SUCCESSFUL BREEDING OF CASPIAN TERNS *HYDROPROGNE CASPIA* IN THE ARCTIC—PART OF THE NEW NORMAL?

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ABSTRACT

HAYNES, T.B., TIBBLES, M., RODRIGUEZ, K., HAGGERTY PERRAULT, B. & ROBARDS, M.D. 2017. Successful breeding of Caspian Terns *Hydroprogne caspia* in the Arctic—part of the new normal? *Marine Ornithology* 45: 143–148.

Caspian Terns *Hydroprogne caspia* have expanded their range in the Eastern Pacific, including southern areas of Alaska, over the past several decades. In 2015, we discovered a pair of Caspian Terns on a small gravel island within Krusenstern Lagoon in Cape Krusenstern National Monument and monitored their breeding status until they successfully fledged two chicks. This site is 653 km north of where Caspian Terns had previously been reported to successfully fledge a chick, and represents the first observations of the species breeding above the Arctic Circle or along the Chukchi Sea coastline. The successful fledging of two chicks at Krusenstern Lagoon suggests that this site, and possibly other Arctic sites, can be suitable breeding habitat. Snow cover and sea-ice duration have decreased dramatically in the Chukchi Sea region over the past four decades; as well, seasonal melt-out has become earlier and freeze-up later. As a result of the longer ice-free season, the Arctic may have recently become available as Caspian Tern breeding habitat as it can now accommodate the long breeding season of this species.

Key words: range expansion, climate change, distribution, sea ice, Caspian Terns, Arctic lagoons, *Sterna caspia*

INTRODUCTION

Caspian Terns *Hydroprogne caspia* occur on all continents except Antarctica (Cuthbert & Wires 1999). During the last century, numbers have dramatically increased on the west coast of North America, and the species has expanded its range northward (Gill & Mewalt 1983, Suryan *et al*. 2004, Wires & Cuthbert 2016). This change in distribution is likely due to a combination of factors, including the Caspian Terns' plasticity in selection of nesting habitats, their ability to respond quickly to changes in habitat availability, their low natal and breeding philopatry, and their ability to disperse widely (Gill & Mewalt 1983). Furthermore, adults and fledglings often fly northward after the breeding season, before dispersing south to overwintering grounds, which may present opportunities to discover new available habitats (Gill & Mewaldt 1983, Suryan *et al*. 2004).

With their expansion into new regions along the west coast of North America, Caspian Terns have demonstrated that they can breed in a wide range of conditions, as long as safe breeding sites and sufficient fish prey are available. Nesting and chick-rearing habitat must provide protection from storms and mammalian predators (Cuthbert & Wires 1999; Gill 2008) and be close to foraging areas containing small forage fish in surface waters (Anderson *et al.* 2007). Given Alaska's extensive coastline and productive marine waters, Gill & Mewaldt (1983) predicted that Caspian Terns would form nesting colonies in Alaska as their range continued to expand.

Caspian Terns were first recorded in Alaska in 1981 and are thought to have been breeding in southeast Alaska since 1989 (Gibson & Kessel 1992). The first documented breeding was in 1996 on Neragon Island in the Bering Sea (McCaffery *et al*. 1997). Since then, reports of breeding in Alaska have expanded to include numerous locations around the state, including the Copper River Delta, Icy Bay, and the Yukon-Kuskokwim Delta (Johnson 2003, Lohse *et al*. 2008, Gill 2008). However, Caspian Terns, including the northern populations in Europe, Asia, and North America, have never been found breeding in the Arctic Basin (Ulrik Lötberg, pers. comm., Aleksandr Andreev, pers. comm.).

Here, we report the first observation of Caspian Terns breeding in the Arctic at a location approximately 585 km north of the previously known most northerly nest at Neragon Island (61.85278°N) in the Bering Sea (McCaffery *et al*. 1997) and 653 km north of the most northerly recorded fledgling on the Yukon-Kuskokwim River Delta (61.15444°N; Gill 2008). Much of the expansion of Caspian Terns in southerly regions has been related to direct human alteration of its habitats (e.g., islands created with dredging materials, prey base increased by hatchery fish releases; Gill & Mewaldt 1983). We suggest that the expansion of Caspian Terns into the Arctic is related to the changing Arctic conditions becoming more favorable to sub-Arctic species (e.g., Gaston & Woo 2008).

