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GRAY SEALS IN NANTUCKET SOUND, MASSACHUSETTS, WINTER AND SPRING, 1994

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ABSTRACT

Aerial and ground surveys of gray seals (Halichoerus grypus) were done between 11 January and 9 May 1994 in Nantucket Sound, Massachusetts, to 1) monitor sites used during the pupping season, 2) individually identify as many breeding females as possible, and 3) determine whether a trend of population increase observed since 1988 was sustained. Fifty-nine pups were counted at Muskeget Island, and at least one at Monomoy National Wildlife Refuge. The number of pups counted at Muskeget Island was nearly twice the number recorded there in 1993. Twenty-five (41%) of the breeding females were identified with photographs. The highest single count of individuals in spring 1994 was 2,010 at both sites, compared to 1,549 at Muskeget alone in 1993. The population growth is likely to continue.

INTRODUCTION

Stock Identification and Distribution

The gray seal is a relatively large, sexually dimorphic species that lives in temperate and subarctic waters of the North Atlantic Ocean. The three major populations are: eastern Canada; northwest Europe, from Iceland to Norway and around Great Britain; and the Baltic Sea. These stocks do not mix (Davies 1957). Estimated world population size is over 240,000. Eastern Canada has about 143,000 (Mohn and Bowen 1994), and in Great Britain, the center of distribution in the northeast Atlantic, there were estimated to be 92,000 in 1985 (NERC 1987). The Baltic Sea presently has 2,500-3,000 (Yablokov and Olsson 1989). The Canadian and British stocks are increasing, while that in the Baltic is stable or declining (Mohn and Bowen 1994; NERC 1987; Yablokov and Olsson 1989).

This report concerns the northwest Atlantic gray seal stock, specifically its southernmost breeding colonies in Nantucket Sound, Massachusetts. The stock ranges from as far north as Hopedale, Labrador, to as far south as Long Island Sound, New York, with strays to Virginia. The center of distribution is in the Gulf of St. Lawrence, where most of the seals breed on ice. Outside the Gulf the seals breed on land, primarily in Nova Scotia at the Basque Islands and Sable Island, and also in small numbers on the east coast of Nova Scotia and near Grand Manan Island in the Bay of Fundy (Mansfield and Beck 1977).

Muskeget Island in Nantucket Sound, Massachusetts was the species' only known pupping site in the United States until 1990, when pups were found at Monomoy National Wildlife Refuge, also in Nantucket Sound (Andrews and Mott 1967; D. Houghton, pers. comm.; V. Rough, unpub. data). In 1994 a third pupping colony was discovered in eastern Maine (J. Gilbert, personal communication).

Breeding biology

Females are sexually mature at three to four years. Most give birth by age five and most do so annually thereafter (Mansfield & Beck 1977; Zwanenburg and Bowen 1990). Females mate about 15 days postpartum. Pupping occurs from late December to early February on remote sandy or rocky islands, or on sea ice. Pups are born with a coat of long, creamy white hair (lanugo). They weigh 16 kg at birth, and are nursed for about 17 days, reaching about 46 kg (Bowen 1991). Weaning is abrupt and weaned pups usually remain ashore for a few days to two weeks, fasting, resting, and completing molt of the natal coat (Mansfield 1988a; V. Rough, unpub. data).

Breeding adult gray seals of both sexes fast during pupping, and afterwards disperse from pupping areas to feed and replenish body reserves. Like many other pinniped species, gray seals haul out in greatest numbers during the molt, which occurs in May-June in eastern Canada; however in Nantucket Sound the molting period begins in early April, with premolting assemblies seen as early as March.

Population trends in Canada

The most complete studies of gray seals in eastern Canada were done at Sable Island since 1962, by the Department of Fisheries and Oceans. Brands were applied to partial cohorts of Sable Island pups in some years from 1969 to 1989, and entire cohorts were tagged from 1977 to 1990. These studies showed that Sable Island pup production increased at an annual rate of 12.6% from 1977 to 1989 (Stobo and Zwanenburg 1990). Pup production at Sable Island in 1993 was estimated at 14,300 (B. Beck, pers. comm.). Some of the Canadian tagged and branded gray seals have migrated into United States waters, and some marked females have pupped in Nantucket Sound (Stobo et al. 1990; V. Rough, unpub. data).

Population Trends in the United States

Much of the data on gray seals in Nantucket Sound were collected by the author, and are contained in unpublished records and reports. Some data from years prior to 1994 are included here for purposes of comparison and discussion.

Before 1958 gray seals were considered extinct in the United States. In that year Nantucket naturalist J.C. Andrews sent a skull to the Museum of Comparative Zoology, Harvard University, where it was identified as a gray seal. Andrews knew a seal distinct from the harbor seal (Phoca vitulina) had occupied Nantucket area waters since the early 1900's. Information he assembled on local seal bounty kills showed that about 40 gray seals, mostly females and pups, were killed at Muskeget Island, 9.6 km west of Nantucket, during the 1940's and 1950's. At the time of the bounty killing these were thought to be harbor seals. Massachusetts repealed the seal bounty in 1962 and enacted legislation protecting gray seals in 1965 (Andrews and Mott 1967).

