

In 1974, the first geese returned to a pasture-river staging area 5 km southeast of Crex Meadows on 9 March. Mated pair A returned with their four neckbanded 1973 offspring and were first observed on the morning of 11 March and were seen loafing together that evening. The next sighting of the family members was on 16 March at which time male A was accompanied by the four offspring. Female A was approximately 100 m away along the river bank with male C. Greeting displays between female A and male C suggested that the two had formed a new pair (AC).

Three of the neckbanded members from family B returned to the study area in 1974, but their arrival dates and behavior suggested the family was no longer intact. One yearling was first seen on 12 March while the female from pair B and another yearling offspring arrived at the staging area on 3 April. At this time, female B was unpaired and was never seen associating with either neckbanded 1973 offspring. By 5 April, male A and female B were observed engaging in greeting and triumph ceremonies that indicated they had paired. The 1973 offspring from pair A remained with male A from 16 March until about 10 April when new pair AB began establishing a nesting territory, at which time the offspring were evicted from the family.

Pair AC initiated a nest on 11 April and all six eggs hatched. Likewise, pair AB initiated a nest on 14 April and all seven eggs hatched. Both pairs fledged young in 1974.

The formation of new pairs in Canada Geese after the death of one member has been documented by several authors (Kossack, *Am. Midl. Nat.* 43:627–649, 1950; Sherwood, *Trans. N. Am. Wildl. Nat. Resour. Conf.* 32:340–355, 1967; Jones and Obbard, *Auk* 87:370–371, 1970). In contrast, new pairings in Canada Geese while both pair members are alive have seldom been described. MacInnes et al. (*J. Wildl. Manage.* 38:686–707, 1974) mention pair separation for Canada Geese nesting at the McConnell River, Northwest Territories, but the circumstances were not documented. The reasons for the separation and re-pairing are unknown and puzzling since pair A successfully raised a brood in 1973 and the family returned to the breeding area together in 1974. The fact that the pair separated before the pair bond was reinforced by active territorial defense may be significant. In addition, geese that formed new pairs in 1974 shared the same molting area in 1973 and thus were probably familiar with each other. Mate swapping in other species generally believed to pair for life has been described for Sandhill Cranes (*Grus canadensis*) (Littlefield, *J. Field Ornithol.* 52:244–245, 1981) and postulated as a rare but possible occurrence for Snow Geese (*Anser caerulescens*) (Cooke and Sulzbach, *J. Wildl. Manage.* 42:271–280, 1978).

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Food habits of wintering Brandt's Cormorants.—Only two studies have examined the diet of Brandt's Cormorants (*Phalacrocorax penicillatus*) during winter. Baltz and Morejohn (*Auk* 94:526–543, 1977) described the food of six Brandt's Cormorants collected offshore in Monterey Bay, California; Ainley et al. (*Condor* 83:120–131, 1981) summarized results of an unpublished study on 13 specimens from near Vancouver Island, British Columbia

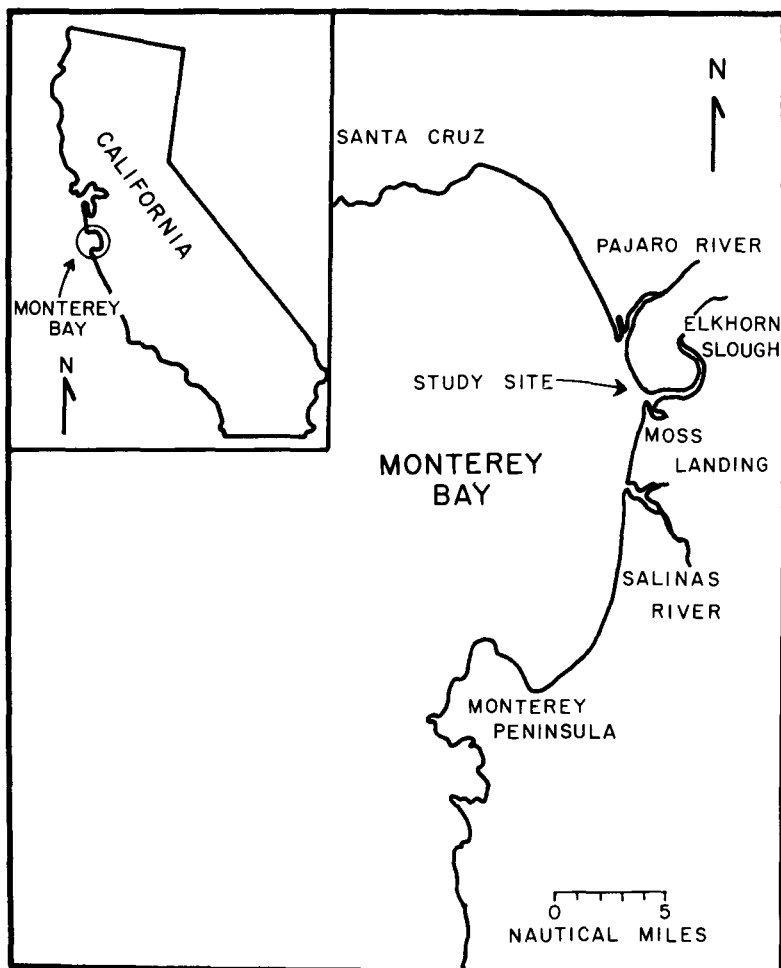


FIG. 1. Map of Monterey Bay, California, showing study area.

