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DISTRIBUTION AND ABUNDANCE OF MARBLED MURRELETS IN ALASKA[1]

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Abstract. Most seabirds breed in colonies on offshore islands, but throughout most of their range from California to Alaska Marbled Murrelets (*Brachyramphus marmoratus*) fly inland to nest on trees in old-growth coniferous forests. Some fraction of the murrelet population nests on the ground in Alaska. The relative distribution and abundance of murrelets in forested and treeless areas of Alaska is poorly known. We analyzed data on seabird abundance at sea and on colonies in Alaska that were obtained under the Outer Continental Shelf Environmental Assessment Program during the 1970s and 1980s. Whereas most seabirds may be censused at breeding colonies, murrelet populations must be estimated from surveys at sea. We compared colony and pelagic population estimates for 13 colonial seabird species in Alaska and found that they were strongly correlated (r^2 = 0.94). We therefore used at-sea censuses to estimate that at least 160,000 murrelets reside in Alaska. Most (97%) Marbled Murrelets are concentrated offshore of large tracts of coastal coniferous forests in southeast Alaska (Alexander Archipelago), Prince William Sound, and the Kodiak Archipelago.

Key words: Murrelet; Brachyramphus; *population; Alaska; old-growth; survey; pelagic; colony.*

INTRODUCTION

The Marbled Murrelet (*Brachyramphus marmoratus*) breeds primarily in old-growth coniferous rainforests along the West Coast of North America from California to Alaska. They may fly up to 70 km inland to nest solitarily on mossy branches of large, old trees (Marshall 1988, Carter and Morrison 1992). Except for the congeneric Kittlitz's Murrelet (*B. brevirostris*), all other auks breed in colonies and nest on the ground—mostly on predator-free islands. In Alaska, an unknown proportion of Marbled Murrelets also breeds on the ground, usually on rocky inland slopes (Mendenhall 1992). In anticipation that "the species is likely to become endangered within the forseeable future throughout a significant portion of its range" (Stein and Miller 1992), largely because of logging of old-growth forests, the U.S. Fish and Wildlife Service (USFWS) recently listed the murrelet as threatened in California, Oregon, and Washington (about 4,500 breeding pairs [b.p.] in total; Carter and Morrison 1992). It is also listed as threatened in British Columbia (about 25,000 b.p.; Rodway et al. 1992). Little is known about the distribution and relative abundance of Marbled Murrelets in Alaska, where the bulk of the North American population resides. Regional estimates have ranged from "hundreds of thousands, to millions" and one state-wide estimate suggests that roughly 250,000 murrelets reside in Alaska (Mendenhall 1992).

Whereas most surface-nesting seabirds may be censused conveniently at their colonies, estimates of burrow-nesting, nocturnal, and forest-nesting seabirds are problematic. Murrelet population estimates are based solely on counts of birds at sea (Carter and Ericksen 1992, Mendenhall 1992, Nelson et al. 1992, Rodway et al. 1992, Speich et al. 1992). A wide variety of observation platforms and sampling methods have been used to collect data and extrapolate abundance—which makes it difficult to pool or compare data from adjacent geographic areas. One controversial aspect of estimating seabird populations from pelagic surveys is the problem of "flux," i.e., the movement of flying birds through the transect corridor. Seabird "flux" may lead to (less than an order of magnitude) overestimation of mean bird densities, especially if vessel speeds are slow

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(Gaston et al. 1987, Spear et al. 1992). This error may be reduced by using correction factors (Spear et al. 1992) or by making regular "instantaneous counts" of flying birds along the transect rather than counting all flying birds (Tasker et al. 1984, Gould and Forsell 1989). In any case, some skepticism exists that pelagic surveys can adequately estimate absolute population sizes (Haney 1985). However, the accuracy of pelagic population estimates has rarely been tested with independent data (but see Ainley 1985).

