MARINE BIRDS OF YAKUTAT BAY, ALASKA: EVALUATING SUMMER DISTRIBUTION, ABUNDANCE AND THREATS AT SEA

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SUMMARY

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Yakutat Bay, Alaska, a large embayment of the northern Gulf of Alaska, is an important stopover, breeding and wintering destination for many marine birds, including five species of conservation concern: Red-throated Loon *Gavia stellata*, Yellow-billed Loon *G. adamsii*, Aleutian Tern *Sterna aleutica*, Marbled Murrelet *Brachyramphus marmoratus* and Kittlitz's Murrelet *B. brevirostris*. Despite being remote, Yakutat Bay also hosts human activity that may negatively impact marine birds. We conducted systematic boat-based surveys to estimate distribution and abundance of marine birds in Yakutat Bay and adjacent fjords on 17–22 June 2009. We also identified locations and intensities of vessel traffic that was a potential source of disturbance to birds and assessed the vulnerability of species of concern to this potential threat. We observed 1496 marine birds, with a total population estimate (± SE) of 36 220 ± 3 906 and density of 33.51 ± 8.11 birds/km^2. We observed diving and surface-feeding birds throughout our study area, whereas we saw benthic-feeding birds rarely. Based on bird and vessel distributions the average probability of an individual bird encountering a vessel at least once a day during the breeding season was 0.0034 ± 0.0015 for Aleutian Tern and higher for Marbled Murrelet (0.0083 ± 0.0013) and Kittlitz's Murrelet (0.0097 ± 0.0031). For all three species, less than 1% of the local population was subject to vessel disturbance each day, yet there may be a cumulative effect of disturbance over time, and additive impacts with other threats. Our threats analysis helps build a better awareness of the risks facing species of concern in remote areas that nonetheless are subject to traffic from large vessels.

INTRODUCTION

Marine birds spend most of their lives at sea; consequently, it is important to evaluate where they spend time at sea, especially when breeding areas are not known or their breeding habits prevent study at colonies (e.g. solitary nesting species). In addition, assessing human impacts, including fisheries bycatch (e.g. Zydelis *et al.* 2009), oil spills (e.g. Carter & Kuletz 1995), pollution (e.g. Laist 1987) and climate change (e.g. Hoegh-Guldberg & Bruno 2010), is vital for a timely response to risks and successful conservation of marine birds.

The coast of Alaska provides important breeding and foraging habitat for many species of marine birds. Nearly 100 Important Bird Areas have been identified along the Gulf of Alaska (GOA) coast from the Aleutian Islands to southeastern Alaska (Kirchhoff 2008). The coastline extending from Cape Suckling to Cross Sound in the northwestern part of southeastern Alaska is very exposed, offering few protected areas for birds to forage, breed or shelter themselves from frequent storms. Yakutat Bay is the largest embayment along this glacially influenced coastline between Prince William Sound and Icy Straits, and it is isolated from other major estuaries and island groups. Hence, Yakutat Bay is an important stopover, breeding and wintering destination for many birds (Shortt 1939, Stephensen & Andres 2001, Andres & Browne 2004).

Over 200 bird species have been recorded in the Yakutat Bay area, with 177 species occurring regularly, 80 species over-wintering and >100 species known to be or likely to be breeding (Andres & Browne 2004). In addition, Yakutat Bay hosts five marine bird species of conservation concern: Red-throated Loon *Gavia stellata*, Yellow-billed Loon *G. adamsii*, Aleutian Tern *Sterna aleutica*, Marbled Murrelet *Brachyramphus marmoratus* and Kittlitz's Murrelet *B. brevirostris* (Kirchhoff & Padula 2010). The reasons for concern about these species include declining population trends (Red-throated Loon and *Brachyramphus* murrelets: Groves *et al.* 1996, Conant & Groves 2005, Piatt *et al.* 2007, Kuletz *et al.* 2011a, Kuletz *et al.* 2011b), gillnet mortality (Marbled Murrelet: Carter & Sealy 1984, and Kittlitz's Murrelet: Day *et al.* 1999), subsistence harvesting (Yellow-billed Loon: Schmutz 2009, US Fish & Wildlife Service [USFWS] 2011a), and anthropogenic disturbance and predation at nesting colonies (Aleutian Tern: North 1997). Because of these and other concerns, two of these species, the Yellow-billed Loon and Kittlitz's Murrelet, are Candidate Species for listing under the US *Endangered Species Act* (USFWS 2011a, USFWS 2011b).

In addition to being an important area for marine birds, Yakutat Bay is also an area with numerous human activities, some of which may disturb or kill birds at sea. Human disturbances may induce stress responses in animals, including energetically costly deviations from behavior, which can reduce reproductive success and fitness (Tarlow & Blumstein 2007, Wright *et al.* 2007). Additionally, certain anthropogenic actions can immediately and directly threaten an animal's health, which may lead to death (Frid & Dill 2002). For marine birds in Yakutat Bay, we considered the potential threat of vessel disturbance. Cruise ship traffic in Alaska has risen dramatically in the past few decades, and visits to Yakutat and Disenchantment bays en route to the Hubbard Glacier have increased at least 10-fold since the mid-1980s (Jansen *et al.* 2010).

