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Movements of Pre-migratory Surf and White-winged Scoters in Response to Pacific Herring Spawn

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Abstract.—We documented the movement and distribution patterns of wintering Surf Scoters (*Melanitta perspicillata*) and White-winged Scoters (*Melanitta fusca*) in relation to herring spawn events in the Strait of Georgia, British Columbia. Radio-telemetry and surveys were conducted in Baynes Sound, an important wintering area where scoters feed primarily on clams. In early March, herring spawn events in areas adjacent to Baynes Sound provide a short-term pulse of abundant and easily accessible food, which could affect habitat use by wintering scoters from Baynes Sound. Radio-marked Surf Scoters and White-winged Scoters exhibited limited movements during winter, in contrast to the spring herring spawn season, when both scoter species moved greater distances to access herring eggs. Most individuals were located near spawning locations at least once during the spawning season, and the majority of telemetry locations were close to spawning sites, with Surf Scoters showing a higher association with spawn for both metrics. A marked decrease (66-98%) in the abundance of both scoter species in Baynes Sound was observed coincident with spawn initiation in adjacent sites. We conclude that scoters altered their movement and habitat use patterns in spring to take advantage of herring roe, an energy-rich food source. This dramatic change in behaviour suggests that herring spawn may be of particular importance to these species. *Received 27 August 2007, Accepted 24 November 2007.*

Key words.—*Clupea pallasi*, habitat use, herring spawn, movement, *Melanitta fusca*, *Melanitta perspicillata*, sea duck, Surf Scoter, White-winged Scoter.

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Many animals modify their habitat use to take advantage of seasonally available foods (Odum *et al.* 1995) that may enhance survival or reproduction, or fuel migration (Botton *et al.*

spawn sites, the influence of herring spawn on distributions and individual movements

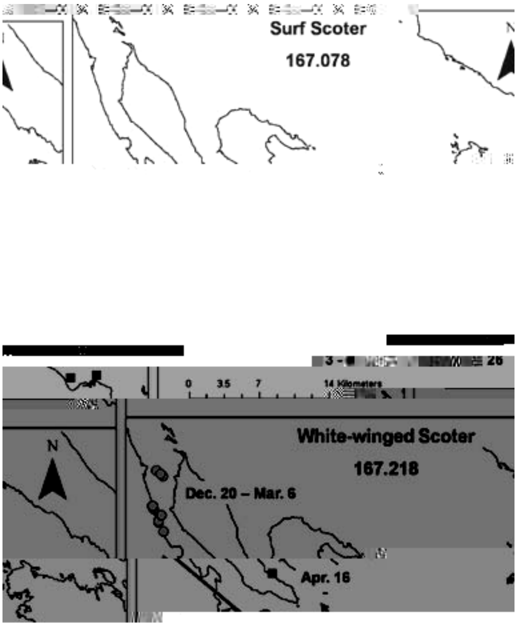

Figure 2. Examples of radio-telemetry locations and

out in ArcView 3.3 using the Animal Movement extension (AME) (Hooge and Eichenlaub 1997).

Scoter Distribution Surveys

Surveys were conducted in Baynes Sound to evaluate seasonal variation in scoter abundance and distribution patterns. The study area (from Comox to Deep Bay) was divided into survey polygons approximately 1.5 km in length that extended 800 m from shore (Fig. 1). Polygons were delineated according to habitat and anthropogenic characteristics of the environment. Counts were made using spotting scopes from one, two, or three observation points along the shore of each polygon. Surveys were conducted approximately biweekly from October to April during winters 2002-2003 and 2003-2004. Surveys were carried out only under good visibility conditions (i.e., surveys were suspended during fog, snow, heavy rain or winds exceeding ten knots). Surveys were not conducted at herring spawn sites outside Baynes Sound.

Data Analyses

Movement metrics. The mean distance between consecutive locations, or interfix distance, was calculated using all locations for each individual using the "Location Statistics" function of AME (Kirk *et al.* 2008). Interfix distances during winter and spawn were calculated for any individual with three or more locations within a season (Surf Scoter N = 66 winter, N = 32 spawn; White-winged Scoter N = 112 winter, N = 51 spawn). Data across years were combined based on the findings of Kirk *et al.* (2008) that winter movements within Baynes Sound were consistently small. In addition, this metric was calculated continuously through the study period for individuals that had at least three locations in both winter and spawn seasons (Surf Scoter N = 28, White-winged Scoter N = 48). The interseason distance, defined as the distance between the harmonic mean location (i.e., centre of activity) for each season (Smith *et al.* 1999), was calculated for individuals that had at least three locations in both winter and spawn seasons. The X and Y coordinates (easting and northing) of the harmonic mean location within each season were used to calculate the interseason distance (d) as:

$$d = [(X_{winter} - X_{spawn})^2 + (Y_{winter} - Y_{spawn})^2]^{1/2}$$

Least squares general linear models were used to evaluate variation in interfix distances in relation to season and individual attributes for both Surf Scoters and White-winged Scoters. An information theoretic approach to model selection (Burnham and Anderson 2002) was used to calculate Akaike's Information Criterion adjusted for small sample sizes (AIC_c) for each model within a candidate set. The candidate model set used for each species separately consisted of the following models: season alone, individual (sex and age class) alone, season and individual additively, a season-individual interaction (season*sex*age), and a null model. The individual parameter included a sex variable (male or female) and an age variable (hatch-year or adult). The AIC_c value of each model was compared to that of the best-fitting model (ΔAIC_c) to assess the relative support for each candidate model. AIC_c weights, which indicate the relative support for each model within the candidate model set, were also calculated. The statistical package SAS (SAS Institute 2003) was used to conduct analyses.