Andrews pursued his study of the local gray seals, assisted from 1960 to 1970 by W. H. Drury, Jr., and from 1966 to 1994 by the author. By 1966, however, it was evident that bounty killing had reduced the population beyond immediate recovery. Annual pup production fell from 14-19 in the early 1950's to 1 in the late 1960's and in 1970. No pups were seen from 1971-1979, and counts of older animals did not exceed 12 during that period.

In 1976 a sandbar (Wasque Shoal) emerged 3.6 km south of Chappaquiddick, Martha's Vineyard and, starting in spring 1977, Wasque Shoal became the gray seals' preferred haulout site. They occupied the remote, undisturbed spit seasonally for the next ten years, making only occasional visits to Muskeget and vicinity. Distinctively marked individuals seen at both sites indicated that interchange was occurring between sites and that gray seals in the area comprised a single group (V. Rough, unpub. data).

The declining trend in numbers of older seals began to reverse in the early 1980's, with aerial counts at Wasque Shoal of 23 in 1983, and 61 in 1984. Also in 1983, six gray seals were recorded at Monomoy National Wildlife Refuge, formerly the exclusive domain of harbor seals. Some of the gray seals sighted had brands from Sable Island, suggesting that immigration from the expanding

stock in eastern Canada was occurring. Nevertheless a dearth of pupping in the Nantucket area persisted well into the 1980's. From 1971-1987 there were only six reports of whitecoat pups in southeastern Massachusetts, of which three were strandings. (J.C. Andrews, pers. comm.; New England Aquarium staff, pers. comm.; V. Rough, unpub. data).

In 1981 four Sable Island-tagged pups stranded at Nantucket and Cape Cod, and in ensuing years sightings and strandings of tagged pups became common, not only along the New England coast, but to as far south as New Jersey (J.C. Andrews; the staffs of Marine Mammal Stranding Center, Mystic Marinelife Aquarium, and New England Aquarium, pers. comm.; V. Rough, unpub. data) and Texas (B. Beck, pers. comm.).

In April 1987 156 gray seals were counted at Wasque Shoal. At the year's end, Wasque Shoal disappeared and, in January 1988, four pups with mothers and one dead pup were observed at Muskeget. No pups were sighted in 1989, but pupping resumed at this site in 1990 and has continued since then with increasing annual production, to 30 in 1993. A few pups were also found at Monomoy, in 1990 and 1991. During the spring molt the number of all-age gray seals increased to 1,549 at Muskeget in April 1993.

In Maine gray seals were censused by D. T. Richardson in the early 1970's and by J. R. Gilbert in 1993 and 1994. In surveys from 1972 to 1975, Richardson (1978) recorded 80 gray seals in Blue Hill, Frenchman's, Jericho, and Penobscot Bays. Gilbert recorded 600-1,300 on the entire Maine coast in 1993 censuses, and documented breeding activity in eastern Maine in winter 1994 (J. R. Gilbert, pers. comm.).

Studies by Allied Whale (College of the Atlantic, Bar Harbor, Maine) at Little Duck Island and Mount Desert Rock in eastern Maine, and by the author at Green Island Seal Ledges in Penobscot Bay, Maine, found numbers of gray seals at those sites increased since 1980 (Allied Whale, unpub. data; V. Rough, unpub. data). Photoidentification studies of female gray seals at Muskeget and Monomoy Islands in Massachusetts, and at Little Duck Island and Green Island Seal Ledges in Maine have shown interchange between the two Maine sites; between the two Massachusetts sites; and between the Maine and Massachusetts sites (V. Rough, unpub. data).

The recovery of the gray seal population in the United States is likely the result of immigration from Canada, and conservation measures such as the Marine Mammal Protection Act, and the Massachusetts legislation noted above. However the present rate of increase observed in Nantucket Sound gray seals carries the potential for adverse interaction with commercial and possibly recreational fisheries. Gray seals may consume commercially important species, and they are a definitive host in the life cycle of codworm (Pseudoterranova decipiens), also known as sealworm. Larvae of this parasite occur in the flesh of some groundfish, making fillets unsightly and sometimes unmarketable. The cost of removing worms from fish in eastern Canada was $30 million in 1984 (Malouf 1986).

OBJECTIVES

Because of observed increases in population and pup production of gray seals at Muskeget since 1990, this site was monitored in 1994.

A. Breeding season objectives were to:

1. Track the onset and progression of pupping at Muskeget by aerial surveys.

2. Once pupping was verified, use ground surveys to:

   a. Photographically identify all or most breeding females, and some breeding males;
   b. Document pup development stages and, where possible, pup sex;
   c. Estimate survival of pups to weaning; and
   d. Where possible, photograph molted pups for future identification.

3. Obtain from U.S. Fish and Wildlife Service personnel and others, information on any gray seal births at Monomoy National Wildlife Refuge.

