Diet Composition of Pilot Whales *Globicephala* sp. and Common Dolphins *Delphinus delphis* in the Mid-Atlantic Bight during Spring 1989

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Several species of marine mammals are found in large numbers along the eastern United States and are seasonally abundant in the Mid-Atlantic Bight (Kenny et al. 1983, Payne et al. 1984). Concentrations of pelagic fishes also occur in the Mid-Atlantic Bight area during winter and spring and are preyed upon by marine mammals, seabirds, and piscivorous fishes (Overholtz et al. 1991). Pilot whales *Globicephala* sp. and common dolphins *Delphinus delphis* are two of the more abundant marine mammals found in the area and potentially account for 30% of the total consumption of pelagic fishes by all cetaceans in the region (Overholtz et al. 1991). Detailed analyses of diet composition, specific rations, and size and age composition of prey consumed by marine mammals are sparse, since few healthy, recently dead animals are available for analysis. Most information on the diet composition of marine mammals found in the northwest Atlantic is from strandings, data from commercial whaling operations in Canada in the 1950s (Sergeant 1962), or incidental kills in commercial fishing operations.

Pilot whales were thought to feed extensively on short-finned squid *Illex illecebrosus* and secondarily on Atlantic cod *Gadus morhua* (Sergeant 1962, Mercer 1975), but more recently have been shown to feed on several other pelagic fishes and squids in the northwest Atlantic. In the area off New England and the Mid-Atlantic, pilot whales coincide with short and long-finned squid as well as Atlantic mackerel and butterfish *Peprilus triacanthus* (Smith et al. 1990). Pilot whales and common dolphins captured in foreign fishing operations during the 1980s were feeding on Atlantic mackerel and long-finned squid during winter and spring in the Mid-Atlantic region (Waring et al. 1990).

Studies quantifying fish consumption in the pelagic ecosystem off the eastern United States have suggested that marine mammals may be important predators (Kenny et al. 1983, Overholtz et al. 1991). Large numbers of marine mammals may reside in this region, but the impact of these predators on prey resources is difficult to assess since so few studies have documented the seasonal prey, ration size, and other dynamics of mammalian diets.

The objectives of this study were to describe prey types and quantities found in pilot whales and common dolphins, investigate the age distribution of their fish prey, and to assess the trophic role of these two mammals in the region. These data are necessary for understanding the sources and magnitudes of predation on fish resources at the age-specific level, a critical component of ecosystem modeling.

Manuscript accepted 9 August 1991.
Fishery Bulletin, U.S. 89:723–728 (1991).

Methods

Stomachs were collected from 5 pilot whales and 4 common dolphins that were taken incidental to fishing operations conducted in the Mid-Atlantic region of the eastern United States. Data were collected by U.S. observers on foreign vessels in the offshore Atlantic mackerel trawl fishery. Animals were obtained on five separate occasions from 19 March 1989 to 17 April 1989 in the Hudson Canyon area (Fig. 1). Sampling involved morphometric measurements of total length, girth, various fin and flipper measurements, determination of sex of the mammals, and excision of the stomach which was frozen for later analysis.

Contents of the thawed stomachs were sorted to the lowest taxonomic group possible and wet weights were obtained to the nearest gram. Individual fish were weighed separately, while squid were weighed as a group. Mantle length of squid was measured to the nearest mm (Lange and Johnson 1981). Fork length was recorded for mackerel to the nearest mm. Skull shape and otoliths were used to identify the Atlantic mackerel which were in various stages of digestion. Long-finned squid were identified by examining mantles, pens, and beaks. Mackerel were aged by mounting whole otoliths in resin and counting growth layers at 60× magnification (Dery 1988).

In some cases mackerel were fragmented usually at the caudal peduncle. Length of these specimens was estimated by realigning fragments or by visual reconstruction of the missing pieces through observations of fresher specimens along with a general knowledge of relative body proportions in the caudal region. Measurement error based on this method is unlikely to be greater than 10–20 mm (3–6% of total body length), and is accurate enough for estimating the relative

