyses. We intended the amalgamation of these categories into one to serve as a rough proxy for distribution and availability of blue mussels, which occur primarily on hard rock surfaces and would be unlikely to be found on the other substrate types. The exposure index is an estimate of wave energy based on the total area visible over water from each shoreline segment and increases with increased wave energy and exposure (Albert and Schoen 2007). In addition, we used this dataset to create a data layer representing the distance to the outer coast of southeast Alaska by selecting only the westernmost shoreline segments (the shoreline segments with the highest exposure index) within the study area. We created this data layer to evaluate site use as a function of distance to the outer coast, which may be relevant to migrating scoters in terms of providing a shortest possible route to inland breeding areas or if there are differential distributions of mussels in an east–west direction.

Presence of streams may influence prey distribution and provide fresh water for birds feeding on marine invertebrates (Nystrom and Pehrsson 1988). We obtained information on stream distribution within southeast Alaska from the United States Geological Survey (USGS) Hydrographic Dataset and created a layer that included only streams that intersect with the ocean. During late winter and early spring, Pacific herring (*Clupea pallasi*) spawn along localized sections of shoreline within southeast Alaska. Only 1.8% of the British Columbia shoreline is utilized by spawning herring in a typical year; it is likely that the proportion of shoreline utilized in southeast Alaska is similar (Hay and McCarter 2006). Surf scoters are known to aggregate at herring spawning sites and forage on abundant and energy-rich eggs (Haegele 1993, Vermeer et al. 1997, Bishop and Green 2001, Sullivan et al. 2002, Rodway et al. 2003), but its influence on stopover site use during spring migration has not previously been quantified. To evaluate site use as a function of distance to herring spawn sites, we compiled the distribution of major herring spawn locations in 2003–2006 from the Alaska Department of Fish and Game. Spawn distributions were typically consistent between years (typically within <5 km of the previous and following year's distribution), so we combined spawn distributions in all 4 years into one layer representing herring spawn distribution within all study years.

Data Analyses

Identification of stopover sites.– We used ArcGIS 9.1 to analyze Selected Locations to determine migration stops on 1:250,000 digital charts. We defined a stopover event as the act of an individual stopping at a site for rest or refueling during migration. Spatially, we defined stopover events as a series of ≥2 consecutive Selected Locations within 22 km of each other. We based this distance on the 95th percentile of mean distances between sequential locations for radio-marked surf scoters in late winter (Lok et al. 2008) and interpreted it as a reasonable non-migratory movement distance within a site. To consider temporal use of sites, we subclassified stopover events as short stopovers if the site was used for 2–7 days and as staging stopovers if the site was used for >7 days (Warnock and Bishop 1998). We recognize the possibility that some short stopover events may have been missed due to transmission rate patterns and duty cycles of PTTs and that stopover durations are minimum estimates.

For each stopover event, we delineated an area of use for each individual by creating either a minimum convex polygon (≥3 locations) or a line (2 locations). We calculated the centroid of each area of use using the XTools Pro Extension for ArcGIS 9.1 (Data East 2007). We defined stopover sites as sites where centroids of the areas of use of ≥2 individuals were within 5 km of each other. We chose a 5-km distance to account for variation in PTT location accuracy and to encompass areas of use of ≥2 individuals. Given the limited number of satellite-tagged individuals, we considered use by 2 individuals adequate to represent selection and use of a specific site. We calculated a centroid of each stopover site from the individual centroids of all areas of use within the 5-km radius.

Habitat attributes of stopover sites.– To identify habitat features associated with stopover sites, we contrasted habitat attributes of 13 identified stopover sites with those of a set of 50 sites randomly distributed throughout the study area. We selected a 5-km radius to be large enough to encompass the locations of ≥2 individuals and the associated shoreline habitat and to be small enough identify a discrete area and minimize overlapping of sites. We created random plot centroids along the shoreline using the random sampling tool in Hawth's Analysis Tools (Beyer 2004). We fixed stopover site centroids related to the shoreline using the snap to line tool. We created 5-km radius plots around important stopover sites and random sites using the Buffer Wizard in ArcGIS 9.1. We then intersected GIS habitat layers with the plots and summarized the following shoreline habitat attributes for each plot: length, depth, width, exposure, percent rocky substrate, distance to outer coast, and distance to herring spawn. We calculated mean weighted depth, width, and exposure by weighting each shoreline segment value by the length of the segment and dividing the sum of weighted segments by the total plot shoreline length. We determined percent rocky substrate within each plot by calculating the length of all segments with a rocky substrate and dividing by the total shoreline length within the plot. We calculated the number of stream outlets within each plot. We determined distance to outer coast and distance to herring spawn as the minimum distance from the center of each plot to the outer coast or herring spawn layers, respectively. We examined habitat attribute data for intercorrelation; correlations between predictor variables were all $r < 0.48$.