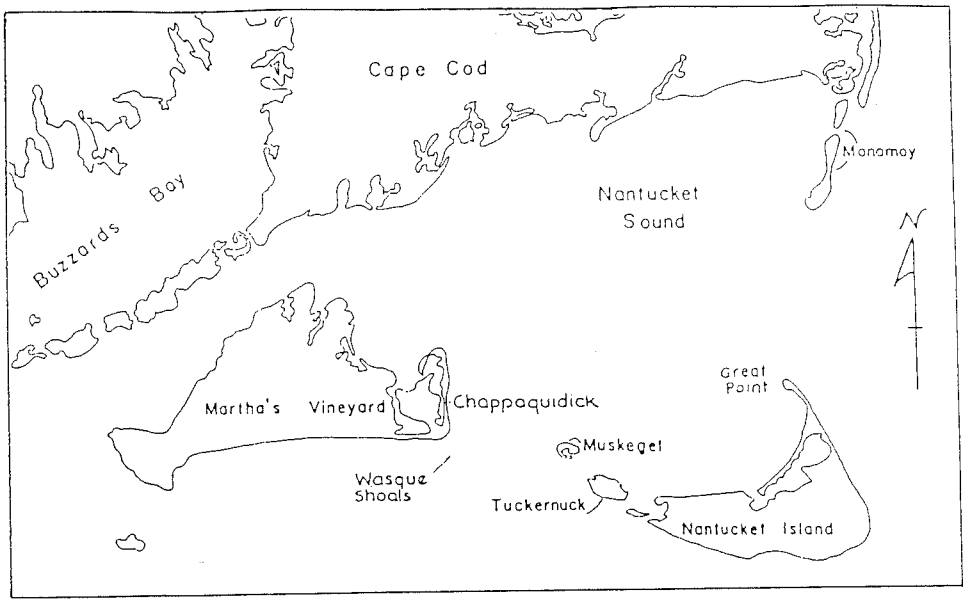
B. Post breeding season objectives:

1. Aerially census the seals during peak spring haulout at Muskeget and Monomoy;

2. On the ground, photograph females and pups of the year; look for brands and tags on individuals; and

3. Collect scat from areas vacated by the seals to determine prey.

Figure 1.
Nantucket Sound, showing places mentioned in text.



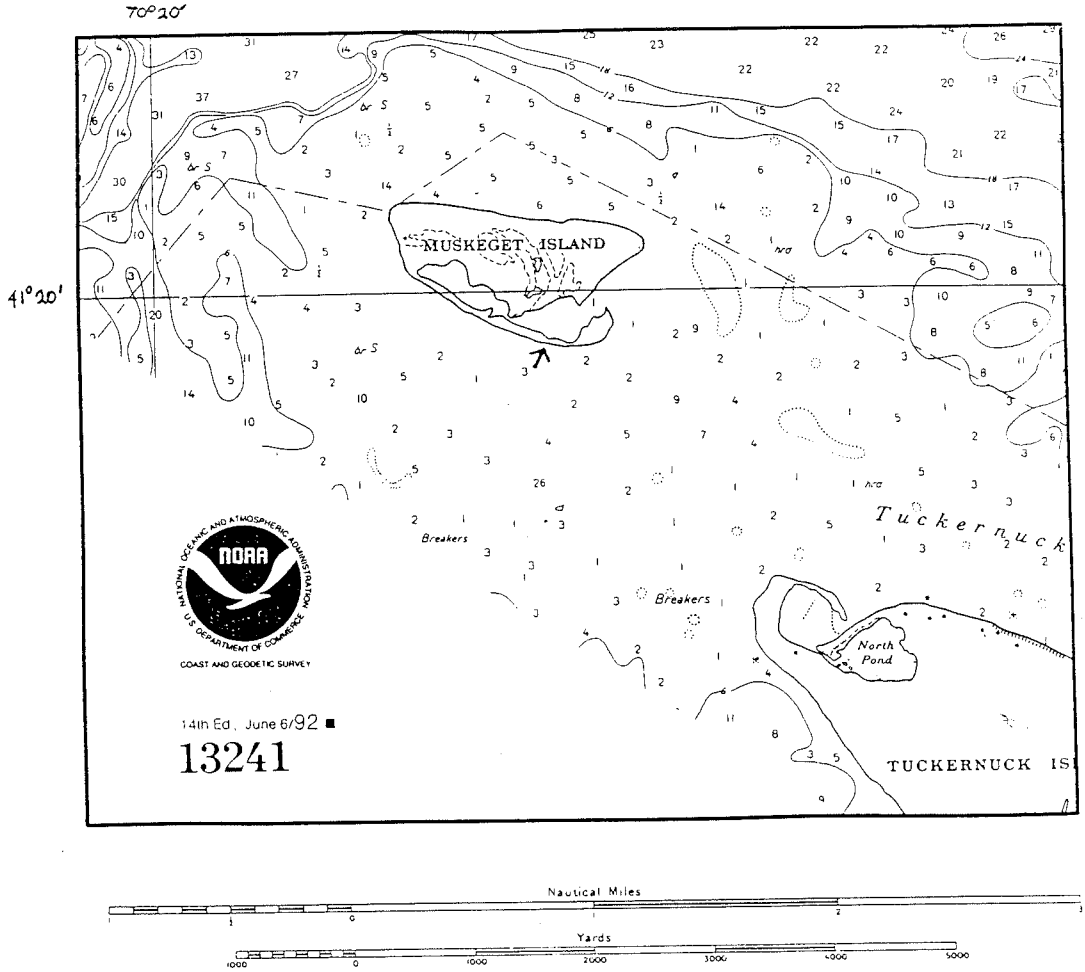
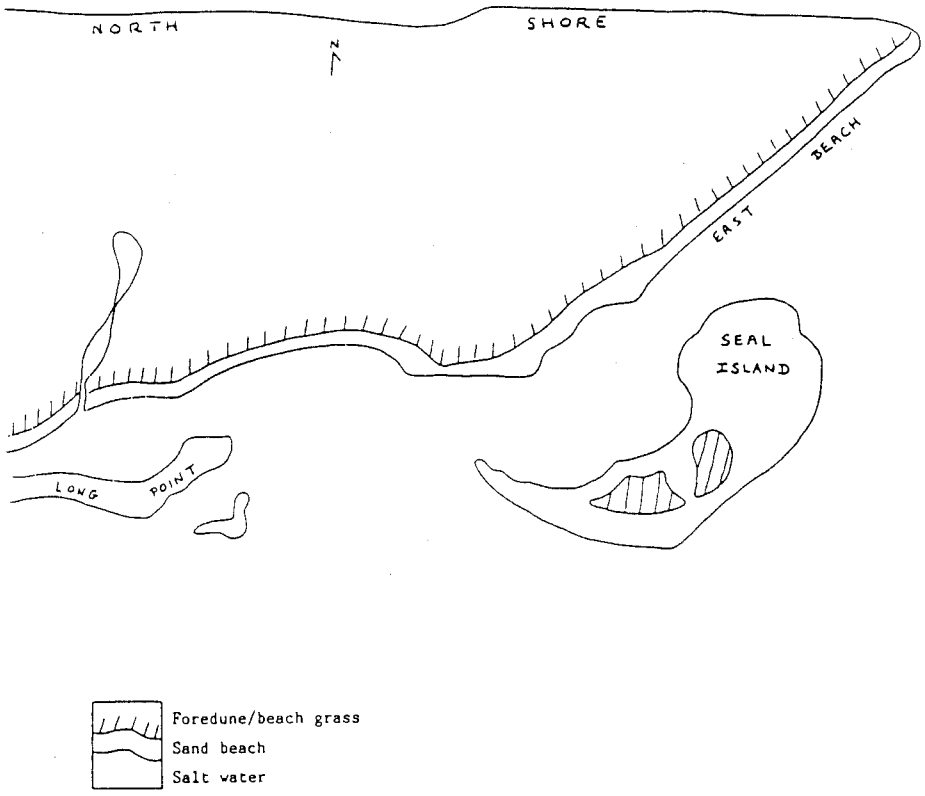


