INTRODUCTION

Shifting distributions of higher trophic level consumers, such as birds, provide some of the most obvious evidence of the effects of global climate change on the biota, and serve as signals for impacts across trophic levels (Valiela & Bowen 2003, Illán et al. 2014, Paprocki et al. 2014, Billerman et al. 2016). The Bering Sea represents an ecotone between Arctic and Subarctic marine ecosystems that is largely governed by sea-ice extent, an environmental factor that varies among years (Stabeno et al. 2001, Ohashi et al. 2013, Wu & Chen 2016). Currently, sea-ice is experiencing a substantial overall reduction in distribution and thickness related to climate change (Wang & Overland 2009, Comiso 2012, Mueller et al. 2018). Because this region faces a range of climate change impacts, an overall northward shift in the biogeographic distribution of the region’s fauna has followed these decreases in sea-ice distribution and the concomitant northward shift in the ecotone between Arctic and Subarctic biomes (Mueter & Litzow 2008). These changes are likely to influence distributions and population dynamics of taxa at all trophic levels (Hunt et al. 2002, Hunt et al. 2011, Ohashi et al. 2013), but they may be most conspicuous when they result in changes to ecosystem members at high trophic levels—such as seabirds (Springer et al. 2007, Renner et al. 2016, Hunt et al. 2018).

Birds are distributed throughout the Bering Sea along gradients of sea surface temperature, salinity, ocean depths, and currents (Iverson et al. 1979, Hunt et al. 2014, Santora et al. 2018). Because of their association with sea ice, these gradients are likely to change as the extent of sea ice changes (Hunt et al. 2018). The Red-legged Kittiwake Rissa brevirostris is a Beringian endemic that remains in the Bering Sea during winter and feeds at the margins of sea-ice (Orben et al. 2015, 2018). Although sea-ice coverage is correlated with higher stress levels and may limit the ability of kittiwakes to obtain food (Will et al. 2018), Red-legged Kittiwake presence at the ice-edge likely reflects the presence of good foraging conditions and the opportunity to employ energy conservative techniques such as perching and foraging. Because fluctuations in sea-ice distribution in the Bering Sea influence reproductive success and productivity for surface feeding consumers such as kittiwakes (including the Black-legged Kittiwake R. tridactyla; Byrd et al. 2008, Zador et al. 2013), recent trends and projections of future sea-ice distributions may impact kittiwake populations.

The Red-legged Kittiwake is thought to feed on a low diversity of prey and possesses physical characteristics such as relatively large eyes and a short bill, indicating the importance of low-light foraging on a specific resource as a life-history strategy (Storer 1987). During the breeding season, Red-legged Kittiwakes feed on a range of prey types (Sinclair et al. 2008). In many years, myctophids (Family: Myctophidae), a diel species that is available to surface feeding consumers such as kittiwakes (including the Black-legged Kittiwake R. tridactyla; Billerman et al. 2016), this does not necessarily indicate a lack of nocturnal foraging. Rather, it may suggest a more energetically conservative nocturnal winter foraging strategy that highlights the importance of prey landscapes in this region during the winter months.

The Red-legged Kittiwake has a breeding distribution restricted to four major breeding locations, all within the Bering Sea (Fig. 1): the Pribilof Islands (St. George, St. Paul, and Otter: 235624 individuals; Thomson et al. 2014, Goyert et al. 2017), the Bogoslof Islands...
(Bogoslof and Fire: 918 individuals; Byrd et al. 2002), the Buldir Islands (Buldir, Outer Rock, Middle Rock: 9,350 individuals; Byrd et al. 1997), and the Commander Islands, Russia (Bering, Toporkov, Mednyi, Arij Kamen: 32,344 individuals; Byrd & Williams 1993, Vyatkin & Artukhin 1994, Byrd et al. 1997). Smaller breeding colonies are located on Amak and Chagulak Islands (16 and 18 individuals, respectively; Byrd et al. 2001, 2004) and Koniuji and Unalga Islands (eight and nine individuals, respectively; J. Williams unpubl. data), in the Aleutian Archipelago. Historically, the Red-legged Kittiwake was thought to be more widespread in the Aleutian Archipelago and elsewhere in the Bering Sea region (Byrd & Williams 1993); however, there is no existing historical evidence of breeding north of their present, northernmost breeding location on St. Paul Island (57°N). Although some Red-legged Kittiwakes winter in the northern Bering Sea (i.e., in waters off mainland Alaska and near St. Lawrence and St. Matthew islands, and Cape Navarin, Russia; Orben et al. 2018), they are rarely observed in this region during the breeding season (Swarth 1934, Faye & Cade 1959, Sealy et al. 1971, Winker et al. 2002); however, in recent years, they have been observed in low densities in waters around St. Matthew and St. Lawrence islands (Kuletz & Labunski 2017).