We used logistic regression models to evaluate the use of stopover sites in relation to habitat characteristics in SAS 9.1 (SAS Institute, Cary, NC). We examined the data for overdispersion by calculating a variance inflation factor for the global model but found that overdispersion was not a concern ($\hat{c} = 0.32$). We used an information theoretic approach to model selection (Burnham and Anderson 2002) and calculated Akaike's Information Criterion adjusted for small sample sizes (AIC_c) for each model within a candidate set. For some models, we grouped habitat attributes into a shoreline suite of predictor variables, which included length, depth, width, exposure, streams, and substrate. The candidate model set consisted of 14 models: 1) length, 2) depth, 3) width, 4) exposure, 5) streams, 6) rocky substrate, 7) shoreline, 8) coast, 9) spawn, 10) coast + spawn, 11) coast + shoreline, 12) spawn + shoreline, 13) coast + spawn + shoreline, and

14) a null model. We wanted to consider the relative effects of shoreline habitat attributes individually and to contrast the importance of physical shoreline features of used sites with food resource features (distance to spawn) and geographic features (distance to outer coast), in addition to considering additive combinations of physical attributes, resource availability, and geography. We compared the AIC_c value of each model to that of the best-fitting model (ΔAIC_c) to assess relative support for each candidate model. We also calculated AIC_c weights (w_i), which indicate the relative support for each model within the candidate model set.

RESULTS

Identification of Stopover Sites

Of the 75 satellite-marked surf scoters that left wintering areas, 37 individuals made migratory stopovers in southeast Alaska. The remainder of the satellite-marked birds migrated using other inland migratory routes and did not use southeast Alaska during migration (Table 1). Analyses and results were limited to location data from these 37 individuals. For these birds, we documented 72 stopover events in southeast Alaska (Fig. 1). Where stopovers of $\geq$2 individual birds overlapped, we identified spatially defined stopover sites within southeast Alaska (Fig. 2). We identified 14 stopover sites, which were used by 35 individual satellite-marked scoters in 62 stopover events (Table 2). Only 14% of individual stopover events were not located within an identified site, and most (95%) marked surf scoters using southeast Alaska visited $\geq$1 of these sites during spring migration. We identified stopover sites at Lynn Canal, Berners Bay, Eagle Harbor, Stephens Passage, Gastineau Channel, Young Bay, Tracy Arm, Seymour Canal, Hobart Bay, Eastern Passage, Vixen Inlet, West Behm Canal, Klawock Inlet, and Annette Island (Fig. 2). We identified the area of Lynn Canal, including Chilkat Inlet, Chilkoot Inlet, and Taiya Inlet, as one important stopover and staging site although it did not strictly meet our criteria. We were unable to identify a distinct 5-km radius circumscribing this important stopover site due to the many overlapping areas of use (22 stopover events, 17 individuals) and instead considered the entire area one important site. Because of the unique nature of this area, and the inability to define it as a discrete stopover site, we did not include it in the habitat analysis.

Temporally, we identified stopovers events as 35 short stopover events (27 individuals) and 37 staging stopover events (32 individuals; Table 2). Approximately half (49%; $n = 37$) of marked surf scoters made staging stopovers within southeast Alaska. Most individuals (54%) stopped (2–7 days) and staged (>7 days) at least once in southeast Alaska, whereas 19% only stopped and 27% only staged. Most of identified sites were used in $\geq$2 years, and 3 sites were used in $\geq$3 study years (Table 2).

