Strong evidence for two disjunct populations of Black Scoters *Melanitta americana* in North America

TIMOTHY D. BOWMAN[1,*], SCOTT G. GILLILAND[2], JASON L. SCHAMBER[3], PAUL L. FLINT[4], DANIEL ESLER[4], W. SEAN BOYD[5], DANIEL H. ROSENBERG[3], JEAN-PIERRE L. SAVARD[6], MATTHEW C. PERRY[7] & JASON E. OSENKOWSKI[8]

[1]U.S. Fish and Wildlife Service, Anchorage, Alaska, USA.
[2]Environment and Climate Change Canada, Canadian Wildlife Service, Sackville, New Brunswick, Canada.
[3]Alaska Department of Fish and Game, Anchorage, Alaska, USA.
[4]U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska, USA.
[5]Environment and Climate Change Canada, Science and Technology Branch, Delta, British Columbia, Canada.
[6]Environment and Climate Change Canada, Science and Technology Branch, Quebec City, Quebec, Canada.
[8]Rhode Island Department of Environmental Management, West Kingston, Rhode Island, USA.
*Correspondence author. E-mail: bowmantim38@gmail.com

Abstract

Black Scoters *Melanitta americana* were marked with satellite transmitters on Atlantic and Pacific coasts of North America to examine continental-scale population delineation. Scoters marked on the different coasts did not overlap at any stage of the annual cycle, suggesting that birds in the two regions could be monitored and managed as separate populations: 1) an Atlantic population, which winters along the Atlantic coast and Great Lakes and breeds from northeast continental Canada westward to the Northwest Territories, and 2) a Pacific population, which winters along the Pacific coasts of Alaska, British Columbia and the Pacific northwest states, and breeds in western Alaska. Range maps for Black Scoter could reflect these distributions revealed by satellite telemetry. Our data provide new information on the distribution of Black Scoters in North America, which can be used to improve the design of future surveys.

Key words: Mergini, population delineation, satellite telemetry, sea duck, surveys.

Black Scoters *Melanitta americana* breed in tundra and taiga areas of Alaska and Canada and winter along the Atlantic and Pacific coasts, with small numbers wintering in the Great Lakes and Gulf of Mexico. They occur in North America and also in eastern Siberia, where they are sympatric with their closest relative, the Common Scoter *Melanitta nigra* (Bordage & Savard 2020; Carboneras & Kirwan 2020).

Black Scoters are among the least studied ducks in North America (Baldassare 2014). Bellrose (1980) described the breeding distribution of Black Scoters as an "enigma" and relatively little is known about their biology (Schamber *et al.* 2010; Bordage & Savard 2020). This species nests later than most other North American duck species, so traditional aerial surveys of breeding waterfowl are not properly timed for monitoring Black Scoter breeding attempts, limiting an understanding of population dynamics. Additionally, it is thought that large-scale aerial surveys cover the species' breeding distributions inadequately and, perhaps most importantly, they do not distinguish among the three North American scoter species (Black Scoters, Surf Scoters *Melanitta perspicillata* and White-winged Scoters *Melanitta deglandi*) because of difficulty identifying scoters to species from the air (Bowman 2014; Bowman *et al.* 2015; Koneff *et al.* 2017). Consequently, the sparse information on distribution and trends for this species suggests a long-term decline for Black Scoters in western North America, whilst trends for the Black Scoter in eastern North America are unknown (Bowman *et al.* 2015, but see Flint 2013). Estimates of winter population size are of 460,000 ducks in the Atlantic (Koneff *et al.* 2017) and 160,000–200,000 in the Pacific region (Bowman *et al.* 2015). Although sport and subsistence hunters in the United States and Canada harvest Black Scoters, harvest levels and harvest potential are uncertain, and the latter may differ between the Pacific and Atlantic flyways. Most of the continental sport harvest (> 90%) occurs in the Atlantic Flyway, whereas most harvest in the Pacific Flyway is through subsistence hunting in Alaska (Rothe *et al.* 2015).

Information about population structure and distribution can inform survey design, facilitate interpretation of survey data, provide insights into potential threats and limiting factors, and allow assessment of harvest potential. Recently, Sonsthagen *et al.* (2019) used multiple genetic markers to assess population structure in North American scoter species and found evidence for elevated levels of divergence for Black Scoters between Alaska and Atlantic sampling sites. Additionally, Pearce *et al.* (2019) examined satellite telemetry, genetic and band recovery data and found little overlap in geographic range and band recovery distributions for Black Scoters from Atlantic and Pacific areas. Those data suggest disjunct populations across North America for Black Scoters but there were no satellite telemetry data available from the Pacific region for consideration in Pearce *et al.*'s study. Here we use additional satellite telemetry data to examine distribution patterns, and to assess the evidence for delineation of Black Scoter populations at a continental scale.