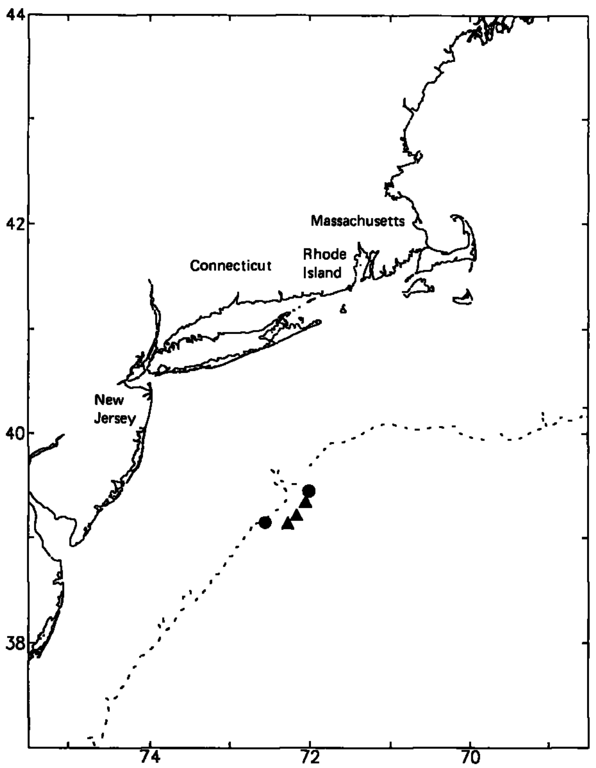

Figure 1
Mid-Atlantic region of the northeastern United States with locations in the Hudson Canyon area (north lat., west long.) of incidental captures of pilot whales (triangles) and common dolphins (circles) along the 100-m contour (dotted line) during March–April 1989.

size distribution of the prey. Partially digested mackerel were also weighed individually when possible, resulting in a minimum estimate of individual weight.

The food habits data were summarized to show diet characteristics of each animal. The age composition data for mackerel from stomach contents were summarized by percent number-at-age and compared with year-class size information from virtual population analysis (VPA) (unpubl. data) to discern if diet composition of the mammals was similar to age composition in the stock. To facilitate this comparison, a food selection index was calculated as

$$Li = ri - pi \qquad (1)$$

where ri is the proportion of prey i in the stomach, and pi is the proportion of prey i in the environment (Strauss 1979). This index ranges from -1 to $+1$ with 0 indicating no predator preference (Strauss 1979).

In addition, the theoretical daily energy budget of each individual animal was compared with the estimated caloric value of the food in the stomach. Individual weights of pilot whales and common dolphins were obtained from length-weight equations (Lockyer 1991, J. Mead, Smithson. Inst., Wash. DC, pers. commun. 1989). Individual daily caloric requirements (Kcal/day) were estimated from a relationship between resting metabolism and body weight (Lockyer 1981), with a correction for assimilation and activity (Hinga 1979, Kenny et. al. 1983). The energy values of each animal's stomach contents were estimated by converting prey weight to caloric content (Kcal) by using conversion rates of 1.43 Kcal/g for Atlantic mackerel and 1.34 Kcal/g for long-finned squid (Steimle and Terranova 1985).

Results

Pilot whale and common dolphin fed on Atlantic mackerel and long-finned squid during March and April of 1989 (Table 1). A few otoliths of hake *Merluccius* sp. were found in two pilot whales and one common dolphin. The condition of prey items in both species ranged from slight to well digested, but could be identified to species. In contrast to previous years (Waring et al. 1990), none of the stomachs contained fresh material, although all the mackerel in pilot whale no. 1 were only slightly digested (Table 1). This suggests that all the animals had fed prior to being captured in the trawl.

The pilot whales that were examined were between 400 and 471 cm, both male and female (Table 1). Total weight of stomach contents in pilot whales were in the range 620–7200 g and averaged 2555 g (Table 1). Atlantic mackerel averaged 71% of the wet weight of stomach contents, and long-finned squid comprised the remaining (Table 1). Atlantic mackerel dominated the diets of individual pilot whales in terms of percent weight, except pilot whale no. 2 which fed exclusively on long-finned squid (Table 1). The estimated mean length of mackerel were in the range 355–460 mm, with mean weights of 332–426 g, and modal age of 7 years. (Table 1). Mean lengths of long-finned squid were 88–146 mm and weights 32–93 g, although both of these measurements are probably underestimates since all squid were at least partially digested.

The four common dolphins were also medium-sized individuals of 170–213 cm (Waring et al. 1990) of both sexes (Table 1). They fed primarily on mackerel, although the remains of long-finned squid were present in the stomachs of two individuals (Table 1). It was impossible to measure any mackerel found in the stomachs since they were well digested, and they were

Table 1

Summary of stomach contents of 5 pilot whales and 4 common dolphins collected in March–April 1989 off the northeastern United States. AM = Atlantic mackerel, LS = long-finned squid.

