UNUSUAL FORAGING OBSERVATIONS ASSOCIATED WITH SEABIRD DIE-OFFS IN ALASKA

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ABSTRACT

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We report the first documentation of off-water foraging by the Fork-tailed Storm-Petrel *Oceanodroma furcata* and Short-tailed Shearwater *Ardenna tenuirostris*, a behavior not previously documented in any member of the families Hydrobatidae or Procellariidae. Over a two-week period in September 2016, we regularly observed individuals of these species over land on an extensive intertidal zone on the Bristol Bay coast of the Alaska Peninsula. We documented irregular feeding behaviors by storm-petrels, including pattering over shallow water and sand, digging into sand to uncover food items, and feeding on beach-cast fish. We revisited the site in August 2017 and did not observe storm-petrels, but we observed four shearwaters feeding on a beach-cast fish. The aberrant feeding behaviors, paucity of stomach contents and emaciated body condition of salvaged and collected birds, together with patterns between bird occurrence and wind speed and direction, indicate to us that these birds were blown to shore while weakened by food stress or compromised health. We further suggest that these aberrant feeding behaviors may be related to massive seabird die-offs that occurred in this region during 2014–2016, die-offs in which Fork-tailed Storm-Petrels have heretofore not been reported as a species affected by this phenomenon.

Key Words: Alaska, seabird die-offs, sea surface temperature anomaly, Fork-tailed Storm-Petrel, *Oceanodroma furcata*, Short-tailed Shearwater, *Ardenna tenuirostris*, off-water foraging

INTRODUCTION

Of the multitude of ecosystems affected by global climate change, marine environments are among those experiencing the most profound and diverse disruptions (Hoegh-Guldberg & Bruno 2010, Doney *et al*. 2012). For instance, climate change impacts resulting in phenomena such as sea surface temperature anomalies (hereafter SSTA) represent rapidly changing marine environments that include cascading effects on food webs and animal behavior (Irons *et al*. 2008, Bost *et al*. 2015, Carroll *et al*. 2016).

Recent seabird mortality events highlight variation of food web dynamics in marine systems. During 2014–2016, a large seabird mortality event occurred in the North Pacific, affecting primarily Common Murres *Uria aalge*, in which hundreds of thousands of birds washed ashore from Alaska to California (Joling 2017, Gibble *et al*. 2018, Piatt *et al*. 2018). Seabirds such as murres have off-shore distributions during the nonbreeding season, and for food depend on fish such as capelin *Mallotus villosus*, sand lance *Ammodytes* spp., and juvenile pollock *Gadus* spp. (Ainley *et al.* 2002). The emaciated condition and empty stomachs of the dead beach-cast seabirds (Joling 2017, Gibble *et al.* 2018), coupled with irruptive movements of individuals to inland sites (Joling 2016), suggested a collapse or redistribution of food stocks on which these seabirds depend, ultimately leading to a mass starvation event (Piatt *et al*. 2018). Substantial SSTA have previously been correlated with food web disruptions of species such as Common Murres (Irons *et al.* 2008), and the large mortality events during 2014–2016 are in accord with SSTA in the region (Walsh *et al*. 2017, Piatt *et al*. 2018).

Like Common Murres, members of the family Procellariidae and Hydrobatidae occupy coastal and pelagic waters during the non-breeding season (*c.* October–March), and depend on surface or subsurface prey. Fork-tailed Storm-Petrels *Oceanodroma furcata* are common in the Bering Sea (Gabrielson & Lincoln 1959) and the Gulf of Alaska (Harrison 1982, DeCicco *et al*. 2017), and typically occur in coastal and off-shore waters from *c.* 40°N latitude to the southern extent of the Bering Sea ice (Boersma & Silva 2001). Two dark-plumaged shearwater species belonging to the genus *Ardenna* (*A. grisea, A. tenuirostris*) also occur in these waters. Although Fork-tailed Storm-Petrels use a variety of foraging habitats, including inshore waters (e.g., Gill 1977, Baird *et al.* 1983, Vermeer & Sealy 1984) and just beyond the surf zone during stormy conditions (Boersma & Silva 2001), and *Ardenna* shearwaters regularly forage in inshore waters (Carboneras *et al*. 2018a, 2018b), we could find no mention in the literature of off-water feeding for any Procellariiform. Herein, we document unusual land-based foraging behaviors by Fork-tailed Storm-Petrels and Short-tailed Shearwaters. We suggest that these behaviors were driven by food stress that may be related to SSTA and seabird die-offs in the region during 2015–2016 (Walsh *et al*. 2017, Piatt *et al*. 2018).