Methods

Satellite telemetry was used to compare migration and distribution patterns throughout the annual cycle for Black Scoters that winter on the east and west coasts of North America. We attempted to mark a sample of scoters geographically representative of each coast, although different approaches were used in each area. In the Atlantic region, 94 scoters were marked at a spring staging area on Chaleur Bay, along the New Brunswick/Quebec border in Canada (12 in 2002, nine in 2003, nine in 2004, 16 in 2009 and 48 in 2010), as well as six marked on wintering areas along the coast of Rhode Island, USA in 2010 (see Loring *et al.* 2014), and two wintering in Chesapeake Bay, Maryland, USA in 2003 (Fig. 1). Based on survey data and anecdotal observations, Chaleur Bay was believed to be a primary spring staging area for most, if not all, of the Black Scoters that winter on the Atlantic seaboard.

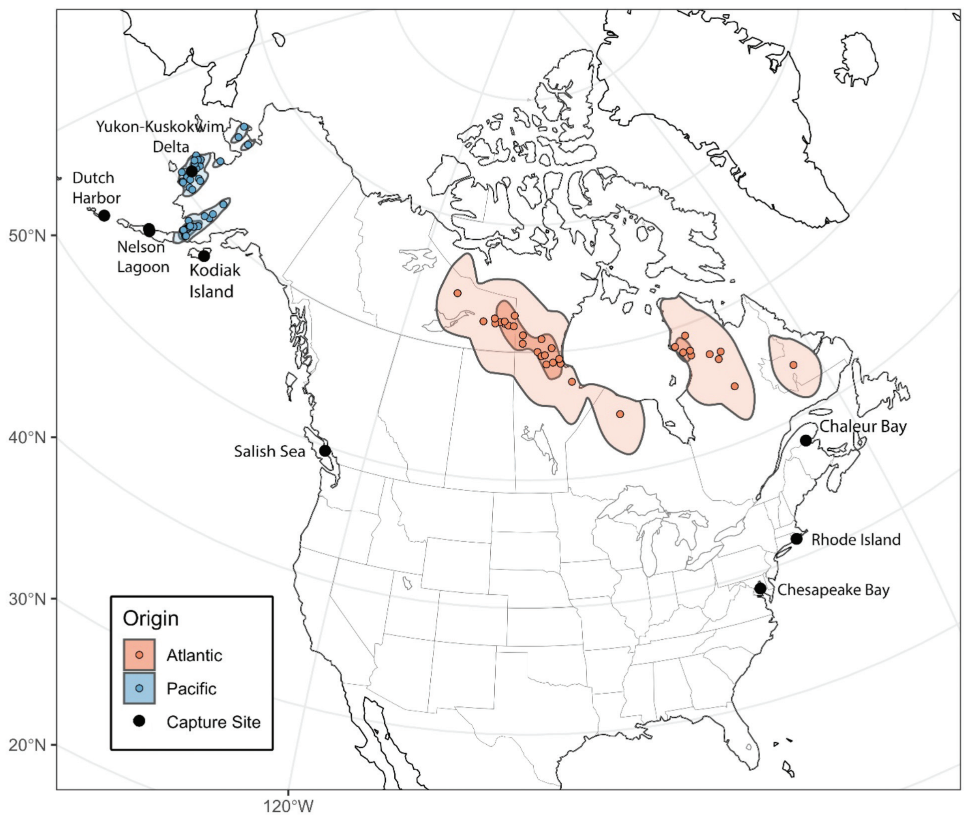

Figure 1. Breeding locations and core breeding ranges of Black Scoters marked with satellite transmitters in North America. Dark shaded areas represent estimates of the 50% (core) and lighter shaded areas represent 95% utilisation breeding distributions.

In the Pacific region, 15 scoters were captured and marked at wintering sites in the Strait of Georgia, British Columbia (five in 2003 and 10 in 2005), Canada, 22 at Kodiak Island, Alaska, USA (eight in 2004, seven in 2005 and seven in 2006), and 10 in Dutch Harbor, Alaska in 2007 (Fig. 1). Thirty-four scoters were marked at a spring staging area at Nelson Lagoon, Alaska (17 in 2003, six in 2004, one in 2015 and 10 in 2015). These birds were presumed to represent Black Scoters that wintered further westward, in the Aleutian Islands or on the Alaska Peninsula (Fig. 1). These wintering and staging areas collectively covered nearly all of the known wintering range for Black Scoters in the Northeast Pacific. Black Scoters were also marked at one breeding site on the Yukon-Kuskokwim Delta, Alaska (10 in 2005 and 10 in 2006; Schamber *et al.* 2010).

Black Scoters were captured using floating mist nets (Brodeur *et al.* 2008) and by night-lighting. Transmitters were implanted surgically in the abdominal cavity by a qualified veterinarian, following the technique described by Korschgen *et al.* (1996). Transmitters weighed 38–45 g, were programmed to transmit for 2–6 h every 3–6 days, and all locations were determined using the Argos system of satellites (CLS America 2020). Sensor data were evaluated to identify mortality (by internal temperature sensor or activity sensor) or battery/tag failure due to low voltage. The last date an individual was known to be alive was recorded for all mortalities during the period of transmitter activity. For all scoters with transmitters that stopped transmitting – either because of low voltage or for unknown reasons – the day after last transmission was considered to be the last date of activity. All data were processed using the Douglas Argos-Filter algorithm (DAF, Douglas *et al.* 2012), available on Movebank (2020). This removed redundant data and utilised Movebank's algorithm that chooses between the primary and secondary Doppler estimates (Douglas *et al.* 2012). Data were omitted for tags that provided locations for < 30 days after capture. Partial data from this study are archived at Flint *et al.* (2020).