Figure 2.

Chart based on aerial photo ca. 1990. Arrow shows where breach occurred during Hurricane Bob, 19 August 1991, creating "Seal Island".

Figure 3.

East part of Muskeget Island showing locations of gray seal pups in 1994. Sketch map, not to scale, based on oblique aerial photos taken April, 1994.



THE STUDY AREA

The primary and secondary study areas, Muskeget and Monomoy islands, lie about 40 km apart in Nantucket Sound, Massachusetts (Fig. 1). Muskeget, composed of unstable, postglacial sand and gravel deposits, has continually changing shoreline contours and diminishing surface area (now about 109 hectares) due to erosion. South Monomoy, a barrier beach island about 8.8 km long, is also subject to frequent topographic change. Nearshore waters of these islands are characterized by shifting shoals and channels, and strong tidal currents. Gray seals prefer haulout sites adjacent to channels or holes at least two meters deep (V. Rough, unpub. obs.).

Figure 3 shows areas of Muskeget used for pupping in 1994: the east beach; Seal Island; and the east part of the north shore. Seal Island, and shoals (not shown on the map) about .7 km north of Muskeget were also occupied by non-breeding seals during pupping, and by gray seals

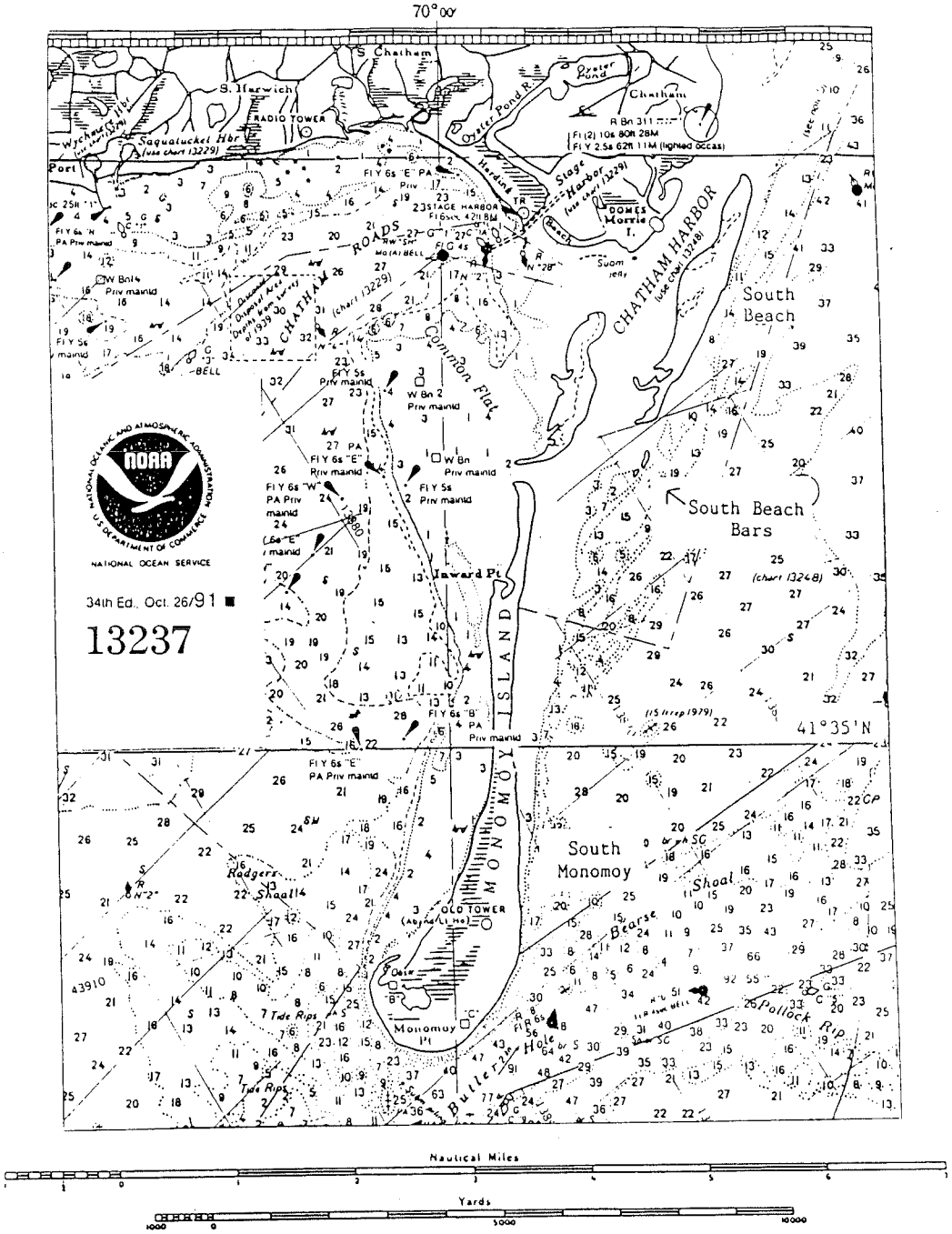


Figure 4. Monomoy - South Beach.

generally after the breeding season. As spring progressed the majority were on the north shoals, and Seal Island was often unoccupied.

At Monomoy (Fig. 4) gray and harbor seals usually occupied the east shore of South Monomoy but also at times South Beach or the South Beach Bars.

METHODS

Aerial surveys were done in a high-wing single-engine aircraft, either a Citabria or Cessna 172. Censusing was conducted at 250-370 m over Muskeget, and 310-400 m over Monomoy where the minimum legal altitude is 308 m. There were 12 flights, six of them at two to eight day intervals during the pupping season from early January to early February; and six after the pupping season at 11 to 20 day intervals. The flights were on the following dates: 11, 13, 21, 24 and 31 January; 5 and 20 February; 12 and 30 March; 15 and 28 April; and 9 May. Flights were made during fair weather and generally without regard to tidal state. (In the Nantucket area gray seals hauled out regardless of tide).

Eight flights were done in the 2-seat Citabria, with only the author and pilot present. Four flights were done in a Cessna, all with a second observer present. On the last flight, 9 May, both the second observer and the author photographed the seals. On six of the Citabria flights and three of the Cessna flights the pilots, who are experienced fish spotters, actively participated in locating and identifying seals.