METHODS

We analyzed and compared two large data sets on the abundance of seabirds at sea and on colonies in Alaska, and then analyzed the pelagic data for Marbled Murrelets to estimate abundance and map distribution patterns. These data were collected in the 1970s and 1980s under the Outer Continental Shelf Environmental Assessment Program (OCSEAP). Data on birds at sea were collected from ships of opportunity as well as dedicated research vessels (Gould et al. 1982). The basic census unit was the 10-min transect, during which birds on the water were counted within a 300-m corridor to one side of the vessel, and instantaneous counts of flying birds within 300 m in all directions were made at regular intervals along the transect (Gould and Forsell 1989). After calculating the area surveyed per transect (ship speed × transect duration × 300 m), seabird densities were calculated as birds/km^2. For our analyses, we used data collected in the months of February through October, comprising about 40,600 km of transects in a marine area of about 2 million km^2.

Colony data for 13 well-studied, diurnal seabird species (with two murre [*Uria*] and three cormorant [*Phalacrocorax*] species grouped) were obtained from an updated and computerized version of the USFWS Seabird Colony Catalog (Sowls et al. 1978), which includes census data on 23,149,000 seabirds in 1,254 colonies located east of 180°W longitude in Alaska. Colonies were censused with a variety of methods, and often only once, so the accuracy of colony estimates is variable and often unknown (Sowls et al. 1978). Many colonies have been repeatedly censused, however, the errors associated with some colonies and species are probably more than ±20–50%.

Mapping and abundance estimations were conducted with the Geographic Information System software CAMRIS (Computer-Aided Mapping and Resource Inventory System, Copyright 1987, 1988 by R. G. Ford). For calculations of seabird abundance, we compiled all transect data into 60 min (1 degree) blocks of latitude and longitude (Fig. 1) east of 180°W, and extrapolated from observed densities in the portion of blocks overlapping with marine areas of Alaska (Table 1) defined by GIS polygonal overlays. Block densities were scaled geometrically. Missing blocks (Fig. 1) were assumed to contain average densities computed for each marine area. For murrelets, populations were estimated for two time periods: breeding (May–July) and nonbreeding (February–April, and August–September). For 13 other seabird species, populations were estimated from 60 min block densities for the period of May–August.

A murrelet distribution map (Fig. 2) was created from data compiled in 30 min latitude × longitude blocks using polygonal density contours for graphic presentation (Fig. 2). Missing blocks were filled using algorithms that extrapolate from densities in adjacent filled blocks. Data collected in April and August were included with May–July data to bracket the breeding period and show areas of habitat used by immediately pre- and post-breeding birds. In this case, density contour levels were scaled arithmetically and approximately 20% of the total area surveyed was apportioned among each contour level. This is useful for visualizing large-scale patterns of habitat use, while making it difficult to pinpoint areas of high concentration.

RESULTS AND DISCUSSION

The overall pattern of distribution apparent in our analysis is well supported by anecdotal data and small-scale surveys that have been conducted in selected areas of Alaska (Forsell and Gould 1981; K. Kuletz, K. Laing, and J. F. Piatt et al., unpubl. data; G. V. Byrd, P. Isleib, M. McAllister, and G. van Vliet, pers. comm.). Although murrelets range widely in the region of study, they are concentrated during the breeding season in three main areas: the Kodiak Archipelago, Prince William Sound, and the Alexander Archipelago (Figs. 1, 2, Table 1). More than 90% of the population is distributed within less than 8% of the total marine area surveyed in Alaska. Because of poor sampling, we did not map murrelet distribution in the Aleutians west of 180°W longitude. Probably less than a few