STUDY AREA AND METHODS

Our study site (58°16′43.09″N, 157°32′27.88″W) is located *c.* 1 km south of the mouth of Big Creek on Bristol Bay, Alaska Peninsula, approximately 12 km north of the village of Egegik, Alaska. The shoreline habitat at this site is dominated by sandy beaches bordered by dunes with extensive cover of beach wild-rye *Elymus*

mollis. Daily tidal fluctuations expose a 3 km wide by 10 km long sandy intertidal zone. This sandflat provides a foraging site for thousands of staging waterbirds (primarily shorebirds) during fall migration. Our observations occurred along this sandflat during 15–28 September 2016 (14 d) and 18–26 August 2017 (9 d).

We recorded the daily abundance of Fork-tailed Storm-Petrels and shearwaters (*Ardenna* spp.; although two species may have been present, all birds that we identified to the species level were Short-tailed *A. tenuirostris*) present both nearshore and on the intertidal zone (all observations are available in eBird: www.ebird.org). Because our daily field time varied, we estimated daily abundance corrected by effort. To do this, we divided the total field hours for each day by the average daily field hours for the entire time spent at the study site in each year, and multiplied this value by the number of birds seen for that day (Fig. 1). As part of specimen collection and salvage efforts unassociated with these observations, we salvaged four beach-cast storm-petrels and collected two others observed foraging over intertidal sites, and assessed the body condition and stomach contents of these birds to provide potential insights into the foraging behaviors observed. To investigate the possible influence of weather on the occurrence of birds at our study site, we extracted 12 hr composite mean vector wind speed and direction from the National Centers for Environmental Prediction (NCEP) North American Regional Reanalysis (NARR) daily datasets (data and images provided by the NOAA/ESRL Physical Science Division, Boulder Colorado from their website at www.esrl.noaa.gov/psd/), following Mesinger *et al*. (2006). We extracted wind vector graphics as a 12 hr composite mean of wind speed and direction, ranging from 06h00–18h00 for the day prior and the day of high storm-petrel and shearwater numbers in 2016, and shearwaters in 2017 (Fig. 2). To investigate the influence of sea surface temperature anomalies in Bristol Bay, we extracted Sea Surface Temperature Anomaly (SSTA) data (Reynolds *et al.* 2007) from the Operational SSTA Charts (NOAA High Resolution SST data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their website at www.esrl.noaa.gov/psd/) for the dates we were present at our study site in 2016 and 2017 using the full global map selection.

RESULTS AND DISCUSSION

In September 2016, we regularly observed Fork-tailed Storm-Petrels feeding off-water in the intertidal zone during low tide. We observed two foraging patterns: 1) pattering on tidal pools and sand to capture items, including inserting the bill into the sand and probing for food items; and 2) stationary feeding on fish carcasses, including salmon *Salmonidae* sp. and flatfish *Pleuronectidae* sp. (Fig. 3). Although we did not observe Fork-tailed Storm-Petrels during a 9-d period in August 2017, we did observe four Short-tailed Shearwaters feeding off-water on a beach-cast salmon (Fig. 3). Taken together, these observations constitute the first documentation of both Fork-tailed Storm-Petrel and Short-tailed Shearwater feeding on dead, beach-cast fish. Birds observed feeding on fish carcasses most often quartered into the wind while pattering during their approach until they reached the carcass, with their wings spread to keep them aloft in the wind as they fed.