Seals and haulout sites were photographed from the back seat through the closed window, using a 35 mm camera with 35, 55, 135 and 300 mm lenses, and Kodachrome 64 slide film. The smaller lenses were used for context pictures, while seal counts were made from photos taken with the 300 mm lens. Several exposures were taken from different angles to facilitate species identification and determination of gray seal pup status.

Seals were counted from slides shown on a Diastar tabletop rear projector, with a 20x20 cm screen. The screen was covered with a transparent acetate sheet which was marked with fine ball point pen, and erased as needed. With a slide on the screen a large haulout of seals was divided into units of about 20 by outlining with the pen on the acetate overlay, allowing for easy and repeatable counting of each unit. An entire haulout of seals was covered in this way, and unit counts were then totalled. Seals in the water were also counted when species could be determined.

All photos were counted only by the author, and most were counted only once. However in photos from flights over Muskeget during the breeding season, all pups and breeding adults were counted at least twice; and photos from the last two flights were counted twice and averaged for each site and species. In the case of Monomoy seals on the last flight, 9 May, the second observer's photos, also taken with Kodachrome 64 slide film, were counted and averaged with the count from the author's photos. The largest variance between first and second counts was 4.6%, giving confidence that the single counts were reasonably accurate.

In ground surveys seals were photographed from a distance of at least 40 m, and up to a distance of about 450 m, using a 35 mm camera with 135 and 300 mm lenses for context pictures, and a Celestron C5 1250 mm lens on a tripod for photos of individuals. The Celestron lens, at aperture F 10, allows the use of fine grain films such as Kodachrome 64 and shutter speeds of 1/60 second and higher. The unique markings of individuals, particularly females, were photographed for identification using Kodachrome 64 or Ektachrome 200 slide film. Females were given priority because of their distinctive markings, and the importance of their reproductive role. Most males lack distinctive markings other than scarring, therefore only males on the breeding ground, and a few others with bold markings, were photographed.