Predator				Prey											
				Species (*N*)		Modal age	Mean length (mm)[1]		Mean wet weight (g)		Total weight (g)[2]		% weight	
Species	Specimen no.	Length (cm)	Sex	AM	LS	AM	AM	LS	AM	LS	AM	LS	AM	LS
Pilot whales														
	1	401.0	M	16	4	7	354.8	88.3	426.8	93.3	6829.4	373.0	94.8	5.2
	2	400.0	F	—	43	—	—	145.8	—	52.8	—	2268.7	—	100.0
	3	463.0	F	1	8	—	460.0	102.0	359.4	32.8	359.4	262.6	57.8	42.2
	4	440.0	M	2	—	—	360.0	—	332.3	—	664.5	182.0	78.5	21.5
	5	471.0	F	3	13	7	378.3	128.8	424.6	43.3	1273.7	563.1	69.3	30.7
Total				22	68	7	363.2	134.0	414.9	51.0	9127.0	3649.4	71.4	28.6
Common dolphins[3]														
	1	170.0	M[4]	4	—	7	—	—	186.9	—	747.5	—	100.0	—
	2	207.0	F	6	—	7	—	—	403.3	—	2420.0	—	100.0	—
	3	200.0	M	4	—	5	—	—	294.3	—	1177.0	—	100.0	—
	4	213.0	M	3	—	7	—	—	113.0	—	339.0	—	100.0	—
Total				17	—	—	—	—	—	—	4683.5	—	100.0	—

[1] Only lengths of measurable prey are included here.
[2] Includes weight of all stomach contents for this species.
[3] Specimens 3 and 4 had long-finned squid pens in the stomach from a previous meal.
[4] Atlantic mackerel found in the stomachs could not be measured or weighed individually due to the state of digestion.

identified by otoliths. The estimated mean weight of mackerel was 113–403g, and modal age was 7 years (Table 1).

The age distribution of mackerel was similar in pilot whales and common dolphins, with age groups 4–8 representing the bulk of the prey items. Age 7 was the dominant age group in the diet of both predators comprising 71% and 56% of the mackerel eaten by pilot whales and common dolphins, respectively (Table 2). This age group is from the very large 1982 year-class of mackerel (Table 2). Values from the food selection index comparing percent in stomachs with the stock, indicate that both predators may have concentrated on mackerel from age group 7. Positive index values were also obtained for ages 5–8 for common dolphins (Table 2).

A comparison of theoretical daily energy budgets of individual animals with the caloric content observed in stomach contents revealed that, in most cases, the diets represented only a small fraction of the daily requirement (Table 3). The amount of observed prey in pilot whale stomachs would supply 1.8–28% of the daily theoretical requirement, and 6–44% in common dolphins.

Discussion

Pilot whales and common dolphins captured during fishing operations for mackerel in 1989 appeared to feed primarily on mackerel and long-finned squid, although three specimens contained otoliths of hake *Merluccius* sp. Waring et al. (1990) reported on the diet of 33 common dolphins collected from 1986 to 1988 during the same time period and found similar prey items, including the presence of a few hake otoliths. Hake may either be consumed infrequently or the otoliths are entering the stomachs through other prey such as long-finned squid.

Capture location of the two mammal species was localized (Fig. 1), but captures extended over a 30-day period. The data may represent a normal pattern for winter-spring feeding or an attraction to fishing activity. This study suggests that the captured mammals were not entirely dependent on fishing operations for prey, since long-finned squid were present in stomachs but not in catches by commercial vessels.

Results from the food selection index analysis suggest a slight positive selection for ages 5,6, and 8 by common dolphins, and moderate selection for age 7 by both cetaceans (Table 2). Statistical tests are possible with this index (Ready et al. 1985); however, they

Table 2

Comparison of abundance of Atlantic mackerel in the sea with numbers in stomach samples from 5 pilot whales and 4 common dolphins taken incidentally during March–April 1989 off the northeastern United States.

Mackerel				Pilot whales			Common dolphins		
Age	Year-class	Abundance[1]	% of population	*N*	% in stomachs	Li[2]	*N*	% in stomachs	Li[2]
2	87	584	14.4	0	0.0	−0.144	0	0.0	−0.144
3	86	471	11.6	1	4.8	−0.068	0	0.0	−0.116
4	85	823	20.3	2	9.5	−0.108	1	6.3	−0.140
5	84	199	4.9	0	0.0	−0.049	2	12.5	0.076
6	83	107	2.6	1	4.8	0.022	2	12.5	0.099
7	82	1538	38.0	15	71.4	0.334	9	56.3	0.183
8	81	245	6.1	1	4.8	−0.013	2	12.5	0.064
9	80	38	0.9	0	0.0	−0.009	0	0.0	−0.009
10	79	5	0.1	0	0.0	−0.001	0	0.0	−0.001
11	78	30	0.7	0	0.0	−0.007	0	0.0	−0.007
12	77	4	0.1	0	0.0	−0.001	0	0.0	−0.001
13	76	7	0.2	1	4.8	0.046	0	0.0	−0.002
Total		4051	100.0	21[3]	100.0		16[3]	100.0	

[1]Millions of fish (unpubl. data).
[2]Linear index of food selection (Strauss 1979).
[3]Numbers reported here are 1 less than in Table 1, because 1 fish from each cetacean could not be aged.

