The Role of the Rhinoceros Auklet (*Cerorhinca monocerata*) in Mixed-species Feeding Assemblages of Seabirds in the Strait of Juan de Fuca, Washington

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Seabirds commonly feed in mixed-species assemblages, exploiting concentrations of prey at the sea's surface (Sealy 1973; Baltz and Morejohn 1977; Hoffman et al. 1981; Porter and Sealy 1981, 1982). These concentrations may be induced by either physical or biological factors (Brown 1980). While physical factors, such as fronts, can often be easily correlated with prey concentrations (Ashmole and Ashmole 1967, Pingree et al. 1974), biological concentrating factors are not always clearly identifiable, especially when observations are made from a distance.

One of the most important biological factors that promotes the formation of dense concentrations of prey species is the action of marine predators (Brown 1980). Through their feeding activities, these predators may incidentally make prey available to species that are restricted to foraging at the surface, e.g. surface-seizing seabirds. Among the predators with which seabirds have been observed to be associated while feeding are tuna (Ashmole 1963, Ashmole and Ashmole 1967, Gould 1974), seals (Ryder 1957), sea lions (Ryder 1957, Baltz and Morejohn 1977), porpoises (Gould 1974), dolphins (Baltz and Morejohn 1977, Brown 1980), and whales (Gould 1974, Overholtz and Nicolas 1979, Harrison 1979).

Seabirds capable of foraging by pursuit diving may also concentrate prey. Herding or driving schools of fish has been reported in a number of species including Brandt's Cormorant (*Phalacrocorax penicillatus*; Gabrielson and Jewett 1940), Double-crested Cormorants (*P. auritis*; Bartholomew 1942), Magellanic Penguins (*Spheniscus magellanicus*; Boswall and MacIver 1975), Grey Pelicans (*Pelecanus rufescens*; Fisher and Lockley 1954), and Rhinoceros Auklets (*Cerorhinca monocerata*; Angell and Balcomb 1982). Few accounts, however, have addressed the nature of the association between pursuit-diving seabirds and mixed-species feeding assemblages. Notable exceptions include Bartholomew (1942) and Hoffman et al. (1981). In San Francisco Bay, long narrow lines of diving Double-crested Cormorants were observed driving schools of fish before them, while gulls flew overhead and dropped to the water to pick up fish at the surface (Bartholomew 1942). In Alaska, alcids were observed diving, apparently beneath and around the fish schools, at the periphery of flocks of feeding seabirds, and Hoffman et al. (1981) suggested that this activity may have concentrated the school of fish or prolonged its contact with the surface-feeding flock.

In the present study, our aim was to identify the central role in concentrating prey near the surface played by the Rhinoceros Auklet in mixed-species feeding assemblages of seabirds. The study involved approximately 50 h of observations, made during June and July 1980 in the Strait of Juan de Fuca, Washington within 20 km (west to south) of Protection Island (48°07'N, 112°55'W). This island is the site of the largest colony of Rhinoceros Auklets in Washington, with the 1980 breeding population estimated to be more than 17,000 pairs (Lora Leschner, Washington Dept. of Game, pers. comm.). The Glaucous-winged Gull (*Larus glaucescens*), a prominent participant in the feeding assemblages, also nests on Protection Island, with the breeding population estimated to be 4,700 pairs in 1980 (Leschner pers. comm.). Concurrent with our observations of feeding assemblages was our visit to Protection Island, where we observed gull chicks and active auklet burrows, which contained young (Leschner pers. comm.).

Analyses of the diet of nestling auklets have revealed that the primary prey species on Protection Island is the Pacific sand lance (*Ammodytes hexapterus*; Richardson 1961, Wilson 1977), which comprised over 85% of the diet in 1980 (Leschner pers. comm.). Other investigations have documented the importance of this prey in the diet of auklets elsewhere in the northeastern Pacific (Destruction Island, Washington, Leschner 1976; Triangle Island, British Columbia, Vermeer 1980). Although the activity of this species varies from season to season, it is generally active by day and inactive and buried in the substrate at night in June and July (Girsa and Danilov 1976). During the day, schools of this fish swim in the water column and forage principally on copepods (Grover 1982). Sand lance possess two basic strategies to avoid predation. They may bury themselves in the sand, much as they do at night, or they may use their schooling as a defense mechanism, in which case they form tight, cohesive balls or pods (Girsa and Danilov 1976). This behavior is common in a number of pelagic, schooling fishes (Breder 1959, Brock and Riffenburgh 1960). It has been suggested that the tight ball confuses the predator and minimizes the surface

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TABLE 1. Feeding methods, relative frequency, and abundance of seabirds in mixed-species feeding assemblages in the Strait of Juan de Fuca during June and July 1980.