Data were filtered differently depending on the objective. For mapping annual distribution, we used the DAF Hybrid filter with the "Best-of-Day" subset. This filter uses unique filtering algorithms for sedentary and migratory periods. To estimate location of breeding sites, data were considered in two steps. In the first step, data were coarsely filtered to include movements < 10 km during the suspected nesting period (15 May–1 July: Savard & Lamothe 1991; Takekawa *et al.* 2011; Bordage & Savard 2020). For scoters that were marked on a breeding area (Yukon-Kuskokwim Delta), only data from the second year were used to estimate breeding locations. In the second step, following Ely *et al.* (2006, 2007) and Takekawa *et al.* (2011), clusters were identified manually with repeated locations in a small area indicating likely breeding activity. Within a breeding season, we chose the first cluster where the bird resided over three duty-cycles (9 days) and calculated likely nesting location as the centre of each cluster of locations. All data were processed using R 3.5.3 (R Core Team 2019). Mean locations were estimated with the *geosphere* package (*vs*. 1.5–10; Hijmans 2019), and the 50% and 95% utilisation distributions were used to identify the core and geographical distribution of the Black Scoter breeding range using the "kernelUD" function in the *adehabitatHR* package (*vs.* 0.4.18; Calenge 2006). Separate kernels were estimated for breeding scoters that originated from Atlantic and Pacific coasts using the Least Square Cross Validation option to select the smoothing parameter.

Our sample was composed largely of adult females because we were primarily interested in determining breeding sites, and data from this cohort would be less ambiguous than from males or subadult birds for identifying nest location. Males were marked, either intentionally to document male moulting areas and site fidelity to those areas, or opportunistically because females could not be captured at a particular location. All marked scoters were used in the examination of both continental-level segregation between Atlantic and Pacific Black Scoters and the location of breeding sites. However, we recognise that the breeding locations of some males may not represent true breeding sites because some marked males may have been unpaired at the start of the breeding season, based on a typically skewed sex ratio (Bordage & Savard 1995; Rodway *et al*. 2015) and possible marking effects (Lamb *et al.* 2020).

Dispersal was defined as any scoter that crossed the 120°W longitude line (in either direction), which was suggested as the dividing line between Atlantic and Pacific populations in the range map provided by Koneff *et al.* (2017). The probability of observing the number of dispersal events was estimated, given the study sample size, and assuming that dispersal was represented as a binomial probability. One thousand Monte Carlo simulations were used to estimate the probability that the observed number of dispersal events would occur, given a base underlying dispersal probability and our sample size. For example, if the true dispersal rate was assumed to be 5%, then the probability of any given number of dispersal events being observed for a given sample size of scoters can be estimated. The proportion of 1,000 random trials where the results were observed, given the sample size, was reported and the probability of true dispersal rates ranging from 0.4–10% was evaluated. For this analysis, the sample size was the number of scoters marked on wintering or spring staging areas that provided locations ≥ 30 days after marking and to at least 1 June, plus the number of scoters marked on a breeding area (Y-K Delta) that provided locations at least until 1 November. This included 89 birds for the Atlantic region and 83 birds for the Pacific region.

Results

A total of 101 Black Scoters were marked in the Pacific, and 102 in the Atlantic (Table 1). Of those marked on wintering or spring staging areas, 91 from the Pacific and 88 from the Atlantic provided location data ≥ 30 days from time of marking through spring, and 32 from the Pacific and 38 from the Atlantic provided data used to identify probable breeding locations (Table 2).

Our results indicated that Black Scoters marked along the Atlantic and Pacific coasts

Table 1. Number of Black Scoters marked with satellite transmitters in Atlantic and Pacific areas of North America (AK = Alaska, BC = British Columbia, QC = Quebec, NB = New Brunswick, MD = Maryland), by year, month, and season.

Marking region and site	**Year**										**Total no. marked**	**Month marked**	**Season marked**
	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2009**	**2010**	**2015**	**2016**			
Pacific													
Salish Sea, BC	0	5	0	10	0	0	0	0	0	0	15	Dec, Feb	Winter
Kodiak Island, AK	0	0	8	7	7	0	0	0	0	0	22	Mar	Winter
Nelson Lagoon, AK	0	17	6	0	0	0	0	0	1	10	34	Apr	Spring staging
Dutch Harbor, AK	0	0	0	0	0	10	0	0	0	0	10	Feb	Winter
Yukon-Kuskokwim Delta, AK	0	0	0	10	10	0	0	0	0	0	20	May/Jun	Breeding
Total Pacific											**101**		
Atlantic													
Chaleur Bay, NB-QC	12	9	9	0	0	0	16	48	0	0	94	May	Spring staging
Rhode Island	0	0	0	0	0	0	0	6	0	0	6	Dec	Winter
Chesapeake Bay, MD	0	2	0	0	0	0	0	0	0	0	2	Apr	Winter
Total Atlantic											**102**		

Table 2. Number of Black Scoters marked with satellite transmitters that lasted for ≥ 30 days, and the number of birds that provided breeding locations, by capture site (AK = Alaska, BC = British Columbia, QC = Quebec, NB = New Brunswick, MD = Maryland).