Slide images showing markings of individual gray seals were transferred, often cropped and enlarged, to color print film using a Spiratone Duplivar slide duplicator. The film was processed commercially, and in some cases a second print of lighter exposure was made from a negative to bring out detail in shaded body areas. Photos were visually compared to previous photos, and catalogued. Identified individual females were assigned a serial number and entered into a Microsoft Works database containing information on sighting and pupping history. All females identified in Nantucket Sound by the author since 1968 are in the photocatalog and the database. Identified males are in the photocatalog but are not yet in a database.

Pups were categorized into one of six age classes, based on observations or photos:

1. 0-5 days old.
2. 6-10 days old.
3. 11-16 days old.
4. 16+ days old, weaned. Usually little or no lanugo molt has occurred.
5. Lanugo being molted.
6. Lanugo entirely molted.

Stages 1-3 are based in part on pup stages described by Mansfield (1988b) and Kovacs and Lavigne (1986). In stage 1 the head, shoulders and pelvis of the pup are prominent relative to the girth. In stage 2 the pup has filled out to become cylindrical in body shape. In stage 3 the pup is barrel-shaped to rotund. Theoretically these indices of condition denote certain ages; in fact there is considerable individual variation so designations are approximate. However, with sufficiently frequent sampling, birth dates of many pups can be determined to within 2 days. Stages 4 and 5, based on pelage state, are variable in duration. Typically stage 4 lasts 2-4 days, and stage 5, 7-10 days (Ling and Button 1975). In some pups lanugo molt may commence before weaning.

Scat analysis

Scat samples were collected from Seal Island, Muskeget, on 6 March, 1 April, 12 April and 3 May, and stored in plastic bags at ambient temperature or in jars with alcohol. Scats were processed by methods described in Treacy and Crawford (1981). All hard parts, scales, representative flesh samples, and parasites were saved. Mr. Brian Beck (Bedford Institute of Oceanography), Dr. Bruce Collette (Smithsonian Institution), Dr. Hugh DeWitt (University of Maine), Dr. Richard Greenfield (Northeast Fisheries Science Center), Dr. Steve Katona (College of the Atlantic), and Dr. Austin Williams (Smithsonian Institution) assisted with identification of some fish parts, otoliths, and invertebrates. Guides by Brodeur (1979) and Harkonen (1986) were also consulted. Dr. Jeff Bier (U.S. Food and Drug Administration) identified parasitic worms and worm eggs.

RESULTS

Pups and females

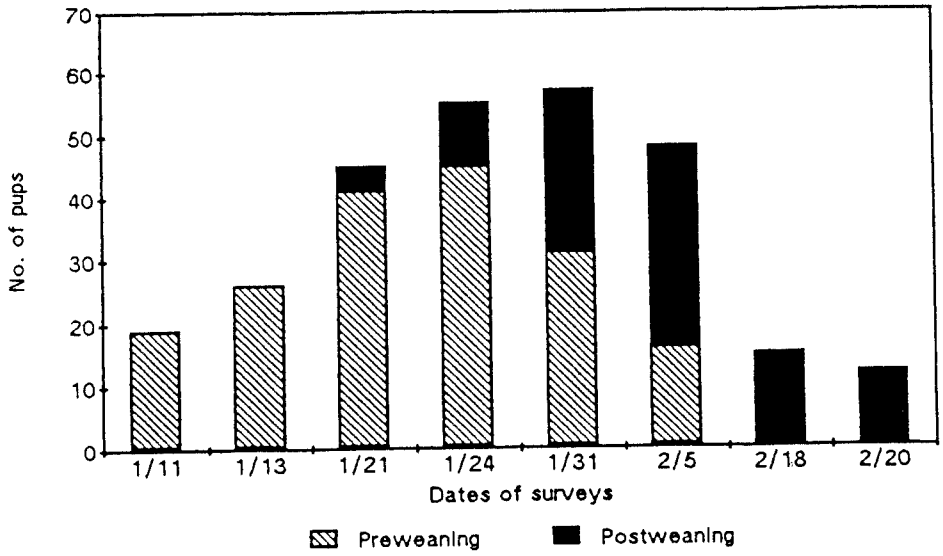
Figure 5 shows the progression of counts of pups of all stages from seven aerial surveys and one ground survey at Muskeget. On the first aerial survey, 11 January, 19 pups were sighted. By the fifth flight, on 31 January, 57 pups were counted. One dead pup was seen; it was observed on 31 January. The last known birth of the pupping season occurred at Muskeget on or about 6 February. Pups were found on the east beach (27 pups), Seal Island (30 pups), and the north shore of Muskeget (two pups), (Fig. 3).

During the pupping season persistent heavy sea ice prevented boat travel to Muskeget except on 2 and 18 February. By 2 February more than half of the pups had been weaned and abandoned. Thus a major study objective, to photograph all or most of the mothers of live pups, was not achieved. By 18 February, date of the second ground survey, 24 (41%) of the females had been photographed. Based on observation of marks unique to individuals it was determined that nine of the females had been seen previously at Muskeget or Monomoy, eight of them with pups. One of the attendant bulls was recognized from previous sightings at Muskeget.

