

**An Attempt to Determine the Prey of the Great Auk
(*Pinguinus impennis*)**

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The flightless Great Auk (*Pinguinus impennis*), the largest of all Recent Alcidae, was exterminated in 1844 (Greenway 1958), and no one who can properly be called a naturalist ever encountered the bird in life. As a consequence, virtually no details are known of its behavior or ecology. One of the principal nesting grounds of the Great Auk was on Funk Island, off the northeast coast of Newfoundland. Several expeditions have been made to Funk Island for the purpose of obtaining remains of these birds, the best documented of these being the visit of the schooner *Grampus* in 1887, in which F. A. Lucas was a participant. Lucas (1890) published a report on this expedition, including a brief history of the Great Auk and observations on its osteology.

Most of the Great Auk bones from Funk Island were accumulated as a result of the birds being slaughtered for oil, the carcasses being rendered on the island and discarded there. Presumably the contents of the digestive tract were discarded with the carcasses, and it therefore seemed likely that hard parts of prey might be preserved in the soil along with Great Auk bones. While there is no reason to doubt that the Great Auk ate mainly fish, as do most other North Atlantic alcids, it would be of interest to determine the sizes and specific identity of its prey, as this might lead to a better understanding of the ecological requirements of the bird.

Until recently there was a venerable wooden crate, stored in the basement of the National Museum of Natural History, that contained the unsorted bones of Great Auks, still in the peaty soil from which they were exhumed on Funk Island by the *Grampus* expedition. This material was evidently in excess of that needed by Lucas for his studies and had never been processed. There is now no way of knowing if this sample represents a collection from a single site or a composite from several sites. From this material we recovered the following long bones of *Pinguinus impennis*: 156 carpometacarpi, 148 ulnae, 99 humeri, 126 coracoids, 124 femora, 123 tibiotarsi, and 150 tarsometatarsi, as well as many cranial elements and an abundance of all the lesser parts of the skeleton. Only six bones of birds other than Great Auk were found; these belong to at least two murrets (*Uria* sp.). Thus, any prey remains from this sample would almost certainly have come from *Pinguinus*.

After the removal of the large bones, there remained about 25,000 cc of matrix, which was subjected to several washings and then screened through fine mesh. The resulting concentrate was examined and sorted under magnification. In the process, hundreds of sclerotic plates and seven stapedes of Great Auk were retrieved. Probably because of the acidic nature of the soil, no otoliths of fish were preserved. Other fish remains were sparse but nevertheless prove of interest. The identity of these specimens is as follows.

Menhaden, *Brevoortia* cf. *tyrannus* (Clupeidae).—Seventy-nine scales and scale fragments to about 11 mm in diameter. These scales are from fish about 140–190 mm standard length (SL).

Shad, *Alosa* sp. (Clupeidae).—Two scales from a fish about 120 mm SL. Only American shad (*A. sapidissima*) and alewife (*A. pseudoharengus*) occur north to Labrador today.

Capelin, *Mallotus villosus* (Osmeridae).—Seven small vertebrae, 1.4–1.6 mm long. These are from fish 80–100 mm SL that would have been 1–2 yr old.

Indeterminable Gadidae.—Three anterior vertebrae, 1 mm long and 3 mm wide, from fish 120–150 mm SL; 1 right fifth pharyngobranchial, 7.1 mm long, from a fish about 250 mm SL; 6 fragmentary vertebrae.

Three-spined stickleback, *Gasterosteus aculeatus* (Gasterosteidae).—One right pectoral spine, 6.2 mm long, slightly worn; 1 dorsal spine pterygiophore, 4 mm long in midline. These elements represent a fish 100–120 mm SL, which is equal to or exceeds the hitherto known maximum size of the species.

Morone cf. *saxatilis* (Percichthyidae).—One complete (6.1 × 7.1 mm) and 2 fragmentary scales. These could possibly be from the white perch, *M. americanus*. They represent a fish 280–320 mm SL, near or about the maximum for white perch, but the size of a 2- or 3-yr-old striped bass, *M. saxatilis*.