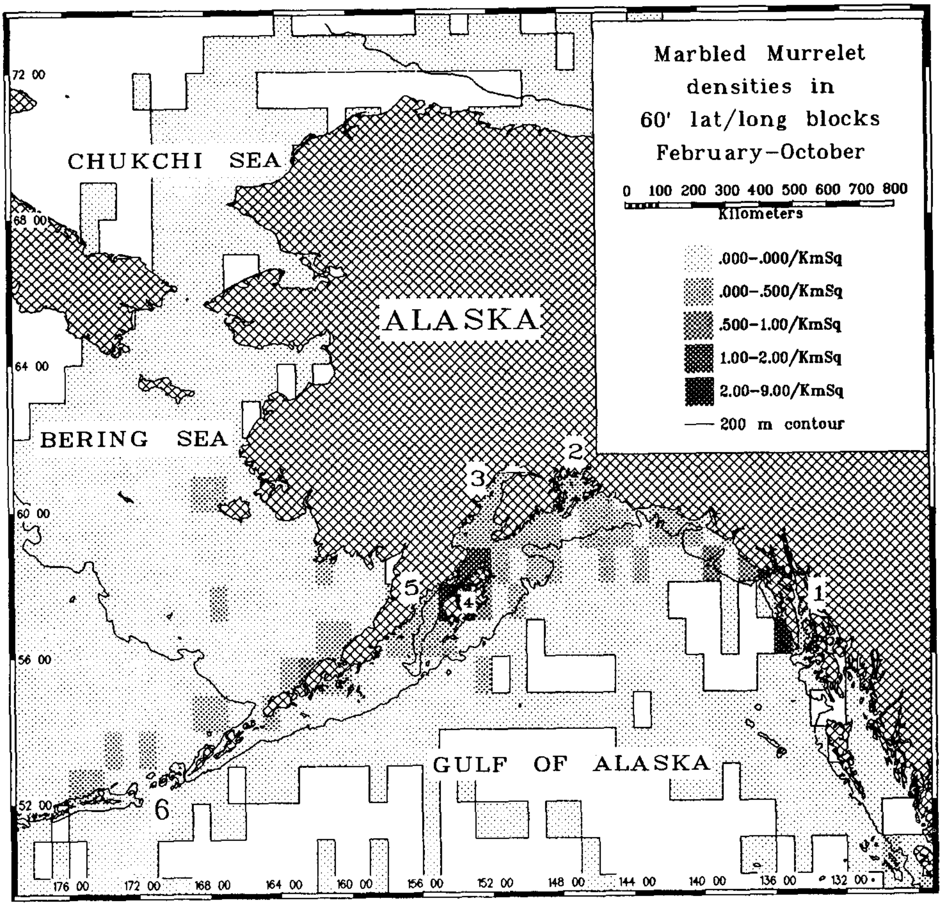

FIGURE 1. Distribution of Marbled Murrelets and survey coverage in 60′ latitude-longitude blocks in Alaska. Data compiled for the months of February–October. Murrelet densities are scaled geometrically. Similarly analyses for breeding and non-breeding seasons were used for estimating population sizes (Table 1). Numbered areas are: 1—Southeast Alaska (Alexander Archipelago), 2—Prince William Sound, 3—Cook Inlet, 4—Kodiak Archipelago, 5—Alaska Peninsula, 6—Aleutian Islands.

hundred murrelets are found in this area, mostly in bays around Attu Island (P. Isleib and G. V. Byrd, pers. comm.; J. F. Piatt, pers. observ.).

Murrelets generally occupy sheltered "inside waters," which includes bays, fiords, and island passes located in coastal areas of the northern Gulf of Alaska (Fig. 2). The pelagic distribution of murrelets also coincides spatially with the terrestrial distribution in Alaska (Viereck and Little 1972, Anonymous 1991, 1992) of coastal old-growth coniferous forests—especially Sitka spruce *Picea sitchensis* and hemlock *Tsuga* spp., which are used for nesting by murrelets (Quinlan and Hughes 1990, Naslund et al. 1993). An exception to this general pattern is found in Cook Inlet where coastal coniferous forests are abundant but murrelets are relatively scarce. However, lowland coastal forests in Cook Inlet include much black spruce (*Picea mariana*), which do not have characteristics (Viereck and Little 1972) apparently favored for nesting by Marbled Murrelets (Naslund et al. 1993; N. Naslund, pers. comm.). Furthermore, ship-based studies of lower Cook Inlet conducted in 1992 (Piatt, unpubl. data) suggest that strong tidal mixing of open waters in Cook Inlet provides poor foraging habitat for murrelets compared to stratified coastal waters. Thus, Marbled Murrelet distribution in summer may be determined largely by the spatial co-occurrence of suitable terrestrial breeding habitat and productive marine foraging areas.

During the breeding season, low densities of

TABLE 1. Estimated abundance of Marbled Murrelets in different marine areas of Alaska during breeding (May–July) and nonbreeding (February–April and August–October) periods.