Here, we provide the first documentation of a Red-legged Kittiwake colony on St. Matthew Island. We report unprecedented numbers and behaviors of Red-legged Kittiwakes for this location, and provide evidence that these birds are likely breeding, which would represent a northern extension of the breeding distribution of this species by ca. 400 km. We discuss the status of colonies on St. George and St. Paul islands, and how breeding trends at these locations and other factors may relate to the discovery of the St. Matthew Island colony.

METHODS

The St. Matthew Island archipelago is part of the Bering Sea Unit of the Alaska Maritime National Wildlife Refuge, administered by the US Fish and Wildlife Service. The archipelago consists of three main islands: St. Matthew (60°24'N, 172°42'W), Hall (60°39'N, 173°05'W), and Pinnacle (60°12'N, 172°45'W). All three islands are uninhabited by humans and designated as Federal Wilderness. These islands are volcanic in origin and located on the Bering Sea Shelf, ca. 230 km east of the shelf break in a roughly central position between the coasts of Russia and Alaska. Because of their position in the Bering Sea, the islands support a mixture of northern Palearctic and Nearctic avifaunas.

During a 31-d visit, from 06 June–07 July 2018, we conducted population counts and productivity monitoring for McKay’s Bunting Plectrophenax hyperboreus and Pribilof Rock Sandpiper Calidris ptilocnemis ptilocnemis on St. Matthew Island. During our fieldwork, we collected data on all noteworthy bird and mammal sightings.

We conducted observations by land-based and boat-based methods. On 19 June, 01 July, and 04 July, we conducted land-based observations above a known seabird colony at cliffs on the northwest side of the island (Location A [60°29′N, 173°3′W], Fig. 2). We checked all visible cliff faces for the presence of Red-legged Kittiwakes, and noted locations where birds were sitting on nests. During land-based observations on 01 and 04 July, conditions were foggy with marginal visibility; however, the fog cleared intermittently on these dates, and we were able to make limited observations. On 06 July, we conducted a boat-based survey along the north and northwest sides of St. Matthew Island, looking for kittiwake breeding habitat and additional Red-legged Kittiwakes. We conducted boat-based observations starting north from camp and continuing around the north end of the island and south towards location A. Our survey platform was a 4.5 m-long inflatable skiff employed by a three-person crew (two observers and one skiff operator). During boat-based observations, we maintained a maximum distance of 100 m from the shoreline to best observe potential Red-legged Kittiwake nesting habitat that we could not see from land-based observation points.

Fig. 1. Red-legged Kittiwake breeding distribution. Colonies are indicated by red circles representing relative colony size (range: 235,624 individuals on the Pribilof Islands to eight individuals on Koniuji Island). St. Matthew Island is located ca. 400 km north of St. Paul Island.
**OBSERVATIONS**

During land-based observations on 19 June, we noted two Red-legged Kittiwakes on the water in mixed flocks with ca. 18 Black-legged Kittiwakes (Location A, Fig. 2). In the same vicinity, we observed Red-legged Kittiwakes both in flight and perched on sea cliffs (ca. 130 individuals) amidst Black-legged Kittiwakes and Common Murres *Uria aalge*. Our count for this day reached ca. 150 Red-legged Kittiwakes across the 1.5 km sea-cliff colony. At this time, we did not observe behaviors that indicated breeding, apart from pairs perched together on the cliffs.