Marking region and site	No. of Black Scoters used in analyses					
	Females ≥ 30 days	Males ≥ 30 days	Total ≥ 30 days	Females breeding	Males breeding	Total breeding
Pacific						
Salish Sea, BC	9	5	14	4	2	6
Kodiak Island, AK	9	7	16	7	2	9
Nelson Lagoon, AK	11	21	32	8	5	13
Dutch Harbor, AK	9	0	9	5	0	5
Yukon-Kuskokwim Delta, AK	20	0	20	5	0	5
Total Pacific			**91**			**38**
Atlantic						
Chaleur Bay, NB-QC	39	41	80	23	8	31
Rhode Island	4	2	6	1	0	1
Chesapeake Bay, MD	2	0	2	0	0	0
Total Atlantic			**88**			**32**

of North America did not overlap in any season or in any year during our study (Fig. 2). We also observed no movements of scoters outside continental North America (*e.g.* to Asia or Greenland). Given our sample size and no observed dispersal events, the true dispersal rate is likely to be < 1% (Fig. 3).

All Black Scoters marked on Pacific wintering or spring staging areas migrated along Pacific coastal areas and either bred on the west Alaskan tundra, or, for non-breeders, remained on coastal marine areas in Alaska. Probable breeding areas included the Alaska Peninsula, Bristol Bay lowlands, Yukon-Kuskokwim Delta, Seward Peninsula and the Selawik region (Fig. 1). Breeding sites for the Pacific scoters were tightly clustered and the 50% utilisation distribution identified two nuclei, with one core area on the Yukon-Kuskokwim Delta and the other in the Bristol Bay lowlands (Fig. 1). Three additional breeding sites were identified on the Seward Peninsula. Wintering areas for Black Scoters marked on the Yukon-Kuskokwim Delta included coastal marine areas along the Aleutian Islands, the Alaska Peninsula, the Gulf of Alaska coast, and the Salish Sea in Washington State and British Columbia,

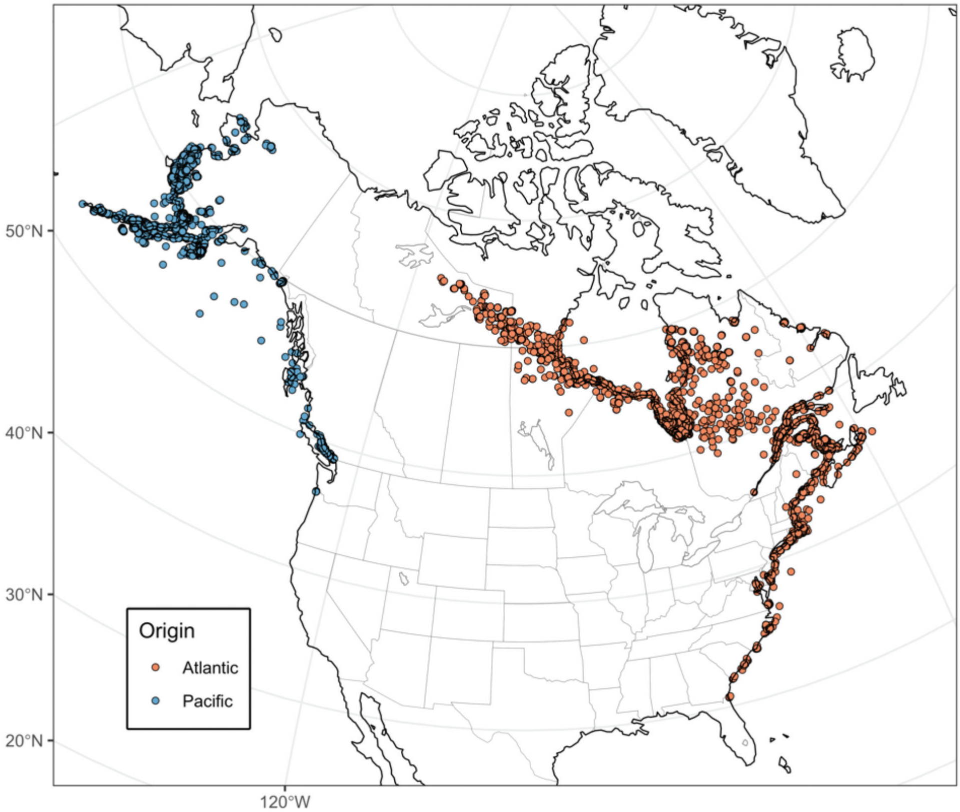

Figure 2. Locations of Black Scoters marked with satellite transmitters in North America.