Our goal was to quantify the abundance and distribution of marine birds at sea in Yakutat Bay and to assess the disturbance of species of concern by vessels given the increases in human activities. To identify which species or species groups might likely encounter vessels, we considered species of concern as well as groups of species that exploit resources in a similar way (i.e., "foraging guilds"; De Graaf *et al.* 1985, Simberloff & Dayan 1991). We used boat-based surveys to estimate distribution and abundance of marine birds from a snapshot in time, with a focus on species of concern, and evaluated the potential overlap between vessel traffic and marine birds in Yakutat Bay. We also qualitatively examined evidence of mortality from gillnet fishing relative to our population estimates.

STUDY AREA AND METHODS

We studied marine birds in Yakutat Bay, near the town of Yakutat, Alaska, USA (59°32′38″N, 139°43′42″W) in northeastern GOA. Our study area included the connected Yakutat and Disenchantment bays (5–35 km in width) and the adjoining Russell and Nunatak fjords (22–50 km in length; Fig. 1), which are separated by the tidewater Hubbard Glacier. The narrow embayment north of Yakutat Bay, Disenchantment Bay, is characterized by an expansive floating ice field caused by glacial calving. Yakutat has maritime weather, with cool summers and mild winters. Precipitation averages 371 cm/year, winds 9–13 km/h, annual air temperature 7 °C, and sea surface temperatures 4 °C–17 °C (Andres & Brown 2004, Ritchie *et al.* 2008).

Field data collection

Following a previous survey of Yakutat Bay (Stephensen & Andres 2001), we divided our study area into two strata: main bays (940 km²) and upper fjords (192 km²; Fig. 1). We conducted systematic boat-based surveys following linear transects from 1–37 km in length and spaced 2.5–7.0 km apart. On 17–22 June 2009 we sampled 23 transects initially surveyed by Stephensen & Andres (2001) and added 10 additional transects (n = 33 total; hereafter, we refer to these as "pelagic transects") to increase spatial coverage to 3.9% of study area (Fig. 1). We placed pelagic transects perpendicular to shore, stopping as near to shore as possible, and typically alternated the direction that we sampled each transect. Some transects in Disenchantment Bay were not accessible because of thick ice, but we surveyed as much of each transect as possible; for consistency we used the same stratum area as Stephensen & Andres (2001). We were unable to survey the lower part of Yakutat Bay that is adjacent to the GOA due to time and logistical constraints (e.g. large swell and chop).

Two observers and one boat driver conducted surveys for seabirds and waterfowl between 08h00 and 18h00. We surveyed from skiffs that were 6–7 m in length, with observer height 3 m above water, traveling at about 10 km/h. We used line-transect methods (Buckland *et al.* 2001) and recorded species, group size, behavior (e.g. flying, water, foraging) and perpendicular distance (m) to all birds observed at unlimited distances on both sides of the boat and 300 m ahead of the boat. We recorded data using a voice-activated recording system with an integrated global positioning system unit, allowing each observation to be stamped with a time and location (Fischer & Larned 2004). Observers had at least two years of experience conducting marine bird surveys in Alaska and were trained in bird identification and distance estimation before surveys. We recorded weather and sea conditions, and ceased surveying when the conditions were not acceptable (i.e., at Beaufort scale >3).

Field data analysis

We assumed that line transects were placed randomly with respect to bird distribution. To be consistent with previous estimates (Stephensen & Andres 2001) we truncated observations at 100 m on both sides of the boat and computed densities of birds assuming perfect detection within the 200 m strip. We included all observations, including birds that were flying. We used a ratio estimator (Caughley 1977) to extrapolate population size and density estimates and associated variances of bird species and foraging guilds from survey data collected along pelagic transects. We grouped seabirds and waterfowl into foraging guilds and categorized birds into three primary foraging strategies: pursuit diving, surface feeding and benthic feeding (Table 1).

Vessel disturbance

To evaluate the spatial overlap between marine birds and vessel traffic, we first mapped the distribution of all bird observations within 100 m of either side of the boat by foraging guilds and for species of concern using a kernel density estimator with output cell size of 100 m and search radius of 3000 m (Spatial Analyst, ESRI, Inc., Redlands, California). We then compiled independent data on vessel traffic patterns (Fig. 1; Marine Exchange of Alaska, Juneau, Alaska) to quantify the likelihood of overlap between birds and moving vessels. We used high-resolution vessel location data that were collected by satellite tracking devices mandatory for all