OBSERVATIONS

Krusenstern Lagoon (56 km^2), the largest lagoon in Cape Krusenstern National Monument (Fig. 1), is seasonally open to the Chukchi Sea via the 15 km Anigaaq Channel. The lagoon's channel generally opens to the Chukchi Sea during spring as a result of ice breakup and closes around mid-July as gravel is pushed up by strong wave action. As a result of limited salt-water intrusion and fresh water input, Krusenstern Lagoon is generally brackish (salinity ranges 1–5 Practical Salinity Units (PSU); Robards 2012, Reynolds 2012, Haynes *et al*. 2017) and has a very small tidal range. It supports high densities of ninespine stickleback *Pungitius pungitius* and pond smelt *Hypomesus olidus*, which are important in the diets of both larger predatory fish and piscivorous birds within the lagoon (Haynes *et al*. 2017). The adjacent Chukchi Sea also supports

high abundances of Pacific herring *Clupea pallasii*, rainbow smelt *Osmerus mordax*, capelin *Mallotus villosus*, and Pacific sandlance *Ammodytes hexapterus* (Haynes *et al*. 2017).

We first observed a Caspian Tern at Krusenstern Lagoon in 2015 (Table 1) but did not document breeding until 2016. On 25 July 2015, in the northwestern portion of Krusenstern Lagoon (~67.15444°N), we observed a Caspian Tern flush from a long, narrow gravel island (Figs. 1, 2). The tern circled our boat while making alarm calls. We did not investigate the island at that time. On 25 July 2016, we again observed an adult Caspian Tern making alarm calls while circling the same gravel island (67.15472°N, 163.70619°W) noted in 2015. Upon further investigation of the island by boat, we found two flightless Caspian Tern chicks (estimated age 15–18 d; Yasuko Suzuki, pers. comm.; Fig. 3) being attended by two adults. As we approached, one tern chick swam away from shore, while the second chick remained on the island. The chick that swam returned to the island after we had left the island. On the island, we found a scrape that was likely a Caspian Tern nest.

The nesting island for these Caspian Terns had high densities of Glaucous Gull *Larus hyperboreus* fledglings (0.15 chicks/m^2 on one occasion). Potential nest predators on the adjacent mainland included red fox *Vulpes vulpes* and brown bear *Ursus arctos*.

We revisited the nesting island six more times during the summer and fall of 2016 (Table 1). On 18 August 2016, we observed three Caspian Terns: an adult, a fledgling capable of flying short distances (Fig. 3), and another individual that flushed before we could determine whether it was a chick or an adult. On 26 August 2016, we saw two adults and two juvenile Caspian Terns flying approximately 1.5 km from the island. These observations suggest that both tern chicks successfully fledged from the island. We did not observe Caspian Terns on our last survey of the island on 13 September 2016. The island had recently been washed over by waves. During the last survey, we measured the island with a handheld global positioning system (GPS), and found that it was 78 m long and, on average, about 3 m wide (range 2–7 m), for a total area of about 312 m^2 (Fig. 2). The highest elevation of the island was about 0.5 m above mean water level.