Habitat use metrics. To estimate the fraction of scoters using spawn, the proportion of marked individuals present during the spawn season that were located at least once within specified distances of known herring spawn sites was determined. Shapefiles of spawn presence in the study area for 2002, 2003, and 2004 were obtained from the Department of Fisheries and Oceans, and buffers of one km and two km around these themes were created in ArcView 3.3. Scoter locations were selected and classified in relation to known spawn sites (≤1 km, ≤2 km, >2 km) for each year.

The proportion of an individual's total number of locations during the spawn season that were within the vicinity of spawn using one km and two km buffers was determined to calculate an index of spawn use by individual scoters. Spawn use was calculated for all individuals with three or more locations within the spawn season (Surf Scoter N = 32, White-winged Scoter N = 51).

Constancy metrics were calculated for marked scoters wintering in Baynes Sound to estimate the likelihood of movement to alternate habitats during winter, in contrast to measures of movement to herring spawn sites. A high constancy rate indicates a more constant presence within the Baynes Sound study area. Individuals confirmed as either mortalities or radio-failures were excluded. The status (present or not detected) of each individual within the study area was determined for each week throughout the winter period (Surf Scoters N = 60, White-winged Scoters N = 100). The fraction of marked individuals that were: (1) present in Baynes Sound every week, (2) not detected for one week only, or (3) not detected for two weeks or more were calculated. To calculate a mean constancy rate for each species, the proportion of "present" locations for each individual throughout the winter period was determined. To estimate the fraction of scoters that may have migrated from the study area (including Baynes Sound and spawning areas) entirely rather than moving to spawn sites, the fraction of individuals not located at any time during the spawn period was determined.

Numerical response. To evaluate seasonal variation in overall scoter numbers within the study area, the total number of Surf Scoters and White-winged Scoters in all survey polygons for each survey for each winter and species was calculated separately. To infer the degree of movement away from Baynes Sound, and presumably to herring spawn sites, the percent change in scoter numbers between surveys immediately preceding and then immediately following spawn initiation was calculated.

RESULTS

Movement Response

Variation in interfix distance was strongly related to season; the season alone model received an AIC_c weight of 0.87 for both species (Table 1). There was little evidence that interfix distance varied by age or sex for either species. Both Surf Scoters and White-winged Scoters moved much longer distances between consecutive observations during spawn than during winter (Table 2). Spawn season mean interfix distances were nearly ten times greater than winter distances for Surf Scoters and more than three times greater for White-winged Scoters. On a continuous time scale, both Surf Scoters and White-winged Scoters showed a marked increase in interfix distances at the initiation of spawn (Fig. 3), with several individuals from both species exhibiting increased movements just prior to spawn initiation. The difference between winter and spawn harmonic mean locations also differed by species, with Surf Scoters moving longer distances between seasons than White-winged Scoters (Table 2). On average Surf Scoters moved more than 17 km, and White-winged Scoters moved more than ten km away from winter foraging sites to spawn locations. Therefore, the interseasonal movements of scoters (winter to spawn) were up to ten times greater in distance than average winter movements.

Habitat Use

The majority of individuals (78-91%) of both species were located close to spawn at least once during the spawn period, although Surf Scoters showed a slightly higher proportional use of spawn than White-winged Scoters (Table 3). The proportion of individual locations within the vicinity of spawn differed by species; the mean individual spawn use by Surf Scoters (73 ± 5% of locations within one km, 82 ± 4% within two km) was higher than that of White-winged Scoters (53 ± 4% within 1 km, 60 ± 4% within 2 km).

Most individuals of both species were present in Baynes Sound every week (63% for both species), or not detected once (13% for both species) during winter (Table 4).

Table 1. Summary of AIC results from general linear models assessing variation in mean interfix distance (km) for Surf Scoters and White-winged Scoters during two seasons (winter and spawn) in Baynes Sound, BC. Individual (Indiv) models include sex and age as variables. Number of parameters includes +1 for intercept and +1 for model variance. Candidate models are listed by ΔAIC_c.

		Surf Scoter			White-winged Scoter		
Model	Number of parameters	ΔAIC_c	AIC_c	R^2	ΔAIC_c	AIC_c	R^2
Season	3	0.00	0.87	0.44	0.00	0.87	0.24
Season + Indiv	6	3.93	0.12	0.46	4.03	0.12	0.25
Season*Indiv	9	8.84	0.01	0.47	7.67	0.02	0.27
Null	2	54.87	0.00	0.00	43.27	0.00	0.00
Indiv	5	60.34	0.00	0.01	46.84	0.00	0.02

The mean constancy rates were high for both Surf Scoters (90 ± 2%) and White-winged Scoters (92 ± 2%). Only a small fraction of Surf Scoters (13%) and White-winged Scoters (12%) were undetected during the spawn period, and it is unknown whether they moved beyond the monitoring area or the radios failed.

Numerical Response

Survey totals of Surf Scoters and White-winged Scoters within Baynes Sound showed generally high winter abundance followed by a decrease in numbers in spring (Fig. 4). Herring spawn was first observed on 13

SCOTERS AND

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