Species	Feeding method[a]	Frequency (%)[b]	Abundance[c]
Pelagic Cormorant (*Phalacrocorax pelagicus*)	Pursuit diving	5	<1
Glaucous-winged Gull (*Larus glaucescens*)	Dipping, surface seizing	100	38
Heermann's Gull (*L. heermanni*)	Dipping, surface seizing, plunging	80	9
Common Murre (*Uria aalge*)	Pursuit diving	25	<1
Rhinoceros Auklet (*Cerorhinca monocerata*)	Pursuit diving	100	10

[a] Feeding methods from Ashmole (1971).
[b] Percentage of feeding assemblages in which each species was represented, based on observations from 20 feeding assemblages. Data were derived from the analysis of slides and movies, as well as field counts.
[c] Mean number of individuals in the assemblages analyzed.

area of the school (Allen 1920, Breder 1959). This "balling-up" behavior of sand lance in response to a swimming predator effectively moves a dense concentration of prey to the surface, where it can be exploited opportunistically by surface-feeding seabirds.

While cod (Girsa and Danilov 1976), fin whales, and humpback whales (Overholtz and Nicolas 1979) have been observed to induce balling-up behavior in the sand lance, our evidence points, circumstantially, to the fact that ball-ups can be generated by birds. On at least 40 occasions when we piloted our boat at high speed toward the center of a mixed-species feeding assemblage in an attempt to capture the ball of sand lance [the subject of a separate study (Grover 1982)], the surface-feeding seabirds scattered, and auklets surfaced around the boat. On approximately 25% of these occasions, a water visibility of 3–5 m enabled us to confirm the presence of auklets beneath the ball of fish. Observing animals beneath the surface in this fashion has certain limitations: the apparent absence of other predators does not entirely preclude their involvement. When auklets dive beneath the ball of fish, however, their presence may be the proximate cause of the balling-up behavior. The capability of the Rhinoceros Auklet to herd fish has been documented in direct underwater observations made off Lopez Island, Washington (Angell and Balcomb 1982). Our attempts to net a ball of sand lance in one instance yielded the ball of fish as well as one auklet, which then flew out of the net. Feeding assemblages were also observed above predatory fish, e.g. spiny dogfish (*Squalus acanthias*) and salmon (*Oncorhynchus* sp.) (Olla unpubl. obs.). These assemblages differed from those in this report in that auklets were absent.

We observed the formation of a number of feeding assemblages from within 50 m. Initially, both gulls and auklets were seen on the sea surface. Auklets began diving diffusely over an area. One or a few gulls that were in the vicinity of foraging auklets soon discovered the ensuing ball of fish and immediately began seizing the fish at the surface. The flurry of feeding activity and the calls of these first arrivals, which could be heard for hundreds of meters, attracted other gulls. Occasionally, auklet recruits were observed flying in with the gulls. In one case, twice as many auklets as were present before the formation of the ball-up flew in and immediately began diving after the fish.

The duration, proximity, and magnitude of feeding assemblages were highly variable. Although we observed one transient assemblage breaking up and reforming six times within a 15-min period, others were more stable, lasting as long as 8–10 min. While many assemblages were rather isolated (i.e. separated from others by >1 km), on one occasion we observed four assemblages within 1 km. The number of gulls that participated in feeding assemblages varied from as few as 7 to as many as 120, and the number of auklets ranged from 4 to 20. Water depths beneath feeding assemblages varied from 3 to 125 m.

Although three pursuit-diving seabirds—the Rhinoceros Auklet, the Common Murre (*Uria aalge*), and the Pelagic Cormorant (*Phalacrocorax pelagicus*)—participated in feeding assemblages, the diving of auklets appeared to facilitate the greatest involvement of surface-feeding species through concentrating the school of fish or delaying its descent from the surface (see Hoffman et al. 1981). Auklets occurred in 100% of the assemblages, with a mean number of 10 per assemblage (Table 1).