Canada. Black Scoters marked on Pacific areas were not detected east of longitude 123°W at any time during the year (Fig. 2).

During the breeding season, about 70% of scoters marked on the Atlantic coast were distributed along the transition zone between taiga and tundra habitat, extending from the Hudson Bay lowlands in northern Manitoba to the north and west of Great Slave Lake, Northwest Territories. There were several possible breeding sites detected in northern Ontario, northern Quebec and Labrador. For the Atlantic scoters, the 50% utilisation distribution consisted of two nuclei, with one core area along the treeline in Northwest Territories and a second in northern Québec on the eastern side of the Hudson Bay (Fig. 1). Wintering areas for Black Scoters in Atlantic North America extended from Nova Scotia to Florida, with most tagged birds found along coastal areas between Massachusetts and South Carolina. Atlantic Black Scoters were never detected west of longitude 115°W (Fig. 2).

Discussion

Results from this study support the existence of two allopatric populations of Black

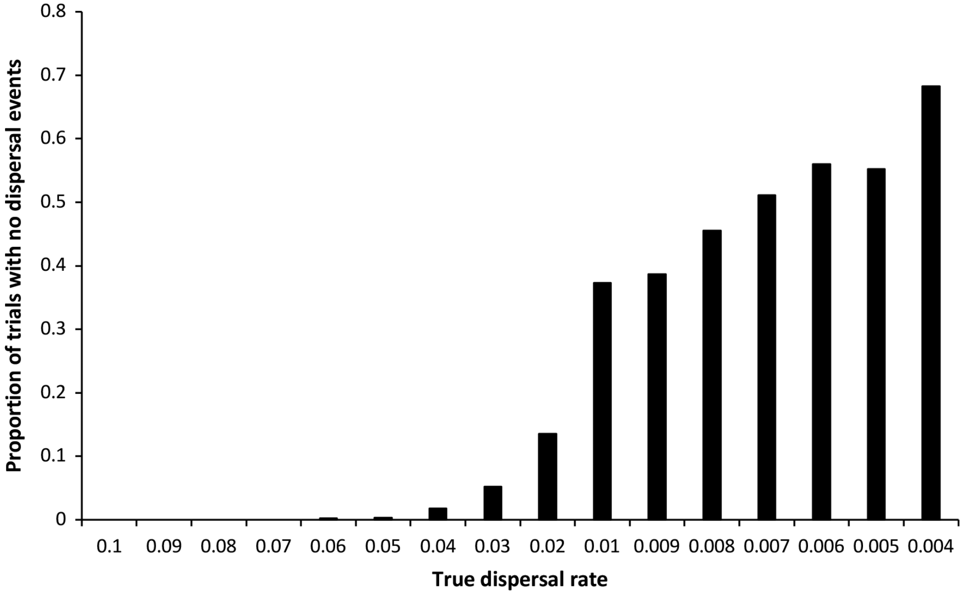

Figure 3. Proportion of 1,000 Monte Carlo trials with 0 dispersal events given our sample size of marked Black Scoters. Each scoter was assumed to have a binomial true dispersal rate, as indicated on the x axis.

Scoters in North America. The first is an Atlantic population that winters along the east coast of North America from the Canadian Atlantic provinces to Florida and breeds along the taiga-tundra transition in eastern and central Canada. The second is a Pacific population that winters along the west coast of North America from Alaska to the Salish Sea and breeds on the tundra of western Alaska. Reasons for the disjunct breeding populations remain unclear, but may be related to glacial isolation and Holocene glacial retreat patterns (Sonsthagen *et al.* 2019).

The distribution of breeding locations of Black Scoters marked along the Atlantic coast suggest a need for significant revision of existing range maps (Bellrose 1980; Baldassare 2014; Bordage & Savard 2020; E-Bird 2020), particularly for areas west of Hudson Bay. Historically, the area west of Hudson Bay was not recognised as being within the species' breeding range, yet our data indicate that it likely constitutes the core breeding area for Atlantic Black Scoters. More recent range maps (Koneff *et al.* 2017; Pearce *et al.* 2019), based largely on a preliminary interpretation of data from this study, portray the North American distribution more accurately. This confirms that the North American breeding waterfowl survey fails to include the majority of the breeding range of the Atlantic population (Bowman *et al.* 2015).