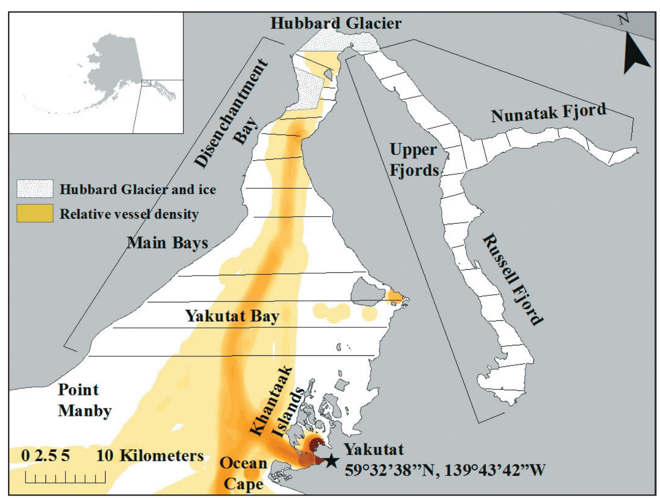

Fig. 1. Pelagic transects surveyed for marine birds in Yakutat Bay, Disenchantment Bay, Russell Fjord and Nunatak Fjord, Alaska, June 2009, and the density of vessel traffic from June through July 2009. Vessel location data were collected from satellite tracking data (Marine Exchange of Alaska, Juneau, Alaska; see Methods), and vessel locations were buffered to represent zones of disturbance to murrelets (120 m for vessels <30 m, 600 m for vessels 30–150 m and 1400 m for vessels >150 m).

vessels >19.8 m in length. We also used data from other vessels that opted voluntarily to carry the device, including passenger and fishing vessels. We selected satellite data collected from moving vessels of known size between 08h00 and 18h00 h each day from 1 June–31 July 2009 to correspond to our bird survey data and to reflect the breeding season of marine birds in Yakutat Bay (Day 1996, North 1997). Additionally, we mapped vessel location data (points transmitted every 6 s), and, based on vessel size, we buffered location to represent disturbance zones within vessel pathways (Fig. 1): 120 m for vessels <30 m (based on Hentze 2006, Bellefleur *et al.* 2009), 600 m for vessels 30–150 m, and 1400 m for vessels >150 m (based on Agness *et al.* 2008).

We analyzed the likelihood of interactions between moving vessels and Aleutian Terns and Marbled and Kittlitz's murrelets; Red-throated Loons were not numerous enough to analyze. We divided Yakutat Bay into a grid of 100 m cells and, using the buffered vessel locations, added up the total number of days throughout the breeding season (1 June–31 July) that a vessel occupied each cell (with a minimum of 0 days occupied, and maximum of 61 days per cell). For each cell, we summed the number of days that it was occupied by vessels, then divided that number by 61 days to estimate the daily probability of vessel occupation. We then identified the cells in which the target species were observed and multiplied the probability of vessel occupation by the number of individuals of a species observed in each cell to calculate the mean daily probability of each individual bird and a vessel occupying the same cell, which we assumed caused a disturbance that displaced or caused a change in behavior of the bird. Finally, we summed the probabilities from all cells, divided that value by the total number of birds observed and multiplied that value by the population estimate to calculate the total number of birds overlapping with vessels in Yakutat Bay each day. We assumed that the location of birds during our surveys was not already altered by vessel traffic.

TABLE 1
Marine birds observed on pelagic transects (200 m strip width) in Yakutat Bay, Alaska, June 2009

Foraging guild	Common name	Scientific name	No. observed (on % of transects)	Population estimate (SE)	Density, birds/km^2 (SE)
Diver	Common Loon	*Gavia immer*	4 (9)	101 (49)	0.09 (0.08)
Diver	Pacific Loon	*Gavia pacifica*	12 (12)	334 (141)	0.27 (0.04)
Diver	Red-throated Loon	*Gavia stellata*	4 (9)	81 (44)	0.09 (0.16)
Diver	Unidentified Loon	*Gavia* spp.	2 (6)	56 (25)	0.04 (0.01)
Diver	Double-crested Cormorant	*Phalacrocorax auritus*	13 (6)	351 (279)	0.29 (0.08)
Benthic Feeder	Canada Goose	*Branta Canadensis*	10 (9)	177 (157)	0.22 (0.50)
Benthic Feeder	Mallard	*Anas platyrynchos*	12 (6)	213 (283)	0.27 (0.39)
Benthic Feeder	American Wigeon	*Anas Americana*	4 (3)	71 (126)	0.09 (0.21)
Benthic Feeder	Surf Scoter	*Melanitta perspicillata*	5 (3)	89 (87)	0.11 (0.26)
Benthic Feeder	Harlequin Duck	*Histrionicus histrionicus*	12 (12)	273 (219)	0.27 (0.59)
Benthic Feeder	Long-tailed Duck	*Clangula hyemalis*	10 (3)	177 (174)	0.22 (0.53)
Pursuit Diver	Common Merganser	*Mergus merganser*	4 (3)	71 (70)	0.09 (0.23)
Pursuit Diver	Red-breasted Merganser	*Mergus serrator*	1 (3)	28 (27)	0.02 (0.03)
Surface Feeder	Parasitic Jaeger	*Stercorarius parasiticus*	10 (18)	258 (59)	0.22 (0.11)
Surface Feeder	Pomarine Jaegar	*Larus Philadelphia*	1 (3)	28 (23)	0.02 (0.00)
Surface Feeder	Mew Gull	*Larus canus*	38 (39)	755 (271)	0.85 (0.89)
Surface Feeder	Herring Gull	*Larus argentatus*	2 (6)	46 (29)	0.04 (0.06)
Surface Feeder	Glaucous-winged Gull	*Larus glaucescens*	112 (39)	2732 (668)	2.51 (2.77)
Surface Feeder	Black-legged Kittiwake	*Rissa tridactyla*	283 (58)	7448 (1081)	6.34 (1.80)
Surface Feeder	Arctic Tern	*Sterna paradisaea*	153 (55)	3138 (1060)	3.43 (2.19)
Surface Feeder	Aleutian Tern	*Sterna aleutica*	44 (33)	1183 (194)	0.99 (0.16)
Diver	Common Murre	*Uria aalgae*	38 (24)	715 (437)	0.85 (1.46)
Diver	Pigeon Guillemot	*Cepphus Columba*	10 (21)	188 (85)	0.22 (0.26)
Diver	Marbled Murrelet	*Brachyramphus marmoratus*	384 (67)	9180 (1406)	8.60 (2.41)
Diver	Kittlitz's Murrelet	*Brachyramphus brevirostris*	96 (36)	2348 (593)	2.15 (1.76)
Diver	Unidentified Murrelet	*Brachyramphus* spp.	103 (36)	2774 (862)	2.31 (0.30)
	All birds observed		1496 (100)	36 220 (3906)	33.51 (8.11)

