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Observations of Foraging Northern Fulmars (*Fulmarus glacialis*) in the Canadian High Arctic

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ABSTRACT. We summarize observations of foraging northern fulmars (*Fulmarus glacialis*) in the Barrow Strait–Lancaster Sound region of the Northwest Territories from June to September 1984-90 and in Admiralty Inlet, N.W.T., in July 1989. In each year, fulmars scavenged hunter-killed marine mammal remains in the vicinity of Resolute Bay. Large feeding flocks, aggregated primarily along tide lines and at upwelling sites, exploited primarily calanoid copepods by surface seizing and diving. Late-season onshore movement of Arctic cod (*Boreogadus saida*) resulted in flocks of several thousand fulmars capturing cod by surface and pursuit diving. We determined experimentally that northern fulmars are capable of diving to 3 m to retrieve cod.

Key words: northern fulmar, *Fulmarus glacialis*, feeding behaviour, diving, Barrow Strait, Lancaster Sound

RÉSUMÉ. On résume les observations faites sur des fulmars boréaux (*Fulmarus glacialis*) en train de se ravitailler dans la région du détroit de Barrow et du détroit de Lancaster dans les Territoires du Nord-Ouest, de juin à septembre 1984 à 1990, et dans l'inlet de l'Amirauté (T.N.-O.) en juillet 1989. Chaque année, les fulmars se repaissaient des restes de mammifères marins tués par des chasseurs à proximité de la baie Resolute. De grandes volées s'attroupaient pour se nourrir, surtout le long des laisses de marée et aux sites d'émergence, et pêchaient principalement des calanus, en les saisissant à la surface et en plongée. La migration de fin de saison de la morue polaire (*Boreogadus saida*) vers le rivage attirait des volées composées de plusieurs milliers de fulmars qui capturaient la morue en piquant à la surface et en la poursuivant sous l'eau. On a déterminé expérimentalement que le fulmar boréal est capable de plonger à 3 m sous la surface pour retrouver la morue.

Mots clés: fulmar boréal, *Fulmarus glacialis*, comportement alimentaire, plongée, détroit de Barrow, détroit de Lancaster

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INTRODUCTION

Despite the abundance of northern fulmars (*Fulmarus glacialis*) in northern oceans, the foraging behaviour of this species under natural conditions remains poorly known. As pointed out by Haney (1988), two major factors contribute to this paucity of information: fulmars typically follow research ships as they move through study areas (e.g., Gould *et al.*, 1982), making it difficult to observe natural feeding aggregations, and they often exploit fish offal discarded from fishing boats or processing plants (Hunt *et al.*, 1981). To date, details of foraging have been inferred primarily from analyses of stomach contents (reviewed by Bradstreet, 1976; Bradstreet and Cross, 1982) or observations of food exchanges at colonies (Nettleship, 1977; Furness and Todd, 1984). Three major colonies exist in Lancaster Sound and Barrow Strait (Brown *et al.*, 1975): about 60 000 nest at Prince Leopold Island, 10 000 at Cape Liddon and 70 000 at Hobhouse Inlet on the south coast of Devon Island (Fig. 1).

As part of a long-term investigation of the dynamics of marine bird and mammal food webs in the Barrow Strait–Lancaster Sound region, we have observed foraging aggregations of fulmars numerous times and under a variety of natural conditions. Many observations were necessarily anecdotal but others were quantitative. In this paper we synthesize these observations and provide additional insight into fulmar diving behaviour (see Wahl, 1984).

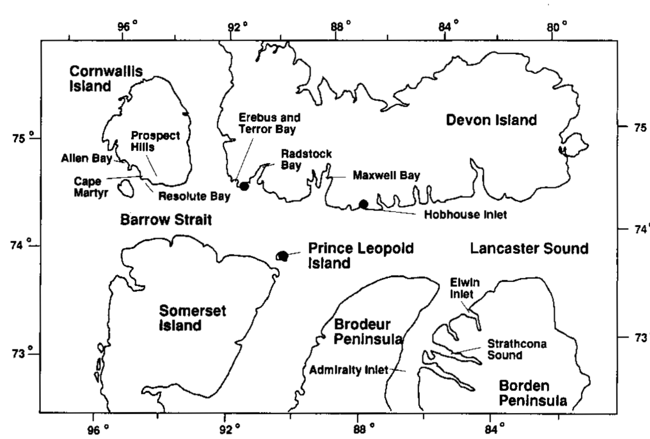

FIG. 1. Study area showing locations of major northern fulmar colonies.

