PREDATION ON SEABIRDS BY PACIFIC COD *GADUS MACROCEPHALUS* NEAR THE ALEUTIAN ISLANDS, ALASKA

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SUMMARY

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In marine systems, most seabirds are considered upper trophic level consumers, yet they may be vulnerable to predation by other marine animals. There are varying accounts of large fish eating birds, but little is known about whether predation by demersal fish predators is an important source of mortality for seabirds. Fish processors in Dutch Harbor, Alaska, have observed seabird remains in Pacific Cod *Gadus macrocephalus* stomachs. We analyzed seabird remains from Pacific Cod caught off Cape Sarichef in Unimak Pass from mid-January through early April 2011. Of 74 different seabird remains examined, five avian genera were identified. These results provide documentation that Pacific Cod consume seabirds; either by predation or scavenging. Overall, the significance of seabird predation by fish is not well known, but may be episodically important.

Key words: Pacific cod, predation, diet, Crested Auklet *Aethia cristatella*

Seabirds by and large exhibit decreasing populations, and current major threats include pollution and commercial fisheries at sea, and alien invasive predators, habitat degradation and human disturbance on land (Croxall *et al*. 2012, Paleczny *et al*. 2015). During the breeding season, seabirds are exposed to both native and alien terrestrial predators while at breeding colonies (Kondratyev *et al*. 2000, Byrd & Williams 2008, Hilton & Cuthbert 2010, Burke *et al*. 2011). In marine systems, most seabirds are considered upper-trophic-level predators, yet they may be vulnerable to predation by other marine animals and thus would be better viewed as mesopredators. Identifying sources of mortality for these species is important for the development of conservation approaches aimed at their recovery (Lewison *et al*. 2012).

One potential rarely examined source of mortality for seabirds is predation by large-bodied fishes. Published accounts of large fish eating birds include Northern Pike *Esox lucius* consuming waterfowl on freshwater lakes (Solman 1945, Dessborn *et al*. 2011), Monkfishes *Lophius* spp. feeding on Dovekies *Alle alle* in the northwest Atlantic Ocean (Perry *et al*. 2013), and Tiger Sharks *Galeocerdo cuvier* predating on various terrestrial bird species (Dodrill & Gilmore 1977). Despite these accounts of large fish eating birds, little is known about whether predation by demersal fish predators is an important source of mortality for seabirds.

In 2011, fish processors in Dutch Harbor, Alaska, observed a consistent presence of seabird remains in Pacific Cod *Gadus macrocephalus* stomachs. Pacific Cod are large-bodied (up to 1 m, 15 kg), generalist predators that exhibit ontogenetic trophic shifts and feed primarily on polychaetes, crustaceans and teleosts (Albers & Anderson 1985, Yang 2004). They range from the Bering Sea to southern California and are usually found in waters less than 350 m deep (Mecklenberg *et al*. 2002). In this study, we identified bird species that were recovered from stomachs of commercially harvested cod and discuss potential mechanisms for this interaction.

From mid-January to April 2011, seabird remains were opportunistically collected from Pacific Cod stomachs when workers at a fish processing plant observed seabird parts within the stomachs. The total number of stomachs sorted to acquire the seabird remains is unknown, as this was not an established study. Cod were caught in the Aleutian Islands, Alaska, off Cape Sarichef in Unimak Pass using trawl and pot gear, and processed at the Unisea facility in Unalaska. Although individual body mass for cod was not recorded, the mean was estimated to be 2 to 3 kg (D. Graves, pers. comm. 23 May 2011). Remains were removed from stomachs, frozen and sent to the Alaska SeaLife Center in Seward, Alaska. Remains were thawed and identified to the lowest taxonomic level based upon morphological characteristics (Hass and Parrish 2002). Because remains are separated from stomachs at the processing plant, there is no additional information on stomach contents.

Of 74 separate individual seabird remains examined, 59 were identified to species and 15 to genus. Four avian species were identified: Crested Auklet *Aethia cristatella* (n = 55), Cassin's Auklet *Ptychoramphus aleuticus* (n = 1), Common Murre *Uria aalge* (n = 2) and Thick-billed Murre *Uria lomvia* (n = 1). Additionally, there were partial remains identified only to genus: *Aethia* sp. (n = 13), *Uria* sp. (n = 1) and *Larus* sp. (n = 1). Remains were primarily made up of carcasses (n = 71) that had undergone varying degrees of digestion, ranging from intact carcasses to feathers and bones (Fig. 1). Additionally, a single *Uria* sp. foot, a *Larus* sp. head, and Crested Auklet wings were identified. There were 8 completely intact carcasses (11%) with no signs of digestion. Most of the remains (41%) were non-degraded carcasses missing either the head or feet. Almost 22% of the carcasses were in varying stages of digestion, and the rest of the remains were almost completely digested, with primarily bones and feathers present.

Land predators of seabirds are well known. Introduced predators such as foxes, rats and other mammals have drastically reduced many seabird breeding colonies (Jones *et al*. 2008). Results from our study show evidence of a little-known source of marine predation on seabirds. We were unable to determine the prevalence of cod predation on seabirds in the current study; however, long-term groundfish food habits data collected in trawl surveys conducted by NOAA Alaska Fisheries Science Center suggest that consumption of seabirds by cod occurs very infrequently on an ocean basin scale (AFSC 2013). Birds were found in stomachs of cod from the Aleutian Islands region during a single survey year between 1991 and 2006. In 2000, unidentified birds made up 0.07% of cod diet by weight and 0.04% by number and were found in 0.21% of sampled cod stomachs (n = 528). Bird prey of cod recorded for the Aleutian Islands, Gulf of Alaska and Bering Sea regions combined consisted of unidentified bird parts, Crested Auklet *Aethia cristatella*, and Tufted Puffin *Fratercula cirrhata*. In our study, because processors at Unisea were inspecting cod stomachs opportunistically, we are unable to evaluate whether the frequency of seabirds in cod from Unimak Pass is similar to that observed across the broader region surveyed by NOAA.