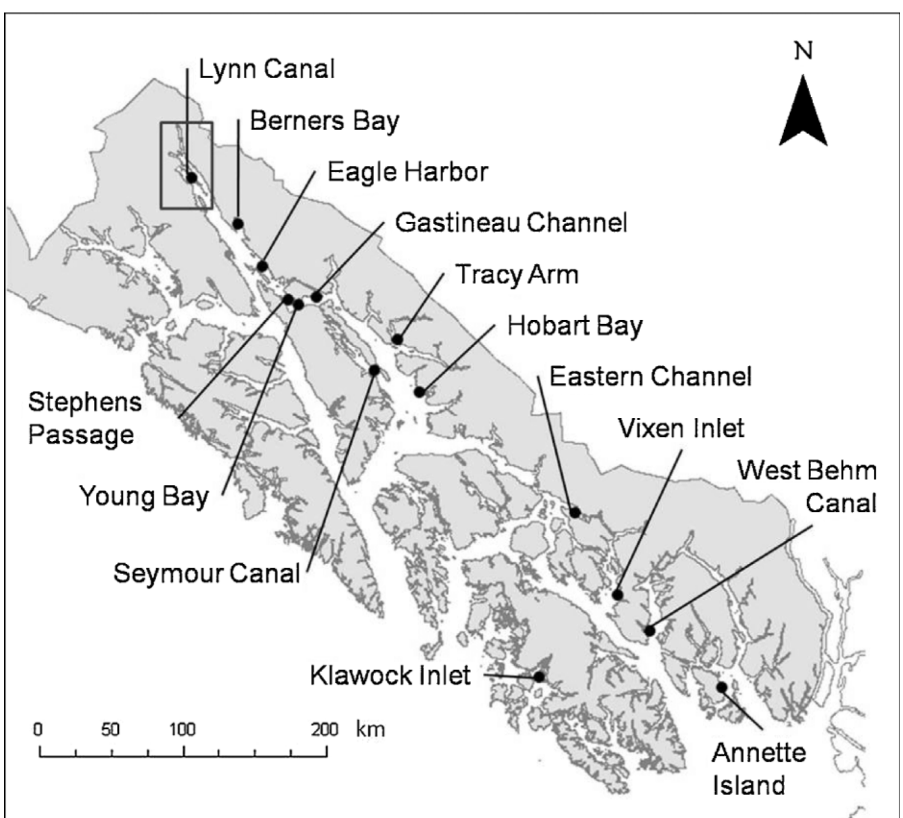

Figure 2. Important stopover sites of satellite-marked spring migrating surf scoters in southeast Alaska, 2003–2006. The box highlights Lynn Canal, which was a unique and heavily used stopover site.

Table 2. Migration stopover sites of satellite marked spring migrating surf scoters in southeast Alaska during 2003–2006. We ordered sites by latitude from north to south.

Stopover site	Coordinates	Individuals	Stopover events			Yr of use
			Total	2–7 days	≥7 days	
Lynn Canal	59.138°N, 135.342°W	17	22	15	7	2003, 2005, 2006
Berners Bay	58.778°N, 134.972°W	2	2	2	0	2003, 2006
Eagle Harbor	58.481°N, 134.827°W	2	2	0	2	2005, 2006
Stephens Passage	58.242°N, 134.654°W	2	2	2	0	2005, 2006
Gastineau Channel	58.205°N, 134.319°W	7	7	0	7	2003, 2005, 2006
Young Bay	58.187°N, 134.548°W	2	2	1	1	2003, 2006
Tracy Arm	57.796°N, 133.558°W	2	2	0	2	2003, 2006
Seymour Canal	57.657°N, 133.917°W	2	2	2	0	2006
Hobart Bay	57.442°N, 133.501°W	2	2	1	1	2005, 2006
Eastern Passage	56.426°N, 132.230°W	2	2	1	1	2003, 2006
Vixen Inlet	55.851°N, 132.092°W	3	3	3	0	2004, 2006
West Behm Canal	55.576°N, 131.876°W	4	4	4	0	2003, 2006
Klawock Inlet	55.521°N, 133.192°W	2	2	1	1	2005
Annette Island	55.092°N, 131.335°W	8	8	7	1	2003, 2004, 2005, 2006