Of the 24 identified females, two had been branded and tagged, and two had been tagged only (no tags were seen, but the individuals were known to have tags in the past). In 1994, by rough estimate, about 15% of Sable Island females of breeding age would have brands and, taking into account tag loss, 47% of them would have tags (Stobo and Zwanenburg 1990; B. Beck, pers. comm.). At Muskeget in 1994 two females (8%) were branded, and four (17%) were tagged (as noted above), suggesting 36-53% of the late-pupping females were of Sable Island origin. Tags are lost at high rates, 50-70% (Stobo and Horne 1994; B. Beck, pers. comm.), and are not always visible when present, limiting their usefulness as a gauge of the Sable Island contribution.

One of the two branded females was pupping here for the fourth time, while the other had not been sighted here previously. The two females with tags only had pupped here in previous years. The 24 identified females are listed in Table 1. Approximate birth dates were determined from observed pup stages. Such observations were limited because each female-pup pair was observed on

Figure 5. Number of pups pre- and post-weaning, from aerial and ground surveys at Muskeget in 1994.



only one date (either 2 or 18 February). A further unanticipated complication on Seal Island on 2 February was that some seals were obscured by beach grass, and an improved vantage could not be gained without disturbing the seals. For the same reason a complete pup count was not attempted on this date; 34 pups were noted, most at stage 3 or later.

Coverage was more complete on 18 February, when one pup with mother and 14 post weaning pups were noted. Otherwise aerial photos yielded the most useful pup counts and also allowed determination of whether pup status was pre- or post-weaning. At Muskeget the last pup was weaned by 20 February.

At Monomoy a newborn pup was found on 1 February (S. Ware, pers. comm.). Thereafter a single pup and mother were sighted by various observers in boats on 7 occasions between 2 and 22 February, with photographs taken on 2, 12 and 22 February (S. Ware, J. Sones, pers. comm.). Because a pup born on 1 February would not likely be with its mother on 22 February, and because the female in photos of

TABLE 1.
Identified gray seal mothers of pups at Muskeget, 1994.

Female	Approx. 1994 pup birth date	Comments	Approx. pup birth dates, previous years
Propt	20 Jan		
Cees	20 Jan		
E494	20 Jan	Born, branded, at Sable Is., 1987.	
Nuck	20 Jan		
Hunt	20 Jan		
Tent	20 Jan		
Box		Copulation observed.	
Quil			
Bar			
Tyk	21 Jan	Pupped here 1993.	20 Jan 1993.
Sy	21 Jan		
Seflor	22 Jan	Pupped here 1992 and 1993.	20 Jan 1992; 15 Jan 1993.
2 Spot	22 Jan	Pupped at Monomoy 1990.	19 Jan 1990.
Twin	22 Jan		
Fowl	23 Jan		
Fluke	23 Jan		
Moby	23 Jan	Pupped here 1992 and 1993; Monomoy 1991. Sable Is. tag: probably born 1985.	25 Jan 1991; 30 Jan 1992; 22 Jan 1993.
Dal	25 Jan		
Late	26 Jan	Pupped here 1993.	8 Feb 1993.
Toon	26 Jan		
Monce	26 Jan?	Pupped here 1992 and 1993; Monomoy 1991.	29 Jan 1991; 24 Jan 1992; 18 Jan 1993.
Perl	27 Jan	Pupped here 1993. Sable Is. tag: 1988 or 1989 cohort.	29 Jan 1993.
Wix	27 Jan	Pupped here 1991-1993. Born, branded at Sable Is., 1978.	3 Feb 1991; 29 Jan 1992; 30 Jan 1993.
Dent	6 Feb	Seen here spring 1986, 1988, and 1989; in Penobscot Bay, ME, late spring, summer 1980-1994. Has neck entanglement.	

2 February is different than the female in photos of 12 and 22 February, it appears probable there were two births at Monomoy. The second birth may have occurred about 6 February. Neither female was recognized from previous sightings.

The 15 new identified females at Muskeget, and 2 at Monomoy, bring the number of known females that have pupped in Nantucket Sound to 60 in 1994 (V. Rough, unpub. data).

Spring counts.

Figures 6 and 7 show aerial counts of gray and harbor seals at Muskeget and Monomoy, respectively, from 12 flights over Muskeget and 7 over Monomoy. The highest number of gray seals counted at Muskeget was 1,206 on 15 April, and the highest number at Monomoy was 892 on 9 May. At both sites 80-85% of the gray seals were males, consistent with past springtime observations in Nantucket Sound (V. Rough, unpub. data).

During the spring, as boat traffic to Muskeget increased, the distribution of gray seals shifted from Seal Island to the shoals north of Muskeget. Throughout the study period most harbor seals in the Nantucket area were on rocks and shoals north of Tuckernuck Island (Figs. 1 and 2), and on the Nantucket Harbor Jetties. At Monomoy both species usually occupied the eastern shore of South Monomoy (Fig. 4). Harbor seal groups were found to the south of gray seal groups, although groups dominated by one species usually contained both species.

Ground surveys.

Five days of ground surveying were done at Muskeget after the breeding season. Thirty-seven females were photographed: 26 adults, including four previously identified individuals; 11 juveniles; and 6 pups of the year. The four known adults included one that pupped at Muskeget in 1994; and two others that pupped there in 1992-1993. Unlike previous years no branded or tagged seals were sighted at Muskeget after the breeding season. After 1 April most of the seals were on shoals north of the island, beyond photographic range.