Intertidal foraging among hydrobatids has elsewhere been addressed in the literature. Our observations of Fork-tailed Storm-Petrels feeding on beach-cast fish complement the report of one individual feeding on a beach-cast gray whale *Eschrichtius robustus* carcass, also on the Alaska Peninsula in September 1976 (Gill 1977). Thomas *et al*. (2006) identified isopod *Eurydice* spp. in the regurgitated stomach contents of European Storm-Petrel *Hydrobates pelagicus*, prey that can occur in the intertidal zone in the water column. Thus, these observations were supportive of intertidal foraging but not off-water foraging. Additionally, Thomas *et al*. (2006) specifically discussed this evidence as indicative of the birds' foraging strategy, explicitly discounting digging through the sand for food items as an explanation for their findings. This is contrary to our observations, where storm-petrels regularly dug into the sand with their bill, another behavior that to our knowledge has not been documented in the literature.

The body condition and stomach contents of collected and salvaged beach-cast birds further indicate that these behaviors were the result of food stress and are likely aberrant. Beach-cast birds were emaciated and lacked fat stores, and we were unable to identify any food items in the stomach contents of the collected birds, finding only parasitic worms, *Elymus* seeds, and a twig.

Based on patterns in our observations, we suggest that storm-petrel and shearwater presence in the intertidal zone at our study site was influenced by strong, onshore winds over pelagic waters that likely pushed both live and dead birds towards our study site, increasing their detectability. We observed peaks in storm-petrel numbers in 2016 on 17, 22 and 28 September (40–100 birds/d), and noted <10 individuals on all other days (Fig. 1). On days prior to peaks in storm-petrel numbers, wind speed at the study location was low (max speed ≤4 m/s) and wind direction was not directed onshore. On days of storm-petrel influx, strong (10–16 m/s) onshore winds

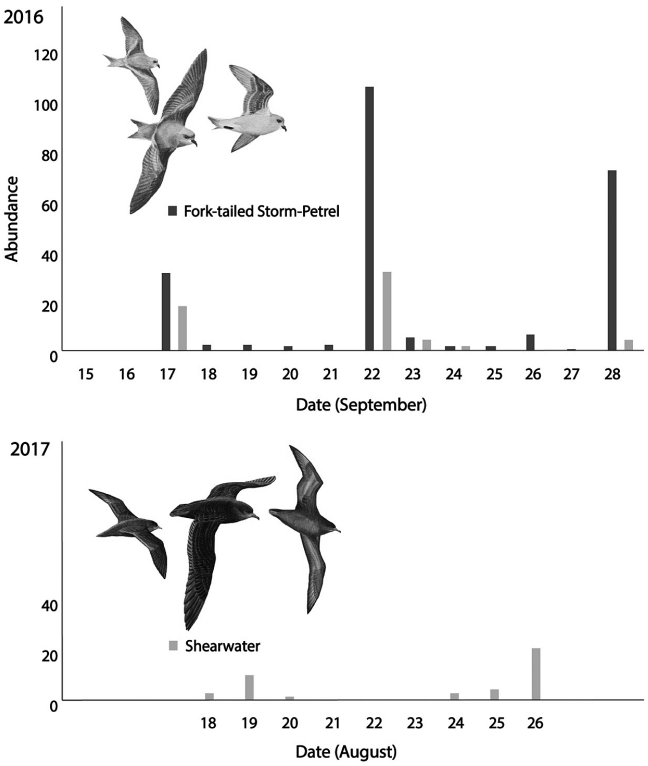

Fig. 1. Abundance of Fork-tailed Storm-Petrel and dark *Ardenna* spp. shearwaters, corrected by daily effort, observed at the mouth of Big Creek, on the Bristol Bay coast of the Alaska Peninsula over a 14-d period in September 2016 and a 9-d period in August 2017.