The sampling strategy in this study was not comprehensive, and small elements of populations on both coasts may not be represented. For example, Figure 1 suggests the geographical distribution for Atlantic Black Scoters breeding east of Hudson Bay was in two disparate regions. However, their distribution is likely continuous through this region as Black Scoters have been detected on breeding waterfowl surveys in eastern Quebec (Lepage & Savard 2013) and western Labrador (SGG, unpubl. data). Black Scoter broods have been reported in alpine areas of the Long Range Mountains in northern Newfoundland (R. Ian Goudie, Memorial University of Newfoundland, pers. comm.) and breeding pairs occur in the Maritime barrens in southern Newfoundland (SGG, unpubl. data). Exploratory aerial surveys west of Hudson Bay suggest that the breeding area may be more extensive than suggested by satellite telemetry data as Black Scoters were detected as far north as Tulemalu Lake, Nunavut (62°N, 54°W) and northeast as Carr Lake, Nunavut (62°N, 9°W; Rhodes *et al.* 2015). In Alaska, Black Scoters are occasionally observed during the breeding season on lakes in interior parts of the state or in northern Alaska on the Arctic Coastal Plain, although none of the marked scoters in this study appeared to breed in these locations. Small numbers of Black Scoters are known to winter in coastal Newfoundland (Goudie & Ankney 1988), yet the farthest north any of the marked scoters in this study wintered (n = 3) was Nova Scotia. Black Scoters also occur, but are uncommon, in the Great Lakes during winter, yet no marked scoters wintered there. Whereas these apparent distributional gaps in the data may warrant further investigation, it is unlikely that more expansive marking efforts would reveal a substantial cross-continental connection between the Atlantic and Pacific populations. Genetic analyses, based largely on samples collected from scoters as part of this study, showed divergence between Black Scoters breeding in Alaska and those breeding in central and eastern North America (Sonsthagen *et al.* 2019). While only small numbers of scoters have been banded in each flyway, band recovery data also suggest the isolation of the two populations (Pearce *et al.* 2019). Thus, all available evidence supports the presumption that dispersal and movements between the Pacific and Atlantic wintering areas are rare and likely inconsequential relative to population demographics.

We conclude that there is strong justification for updating the range map for Black Scoter (Sea Duck Joint Venture 2020) based on satellite telemetry data, and for recognising two allopatric populations in North America. The Atlantic and Pacific population ranges are geographically distinct and likely experience very different environmental and anthropogenic conditions, providing compelling justification that these populations could be monitored and managed independently. This study has highlighted the great value of satellite telemetry data in delineating sea duck populations and in informing design of surveys. Preliminary data from this study have already been used to help design surveys to better estimate relative densities and distribution of Black Scoters across their breeding range in North America with the goal of understanding population trends (Stehn 2012; Rhodes *et al.* 2015; Reed *et al.* 2019).

Acknowledgements

Funding and/or logistical assistance was provided by the US Fish and Wildlife Service (through the Sea Duck Joint Venture), Simon Fraser University, Environment and Climate Change Canada, Alaska Department of Fish and Game, US Geological Survey (Alaska Science Center and Patuxent Wildlife Research Center), Kodiak National Wildlife Refuge, Rhode Island Department of Environmental Management, New Brunswick Department of Natural Resources, and Wild Waterbird Conservancy. Veterinarians were Pam Tuomi, Scott Ford, Glenn Olsen, Corrine Brown, Dan Mulcahy, Malcolm McAdie and Samantha Gibbs. Andrew Gilbert compiled all the Atlantic data, Michael Sumner modified the Trip package to read problem data, and Dave Douglas graciously recovered several data sets that had lost some of the original information. We thank the following people for help with scoter captures and surgeries: Blake Bartzen, Joshua Beuth, Caroline Brady, Andre Breault, Todd Byers, Carlyn Caldwell, Peter Clarkson, Kevin Connor, Rian Dickson, Tasha DiMarzio, Stuart Fety, Denis Gagnon, Steve Gordon, Garry Grigg, Denis Guitard, Brendon Hicks, Doug Hill, Doug Howell, Sam Iverson, Molly Kirk, Jeff Lewis, Tyler Lewis, Pamela Loring, Joanne Luebert, Dennis Marks, Keith McAloney, Sarah McCloskey, Scott McWilliams, Peter Osenton, Mike Petrula, John Reed, Dave Safine, Roger Selesse, Dave Sinnett, Kyle Smith, Ron Therrien, Declan Troy, Nina Valadez, Vicky Vanek, Jeff Wasley, Alicia Wells-Berlin, Ken Wright, Ramunus Zydelis and Denny Zwiefelhofer. We thank John Pearce, Daniel Ruthrauff and two anonymous referees for constructive comments on a draft of the manuscript. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the US Government.

References

Baldassare, G.A. 2014. *Ducks, Geese, and Swans of North America*. John Hopkins University Press, Baltimore, USA.

Bellrose, F.C. 1980. *Ducks, Geese, and Swans of North America*. Stackpole Books, Harrisburg, USA.

Bordage, D. & Savard, J.-P.L. 1995. Black scoter (*Melanitta nigra*). *In* A. Poole & F. Gill (eds.), *The Birds of North America*, No. 177. The Academy of Natural Sciences, Philadelphia, USA.

Bordage, D. & Savard, J.-P.L. 2020. Black Scoter (*Melanitta americana*), version 1.0. *In* A.F. Poole (ed.), *Birds of the World*. Cornell Lab of Ornithology, Ithaca, USA. Available at https://doi.org/10.2173/bow.blksco2.01 (last accessed 26 June 2020).