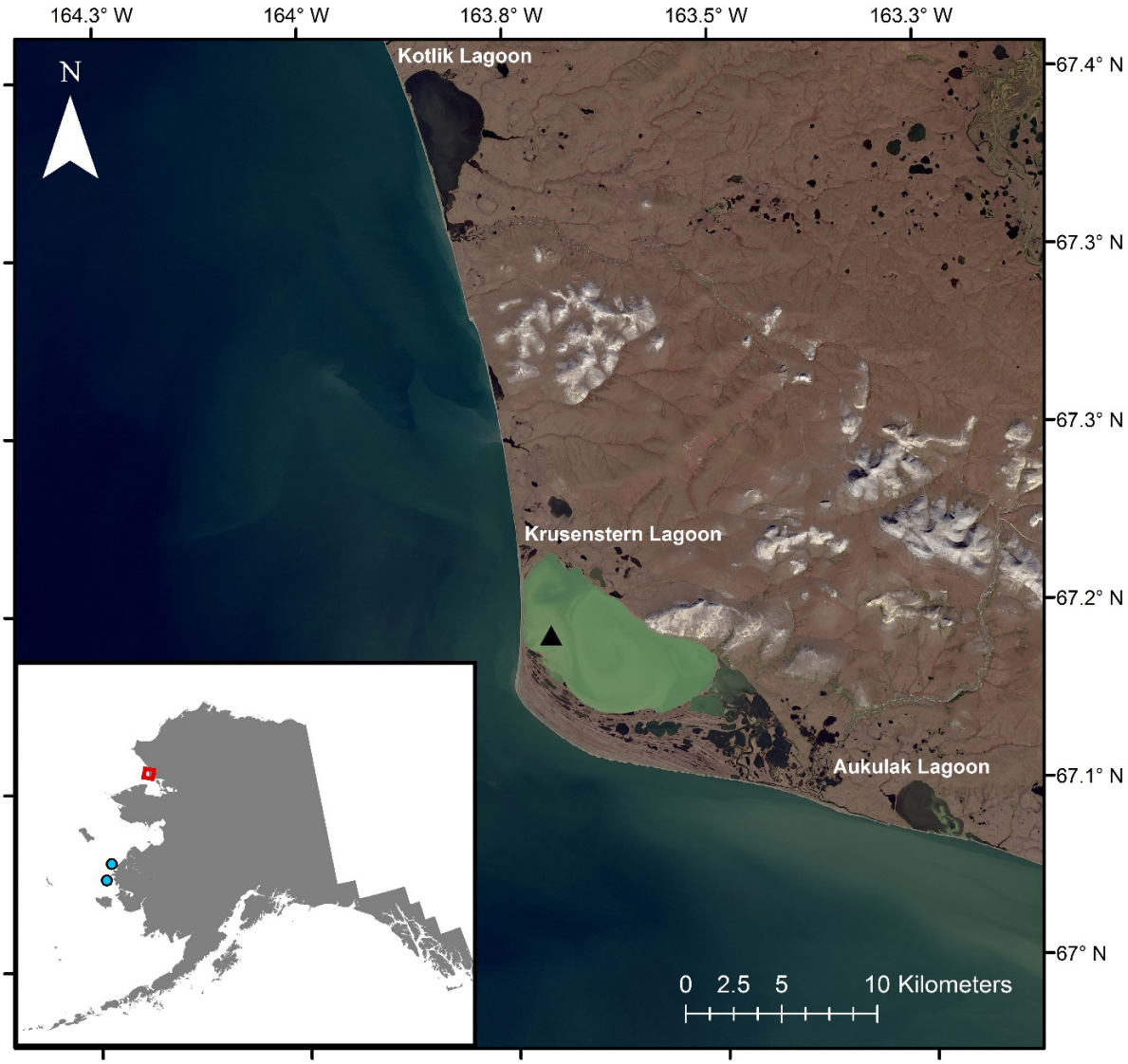

Fig. 1. Location of a small gravel island (black triangle) in Cape Krusenstern National Monument where we discovered two flightless Caspian Terns attended by two adults. Inset shows study area (red box) and previously recorded most northern breeding locations (blue dots).

On several occasions (31 July, 1 and 27 August 2016) we noted Caspian Terns, including a newly fledged chick, at Kotlik Lagoon, 23 km north of the nesting location at Krusenstern Lagoon, and on one occasion (22 July 2016), an adult 25 km south at Aukulak Lagoon. Kotlik Lagoon has several colonies of Arctic Terns and at least one colony of Aleutian Terns, and thus may provide suitable breeding habitat for Caspian Terns. We actively searched for nests at Kotlik on two occasions (31 July, 2 August, 2016) and at Aukulak Lagoon on one occasion (25 July 2016), but we did not find any nesting activity. We cannot conclusively determine whether the Caspian Terns observed at Kotlik and Aukulak lagoons were different terns from those we followed at Krusenstern Lagoon.

DISCUSSION

Our observations of Caspian Terns on successive seasons at Krusenstern Lagoon, including the confirmation of fledging, represent the first documented breeding of Caspian Terns north of the Arctic Circle or along the Chukchi Sea coastline. The observed range expansion is likely related to newly available nesting habitat, coupled with the species' expanding population and its propensity to disperse to areas providing sufficient prey and suitable nesting habitat.