(this study also summarized all available information on the species' diet during summer). The present paper examines the food habits of Brandt's Cormorants feeding inshore in Monterey Bay during winter.

Eleven Brandt's Cormorants (9 male, 2 female) were collected from 1 December 1970–March 1971 inshore near Moss Landing, California (Fig. 1). Water depth varied from 25–50 m and the substrate was of sand and mud.

Cormorants were collected in the morning just after they had fed and contents of their esophagus, proventriculus, and ventriculus were removed. Food items consisted of either whole, undigested prey, referred to hereafter as whole prey samples, or fish otoliths. The

number of each species of whole prey was recorded and the volume of each item was determined by water displacement. Because otoliths represented prey captured by cormorants on previous feeding trips (probably on the day before the bird was obtained), they were treated separately and are referred to as otolith samples. Otoliths were washed and stored dry, and later identified with the aid of a reference collection. The number of fish represented in each otolith sample was determined by dividing the total number of otoliths (sagittae) by two.

The Index of Relative Importance (IRI) was used to rank the importance of each prey species in whole prey food samples. The IRI (number + volume) \times (frequency) of each food item was established as a linear combination of its numerical importance, volumetric importance, and frequency of occurrence (Pinkas et al., Calif. Dept. Fish and Game, Fish Bull. 152:1-105, 1971). The value of the IRI ranges from 0, when all three values are 0, to 20,000 when all three indices are 100%. A modified Index of Relative Importance (mIRI) was used to rank the importance of each prey species in otolith food samples. It was also used to make comparisons with whole prey samples. The mIRI (number \times frequency) ranges from 0, when both values are 0, to 10,000 when both indices are 100%.

The Brillouin formula:

$$H = (1/N) \left(\ln N! - \sum_{i=1}^s \ln N_i! \right)$$

where N is the total number of individuals and N_i is the number of individuals of the i th species, was used to calculate trophic diversity indices for prey items in stomach contents (Pielou, J. Theoret. Biol. 13:131-144, 1966; Am. Nat. 100:463-465, 1966). Trophic diversity was calculated for each food sample; the total accumulated trophic diversity of all food samples was calculated by randomly pooling individual samples (Hurtubia, Ecology 54: 885-890, 1973).

I used the index of Morisita (Mem. Fac. Sci. Kyushu Univ. Ser. E (Biol.) 3:65-80, 1959), as modified by Horn (Am. Nat. 100:419-424, 1966), to determine the degree of similarity of whole food and otolith samples. The coefficient of overlap was estimated by

$$C = \frac{2 \sum_{i=1}^s x_i y_i}{\sum_{i=1}^s x_i^2 + \sum_{i=1}^s y_i^2}$$

where s is the total number of food categories and the data are expressed as the numerical proportions x_i and y_i of prey items in the whole prey and otolith samples of i prey species in samples x and y . The coefficient varies from 0 when samples are completely distinct to 1 when samples are identical.

Brandt's Cormorants fed entirely on fishes (Table 1). Bottom dwelling species, principally Pacific sanddabs (*Citharichthys sordidus*), but also English sole (*Parophrys vetulus*), and plainfin midshipman (*Porichthys notatus*) were the most important prey items in both whole prey and otolith food samples. Juvenile rockfish (*Sebastes* spp.) were also important prey items. Though known to occur from bottom to mid-depths, they too were likely caught near the bottom judging from the preponderance of bottom species in the diet. These species are also important to Brandt's Cormorants in central California during summer, though their ranking may differ (Ainley et al. 1981).

The whole prey and otolith samples were quite similar ($C = 0.84$); the only apparent difference was that juvenile rockfish were more important in otolith samples. However, the difference was not significant (paired $t = 0.07$, $df = 9$, NS), which indicated that the cor-

TABLE 1
ANALYSIS OF 11 WHOLE PREY AND 10 OTOLITH SAMPLES FROM BRANDT'S CORMORANTS
COLLECTED NEAR MOSS LANDING, CALIFORNIA

Prey species	Whole prey					Otolith		
	%N ^a	%V ^b	%FO ^c	IRI	mIRI	%N	%FO	mIRI
<i>Scomberesocidae</i>								
<i>Cololabis saira</i>	4.2	0.7	9.1	45	38	2.0	10.0	20
<i>Scorpaenidae</i>								
<i>Sebastes</i> spp. (juvenile)	4.2	2.5	9.1	61	38	38.0	30.0	1140
<i>Atherinidae</i>								
<i>Atherinopsis californiensis</i>	4.2	25.1	9.1	266	38	2.0	10.0	20
<i>Bothidae</i>								
<i>Citharichthys sordidus</i>	75.0	60.6	63.6	8624	4770	54.0	70.0	3780
<i>Pleuronectidae</i>								
<i>Parophrys vetulus</i>	8.3	5.4	18.2	249	151	2.0	10.0	20
<i>Batrachoididae</i>								
<i>Porichthys notatus</i>	4.2	5.7	9.1	90	38	2.0	10.0	20

^a Percentage of total number of individuals.