		Estimated number of murrelets			
		Breeding		Non-breeding	
Marine area	km^2	*n*	%	*n*	%
Gulf of Alaska*					
Offshore (50–300 km)	488,000	9,820	6.4	30,000	18.0
Alexander Archipelago	48,200	96,200	62.9	87,100	52.3
Northern Gulf Coast	83,000	21,200	13.9	12,800	7.7
Kodiak Archipelago	30,300	21,900	14.3	27,800	16.7
Alaska Peninsula	40,500	1,580	1.0	2,420	1.5
Aleutian Is. (<100 km)	95,000	370	0.2	1,840	1.1
Bering Sea					
Alaska Pen. (<50 km)	27,700	1,300	0.8	3,380	2.0
Bering Shelf	570,000	660	0.4	1,130	0.7
Chukchi, Beaufort Sea	685,000	0	0.0	0	0.0
Total	2,067,700	153,030		166,470	
Survey Effort					
60′ blocks sampled		510		553	
Transect dist. (km)		18,224		22,400	

* Area within ca. 50 km of coast unless otherwise stated.

murrelets (possibly nonbreeders) may be found in outside waters (>50 km from shore). Excluding these offshore birds during the breeding season, only 3.1% of all murrelets are distributed outside the range of coastal coniferous forests in Alaska (i.e., west of and including the Alaska Peninsula). It appears that murrelets disperse to the south and west in winter, as numbers decline in sheltered northern Gulf waters, but increase offshore, along the Alaska Peninsula and in the Aleutians (Table 1). Limited data collected in November–January (not presented) suggests that numbers in the Alexander Archipelago decline to the low tens of thousands in mid-winter. Similarly, murrelet populations in Prince William Sound may diminish by about 75% in winter (K. Laing, pers. comm.).

Despite uncertainties that surround the use of pelagic data for estimating seabird populations, and the difficulties inherent in censusing remote seabird colonies, estimates derived from the Alaska pelagic database for 13 common Alaskan seabird species are well correlated with estimates obtained from whole-colony counts (Fig. 3). Even the absolute numbers appear reasonable, because the pelagic populations should include nonbreeding birds (ca. 30–50%) that are not associated with colonies (Gould et al. 1982, Ford et al. 1982). The agreement between these two large and independent data sets provides some confidence that both censusing techniques provide reasonable order-of-magnitude estimates of colonial seabird populations in Alaska. A comparison of population estimates for marine mammals in the Ross Sea, Antarctica, which were derived independently by researchers in contemporary but different survey efforts, also suggests that the relatively simple method of extrapolating population estimates from sampled latitude-longitude blocks can be reasonably precise (Ainley 1985; D. Ainley, pers. comm.).

How much confidence can we place in the estimates (Table 1) of absolute abundance for Marbled Murrelets derived from pelagic data? OCSEAP surveys were conducted opportunistically by many investigators over a long period. Survey effort was not randomly distributed among and within sampling blocks, and it is highly unlikely that sequential 10 min seabird transects are ever independent (Schneider and Piatt 1986, Schneider 1990). Therefore, we can place no valid confidence limits on these estimates. OCSEAP surveys were generally conducted from large vessels operating in outside waters. Thus, some sheltered inside waters preferred by murrelets were not sampled, and OCSEAP population estimates may be conservative for some areas. For example, the estimated population in the Northern Gulf of Alaska (Table 1) is probably low due to poor sampling in Prince William Sound. Isleib and Kessel (1973) estimated that about 250,000 murrelets occupied Prince William Sound in July