RESULTS

We recorded 1496 individual birds of 24 species on 33 pelagic transects (225 km in total length). We estimated the population size (± SE) of marine birds in Yakutat Bay in 2009 to be 36 220 ± 3 906, and bird densities to be 33.51 birds/km^2 ± 8.11 (Table 1). The most abundant bird species observed were Marbled Murrelet, Black-legged Kittiwake *Rissa tridactyla* and Arctic Tern *S. paradisaea* (Table 1). The species of concern observed in greatest abundance were Marbled Murrelet, followed by Kittlitz's Murrelet, Aleutian Tern and Red-throated Loon. Yellow-billed Loons were not observed on transect, but one was opportunistically observed inside Ocean Cape. We observed diving birds throughout most of our study area, with higher densities observed in the upper fjords

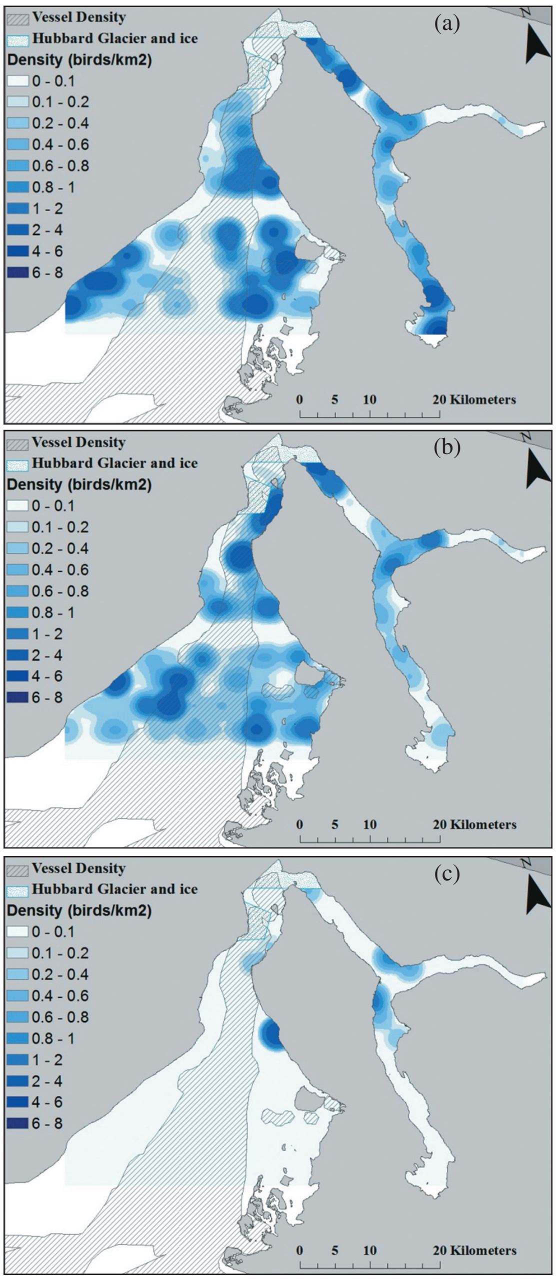

Fig. 2. Distribution and density of (a) diving birds, (b) surface-feeding birds and (c) benthic-feeding birds and vessel activity (hatched area) in Yakutat Bay, Alaska, June 2009.