METHODS

Observations were made opportunistically from shore, from landfast and drifting pack ice, and from small boats from June through September 1984-90, primarily along the south coasts of Cornwallis and Devon islands (Fig. 1). During the summers of 1988-90, we conducted field work also aboard the research vessel *FRV Ogac* in order to locate and collect foraging birds. One field collection was obtained in Admiralty Inlet during late July 1989. In addition, regular bi-weekly land-based counts of seabirds using Resolute Bay and Allen Bay on Cornwallis Island were conducted from July to September, 1989 and 1990.

Birds were collected at sea by shooting. Upon retrieval, the oesophagus, proventriculus, and gizzard were together either removed immediately and stored in a freezer or were removed a few hours later after 70% ethanol was injected into the oesophagus in order to reduce post-mortem digestion of food items. Where possible, surface plankton tows were taken at sites of foraging birds. After sorting, stomach and tow samples were frozen or placed in 10% neutral formalin and stored in

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vials for later identification. Fish otoliths were removed and stored in glycerine.

During July-August 1989 and 1990, we observed the diving behaviour of fulmars over concentrations of Arctic cod (*Boreogadus saida*) in Allen Bay (Fig. 2). Sizes of cod schools were estimated both visually and with the help of a depth sounder. We determined depths to which fulmars dived by tethering freshly trawled live 20 cm Arctic cod to a weighted line at various depths. Each fish was tethered by the lower jaw with an 8 cm length of 4 kg test monofilament connected to a similar monofilament line that extended between a 100 cm^3 surface float and a 75 g lead weight.

RESULTS

In the High Arctic, northern fulmars feed primarily on Arctic cod and invertebrates, including squid (Bradstreet, 1976; Bradstreet and Cross, 1982; Nettleship, 1977; pers. obs.). This broad diet apparently resulted in diverse feeding behaviours. Below, we describe the context of several fulmar feeding aggregations and summarize the four foraging categories we observed, defined according to Ashmole (1971) as surface seizing, pursuit diving, surface diving, and piracy. Surface seizing is characterized by grasping of individual prey with the bill and may involve the bird sitting on the surface or perhaps briefly submerging the body to obtain material below the surface. Pursuit diving occurs when a bird dives and pursues its prey underwater by pursuit swimming that may be either wing or foot propelled. Surface diving, on the other hand, occurs when a bird submerges only momentarily, directly onto prey with little or no pursuit swimming, and so intergrades with surface seizing. Piracy occurs when a bird pursues other birds for their food. We used stomach contents to confirm types of prey used by birds in foraging aggregations. A more complete quantitative analysis of fulmar stomach contents will be presented elsewhere.

Surface Seizing

Surface seizing was used by fulmars when taking both live prey and when scavenging. Although scavenging did not appear to be important to northern fulmars during our study, each year we observed birds scavenging marine mammal remains, especially blubber, left by hunters near Resolute Bay. Birds were observed taking only remains that were floating or

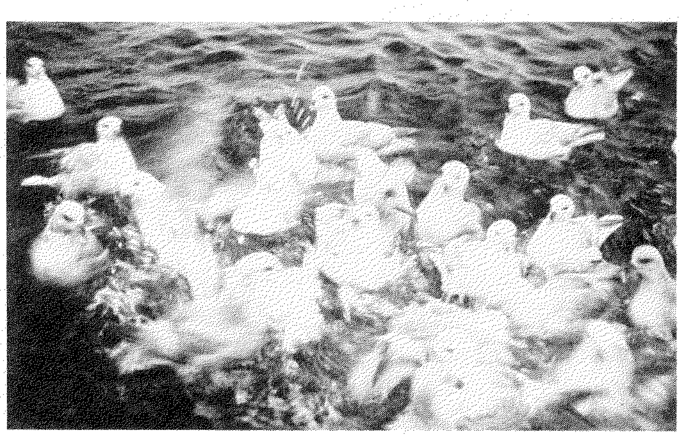

FIG. 2. Northern fulmars feeding on Arctic cod in Allen Bay, 1989. One bird has just brought up a cod captured several metres below surface and is being harassed by its neighbours.

partially submerged. Despite often considerable quantities of marine mammal remains left onshore, fulmars were never observed feeding on land or ice. Beached mammal carcasses were conspicuous but were typically visited by at most only a few dozen fulmars at any one time, and here fulmars seized material available from the water.