Atmospheric warming in the Arctic has resulted in dramatic reductions in sea-ice in the Arctic Ocean (Wang & Overland 2009,

TABLE 1
Summary of observations of Caspian Terns from 2015 and 2016 in Cape Krusenstern National Monument

Date	Location	Coordinates	Caspian Terns observed	Notes
25 July 2015	Krusenstern Lagoon	67.15472°N, 163.70619°W	1 adult	Adult flew off the sand island as we drove by on the boat. Did not investigate island.
22 July 2016	Aukulak Lagoon	67.05851°N, 163.23834°W	1 adult	On the eastern basin of the lagoon, observed flying and calling.
23 July 2016	Krusenstern Lagoon	67.15472°N, 163.70619°W	2 chicks, 2 adults	Discovered two chicks being attended by two adults on small island on the east side of lagoon.
25 July 2016	Aukulak Lagoon	67.05851°N, 163.23834°W	none	Nest searched in the eastern basin of Aukulak Lagoon, no Caspian terns detected.
26 July 2016	Krusenstern Lagoon	67.15472°N, 163.70619°W	2 chicks, 2 adults	Visited breeding pair on island. Took photos of adults and chicks.
31 July 2016	Kotlik Lagoon	67.346467°N, 163.845854°W	2 adults	Observed flying at Kiligmak Inlet. Searched for nest/chick in Kiligmak wetland. No Caspian Terns detected.
1 August 2016	Kotlik Lagoon	67.346467°N, 163.845854°W	1 adult	Observed flying at Kiligmak Inlet.
2 August 2016	Kotlik Lagoon	67.346467°N, 163.845854°W	none	Searched for nest/chick in Kiligmak wetland. No Caspian Terns detected.
8 August 2016	Krusenstern Lagoon	67.15472°N, 163.70619°W	1 adult	Visited nesting island—one adult seen but chicks likely flushed on approach. Low light prevented good viewing.
18 August 2016	Krusenstern Lagoon	67.15472°N, 163.70619°W	1 fledgling, 1 adult, 1 unidentified life stage	Visited nesting island. Fledgling starting to fly short distances. One of the Caspian Terns flushed before we could identify whether it was an adult or juvenile.
23 August 2016	Krusenstern Lagoon	67.15472°N, 163.70619°W	2 fledglings, 2 adults	Three Caspian Terns seen on nesting island (one confirmed adult and one confirmed fledgling). Four Caspian Terns (two fledglings and two adults) seen flying on mainland approximately 1 km from nesting island.
27 August 2016	Kotlik Lagoon	67.346467°N, 163.845854°W	1 fledgling, 2 adults	Observed flying at Kiligmak Inlet.
2 September 2016	Krusenstern Lagoon	67.15472°N, 163.70619°W	1 fledgling, 1 adult	Observed on nesting island. Terns flushed off island as boat approached.
13 September 2016	Krusenstern Lagoon	67.15472°N, 163.70619°W	None	Visited nesting island. Did not observe signs of Caspian Terns.

Stroeve *et al*. 2012) and in the duration of snow cover (Callaghan *et al.* 2011). Across the North American Arctic, the extent of June snow cover has decreased by 21.5% per decade, and the extent of September sea-ice cover has decreased by 10.8% per decade (1979–2012; Derksen & Brown 2012). Of the seas that constitute the Arctic Ocean, the Chukchi Sea has experienced one of the most profound trends in the lengthening of the ice-free season, with an earlier onset of ice melt in the spring and later ice formation in the fall (Markus *et al*. 2009, Wood *et al*. 2015, Gall *et al.* 2016). From 2011 to 2015, the nearshore Chukchi Sea adjacent to the nesting island had ≤10% ice cover for an average of 4.5 months (standard deviation [SD] 0.54 months) compared with 2.9 months (SD 1.0 months) over the past century (Historical Sea Ice Atlas, University of Alaska, 2016). Timing of loss of snow cover and sea-ice break-up, as well as the extent of seasonal ice, have strong influences on Arctic marine ecosystems and wide-ranging effects on ecosystem processes (Post *et al*. 2013) that can affect bird distributions (Mallory *et al*. 2010, Gaston & Woo 2008, Gall *et al.* 2016) and phenology (e.g., Smith *et al.* 2010, Liebezeit *et al.* 2014). A longer snow- and ice-free season can provide new opportunities for lower-latitude species that require a suitable duration of temperate summer conditions for successful breeding in the Arctic. Furthermore, such opportunities may persist, now that these new conditions in the Arctic are no longer regarded as part of a transient cycle but rather as the "new normal" (Moore & Stabeno 2015).