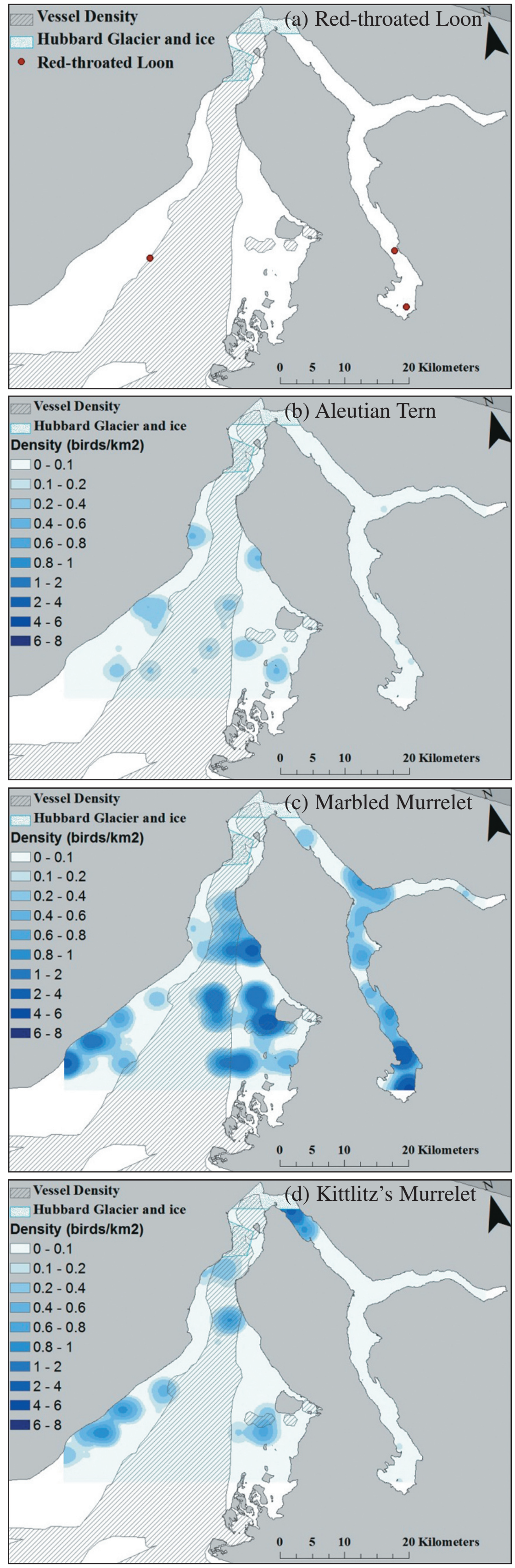

Fig. 3. Distribution and density of (a) Red-throated Loon (point locations only), (b) Aleutian Tern, (c) Marbled Murrelet and (d) Kittlitz's Murrelet and vessel activity (hatched area) in Yakutat Bay, Alaska, June 2009.

and close to shore (Fig. 2a). Surface feeders were also observed throughout the study area, but they had areas of high densities in nearshore and mid-bay areas (Figs. 2b). Benthic feeders were observed only in a few areas, with one high density area in the east side of the main bay (Fig. 2c).

During 1 June–31 July 2009, an average of 2.73 (SD 1.78) ships per day transmitted locations from within Yakutat Bay. The areas with the most vessel traffic were near the town of Yakutat and in the center of Yakutat and Disenchantment bays; no ships were recorded in Russell and Nunatak fjords (Fig. 1). Larger vessels moved faster than smaller vessels. The average speed (± SD) of ships <30 m in length (n = 15) underway was 13.13 (5.47) km/h, ships 30–150 m (n = 12) traveled 15.62 (6.95) km/h, and ships >150 m (n = 11) traveled 29.02 (3.76) km/h. Cruise ships (n = 10) were the largest and fastest vessels and operated only in the center of Yakutat Bay and in Disenchantment Bay.

Vessel traffic overlapped spatially to varying extents with all foraging guilds in Yakutat Bay (Figs. 2a-c). Overlap between vessels and diving birds was greatest in the upper part of Yakutat Bay and in the center of Yakutat Bay, although diving birds were primarily outside of the main vessel traffic areas in the central bay (Fig. 2a). Distribution of surface feeders and vessel traffic intersected most in upper Yakutat and Disenchantment bays and in west central Yakutat Bay (Fig. 2b). Overlap between benthic feeders and vessel traffic occurred primarily in Disenchantment Bay, but was minimal (Fig. 2c). Of the four Red-throated Loons observed, only one occurred within a low-vessel-density area in the central part of Yakutat Bay (Fig. 3a). Aleutian Tern overlapped with vessel traffic primarily in the central part of Yakutat Bay (Fig. 3b). The greatest spatial overlap of Marbled Murrelet and vessels was in the central part of Yakutat Bay as well as the head of the bay (Fig. 3c). Kittlitz's Murrelet overlapped with vessel traffic only near the head of Yakutat Bay (Fig. 3d).

The mean (± SE) probability of an individual bird overlapping with vessel traffic at least once a day from 1 June–31 July was greatest for Kittlitz's Murrelet, followed closely by Marbled Murrelet, and then by Aleutian Tern (Table 2). We were unable to assess vessel disturbance to either loon species because of the few observations of these species. The number of individual birds susceptible to disturbance each day during the breeding season was highest for Marbled Murrelet, followed by Kittlitz's Murrelet and finally Aleutian Tern (Table 2). However, given local population estimates (Table 1), a higher proportion of Kittlitz's Murrelets were susceptible to vessel disturbance, followed closely by Marbled Murrelet and then Aleutian Tern (Table 2).