Flatfish, cf. Pleuronectidae.—One left supracleithrum, 6.1 mm long. This bone is from a fish 80–100 mm SL.

Indeterminable Teleostei.—Seven vertebrae, 1.5–2 mm long; 1 glossohyal (?); 1 exoccipital facet for reception of atlas vertebra; 1 half fin ray; 6 bone fragments.

The following ecological and distributional information on these fishes is summarized from Bigelow and Schroeder (1953, 1964), Leim and Scott (1966) and Scott and Crossman (1973). South of Funk Island in the Gulf of Maine, Atlantic menhaden appear inshore between May and June, when temperatures reach about 50°F (10°C), and are gone by October or early November. They do not enter brackish water in the north and in some years have failed to appear north of Cape Cod. Before about 1850, menhaden occurred periodically as far north as the Bay of Fundy. The scales from Funk Island provide evidence of the species about 800 km northeast of its known historic range, suggesting that its distribution has become more southerly. American shad and alewife remain offshore most of the year; north of Cape Cod they enter freshwater streams to breed between late April and early July. Adult capelin move inshore to spawn in June or July at water temperatures of 40–47°F (4–8°C), while large numbers of juveniles remain just offshore. Spawning occurs from Newfoundland northward, after which the adults return to deep water. Stickleback primarily inhabit freshwater, estuaries, and the nearshore environment, but it is not uncommon to encounter individuals in floating masses of seaweed offshore. Striped bass are inshore fish rarely taken more than 7 or 8 km from the coast from May to October. The remainder of the year they occur in freshwater rivers.

In the area from Cape Cod to the mouth of the St. Lawrence River, the species of fish recorded here are available in shallow marine waters only during five or six warm months (May to October). Only *Gasterosteus* would be available in the shore zone in winter, because *Brevoortia* departs southward, *Morone* invades freshwater, and *Mallotus* and *Alosa* move into deeper water. The remains could thus have been accumulated at Funk Island only coincident with the breeding season of the Great Auk.

All prey species in the sample could be obtained in the water column from near the bottom to near the surface, except for the one flatfish, which is benthic. The remains suggest that the birds fed in water less than about 18 m deep and within 2 km of shore. The combination of *Brevoortia* and *Mallotus* would probably not occur in shallow water today, but as noted, the range of *Brevoortia* has evidently been shifting southward in historic times. Such factors of fish distribution as the former overlap of *Brevoortia* and *Mallotus* may have played an important role in the location of breeding colonies of the Great Auk.

The size of the fishes indicates juveniles (1–2 yr old) of *Brevoortia*, *Alosa*, *Mallotus*, and most Gadidae; subadults of *Morone* and one of the Gadidae; and an adult *Gasterosteus*. Almost all the specimens would have ranged from 70–190 mm SL, thus being of an appropriate size for prey of *Pinguinus*. The specimen of *Morone* and one specimen of Gadidae were 240–320 mm SL and may have been near the maximum size that a Great Auk could manage.

The overall taxonomic composition of the fish remains from Funk Island corresponds closely with that reported for the prey of the larger extant species of Atlantic alcids (see references in Swennen and Duiven 1977). In alcids, prey may apparently be determined not only by availability but also by selection of species with higher caloric value (Harris and Hislop 1978), thus perhaps explaining the predominance of *Brevoortia* and *Mallotus* in our sample, both of these fishes being relatively oily.

Because there is extensive overlap in the prey species taken by the larger North Atlantic alcids, it is believed that ecological segregation of these birds is facilitated by their taking prey of different sizes (Harris 1970). Swennen and Duiven (1977) found in experiments with captives of three species of Atlantic alcids that prey diameter rather than length was the principal factor affecting the size of prey selected. Common Murres (*Uria aalge*) took larger (deeper-bodied) fish than did the smaller Razorbill (*Alca torda*) or the Common Puffin (*Fratercula arctica*). All three species preferred prey smaller than the maximum size manageable.