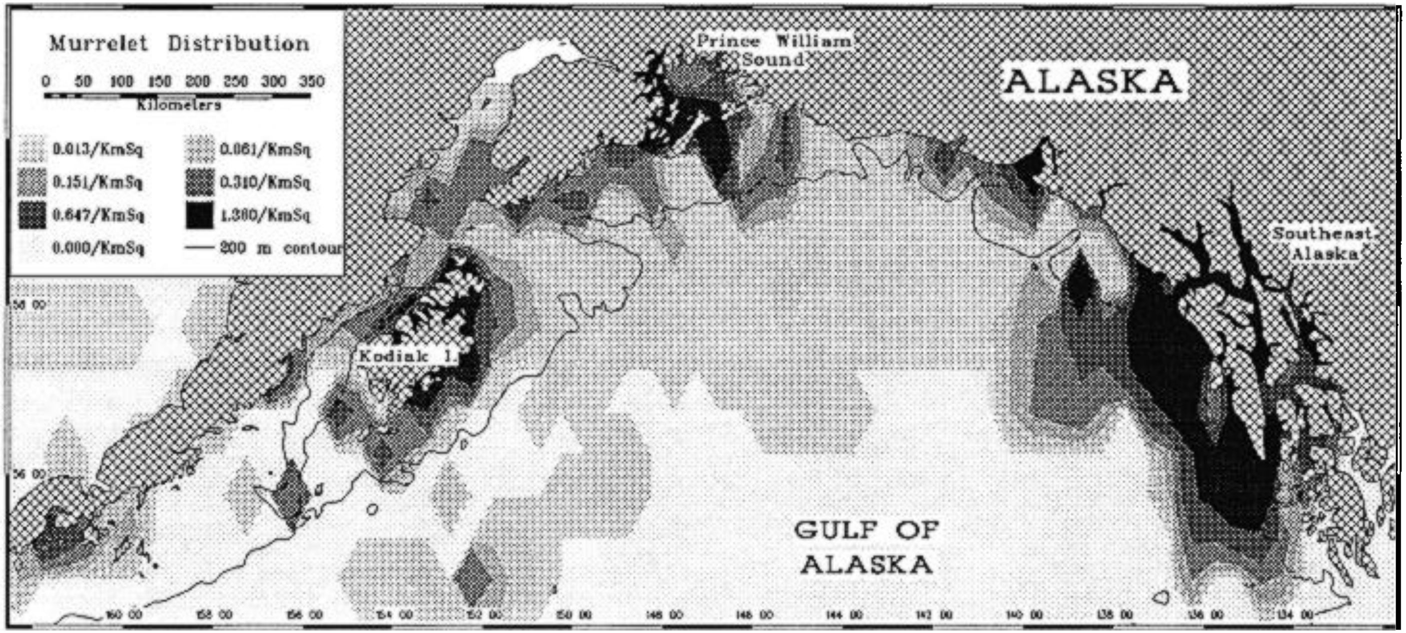

FIGURE 2. Distribution of Marbled Murrelets in the northern Gulf of Alaska. Density contour polygons calculated from data grouped in 30′ latitude-longitude blocks and scaled arithmetically.

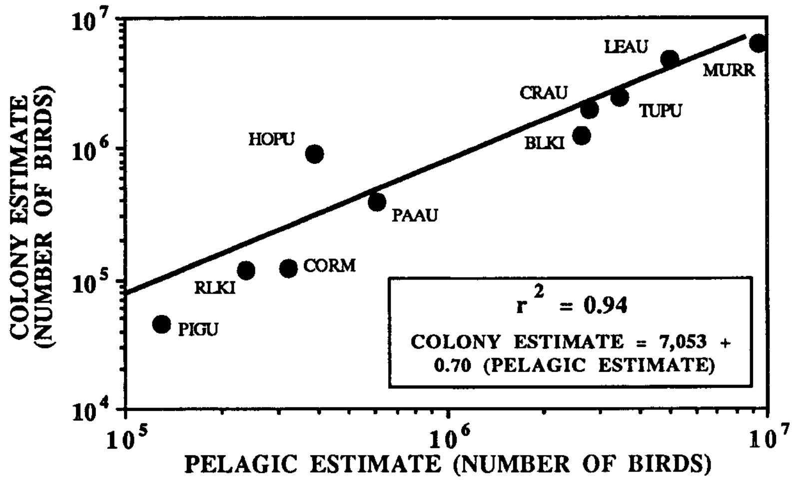

FIGURE 3. The relation between seabird population estimates derived from colony-based counts (Alaska Colony Catalog) and by extrapolation from pelagic densities (OCSEAP Pelagic Database). Species include: PIGU (Pigeon Guillemot *Cepphus columba*), RLKI (Red-legged Kittiwake *Rissa brevirostris*), CORM (Double-crested Cormorant *Phalacrocorax auritus*, Pelagic cormorant *P. pelagicus*, Red-faced Cormorant *P. urile*, and unidentified cormorants), HOPU (Horned Puffin *Fratercula corniculata*), PAAU (Parakeet Auklet *Aethia psittacula*), BLKI (Black-legged Kittiwake *R. tridactyla*), CRAU (Crested Auklet *A. cristatella*), TUPU (Tufted Puffin *F. cirhatta*), LEAU (Least Auklet *A. pusilla*), and MURR (Common Murre *Uria aalge*, Thick-billed Murre *U. lomvia*, and unidentified murres).