On 01 July, we visited the sea-cliff colony (Location A, Fig. 2) and observed ca. 100 Red-legged Kittiwakes. Of these birds, we observed individuals conducting courtship behaviors, carrying nest material, and building and stamping nests. Unfortunately, visibility on this date was restricted by dense fog and we were unable to fully count birds attending ledges throughout the sea-cliff colony. However, we intermittently obtained views and were able to photograph the kittiwakes on the cliff (e.g., Fig. 3). When conditions permitted, we observed ca. 10 Red-legged Kittiwakes sitting on nests. On one occasion, we observed two individuals for ca. 30 min until they stood and revealed empty nests.

On 06 July, we successfully surveyed the north end of the island, where we found only Black-legged Kittiwakes on the cliffs; however, we found ca. 30 Red-legged Kittiwakes on the west side at a cliff face where they had not been seen previously (Location B [60°32′N, 173°03′W], Fig. 2), ca. 5.8 km north of Location A. At Location B, we observed pairs nest stamping, as well as standing and sitting on nests (Fig. 4). Unfortunately, owing to rough seas, we were unable to reach Location A to survey, from the water, the ca. 3 km of cliff habitat that was mostly not visible from our land-based observations.

Based on our combined high counts at Locations A and B, we conservatively estimate that there are ca. 200 adult Red-legged Kittiwakes present at the locations we visited (representing only ca. 12% of potential kittiwake nesting habitat on St. Matthew, Hall, and Pinnacle islands; World Seabird Union 2019). At the time of our departure from St. Matthew Island on 07 July, we were unable to confirm Red-legged Kittiwake egg-laying.

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**Fig. 2.** The St. Matthew Islands including St. Matthew, Hall, and Pinnacle islands, along with an inset of the north end of the island where our observations were focused. Black circles indicate locations and approximate numbers of Black-legged Kittiwake, and red circles indicate location and approximate numbers of Red-legged Kittiwake.

**Fig. 3.** Kittiwake cliff nesting habitat at a portion of the cliff faces at Location A (Fig. 1). Dots illustrate the abundance and distribution of Red-legged Kittiwake from this observation point. Other habitat where kittiwakes could be heard at Location A were out of view from land-based observers.
We document substantial numbers (ca. 200) of Red-legged Kittiwakes on St. Matthew Island, along with observations of copulation and nest building that likely indicate that this species is breeding there. Although we provide the first documentation for this species occupying cliffs on St. Matthew Island, it is possible that the birds have been present on the island for some time and have gone unnoticed. Previously, the species’ status at St. Matthew has been considered casual or accidental in summer, with the earliest known record of one adult observed in August 1985 (Winker et al. 2002). The species has since been observed near the island on a few other occasions, including an eBird report listing two individuals seen in waters south of the island on 01 October 2006 (ML S9104078, www.ebird.org) and a single individual sighted in 2012 near Cape Upright, on the southern tip of St. Matthew Island (T. DeGange in litt.). More recently, one individual was observed at Pinnacle Island and two individuals were observed at Hall Island on 18 August 2018 by a tour group (Scott Schuette pers. comm; ML S47934195, S47921944; www.ebird.org). In the broader region of the north Bering Sea, Red-legged Kittiwakes have been documented in low numbers during the breeding season since 2006 (Kuletz & Labunski 2017).

Because of its remote location and challenging weather, very few targeted avian studies have been conducted on St. Matthew Island (Winker et al. 2002). Despite this, several notable previous expeditions to the area failed to document Red-legged Kittiwake (Hanna 1917, Gabrielson 1944, Goetzman & Sloan 1982). The failure to record the species was not due to lack of observer effort, as the topic is explicitly addressed in Gabrielson (1944, pg. 130): “We also looked carefully over the kittiwakes on St. Matthew and Hall islands for [Red-legged Kittiwake] but found none.” More recently, several expert research teams have visited the islands to conduct standardized seabird monitoring, and none recorded the species (DeGange & Sowls 1978, Byrd & Early 1985, Murphy et al. 1987, Mendenhall 1994, Renner & Sowls 2005, Romano & Renner 2012). The absence of previous observations of Red-legged Kittiwakes by so many different teams of trained observers who were familiar with this species supports the scenario that it has only recently begun to occupy St. Matthew Island. However, our land-based observations were made in a very remote part of the island, well away from the usual camp locations of previous expeditions. It is unclear whether previous observers visited Locations A and B, or looked closely over the cliffs for Red-legged Kittiwake. Additionally, most previous observers were conducting their work from land-based sites. The boat-based aspect of our survey helped confirm our land-based observations and allowed us to survey areas inaccessible to land-based crews, which increased our estimate for the number of Red-legged Kittiwakes conducting nesting activities on the island.