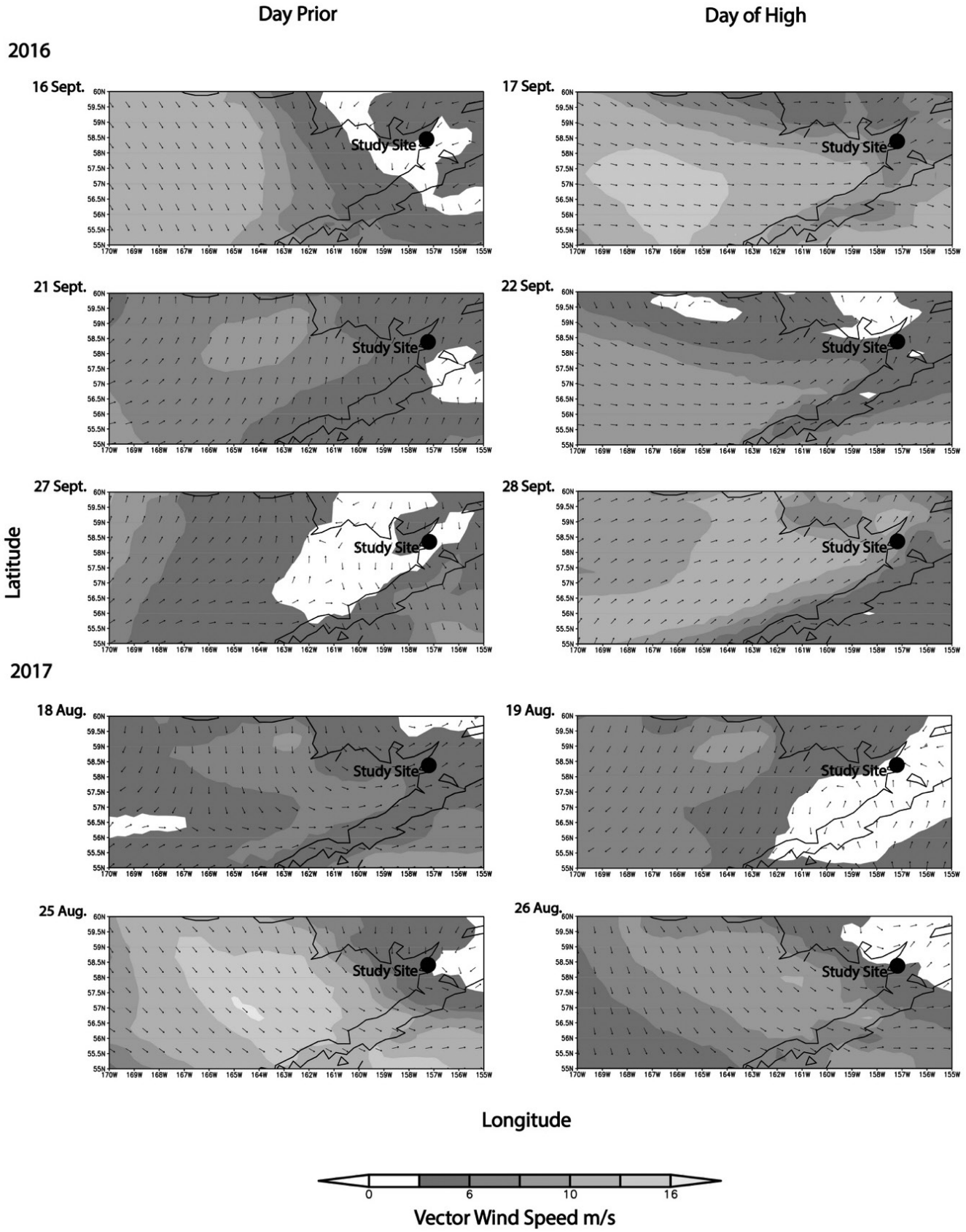

Fig. 2. Vector wind speed graphics (m/s) illustrating the pattern between directional wind speed and days of high storm-petrel and shearwater counts at our study site on the Bristol Bay coast, Alaska Peninsula, in September 2016 and August 2017. Days of influx have the general pattern of directional, high west/northwest winds blowing from pelagic waters towards the study site. Days prior show areas of low pressure over the study site, and directionless, offshore, or latitudinal winds.

occurred at our study location (Fig. 2). During all three observed peaks in bird numbers, wind vector data illustrate a directional high wind over pelagic waters. These patterns also were present on days of high shearwater numbers in 2017 (Fig. 2).