Fulmars fed on invertebrates almost exclusively by surface seizing. Invertebrate prey, determined through analyses of stomachs, included squid (*Gonatus fabricii*) and a variety of zooplankters including amphipods (*Gammarus setosus*, *G. wilkitzkii*, *Parathemisto libellula*, *Onisimus glacialis*), mysids (*Mysis oculata*), and copepods (*Calanus hyperboreus*). Only squid beaks were obtained from stomachs and, because these can remain in stomachs for considerable periods (Furness *et al.*, 1984), we do not know how important squid were to fulmars in this area (we have never observed squid near Resolute). Fulmars obtained zooplankton often where invertebrates were concentrated by upwellings, tide and rip currents, and eddies caused by landforms and ice. For example, on 25-28 July 1989, eight feeding flocks were observed along the east shore of Admiralty Inlet between Cape Strathcona and Elwin Inlet. Five of these flocks (involving approximately 400, 167, 100, 45, and 37 individuals respectively) formed in calm water along tide lines; individuals spread out along tide lines linearly 2-5 m apart and fed with rapid head dips. No aggressive interactions between individuals were observed. Five fulmars were collected from the largest flock and their stomachs contained exclusively copepods (*Calanus* spp.). Plankton sampling at this location confirmed that *Calanus hyperboreus* was the primary zooplankter. At the remaining feeding flocks no fulmars were collected but plankton tows at each site again confirmed concentrations of this copepod. During the same period, loose flocks of 79, 32, and 12 birds were observed surface feeding among loose pack ice at the head of Admiralty Inlet. On 31 July 1989, we observed approximately 240 fulmars foraging along a tide line just off the colony at Hobhouse Inlet, south Devon Island. Stomachs of 2 birds collected here contained only calanoid copepods (*Calanus* spp.) and squid beaks.

Because fulmars were often observed in areas where hydrographic conditions brought food close to the surface, it is not surprising that certain locations were frequented often by surface-feeding birds. These included shallow (5-15 m) water off the Prospect Hills between Resolute and Assistance bays, a rip off the southwest corner of Cape Martyr, and an upwelling caused by a submerged reef in relatively deep (>30 m) water 5 km east of Cape Riley, south Devon Island (Fig. 1). Copepods and *Parathemisto* appeared to be the usual prey, but on 5 September 1988, we observed hundreds of fulmars surface seizing offshore and in the shallows of Erebus and Terror Bay, taking pteropods (*Limacina*), which were visibly abundant at the water surface.

During 20-21 August 1989, approximately 700 fulmars were observed surface seizing invertebrates in Resolute Bay during a strong offshore wind. Birds were spread out along the north shore of the bay approximately 5 m from shore, where they fed on *Parathemisto libellula*. The offshore wind resulted in upwelling of these invertebrates close to shore. A similar phenomenon involving upwelling of invertebrates and the subsequent response of several hundred fulmars in Resolute Bay and Erebus and Terror Bay was observed at least four times previously. Each event was caused by moderate to strong northwesterly winds that concentrated at the surface copepods, pteropods, gelatinous predators, chaetognaths, *Parathemisto*, and scavenging amphipods in various combinations, in less than 1 m water depth against the windward shore.

Pursuit Diving, Surface Diving, and Piracy

In fulmars, pursuit diving, surface diving, and piracy were almost exclusively associated with predation on schools of Arctic cod and were observed on numerous occasions, for example:

8 August 1985: A dense school of adult cod (typically 19-23 cm length) 5 m wide and >200 m long moved westward in 4 m water depth 1 km southwest of Gascoyne Inlet. Over 1000 fulmars and black-legged kittiwakes (*Rissa tridactyla*) (approximately 50:50) fed on the cod. Fulmars used primarily surface diving. Associated with this aggregation were 100-200 beluga (*Delphinapterus leucas*), hundreds of harp seals (*Pagophilus groenlandica*), and several ringed and bearded seals (*Phoca hispida* and *Erignathus barbatus*).