Table 3

Comparison of daily estimated ration with amount of food in stomachs for 5 pilot whales and 4 common dolphins taken incidentally during March–April 1989, off the northeastern United States. AM = Atlantic mackerel, LS = long-finned squid.

	Predator				Prey					
					Total weight (g)		Caloric content[3] (Kcal)			
Species	Specimen no.	Length (cm)	Weight[1] (kg)	Ration[2] (Kcal/day)	AM	LS	AM	LS	Total caloric content (Kcal)	% of ration
Pilot whale										
	1	401.0	760	37184	6829.4	373.0	9766	500	10266	27.6
	2	400.0	725	35844	—	2268.7	—	3040	3040	8.5
	3	463.0	1049	47841	359.4	262.6	514	352	866	1.8
	4	440.0	957	44541	664.5	182.0	950	244	1194	2.7
	5	471.0	1095	49487	1273.7	563.1	1821	755	2576	5.2
Common dolphin										
	1	170.0	62	5236	747.5	—	1069	—	1069	20.4
	2	207.0	104	7850	2420.0	—	3461	—	3461	44.1
	3	200.0	94	7253	1177.0	—	1683	—	1683	23.2
	4	213.0	110	8203	339.0	—	485	—	485	5.9

[1]Obtained from a length-weight relationship from Lockyer (1991) for pilot whales, and from J. Mead (Smithson. Inst., pers. commun. 1989) for common dolphins.
[2]From a relationship between resting metabolism and body weight (Lockyer 1981) and a correction for assimilation and activity (Kenny et al. 1983).
[3]Obtained by converting prey weight to Kcal by using 1.43 Kcal/g for Atlantic mackerel and 1.34 Kcal/g for long-finned squid (Steimle and Terranova 1985).

cannot be used on these data since current methodology is not available to calculate the variance of stock size estimates based on the VPA. Mackerel school by size-age groups, and the older fish tend to be distributed farther offshore than younger fish (Sette 1950). The observed feeding pattern may reflect the absence of smaller, younger fish offshore and low abundance of older, larger fish (Table 2).

The age distribution of mackerel in the diet indicates that these smaller odontocetes are probably feeding on the older age groups of mackerel during the winter-spring season (Table 2). This is in contrast to fish predators such as Atlantic cod and spiny dogfish *Squalus acanthias* that feed on younger age groups of mackerel (Overholtz et. al. 1991). Smaller mouth size of the predatory fish probably limits their prey size. Marine mammals can feed on larger prey and are in direct competition with fisheries targeting these older, larger fishes (Overholtz et. al. 1991).

Energy budget calculations, when compared with caloric values of stomach contents, indicate that both pilot whales and common dolphins may need to feed several times per day to obtain their needed ration (Table 3). Although the analysis may be biased low and therefore somewhat conservative, it does suggest that the observed stomach contents may represent only a percentage of estimated daily requirement (Table 3). Therefore, stomach data from these cetaceans may underestimate the actual impact on prey resources.

The role of marine mammals has not been adequately described in many ecosystems since many populations are remote and the autopsy of fresh animals is infrequent. In the northwest Atlantic, most information on the diet composition of cetaceans has come from stranded incidentally captured animals, and commercial harvests (Sergeant 1962, Mercer 1975, Sergeant et al. 1980) or observations of codistributed mammals and prey (Overholtz and Nicolas 1979, Payne et al. 1986, Mayo et al. 1988, Smith et al. 1990). In the future, collection of more data on feeding behavior, prey species consumed, and overlapping distributions of mammals and prey on a seasonal basis, as well as a thorough sampling of incidental captures, will be necessary if the trophic role of marine mammals is to be determined. An intensive survey of the entire mammal population during this winter-spring period and in other seasons, along with some observations of activity around fishing vessels, would help determine how important the mackerel fishery is in influencing the behavior of smaller cetaceans.

Acknowledgments

We thank the foreign fishery observers for their diligent work in collecting stomach samples that we analyzed. We also want to thank N. Shepherd for ageing the fish from this study. Thorough reviews of initial drafts of this manuscript by J. Burnett and G. Shepherd, and advice from D.Hayes on the use of the food selection index, are much appreciated.

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