Recent documentation of aberrant onshore feeding behaviors for otherwise strict on-water foragers (e.g. Eared Grebe *Podiceps nigricollis*; Wilcox 2018) suggests that these behaviors may occur as a foraging strategy in healthy birds, but have yet to be reported in the literature. However, we suggest that the unusual intertidal foraging behaviors that we observed for both Fork-tailed Storm-Petrel and Short-tailed Shearwater were indicative of food stress. SSTA in the North Pacific during 2014–2016 were in accord with negatively impacted oceanic food webs that culminated in massive seabird die offs in which tens of thousands of seabirds washed ashore across coastal Alaska alone (Walsh *et al*. 2017). Given the body condition of the birds that we observed, and that SSTA for waters in Bristol Bay at our study site were positive ($\bar{x}$ = 3.83 ± 0.46 °C for 14 d in 2016, and 1.22 ± 0.25 °C for 9 d in 2017) in both years, we suggest that the abnormal foraging behaviors were related to the massive seabird die-off events during 2014–2016 and represent the first documentation of Fork-tailed Storm-Petrel being implicated in these die-off events.

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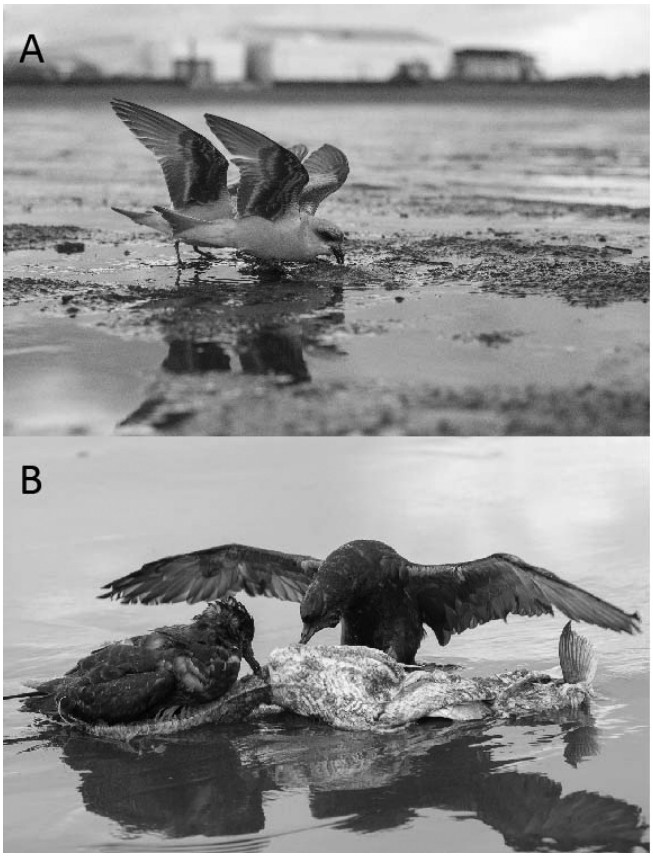

Fig. 3. A) Fork-tailed Storm-Petrels feeding on the carcass of a flat fish in the intertidal zone of Bristol Bay, Alaska Peninsula (22 September 2016); and B) Short-tailed Shearwaters feeding on a beach cast salmon at the same location (August 2017). Photos: Robinson/USFWS (A) and Gerrit Vyn (B).

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