21 August 1985: dense cod schools were present in 4 m water immediately west of Gascoyne Inlet, as well as in the inlet itself. Fulmars aggregated on water above the cod schools and included one flock of at least 2000 birds over a school 20 m wide and 600-800 m long. Many harp and ringed seals as well as approximately 500 beluga whales were associated with the schools. On 23 August a similar aggregation of feeding fulmars was seen over a 75 × 75 m school of cod inside Gascoyne Inlet.

19 August 1988: A school of cod about 2 m wide by 300 m long was present in 4 m water depth west of Gascoyne Inlet. About 500 fulmars fed on cod along with approximately 300 beluga and several harp seals. About 250 kittiwakes foraged also at this location but we observed no obvious interactions between this species and fulmars. Stomach analyses of 7 fulmars revealed primarily 4-year-old cod (19-23 cm) and corresponded to the usual size frequency of cod obtained from trap net and trawl samples conducted simultaneously in that area (H. Hop, *pers. comm.* 1990).

July-September 1989: Cod aggregations were present continually in both Resolute and Allen bays through 16 September but were not exploited by fulmars until after the fast ice left in early August. At that time, flocks of several thousand fulmars were usually present and feeding on cod. Typically cod were in midwater between 15 and 30 m depth and in basins 30-40 m deep. It appeared that tidal currents passing over bottom structures caused local upwellings in which cod were transported near the surface and seized by fulmars, usually by pursuit diving. On 28 August 1989, we observed fulmars feeding in small (5-20 m) melt openings in a large first-year ice pan below which a school of cod swam. Again, cod were usually captured by pursuit diving.

On 31 August 1989, after a pod of beluga had moved through the vicinity of the McMaster River estuary in Allen Bay, we observed about 1000 fulmars feeding on cod close to shore. Most birds removed viscera (comprised mostly of oil-rich livers) from larger cod and let the carcasses sink. After birds were disturbed from the area we found a 70 m strand line of thousands of dead but undamaged cod along the beach as well as hundreds of eviscerated cod carcasses in shallow water.

During the summer of 1990, in anticipation of a similar fulmar response to late-summer movements of Arctic cod, we established regular counts of birds using both Resolute and Allen bays (unpubl. data). Large schools of cod were again present in Allen Bay and, despite the presence of kittiwake feeding flocks, few large feeding flocks of fulmars were seen. Local Inuit informed us that fulmars were seen in large flocks closer to colonies on south Devon Island, although none was seen during two helicopter and one boat trip to this area and a remote camera photographing the water below the cliff to the west of Gascoyne Inlet at 7.5 minute intervals did not record any cod schools.

Only twice did we observe fulmars submerging completely after non-fish prey. On 4 August 1986, fulmars surface seized and surface dived for prey in slicks off Radstock Bay. A single bird examined had crustaceans in its stomach. On 29 August 1989 we watched 20 fulmars again making shallow surface dives in a 30 × 30 m patch of deep water. Twice we passed through the patch, scattering the birds, but could see nothing in the water column. However, a paper chart depth recorder showed a high density of large zooplankter in the patch, compared with the surrounding area. After each pass the flock reaggregated over the patch. We surmise that the birds located invertebrates visually and then dived for them.

On 16 September 1989 we determined experimentally that fulmars can retrieve 20 cm cod tethered but swimming normally as deep as 3.0 m below the surface (N = 10 trials). Birds appeared reluctant to initiate dives for bait below 2 m and, in these cases, typically viewed the bait for at least a minute before diving. However, birds may have been close to satiation during our experiments. Fulmars dived using strong leg thrusts followed by a push against the water with half-opened wings. Once under water, birds propelled themselves with their wings but we could not determine if they also used their feet. Comparisons of the relative durations of experimental and natural fulmar diving attempts suggest to us that birds may routinely dive to 3 m when pursuing Arctic cod.

Piracy by conspecifics or glaucous gulls (*Larus hyperboreus*) on fulmars that captured cod by surface or pursuit diving was common in most feeding flocks. Usually, the initial submergence of a diving bird triggered a response by nearby birds to rush to the dive site. Upon surfacing with cod, fulmars were usually attacked immediately.