Although our survey occurred during the early part of the seabird nesting cycle and we did not observe eggs or young, our observations of nest building and breeding behavior (courtship behavior, birds in incubation posture) provide strong evidence that Red-legged Kittiwakes attempted to breed on St. Matthew Island. The closest Red-legged Kittiwake colony with breeding phenology data for 2018 is located on St. George Island, ca. 470 km south of St. Matthew Island. During 2018, laying success of Red-legged Kittiwakes at St. George was very low, and breeding was delayed (Guitart et al. 2018). Mean hatch of Red-legged Kittiwakes there occurred on 16 August (n = 2), 32 d later than the long-term mean from 1975–2017. Assuming a ca. 30-d incubation period (Byrd & Williams 1993), mean laying on St. George occurred on 17 July (Guitart et al. 2018). Given the late breeding on St. George in 2018, it is possible that that the Red-legged Kittiwakes that we observed on St. Matthew Island may have initiated clutches following our departure from the island on 07 July. This possibility is further supported by our lack of observations of eggs or young of Black-legged Kittiwakes, which we also observed conducting courtship behaviors and nest building. Black-legged Kittiwake is a locally abundant species with a mean laying date that occurs later at higher latitudes (Dragoo et al. 2018) and has very similar breeding phenology to Red-legged Kittiwakes when in sympatry (Guitart et al. 2018).

Our observations suggest a substantial extension of the Red-legged Kittiwake breeding distribution during a time of great change in the Bering Sea. If their presence at this location continues, it provides an opportunity to understand mechanisms involved in the capacity of this regional endemic to shift its breeding range northward. For instance, it is possible that Red-legged Kittiwake presence at St. Matthew Island was facilitated through prospecting movements, much like those documented in Black-legged Kittiwake (Ponchon et al. 2015). Methods such as satellite telemetry on St. Paul and St. George islands may reveal the role of such mechanisms in shifting breeding distribution in response to climatic changes in the Bering Sea region (Ponchon et al. 2012).

In some ways, St. Matthew is a surprising location for Red-legged Kittiwakes to colonize. This species is thought to specialize on food resources such as Stenobrachius leucopsarus (Family: Myctophidae), which are generally found in waters deeper than 200 m (Beamish et al. 1999). St. Matthew Island is located on the Bering Sea Shelf in an area where ocean depth is generally less than 200 m; therefore, deep-water myctophids may not be available as food resources to Red-legged Kittiwakes in close proximity to this breeding location. However, deep water at the shelf break may be within foraging range, although trips to obtain such food resources would be longer than those at breeding locations such as at the Pribilof Islands (ca. 230 km from St. Mathew Island compared to ca. 100 km from St. Paul). For instance, Black-legged Kittiwakes have been documented making extended foraging trips to access...
resources during the brood-rearing period, across distances as large as 201.4 ± 6.9 km (n = 18; Paredes et al. 2014). Further focus on the breeding status, movements, and diet of St. Matthew Island Red-legged Kittiwakes may provide insight into the species’ capacity to shift its range northward through their ability to utilize alternate food resources, or to extend foraging trips to deep water where resources are available.

The Red-legged Kittiwake is listed as vulnerable by the IUCN, a cautionary designation owing to its restricted breeding range and past population decrease (IUCN 2017). Given this status, our finding of Kittiwakes on St. Matthew Island may provide some clarity around downward trends in population and productivity on the Pribilof Islands (Guitart et al. 2018). Throughout their annual cycle, changed changes to the oceanographic regime in this region will likely have important implications for Red-legged Kittiwake distribution and population status (Orben et al. 2015). Thus, our observations underscore the need for continued focus on Red-legged Kittiwake occupancy at St. Matthew Island, as well as the multitude of other seabirds that breed at this remote Bering Sea location.

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REFERENCES