Fig. 1. Example of seabird remains from stomachs of Pacific Cod caught off Unimak Pass, Alaska, from mid-January through April 2011: (a) partially digested Thick-billed Murre, (b) complete, undigested carcass of Crested Auklet, (c–f) Crested Auklets in various stages of digestion. A 150-mm white ruler is present for size relationship.

To assess whether birds were living or dead when consumed by cod, we placed lung tissue samples from 33 Crested Auklet in 10% neutral buffered formalin to test whether tissue would float or sink. Lung tissue from three birds was found floating, suggesting that there was air in the lungs and that the bird was alive when it was taken. Lung tissue from 30 birds was found sinking in formalin, suggesting air was not present in the tissue and that the bird had been drowned before it was consumed.

Based on these results, we hypothesize several potential mechanisms by which cod acquire seabirds. Based on the feeding behavior and depth distributions of cod and seabirds, it is plausible that cod could consume diving birds opportunistically. All of the seabirds found in cod stomachs exhibit diving behavior that could bring them into the range of demersal, sedentary predators like cod (Fig. 2), which occur from shallow nearshore habitat to depths of more than 800 m (Mecklenberg *et al*. 2002). Overall, 91% of remains were *Aethia* sp., which forage underwater by pursuit diving to a maximum of 100 m. Whiskered Auklet dive depths are unknown, but they are mostly found in waters <100 m deep (Haney *et al*. 1991). The maximum diving depth for the Parakeet Auklet is estimated at 49 m (Burger & Powell 1990), while the Least Auklet is most likely capable of diving to 15 m (Obst *et al*. 1995). The maximum diving depth of Cassin's Auklet (1% of remains) is estimated at 43 m (Burger & Powell 1990). Cod may also exhibit vertical movements in response to food, temperature and light conditions (Davis & Ottmar 2009), so they could potentially intercept diving birds in the water column above the seafloor. If cod take advantage of locally abundant prey, they could potentially show a functional response to aggregations of diving seabirds. The majority of the identified remains (73%) were those of Crested Auklets, which often forage in large groups (Jones 1993), feed upon swarming and schooling prey (Hunt *et al*. 1993), and winter in the open ocean. There is little known about the Crested Auklet's underwater foraging behaviors, but a maximum dive depth has been estimated to be about 30 m (Haney 1991). The maximum diving depth of 180 m for the Common Murre (Piatt & Nettleship 1985) and 210 m for the Thick-billed Murre (Croll *et al*. 1992) allows for an interaction at deeper water depths. Alternatively, cod, like Antarctic toothfish *Dissostichus mawsoni,* which consume penguins (Roberts *et al.* 2011), may scavenge on the seafloor for carcasses of birds that have died from a variety of natural or anthropogenic causes, such as predation, starvation, disease, contaminants or incidental mortality from fishing gear. Whether the interaction between cod and seabirds is natural, mediated by fishery bycatch, or some combination is yet to be determined. Regardless of the mechanism, interactions between cod and seabirds identified in this study likely occurred in waters shallower than 160 m, the maximum depth of Unimak Pass (Stabeno *et al*. 2002).

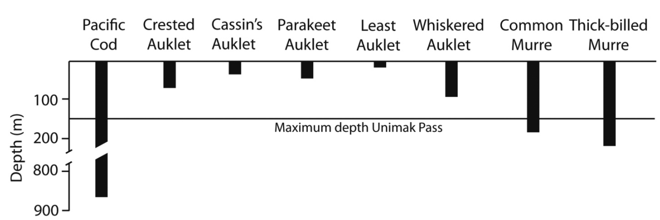

Fig. 2. Maximum depth of Unimak Pass, Alaska, and the observed depth (m) ranges of Pacific Cod and seabird taxa found in cod stomachs during mid-January through April 2011 from Unimak Pass.

Cod predation on seabirds may vary in response to environmental and ecological conditions that affect their degree of spatial and temporal overlap. Concentrations and abundance of Crested Auklets peak during the winter in Unimak Pass area, when euphausiid prey concentrations are high (Troy 1990). The Unimak Pass area appears to support about 10%–20% of the Bering Sea population of Crested Auklets, which is about 200000 to 400000 individuals (Troy 1990). Given the high winter concentrations of Crested Auklets at Unimak Pass, as well as the timing and location of our samples, cod may be targeting seabirds or encountering them opportunistically while foraging for other prey. Foraging for shared prey could mediate overlap of cod and seabirds in space and time, thus facilitating opportunities for cod to consume birds.

Overall, the significance of seabird predation by fish is not well known, but may be episodically important (Perry *et al*. 2013). Our study confirms that Pacific Cod consume seabirds near the Aleutian Islands. Obtaining further information on the prevalence, seasonal occurrence and spatial distribution of these trophic interactions, as well as on the sizes of cod to which seabirds are most vulnerable, requires additional studies.

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