Bowman, T.D. 2014. *Aerial Observer's Guide to North American Waterfowl*. US Fish and Wildlife Service Publication No. 6003. USFWS, Denver, Colorado, USA.

Bowman, T.D., Silverman, E.D., Gilliland S.G. & Leirness, J.B. 2015. Status and trends of North American sea ducks: reinforcing the need for better monitoring. *In* J.-P.L. Savard, D.V. Derksen, D. Esler & J.M. Eadie (eds.), *Ecology and Conservation of North American Sea Ducks*, pp. 1–27. Studies in Avian Biology, CRC Press, New York, USA.

Brodeur, S., Mittelhauser, G.H., Savard, J.-P.L., Thomas, P.W., Titman, R.D. & Comeau, D. 2008. Capture methods for migrating, wintering and molting sea ducks. *Waterbirds* 31: 133–137.

Calenge, C. 2006. The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. *Ecological Modelling* 197: 516–519.

Carboneras, C. & Kirwan, G.M. 2020. Common Scoter (*Melanitta nigra*), version 1.0. *In* J. del Hoyo, A. Elliott, J. Sargatal, D.A. Christie & E. de Juana (eds.), *Birds of the World*. Cornell Lab of Ornithology, Ithaca, New York, USA. Available at https://doi.org/10.2173/bow.blksco1.01 (last accessed 17 August 2021).

CLS America. 2020. *Environment and Climate Modelling*. Available at https://www.cls.fr/en/environmental-monitoring/ (last accessed 26 June 2020).

Douglas, D.C., Weinzierl, R., Davidson, S.C., Kays, R., Wikelski, M. & Bohrer, G. 2012. Moderating Argos location errors in animal tracking data. *Methods in Ecology and Evolution* 3: 999–1007.

E-Bird. 2020. Black Scoter *Melanitta americana* range map. Available at https://ebird.org/science/status-and-trends/blksco2/range-map (last accessed 26 June 2020).

Ely, C.R., Bollinger, K.S., Hupp, J.W., Derksen, D.V., Terenzi, J., Takekawa, J.Y., Orthmeyer, D.L., Rothe, T.C., Petrula, M.J. & Yparraguirre, D.R. 2006. Traversing a boreal forest landscape: summer movements of Tule Greater White-fronted Geese. *Waterbirds* 29: 43–55.

Ely, C.R., Bollinger, K.S., Densmore, R.V., Rothe, T.C., Petrula, M.J., Takekawa, J.Y. & Orthmeyer, D.L. 2007. Reproductive strategies of northern geese: why wait? *Auk* 124: 594–605.

Flint, P.L. 2013. Changes in size and trends of North American sea duck populations associated with North Pacific oceanic regime shifts. *Marine Biology* 160: 59–65.

Flint, P.L., Schamber, J.L. & Douglas, D.C. 2020. Tracking data for Black Scoters (*Melanitta americana*) (version 1.0, March 2020): US Geological Survey data release. USGS Alaska Science Center, Anchorage, Alaska. Available at https://doi.org/10.5066/P93EF3TH (last accessed 17 August 2021).

Goudie, R.I. & Ankney, C.D. 1988. Patterns of habitat use by sea ducks wintering in southeastern Newfoundland. *Ornis Scandinavica* 19: 249–256.

Hijmans, R.J. 2019. *Geosphere: Spherical Trigonometry*. *R Package Version 1.5-10*. Available at https://CRAN.R-project.org/package=geosphere (last accessed 26 June 2020).

Koneff, M.D., Zimmerman, G.S., Dwyer, C.P., Fleming, K.K., Padding, P.I., Devers, P.K., Johnson, F.A., Runge, M.C. & Roberts, A.J. 2017. Evaluation of harvest and information needs for North American sea ducks. *PLoS ONE* 12: e0175411. https://doi.org/10.1371/journal.pone.0175411 (last accessed 26 June 2020).

Korschgen, C.E., Kenow, K.P., Genron-Fitzpatrick, A., Green, W.L. & Dein, F.J. 1996. Implanting intra-abdominal radio transmitters with external whip antenna in ducks. *Journal of Wildlife Management* 60: 132–137.

Lamb, J.S., Paton, P.W.C., Osenkowski, J.E., Badzinski, S.S., Berlin, A.M., Bowman, T., Dwyer, C., Fara, L.J., Gilliland, S.G., Kenow, K., Lepage, C., Mallory, M.L., Olsen, G.H., Perry, M.C., Petrie, S.A., Savard, J.-P.L., Savoy, L., Schummer, M., Spiegel, C.S. & McWilliams, S.R. 2020. Implanted satellite transmitters affect sea duck movement patterns at short and long timescales. *The Condor* 122: 1–16.

Lepage, C. & Savard, J.-P.L. 2013. Black Scoter. *In* C. Lepage & D. Bordage (eds.), *Status of Quebec Waterfowl Populations, 2009*, pp. 170–174. Canadian Wildlife Service Technical Report Series No. 525. CWS, Environment Canada, Quebec Region, Quebec City, Canada.