TABLE 2
Disturbance by vessels to species of concern, Yakutat Bay, Alaska, June 2009

Species of concern	Probability of disturbance ≥ once per day (SE)	Mean number of birds disturbed per day	% of population disturbed per day
Aleutian Tern	0.0034 (0.0015)	4	0.34
Marbled Murrelet	0.0083 (0.0013)	76	0.83
Kittlitz's Murrelet	0.0097 (0.0031)	23	0.98

DISCUSSION

Cruise ship traffic in Yakutat and Disenchantment bays has increased dramatically from 15 ship visits per year in 1989 to 170 in 2007 (Jansen *et al*. 2010). The close approach of cruise ships to harbor seals in Disenchantment Bay changed seal behavior and may have impacted their energetics (Jansen *et al*. 2010), and cruise ships may similarly disturb bird species of concern. Because of small sample sizes, we were unable to assess how vessel disturbance might affect loons, but nearly all of the loons observed were located in the upper fjords where vessel traffic was rare. Although Aleutian Tern overlapped with vessel distribution, they were seldom observed on the water (11% of observations), where direct disturbance from vessels would occur, so we conclude that disturbance was likely minimal. Conversely, Marbled and Kittlitz's murrelets were often observed on the water (80% and 86% of observations, respectively), and thus were more likely to be disturbed by vessels. Similarly, although birds in the surface-feeder guild overlapped with vessel traffic in the main bay, they were typically in the air, thus were less likely to be susceptible to vessel disturbance than diving birds.

Murrelets appear to be sensitive to differences in vessel size and speed, with larger and faster-moving vessels more likely to disturb birds and to do so at farther distances compared with smaller, slower-moving vessels (Agness *et al.* 2008, Bellefleur *et al.* 2009). Based on the distributions of birds in June 2009, less than 1% of the local population of Marbled and Kittlitz's murrelets were likely to be disturbed each day by vessel traffic. However, our surveys did not extend to the area with high vessel traffic, from near the town of Yakutat to Ocean Cape (Fig. 1); thus, our estimated probabilities of encounters with vessels should be considered a minimum index. In addition, over the entire breeding season the cumulative impact of disturbance to an individual may negatively affect energetics or even reproduction. Vessel disturbance may evoke changes in foraging and resting behavior of murrelets that can be energetically costly (Piatt *et al.* 2007, Agness *et al.* 2008) and may alter chick provisioning rates (Speckman *et al.* 2004), both of which could impact reproduction. Mack *et al*. (2002) found that single murrelets, which are more likely to be breeders, were more likely to flush from vessels than groups of two or more murrelets. For these reasons, vessels may disproportionately disturb breeding murrelets (Hentze *et al.* 2006).

We present the first systematic evaluation of vessel disturbance to marine birds in Yakutat Bay and provide a starting point for assessing the potential threat of vessel disturbance to marine birds in a remote area at a localized scale. We did not evaluate the impact of any disturbance; rather, we considered the spatial and temporal overlap of bird distribution and abundance from a snapshot in time with presumed threats. These threats are additional to those posed by predation and prey availability (Nelson & Hamer 1995, Day *et al.* 1999, USFWS 2011b), degradation of nesting habitat and harvest by humans (Nelson 1997, North 1997, Day *et al.* 1999, Schmutz 2009) and climate change (USFWS 2011b). Oil spills could also pose a threat in Yakutat; however, only 30 small oil spills from 20 events were reported in the Yakutat Bay marine area between 1995 and 2008 (we could not find records prior to 1995), none of which occurred within our survey area (ADEC 2010); thus, we did not include oil spills in our analysis.

Gillnet fishing bycatch also represents a known threat to marine birds in Yakutat Bay, with hundreds of birds from seven species reported to be killed from bycatch in the Yakutat Bay salmon gillnet fishery in 2007 and 2008, including three species of concern: Red-throated Loon, Marbled Murrelet and Kittlitz's Murrelet (Appendix A available on the Web site; Manly 2009). The mean annual estimated bycatch was greatest for Marbled Murrelet, followed by Common Murre and Red-throated Loon (Appendix A; Manly 2009). If we compare the estimated bycatch in Yakutat Bay (Manly 2009) with our 2009 population estimates, the Red-throated Loon had the highest annual mortality from gillnets relative to its population, at 26.9%, followed by Pigeon Guillemot (8.6%) and Common Murre (5.5%; Appendix A). Given concern over the declining population trends of Red-throated Loon in Alaska (Groves *et al.* 1996), further study of the bycatch of this species may be warranted. The overall incidental take of Marbled Murrelet was relatively low (1.2% of the 2009 local population); however, bycatch could have population-level effects for a long-lived species such as the Marbled Murrelet if locally breeding individuals are taken. Both murrelet species and Pigeon Guillemots nest in the Yakutat Bay area (Andres & Brown 2004), and because male and females of these species share incubation and chick-rearing duties (Ewins 1993, Nelson 1997, Day *et al.* 1999), the mortality of a nesting adult from bycatch likely results in a failed breeding effort (egg or chick) in that year as well.

We observed high abundances of many bird species, including several species of concern, in Yakutat Bay, supporting its identification as an Important Bird Area (Kirchhoff 2008). In addition to the biological importance of this bay, tourism and vessel traffic has increased and commercial fishing is a known source of mortality to diving birds. The presence of these threats emphasizes the importance of monitoring the abundance and distribution of birds, as well as their overlap with threats.