Habitat Attributes of Stopover Sites

Stopover site use was strongly related to small distances from herring spawn and to greater distance from the outer coast. Within the candidate model set, the coast + spawn model best explained stop site use ($w_i = 0.97$), with no other model receiving strong support (Table 3). Models with the highest ΔAIC_c values included distance to coast and distance to spawn parameters, suggesting that the distance from the outer coast and distance from herring spawn provided the best explanation of variation between stopover and random sites. Because the model with distance to coast and distance to spawn parameters received such strong support, we based our inference entirely on that model. The best supported model showed no evidence of lack of fit based on a Hosmer and Lemeshow test ($\chi^2 = 5.56$, df = 8, $P = 0.70$) and a classification table indicated that, at a cut-off probability of 0.5, 89% of observations were correctly classified by the model. Parameter estimates (±SE) from the best supported model were: 1.827 (±1.497) − 0.052 (±0.021) distance to coast + 0.160 (±0.057) distance to spawn, where distances are measured in kilometer.

Stopover sites were located an average of <10 km away from spawn sites, whereas random sites were located >50 km away (Table 4). Eight of the identified stopover sites (Berners Bay, Young Bay, Seymour Canal, Hobart Bay, Vixen Inlet, West Behm Canal, Klawock Inlet, and Annette Island) had well documented herring spawn activity in recent history. On average, stopover sites were located approximately twice as far from the outer coast as were random sites. Stopover sites also contained fewer streams were more exposed than random sites, although these parameters contributed far less to model fit than herring spawn and distance to outer coast.

DISCUSSION

We identified 14 stopover sites for spring migrating surf scoters in southeast Alaska. Most marked surf scoters made multiple stopovers within southeast Alaska, indicating that

Table 3. Akaike's Information Criterion (AIC) results from logistic regression models assessing habitat attribute variation in relation to whether plots were surf scoter stopover sites ($n = 13$) in southeast Alaska in 2003–2006 or random points ($n = 50$).

Model	No. of parameters[a]	ΔAIC_c[b]	AIC_c	w_i	McFadden's R^2
Coast + spawn	3	0.00	28.27	0.97	0.66
Spawn	2	7.70	35.97	0.02	0.51
Spawn + coast + shoreline[c]	9	10.30	38.57	0.01	0.73
Spawn + shoreline[c]	8	13.72	41.98	0.00	0.63
Coast + shoreline[c]	8	23.61	51.88	0.00	0.48
Coast	2	26.11	54.37	0.00	0.22
Streams	2	33.86	62.13	0.00	0.10
Exposure	2	33.88	62.15	0.00	0.10
Length	2	37.23	65.50	0.00	0.04
Shoreline[c]	7	37.77	66.04	0.00	0.22
Null	1	37.94	66.21	0.00	
Width	2	39.61	67.88	0.00	0.01
Rocky substrate	2	40.03	68.29	0.00	0.00
Depth	2	40.08	68.34	0.00	0.00

[a] No. of parameters includes +1 for intercept.
[b] We ranked models according to Akaike's Information Criterion values (AIC_c adjusted for small sample size), which indicate the relative support for each model, given the data. w_i indicates Akaike weight.
[c] Shoreline models include length, depth, width, exposure, streams, and percent rocky substrate.

Table 4. Habitat attributes of important stopover sites of spring-migrating surf scoters in southeast Alaska during 2003–2006 ($n = 13$) in comparison to random sites ($n = 50$). We summarized attributes by 5-km-radius plots. We report averages with 95% confidence limits (±CL).

	Stopover sites			Random sites		
Predictor variable	**Average**	**CL**	**Range**	**Average**	**CL**	**Range**
Distance to herring spawn (km)	8.2	6.2	0.01–30.3	47.2	7.9	4.5–145.8
Distance to outer coast (km)	88.2	17.8	30.1–124.8	45.7	9.8	0–144.4
Depth (m)	79.5	27.7	22.9–186.7	79.1	19.8	1.7–309.5
Width (m)	118.6	47.9	29.7–264.7	153.5	54.6	27.0–779.8
Length (km)	28.9	7.6	3.0–54.0	40.4	7.9	6.4–163.8
Rocky substrate (%)	48.3	13.9	3.4–78.3	50.1	7.8	0.9–99.1
Streams (no.)	8.5	3.5	0–20	19.9	6.1	0–109
Exposure index	212.5	17.2	172.1–274.1	171.1	16.3	100.0–298.3