^b Percentage of total volume of individuals.

^c Frequency of occurrence (%).

morants sampled probably fed consistently one day to the next in the study area, or in similar habitat with comparable fish populations.

The prey of Brandt's Cormorants feeding in the inshore zone in 1970–71 differed from prey of cormorants feeding offshore in 1974–75. Baltz and Morejohn (1977) found that mid-water species, mostly juvenile rockfish, northern anchovy (*Engraulis mordax*), and market squid (*Loligo opalescens*) were the most important prey of wintering Brandt's Cormorants feeding in the offshore zone. None of these prey, except juvenile rockfish, was present in the diets examined during my study. However, the comparison is not conclusive because both studies were conducted over a short duration, 4 years apart, and the diet may well differ one year to another even in the same locality.

Individual trophic diversity indices averaged 0.0992 (range 0–0.3465) and 0.1692 (range 0–0.5868) for whole prey and otolith food samples, respectively, and were not significantly different (paired $t = 0.84$, $df = 10$, NS). The total accumulated trophic diversity was 0.7373 for whole prey, 0.8916 for otolith, and 0.9762 for all food samples combined. This latter value is 39% lower than the accumulated trophic diversity value reported by Baltz and Morejohn (1977). Whether prey available to Brandt's Cormorants are less diverse inshore than offshore in Monterey Bay needs further study.

The plot of the accumulated trophic diversity indices of Brandt's Cormorants (Fig. 2) appeared to approach an asymptote as the contents of individual samples were pooled. Hurtubia (1973) pointed out that if pooled samples reach the asymptote, food specialization and niche breadth of populations can be compared. If this is so, my results represent a good estimate of the food niche breadth of Brandt's Cormorants feeding inshore over a sand and mud substrate in Monterey Bay during the winter of 1970–71.

The relative importance of the study-site or similar habitat in Monterey Bay as feeding

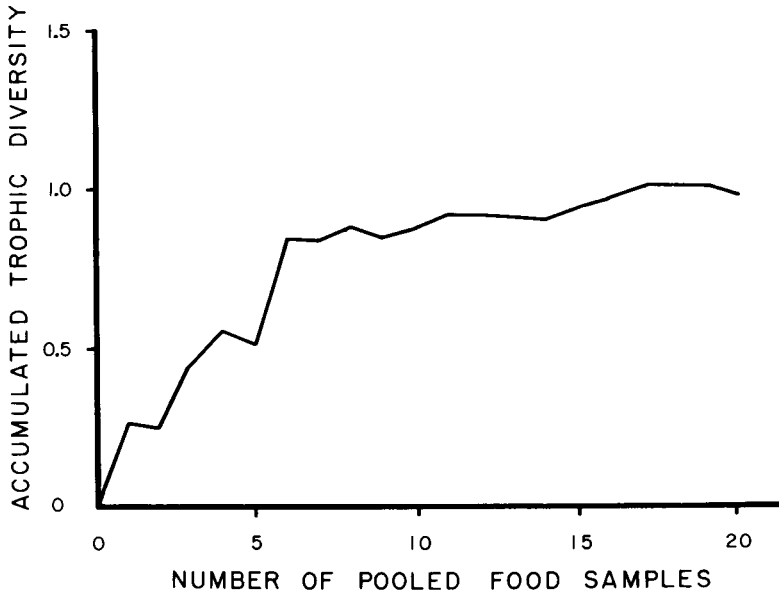


FIG. 2. Curve of accumulated trophic diversity vs counts of individual food samples of Brandt's Cormorants collected near Moss Landing, California.

areas of Brandt's Cormorants is unknown. No study has examined habitat use patterns of individual Brandt's Cormorants and little is known about feeding-site fidelity of individuals. My results, however, suggest that most of the cormorants collected had fed for at least 2 days on fish species predominantly found over a sand and mud substrate. Nevertheless, use of the study area by feeding adult Brandt's Cormorants was almost totally restricted to winter, although a few subadult birds used the study area throughout the year (Talent, unpubl.).

Apparently, most cormorants that fed at the study-site roosted on the numerous offshore rocks and islands around the Monterey Peninsula (Talent, unpubl.). The round trip from roosting site to the study area off Moss Landing was about 55 km. The energetic cost of these winter feeding flights is unknown, but cormorants making the trip were able to utilize an abundant food source, e.g., Pacific sanddabs, and avoid competition with the hundreds of Brandt's and Pelagic (*Phalacrocorax pelagicus*) cormorants that fed within the rocky inshore zone around Monterey Peninsula.

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