In conclusion, the presence of threats and the regional importance of Yakutat Bay to birds along the exposed "lost coast" warrant a comprehensive management and conservation plan for marine birds of Yakutat Bay. Threats to species of concern in Yakutat Bay could be important to the Alaska populations of these species. Moreover, the co-occurrence of multiple potential threats may have a cumulatively negative effect on birds. More information about bird distribution in Yakutat Bay within or among years, and biological consequences with respect to vessel disturbance, would be helpful in developing specific management actions.

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REFERENCES

AGNESS, A.M., PIATT, J.F., HA, J.C. & VAN BLARICOM, G.R. 2008. Effects of vessel activity on the near-shore ecology of Kittlitz's Murrelets (*Brachyramphus brevirostris*) in Glacier Bay, Alaska. *Auk* 125: 346–353.

ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION (ADEC). 2010. Division of oil spill prevention and response, Prevention and emergency response program. Spills database online query. [Available online at: http://www.dec.state.ak.us/spar/perp/seakpor/home.htm; accessed 25 February, 2011].

ANDRES, B.A. & BROWNE, B.T. 2004. The birds of Yakutat, Alaska. General Technical Report R10-TP-131. Juneau, Alaska: US Forest Service.

BELLEFLEUR, D., LEE, P. & RONCONI, R.A. 2009. The impact of recreational boat traffic on Marbled Murrelets (*Brachyramphus mamoratus*). *Journal of Environmental Management* 90: 531–538.

BUCKLAND, S.T., ANDERSON, D.R., BURNHAM, K.P., LAAKE, J.L., BORCHERS, D.L. & THOMAS, L.J. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford: Oxford University Press.

CARTER, H.R. & KULETZ, K.J. 1995. Mortality of Marbled Murrelets due to oil pollution in North America. In: Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G. & Piatt, J.F. (Eds.). Ecology and conservation of the Marbled Murrelet. General Technical Report PSW-GTR-152. Albany, California: US Forest Service, Pacific Southeast Research Station. pp. 261–269.

CARTER, H.R. & SEALY, S.G. 1984. Marbled Murrelet mortality due to gill-net fishing in Barkley Sound, British Columbia. In: Nettleship, D.N., Sanger, G.A. & Springer, P.F. (Eds.). Marine birds: their feeding ecology and commercial fisheries relationships. Special publication. Ottawa: Canadian Wildlife Service. pp. 212–220.

CAUGHLEY, G. 1977. Sampling in aerial survey. *Journal of Wildlife Management* 41: 605–615.

CONANT, B. & GROVES, D.J. 2005. Alaska–Yukon Waterfowl Breeding Population Survey, May 15 to June 7, 2005 [unpublished report]. Juneau, AK: US Fish and Wildlife Service.

DAY, R.H. 1996. Nesting phenology of Kittlitz's Murrelet (*Brachyramphus brevirostris*). *Condor* 98: 433–437.

DAY, R.H., KULETZ, K.J. & NIGRO, D.A. 1999. Kittlitz's Murrelet (*Brachyramphus brevirostris*). In: Poole, A. (Ed). The birds of North America, No. 435. Philadelphia, PA & Washington, DC: Academy of Natural Sciences & American Ornithologists' Union.

DE GRAAF, R.M., TILGHMAN, N.G. & ANDERSON, S.H. 1985. foraging guilds of North American birds. *Environmental Management* 9: 493–536.

EWINS, P.J. 1993. Pigeon Guillemot (*Cepphus columba*). In: Poole, A. and Gill, F. (Eds.). The birds of North America, No. 49. Philadelphia, PA & Washington DC: Academy of Natural Sciences & American Ornithologists' Union.

FISCHER, J.B. & LARNED, W.W. 2004. Summer distribution of marine birds in the Western Beaufort Sea. *Arctic* 57: 143–159.

FRID, A. & DILL, L.M. 2002. Human-caused disturbance stimuli as a form of predation risk. *Conservation Ecology* 6: 11.

GROVES, D.J., CONANT, B., KING, R.J., HODGES, J.I. & KING, J.G. 1996. Status and trends of loon populations summering in Alaska, 1971-1993. *Condor* 98: 189–195.

HENTZE, N.T. 2006. The effects of boat disturbance on seabirds off southwestern Vancouver Island, British Columbia [BSc thesis]. Victoria, British Columbia: University of Victoria.

HOEGH-GULDBERG, O. & BRUNO, J.F. The impact of climate change on the world's marine ecosystems. *Science* 328: 1523–1528.

JANSEN, J.K., BOVENG, P.L., DAHLE, S.P. & BENGTSON, J.L. 2010. Reaction of harbor seals to cruise ships. *Journal of Wildlife Management* 74: 1186–1194.

KIRCHHOFF, M.D. 2008. Alaska's Important Bird Areas Program. [Available online at: http://iba.audubon.org/iba/viewState.do?state=US-AK; accessed 5 January, 2011].

KIRCHHOFF, M.D. & PADULA, V.M. 2010. The Audubon Alaska WatchList 2010. Anchorage, Alaska: Audubon Alaska.

KULETZ, K.J., NATIONS, C.S., MANLY, B.F.J., ALLYN, A., IRONS, D.B. & MCKNIGHT, A. 2011a. Distribution, abundance, and population trends of the Kittlitz's Murrelet *Brachyramphus brevirostris* in Prince William Sound, Alaska. *Marine Ornithology* 39: 97–109.