Two surface-feeding gull species—the Glaucous-winged Gull and Heermann's Gull (*L. heermanni*)—also participated in feeding assemblages. A mean number of 47 gulls occurred per assemblage, with Glaucous-winged Gulls occurring more frequently and more abundantly than Heermann's Gulls (Table 1).

Auklets that surfaced during ball-ups frequently had no fish in their bills. There are two possible explanations for this. On the one hand, balling-up may be a successful antipredator strategy for the sand lance against auklet predation, although the strategy is unsuccessful against the opportunistic, surface-feeding gulls, which commonly had fish in their bills. On the other hand, auklets may ingest fish before surfacing. Their ability to do this has been demonstrated in captive birds. When auklets were fed live Pacific herring (*Clupea harengus pallasi*), more than 90% of their prey were ingested underwater (Gary Ballew, Seattle Aquarium, pers. comm., in prep.). Further contributing to the absence of fish in auklet bills was the possibility that the birds were feeding themselves rather than gathering food for young. Feeding of the young occurs only after dark on Protection Island (Richardson 1961, Wilson 1977). At that time adults return to the nest, carrying up to 13 fish in the bill (Richardson 1961). All our observations were made between early morning and late afternoon.

When visible at the surface, alcids were characteristically located at the periphery of feeding assemblages, as reported by Hoffman et al. (1981) and Porter and Sealy (1982). While this arrangement may have been in response to kleptoparasitism in Alaska (Hoffman et al. 1981), we found no evidence to support this hypothesis.

One entire school of sand lance was captured from a ball-up on 25 June 1980 off Green Point in the Strait of Juan de Fuca. The school had been compressed by auklets into a ball less than 50 cm in diameter. The involvement of auklets in this concentration of prey was evident from the capture of an auklet in the scoop-net along with the ball of fish. Each fish was measured, and a frequency distribution of total lengths was generated (Fig. 1). The school was composed of 541 fish, with a mean length of 140.9 mm ($s = 13.80$) (handling losses were estimated at <4% of the fish). A subsample of 157 fish (29% of the school) was weighed. The mean weight was 8.72 g ($s = 2.27$), and the biomass of the entire school was estimated to be 4,718 ± 192 g (a 95% confidence interval, Snedecor and Cochran 1967).

Auklets that were not feeding were frequently gathered into "loafing" rafts, which merit further investigation. The majority of rafts consisted of 20–40 birds, although we observed rafts as large as 400 birds.

It is clear from our own observations and the observations of others (Sealy 1973, Hoffman et al. 1981, Porter and Sealy 1982) that the discovery of surface concentrations of prey by certain "catalyst" species (Hoffman et al. 1981) was responsible for the rapid development of mixed-species feeding assemblages. Off Langara Island, British Columbia, Black-legged Kittiwakes (*Rissa tridactyla*) were most often the species that located prey concentrations (Sealy 1973). Off Alaska, the most important catalysts were Black-legged Kittiwakes and Glaucous-winged Gulls (Hoffman et al. 1981). In Barkley Sound, British Columbia,

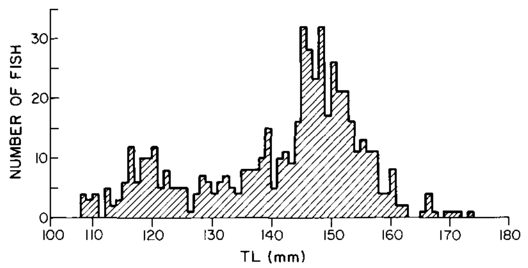

Fig. 1. The distribution of total lengths (TL) of Pacific sand lance in a school of 541 fish that was being preyed upon by Rhinoceros Auklets and other seabirds in a mixed-species feeding assemblage in the Strait of Juan de Fuca on 25 June 1980.

California gulls (*L. californicus*) initiated most of the flocks (Porter and Sealy 1982). Off Protection Island, auklets appeared to play a major role in concentrating prey at the surface. Glaucous-winged Gulls were always the species to discover these balls of fish and thus accelerated the development of all the observed mixed-species feeding assemblages.

It is not our intention to suggest that Rhinoceros Auklets are the only factor responsible for concentrations of prey exploited by seabirds in the Strait of Juan de Fuca. Rather, we suggest that pursuit-diving seabirds may be an important, but often overlooked, biological factor that concentrates prey in other locations, particularly in proximity to large colonies.

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