In this regard it is of considerable interest that the specimens of *Brevoortia* in our Funk Island sample come from individuals with a minimum body depth of about 42–57 mm and a maximum body depth of approximately 49–66 mm. Common Murres can take prey up to 44 mm maximum depth, but only very reluctantly consume fish of more than 40 mm depth and prefer those about 23 mm (Swennen and Duiven 1977). Therefore, the Funk Island remains of *Brevoortia* are in accord with the expected dimensions for the prey of an alcid the size of the Great Auk.

Any conclusions from this study are necessarily based on very slender evidence. We would anticipate, however, that the collection of larger and more carefully controlled samples from Funk Island could result in statistically meaningful data on the prey of *Pinguinus*, thus filling in our knowledge of food habits in Recent North Atlantic alcids. If nothing else, we hope we have demonstrated the feasibility of such a study.

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Tufted Puffins Nesting in Estuarine Habitat

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The Tufted Puffin (*Lunda cirrhata*) apparently has the most extensive breeding distribution of any North Pacific seabird, extending in the western North Pacific from Hokkaido to the north Chukotsk Peninsula on the Chukchi Sea, and in North America from Cape Lisburne on the Chukchi Sea, south to the Farallon Islands off central California (Udvardy 1963). Despite this wide breeding distribution, the reported nesting habitat is generally restricted to steep, rocky islands and continental headlands (see Dement'ev and Gladkov 1951, Kozlova 1957, Gabrielson and Lincoln 1959, Portenko 1973, Sealy 1973, and Sows et al. 1978). Nests are typically excavated in steep slopes and/or on vegetated plateaus, well above normal tidal influence but occasionally within the spray or storm-wash zone. Nowhere has *L. cirrhata* or any other puffin species been reported to nest in a flat, estuarine habitat in substrate normally affected by tides during the breeding season. Portenko (1973: 137) refers to Tufted Puffins breeding on Alyumka Island in the Anadyr "estuary" (64°40'N, 177°37'E), but Alyumka Island is a rocky coastal island having immediate offshore waters between 3–18 m deep (A.A. Kistchinski, The Ringing Center, Moscow, and George Tyner, U.S. Defense Mapping Agency, pers. comm.).

During the summers of 1976, 1977, and 1978, we found 14–18 pairs of Tufted Puffins nesting on 4 narrow sand islands (5–7 ha each) along the northcentral Alaska Peninsula at Nelson Lagoon (56°00'N, 161°10'W). As of June 1979, 25 active burrows had been reported there (Margaret R. Petersen, pers. comm.). The islands lie approximately 1.3 km from the Bering Sea coast and are protected from the sea by a long, narrow (0.5 km) sand peninsula. The main deepwater channel in the lagoon, 3–7 m deep and 100–300 m wide at mean low water (MLW), separates the islands from the peninsula. The islands, which are free of permafrost, have a uniformly low profile with the highest elevation 1–2 m above mean high water (MHW) (Fig. 1). Each island is circumscribed by a gently sloping (<5°), narrow (5–15 m) sand/gravel beach that graduates at MLW to intertidal mud- and sandflats. These are extensive on the south and southeast sides (several hundred m) and relatively narrow (10–20 m) on the north and northwest or channel sides. The banks of each island are moderate to near vertical in slope. Puffin burrows face the channel, are located at or near the vegetation/beach interface, and extend into the bank horizontally or slightly downward. Beach rye (*Elymus arenarius mollis*) grows over most of each island and is used as nesting cover by several hundred Glaucous-winged Gulls (*Larus glaucescens*) and lesser numbers of Common Eiders (*Somateria mollissima v-nigra*). Predation by gulls on puffin eggs or chicks was not observed, nor did we see gulls rob food from adult puffins returning to their burrows from foraging in the Bering Sea (cf. Nettleship 1972). Puffins were never observed feeding in the lagoon.