Because they have a longer breeding period than other tern species (Cuthbert & Wires 1999), Caspian Terns are likely one of these lower-latitude species that requires a long period of temperate, snow- and ice-free conditions during the breeding season to be successful in the Arctic. With the Caspian Tern's incubation period of 25–28 d and pre-fledging period of 53–59 d, it takes Caspian Terns 78–87 d to fledge two chicks. By contrast, Arctic Terns *Sterna paradisaea* and Aleutian Terns *Onychoprion aleuticus,* which breed in the Arctic, including close to Krusenstern Lagoon, can fledge two chicks in 52–58 d and 54-64 d, respectively (Hatch 2002, North 2013). Even with this shorter breeding duration, during cold springs with high sea-ice cover, Arctic Terns that are restricted to using marine waters may have to delay breeding (Evans & McNicholl 1972) or to restrict breeding to certain locations (Lack 1933, Bird & Bird 1940). Thus, the length of the snow- and ice-free season in the Arctic represents a key constraint on the time available to complete all of the requisites of a successful breeding season (i.e., initiate a nest, lay, incubate and hatch eggs, and fledge chicks).

Fig. 2. The breeding island in Krusenstern Lagoon taken from the south end of the island on 13 September 2016 (Photo Trevor B. Haynes).

With the earlier onset of snow and ice melt in the Chukchi Sea, Caspian Terns can now initiate nests earlier—consistent with warmer Arctic springs, which have been associated with earlier egg laying in other seabirds as well (e.g., Gaston *et al*. 2005, Moe *et al*. 2009, Møller *et al*. 2006). For the Caspian Tern nest at Krusenstern Lagoon, the chicks likely hatched on 5 July and did not fledge until 23 August, which is similar to the hatch date on Neragon Island (McCaffery *et al*. 1997) and the Yukon-Kuskokwim River Delta (Gill 2008), but about a month later than Caspian Terns on the Copper River Delta (Suzuki & Bishop, pers. comm.). Despite the ameliorating conditions, Caspian Terns still likely initiate nests relatively late because of timing of ice break-up. They are fledging chicks only weeks before ice begins to form on the lagoon and the fall storm season begins. Low-relief islands are likely washed over by fall storm waves, as demonstrated by the visit to the island at Krusenstern Lagoon on the 13 September visit. If the chicks had fledged later, fall storms would have likely caused fledgling death (e.g., Gill 2008).

Alaska may have extensive barrier islands with available nesting habitat, although predation from Glaucous Gulls may be a factor that limits the breeding habitat of Caspian Terns (Gill 2008). Caspian Terns nested sympatrically with Glaucous Gulls at Cape Krusenstern Lagoon; however, tern adults could protect their nest from Glaucous Gulls by mobbing gulls when the colony was disturbed. Based on island area, the island used by the Caspian Terns for breeding may have the capacity to support more breeding pairs. However, it is unclear whether increased numbers of terns would displace the high densities of Glaucous Gulls, or whether gulls would be a source of breeding failure as the tern colony increases.

Fig. 3. Top, a flightless Caspian Tern chick on 23 July 2016; bottom, a volant Caspian Tern fledgling on 16 August 2016 (photos Kevin Rodriguez).

Previously, Gill (2008) suggested that it would be unlikely for Caspian Terns to continue to expand their range northward from the southern Bering Sea, given the projection of more frequent storm surges and flooding of that area's low-lying habitat (e.g., Arp *et al*. 2010, Terenzi *et al*. 2014). However, with the increases in the ice-free season north of the Arctic Circle (e.g., Markus *et al.* 2009, Wang & Overland 2009, Stroeve *et al*. 2012), new areas not previously considered may open and provide available breeding habitat for Caspian Terns. For example, in relatively sheltered systems such as Krusenstern Lagoon, potential nesting habitats are protected from oceanic storm surges, but not wind-driven surges, as we observed in September 2016. A pair of courting Caspian Terns were observed at Safety Sound (a lagoon system east of Nome in Alaska) on 10 June 2016 (Robert Gill, pers. comm.), suggesting recent interest in another lagoon system location. Lagoon systems could offer extensive areas of potential habitat, given that about a third of Alaska's coastline north of Bering Strait is made up of lagoons and barrier island habitat, where forage fish species can be locally abundant (Haynes *et al*. 2017).

Continued warming of the Arctic will lead to further loss of summer sea-ice and increase the duration of the snow-free season. Such changes promote the ability of lower-latitude species to move north, with the potential to impact current Arctic marine and terrestrial ecosystems (Killengreen *et al*. 2007, Moore *et al*. 2014). While seabird species from temperate regions that expand their range northward have already been shown to negatively affect Arctic ecosystems (Divoky 1982, Gaston *et al*. 2005), the ability of Caspian Terns to form large colonies and thrive in the Arctic is still unknown.

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