this region was heavily used and likely important for migrating scoters. Most marked individuals stopped at identified stopover sites, and one site, Lynn Canal, was used for stopovers by approximately half of the scoters within southeast Alaska. Most identified stopover sites were used in ≥2 years, indicating reasonably consistent use among years, which suggests that specific sites are used for stopovers. We are confident that migration patterns of marked scoters are indicative of stopover site use by surf scoters in general, given the gregarious nature of scoters and observations of large aggregations of scoters at many of these sites. Radiotelemetry and survey observations in 2005 and 2006 confirm that southeast Alaska is used by tens of thousands of surf scoters during spring migration (Lok 2008).

We found a strong relationship between scoter stopover sites and the combination of decreasing distance to herring spawn sites and increasing distance to the outer coast. Herring spawn availability may be an important habitat attribute because it is an easily accessible and energy-rich food source that coincides with the need for abundant energy for fueling migration and subsequent reproduction (Paul and Paul 1999, Bishop and Green 2001, Bond and Esler 2006, Willson and Womble 2006). Increased distance from the outer coast may be important for several reasons. Much of the herring spawning activity in southeast Alaska occurs along the inner coast, and scoter habitat use may mirror habitat use by spawning herring. Although we found that physical shoreline attributes were generally poor predictors of site use within southeast Alaska during spring, habitat use by surf scoters during winter is related to shoreline characteristics and associated bivalve prey distribution and densities (Žydelis et al. 2006). Recent habitat mapping in southeast Alaska indicates that distribution of blue mussels is more continuous in regions closer to the mainland coast (ShoreZone Program 2006), which would provide predictable food resources for scoters. From a migratory perspective, the inside coast is more sheltered and may provide access to preferred migration pathways inland.

Stopover sites were used for both short stopovers and longer duration staging, and most individuals both stopped and staged within southeast Alaska. The frequent and consistent use of Lynn Canal by many individuals indicates that it is an important stopover site for migrating surf scoters. More individuals staged here than at any other site, suggesting that this site may serve more as a longer term staging site than a short stopover stepping stone. Many of the used sites are well documented herring spawn sites; however, Lynn Canal was a particular exception in that there was no documented herring spawn within the site during study years, having experienced marked declines in herring stocks in recent years (Willson and Womble 2006). Geographical context may be an important factor in the use of Lynn Canal as a stopover and staging site, given its location as the most northeastern waterway in southeast Alaska. This region is likely a natural break for scoters to take advantage of abundant marine resources and gauge weather conditions before turning inland to migrate into the boreal forests of northern Canada. Overall, stopover site use appears to be influenced by multiple factors, suggesting that that not all spring migration habitats serve the same stopover function and the aggregate value of these sites must be considered (Mehlman et al. 2005).

MANAGEMENT IMPLICATIONS

Management and conservation of spring migration habitat requires management of individual identified stopover sites, the aggregate value of multiple spring migration habitats, and the resources that make these sites attractive to migrants. Aggregations of birds, such as the scoters within Lynn Canal during spring migration, are vulnerable to stochastic natural events and human activity impacts (Ford et al. 1982). Of the 14 sites we identified as stopovers for surf scoters, only Berners Bay has been identified as an important bird area (IBA; Audubon 2008). Given the many scoters from throughout the Pacific surf scoter population using this specific area during such an important period in their annual cycle, scoters in this region may be particularly vulnerable to events such as contaminant spills.

The strong relationship between stopover sites and herring spawn emphasizes the need for integrating management of herring fisheries with management of sea ducks. Several herring stocks in southeast Alaska have decreased to levels that are no longer commercially viable (Willson and Womble 2006). The identification of Berners Bay as an IBA is largely based on its importance to numerous species that depend on Pacific herring runs, which were once widespread throughout Lynn Canal but that now occur mainly in Berners Bay (Audubon 2008). Understanding the importance of herring spawn during stopover and staging and the energy requirements for migration and reproduction is critical for management and conservation of scoter populations, as well as other species that use this ephemeral spring resource.

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