KULETZ, K.J., SPECKMAN, S.G., PIATT, J.F. & LABUNSKI, E.A. 2011b. Distribution, population status and trends of Kittlitz's Murrelet *Brachyramphus brevirostris* in Lower Cook Inlet and Kachemak Bay, Alaska. *Marine Ornithology* 39: 85–95.

LAIST 1987. Overview of the biological effects of lost and discarded plastic debris in the marine environment. *Marine Pollution Bulletin* 18: 319–326.

MACK, D.E., RAPHAEL, M.G. & LAAKE, J.L. 2002. Probability of detecting marbled murrelets at sea: effects of single versus paired observers. *Journal of Wildlife Management* 66: 865–873.

MANLY, B.F.J. 2009. Incidental take and interactions of marine mammals and birds in the Yakutat salmon setnet fishery, 2007 and 2008. [Available online at: http://www.fakr.noaa.gov/protectedresources/observers/bycatch/yakutat07-08.pdf; accessed 6 October 2012].

NELSON, S.K. 1997. Marbled Murrelet (*Brachyramphus marmoratus*). In: Poole, A. (Ed.). The birds of North America, No. 276. Philadelphia, PA & Washington DC: Academy of Natural Sciences & American Ornithologists' Union.

NELSON, S.K. & HAMER, T. 1995. Nest success and the effects of predation on Marbled Murrelets. In: Ralph, C.J., Hunt, G.L. Jr., Raphael, M.G. & Piatt, J.E. (Eds.). The ecology and conservation of the Marbled Murrelet in North America: an interagency scientific evaluation. General Technical Report PSW-GTR-152. Arcata, California: US Forest Service, Pacific Southeast Research Station. pp. 89–98.

NORTH, M.R. 1997. Aleutian Tern (*Onychoprion aleuticus*). In: Poole, A. (Ed.). The birds of North America, No. 291. Ithaca, New York: Cornell Lab of Ornithology.

PIATT, J.F., KULETZ, K.J., BURGER, A.E., HATCH, S.A., FRIESEN, V.L., BIRT, T.P., ARIMITSU, M.L., DREW, G.S., HARDING, A.M.A. & BIXLER, K.S. 2007. Status review of the Marbled Murrelet (*Brachyramphus marmoratus*) in Alaska and British Columbia. Open File Report 2006–1387. Anchorage, Alaska: US Geological Survey.

RITCHIE, J.B., LINGLE, C.S., MOTYKA, R.J. & TRUFFER, M. 2008. Seasonal fluctuations in the advance of a tidewater glacier and potential causes: Hubbard Glacier, Alaska, USA. *Journal of Glaciology* 54: 401–411.

SCHMUTZ, J.A. 2009. Model-based predictions of the effects of harvest mortality on population size and trend of Yellow-billed Loons. Scientific Investigations Report 2009-1040. Anchorage, Alaska: US Geological Survey.

SHORTT, T.M. 1939. The summer birds of Yakutat Bay, Alaska. *Contributions of the Royal Ontario Museum of Zoology* 17.

SIMBERLOFF, D. & DAYAN, T. 1991. The guild concept and the structure of ecological communities. *Annual Review of Ecology and Systematics* 22: 115–143.

SPECKMAN, S.G., PIATT, J.F. & SPRINGER, A.M. 2004. Small boats disturb fish-holding Marbled Murrelets. *Northwestern Naturalist* 85: 32–34.

STEPHENSEN, S.W. & ANDRES, B.A. 2001. Marine bird and mammal survey of Yakutat Bay, Disenchantment Bay, Russell Fjord, and Nunatak Fiord, Alaska, 2000 [unpublished report]. Anchorage, Alaska: US Fish and Wildlife Service.

TARLOW, E.M. & BLUMSTEIN, D.T. 2007. Evaluating methods to quantify anthropogenic stressors on wild animals. *Applied Animal Behaviour Science* 102: 429–451.

US Fish and Wildlife Service (USFWS). 2011a. Species assessment and listing priority assignment form for Yellow-billed Loon. Anchorage, Alaska: US Fish and Wildlife Service.

USFWS. 2011b. Status assessment and listing priority assignment form for Kittlitz's Murrelet. Anchorage, AK: US Fish and Wildlife Service.

WRIGHT, A.J., SOTO, N.A., BALDWIN, A.L., BATESON, M., BEALE, C., CLARK, C., DEAK, T., EDWARDS, E.F., FERNÁNDEZ, A., GODINHO, A., HATCH, L., KAKUSCHKE, A., LUSSEAU, D., MARTINEAU, D., ROMERO, L.M., WEILGART, L., WINTLE, B., NOTARBARTOLO DI SCIARA, G. & MARTIN, V. 2007. Do marine mammals experience stress related to anthropogenic noise? *International Journal of Comparative Psychology* 20: 274–316.

ZYDELIS, R., WALLACE, B.P., GILMAN, E.L. & WERNER, T.B. 2009. Conservation of marine megafauna through minimization of fisheries bycatch. *Conservation Biology* 23: 608–616.