DISCUSSION

Cullen (1954) noted a diurnal rhythm of colony attendance of fulmars at 71°N with partial evacuation of the breeding cliffs around midnight (see also Moss, 1965). The majority of our observations of birds foraging were made between 0700 and 1000 h, when we were engaged in field work. However, fulmars foraged on large cod schools in Allen Bay throughout the evening in late August 1989, and further investigation of the times of intense feeding at these high latitudes would prove informative.

Northern fulmars forage opportunistically on fish and invertebrate prey, as well as offal (Fisher, 1966). In the High Arctic, we witnessed considerable plasticity in foraging behaviour depending on prevailing conditions. Use of offal was opportunistic. Bradstreet and Cross (1982) found that fulmars scavenged hunter-killed marine mammal remains at the Pond Inlet ice edge, where carcasses were abundant, but found little dependence on scavenging at a Barrow Strait ice edge, where carcasses were less available (see also Bradstreet, 1982). Similar to our observations, these authors noted also that fulmars scavenged material from water but never from land or ice.

Feeding aggregations that exploited local concentrations of invertebrates at or near the surface were observed frequently in our study area. Similarly, Haney (1988) described foraging by northern fulmars on invertebrates at a tidal eddy in the northern Bering Sea, Alaska, and suggested that such eddies depend on a combination of conditions that may be rare and unpredictable. We did not determine the duration of such feeding aggregations at tide lines or upwelling sites. However, we noted that many aggregations occurred at tide lines emanating from headlands in Admiralty Inlet and along the south coast of Devon Island, and some of these events may occur predictably. Seabirds elsewhere feed at recurring patches of zooplankton formed by eddy currents or other fine-scale phenomena (Brown, 1988).

In Lancaster Sound and Barrow Strait, Arctic cod appear to concentrate seasonally in inshore waters. This provides a temporarily abundant and likely important food supply for fulmars that may forage extensively on these schools for several days. However, because the dynamics of cod movements in this area are poorly understood, we do not know to what extent fulmars depend on these aggregations. Fulmars did not respond to cod schools in Allen Bay in 1990, but this may be due to their exploitation of similar schools off south Devon Island, which were closer to breeding colonies. Nettleship (1977) found that Arctic cod appeared in the diet of fulmars at Prince Leopold Island at hatching and constituted a high percentage of the foods examined until mid-September. However, Bradstreet (1976) concluded that fulmars typically use invertebrates and take fish only opportunistically.

We do not know why cod aggregate in shallow waters. One possibility is that they are forced into shallows by marine mammals. We frequently observed whales and seals at Gascoyne Inlet and Allen Bay, where fulmars aggregated to feed on cod. Bradstreet *et al.* (1986) summarized twelve observations of feeding aggregations of marine mammals and seabirds in response to Arctic cod in the eastern Canadian Arctic from 1976 to 1983. Similar to our findings, four of these records include observations of large numbers of Arctic cod washed up on shore during or following marine mammal and seabird foraging activity. Further studies are required to ascertain the role of marine mammals in making Arctic cod available to seabirds in this area (see Pierotti, 1988). Of note also in the summary of Bradstreet *et al.* (1986) was the observation of Finley and Gibb, who witnessed kittiwakes and fulmars feeding selectively on the livers of cod, leaving the bodies intact. As with our observations at Allen Bay, birds responded to an apparent surfeit of food by selecting only oil-rich tissues.

Despite the density of inshore cod schools, these prey are accessible to fulmars only under fairly narrow conditions. In shallow water, cod are readily obtained by fulmars and other seabirds. In situations where cod aggregate a few metres below the surface, fulmars show a remarkable ability to capture them by pursuit diving. Fulmars are not well adapted anatomically for diving, and to date, the literature contains much controversy over the importance of this behaviour (reviewed by Wahl, 1984). We are aware of only one other study that attempted to ascertain the depths to which fulmars can dive (Ogi, quoted in Wahl, 1984). In that study, Ogi determined that fulmars did not dive for baits deeper than 80 cm. Our experiments showed that fulmars feeding on Arctic cod are able to dive regularly as deep as 3 m.

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