of 1972, and that the northern Gulf of Alaska population might be "several 100,000s, probably 1,000,000s." However, these estimates were very preliminary and should be discounted in the light of more extensive standardized surveys (P. Isleib, pers. comm.). Surveys conducted in Prince William Sound after the "Exxon Valdez" oil spill yielded summer (June–August) population estimates ranging between 47,000–107,000 *Brachyramphus* murrelets (K. Laing and S. Klosiewski, unpubl. data). These estimates were derived from random sampling, but survey methods were different from OCSEAP protocols (e.g., they used small boats traveling at variable speeds, and all flying birds were counted continuously), so results are not directly comparable. Furthermore, about 80% of their population estimates were derived by extrapolation from pelagic (non-shoreline) transects, and only about 3% of pelagic habitat was sampled. In any case, we believe that the OCSEAP population estimate for the Northern Gulf Coast is low (see below also).

The OCSEAP estimate for murrelet populations throughout the entire Kodiak Archipelago in winter (Table 1) appears quite reasonable compared to the estimate (15,000–20,000) given by Forsell and Gould (1981) for wintering populations of *Brachyramphus* murrelets in selected bays of Kodiak and Afognak islands. Their estimates were based on small boat surveys using OCSEAP protocols, and much of their data was included in our analysis (although we extrapolated over a larger area).

There are no other published data on the abundance of murrelets in Alaska with which to compare OCSEAP estimates. However, Mike McAllister (unpubl. data) conducted hundreds of surveys throughout much of the northern Gulf of Alaska between 1983 and 1991. Based on a preliminary examination of his data (M. McAllister, pers. comm., 1992), he made the following summer population estimates: Southeast Alaska: 45,000–70,000; Northern Gulf Coast (including Prince William Sound): 32,000–60,500; Kodiak Archipelago: 7,000–13,000; Alaska Peninsula: 4,000–10,000. His total regional estimate of 88,000–152,500 murrelets is similar to the total OCSEAP estimate (140,880) for the same subareas (Table 1).

The total population estimate for Marbled Murrelets in Alaska (Table 1) derived from OCSEAP data is tenatative, but is a reasonable estimate until detailed and comparable fine-scale surveys can be conducted throughout coastal and inside waters of the northern Gulf of Alaska. The strength of the OCSEAP data is that the 40,624 transects are internally consistent with regard to methodology, they cover most marine areas of Alaska, and pelagic population estimates are corroborated by independent colony data. The main weakness of the data arises from the sampling design (or lack thereof). We conclude that populations in Alaska during the late 1970s and early 1980s were in the low hundreds of thousands, possibly around 200,000 individuals. Oil pollution and gill-net mortality have probably reduced the size of populations since that time (Piatt et al. 1990, Mendenhall 1992).

Perhaps the most important implication of the OCSEAP data is that only about 3% of the Alaskan Marbled Murrelet population resides in wholly nonforested regions during the breeding season. Presumably this fraction of the population nests on the ground (Mendenhall 1992), although murrelets may also nest on the ground in alpine areas above the tree line. Outside Alaska, the Marbled Murrelet is probably even more restricted in its breeding to high-volume old-growth than the Northern Spotted Owl *Strix occidentalis* (Paton and Ralph 1990, Abate 1992, Carter and Morrison 1992). Of 17 tree nests that have now been found in Alaska, all were in old-growth coniferous trees and most were in large trees in high-volume stands (Quinlan and Hughes 1990; Naslund et al. 1993; N. Naslund, pers. comm.). Taken together, these observations suggest that Marbled Murrelet populations in Alaska are just as vulnerable to logging of old-growth forests as populations in the south.

In summary, it is evident from OCSEAP data and other studies that the Alexander Archipelago, Prince William Sound, and the Kodiak Archipelago provide breeding and foraging habitat for most (ca. 65%) of the North American population of Marbled Murrelets. Murrelets in these areas are threatened directly by logging, oil pollution, and gill-net fisheries. It therefore seems appropriate that conservation efforts for the Marbled Murrelet, which are now directed at remnant southern populations, should also focus on these areas of Alaska.

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