Loring, P.H., Paton, P.W.C., Osenkowski, J.E., Gilliland, S.G., Savard, J.-P.L. & McWilliams, S.R. 2014. Habitat use and selection of Black Scoters in southern New England and siting of offshore wind energy facilities. *Journal of Wildlife Management* 78: 645–656.

Movebank. 2020. *Movebank Data Repository*. Movebank, coordinated by the Max Plank Institute of Animal Behaviour, Munich, Germany, the North Carolina Museum of Natural Sciences, Raleigh, USA and the University of Konstanz, Konstanz, Germany. Available at https://www.movebank.org/ (last accessed 26 June 2020).

Pearce, J.M., Flint, P.L., Whalen, M.E., Sonsthagen, S.A., Stiller, J., Patil, V.P., Bowman, T., Boyd, S., Badzinski, S.S., Gilchrist, H.G., Gilliland, S.G., Lepage, C., Loring, P., McAuley, D., McLellan, N.R., Osenkowski, J., Reed, E.T., Roberts, A.J., Robertson, M.O., Rothe, T., Safine, D.E., Silverman, E.D. & Spragens, K. 2019. *Visualizing populations of North American Sea Ducks – Maps to Guide Research and Management Planning*. US Geological Survey Open-File Report No. 2019-1142. USGS, Reston, Virginia, USA. Available at https://doi.org/10.3133/ofr20191142 (last accessed 26 June 2020).

R Core Team. 2019. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. Available at https://www.R-project.org/ (last accessed 26 June 2020).

Reed, E.T., Gilliland, S.G., Lepage, C., Roy, C., Wood, C., Koneff, M., Rhodes, W. & Silverman, E. 2019. *Integrating Fixed-Wing and Helicopter Survey Platforms to Improve Detection and Species Identification of North American Breeding Scoters*. Annual report to the Sea Duck Joint Venture, Anchorage, Alaska. Available at https://seaduckjv.org/wp-content/uploads/2014/11/SDJV-PR154-Annual-Report-2019_Reed-CWS-scoter-survey.pdf (last accessed 26 June 2020).

Rhodes, W., Gilliland, S. & Silverman, E. 2015. *Canadian Barrenlands Experimental Breeding Sea Duck Survey, Year 2*. Annual report to the Sea Duck Joint Venture, Anchorage, Alaska. Available at https://seaduckjv.org/wp-content/uploads/2014/11/SDJV-PR141-Rhodes-annrpt-FY15.pdf (last accessed 26 June 2020).

Rodway, M.S, Regehr, H.M., Boyd, W.S. & Iverson, S.A. 2015. Age and sex ratios of sea ducks wintering in the Strait of Georgia, British Columbia, Canada: Implications for monitoring. *Marine Ornithology* 43: 141–150.

Rothe, T.C., Padding, P.I., Naves, L.C. & Robertson, G.J. 2015. Harvest of sea ducks in North America: a contemporary summary. *In* J.-P.L. Savard, D.V. Derksen, D. Esler & J.M. Eadie (eds.), *Ecology and Conservation of North American Sea Ducks*. Studies in Avian Biology, CRC Press, New York, USA.

Savard, J.-P.L. & Lamothe, P. 1991. Distribution, abundance, and aspects of breeding ecology of Black Scoters, *Melanitta nigra*, and Surf Scoters, *M. perspicillata*, in northern Quebec. *Canadian Field-Naturalist* 105: 488–496.

Schamber, J.L., Broerman, F.J. & Flint, P.L. 2010. Reproductive ecology and habitat use of Pacific Black Scoters (*Melanitta nigra americana*) nesting on the Yukon-Kuskokwim Delta, Alaska. *Waterbirds* 33: 129–139.

Sea Duck Joint Venture. 2020. Black scoter *Melanitta americana*. Sea Duck Joint Venture, Anchorage, Alaska. Available at https://seaduckjv.org/meet-the-sea-ducks/black-scoter/ (last accessed 26 June 2020).

Sonsthagen, S.A., Wilson, R.E., Lavretsky, P. & Talbot, S.L. 2019. Coast to coast: high genomic connectivity in North American scoters. *Ecology and Evolution* 9: 7246–7261.

Stehn, R.A. 2012. *Pacific Black Scoter Breeding Survey*. Annual report to the Sea Duck Joint

Venture, Anchorage, Alaska. Available at https://seaduckjv.org/pdf/studies/pr96.pdf (last accessed 26 June 2020).

Takekawa, J.Y., De La Cruz, S.W., Wilson, M.T., Palm, E.C., Yee, J., Nysewander, D.R., Evenson, J.R., Eadie, J.M., Esler, D., Boyd, W.S. & Ward, D.H. 2011. Breeding distribution and ecology of Pacific coast Surf Scoters. *In* J.V. Wells (ed.), *Boreal Birds of North America: a Hemispheric View of their Conservation Links and Significance. 1st edition.* University of California Press, Oakland, California, USA.

Photograph: A pair of Black Scoters in flight, by Milo Burcham.