At Monomoy six new females were photographed in March and April by staff of Massachusetts Audubon Society; these images were added to the photo-catalog. The Audubon photos also show two branded adult males.

Figure 6. Number of gray and harbor seals counted during aerial surveys at Nantucket in 1994.

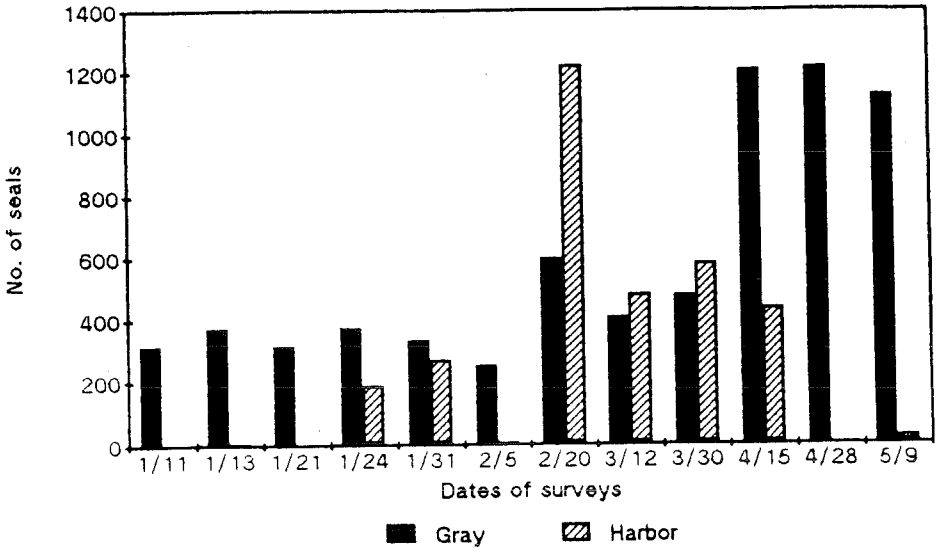
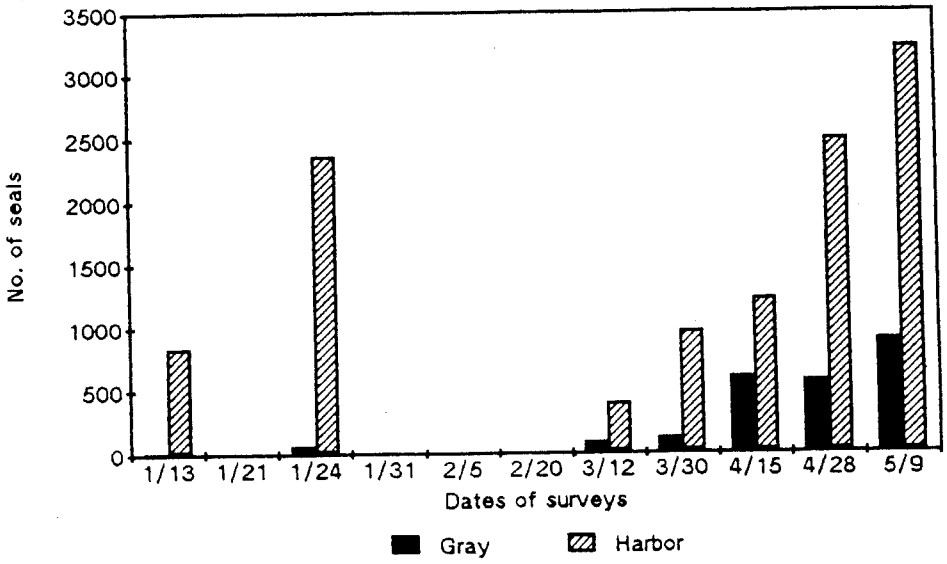


Figure 7. Number of gray and harbor seals counted during aerial surveys at Monomoy in 1994.



Lack of data indicates that surveys were not conducted.

TABLE 2.
Occurrence of prey items and parasites from gray seal scats collected at Muskeget in 1988 and 1994.

	Number of samples containing items listed.	
Collection date	March-April	March-May
	1988	1994
No. of samples	16	26
Otoliths of:		
Sandeel (*Ammodytes* sp.)	6	
Winter flounder (*Pseudopleuronectes americanus*)		5
Windowpane flounder (*Scophthalmus aquosus*)	3	2
Silver hake (*Merluccius bilinearis*)	1	2
Hake (*Urophycis* spp.)		3
Possible wolffish (*Anarhichas*) teeth		1
Scales similar to black sea bass (*Centropristes*)	3	
Clupeid-like scales	1	
Hagfish teeth (*Myxine glutinosa*)		1
Skate thorns (Rajidae)	6	3
Squid beak (*Loligo pealei*)	1	
Possible echinoderm plates	6	5
Nereid jaws	2	
Parasitic worms:		
Nematodes: *Anisakis*-like	1	
Pseudoterranova		3
Tricurids		1
Acanthocephalans		1
Unidentified annelids		4
Parasitic worm eggs:		
Cestodes: *Taenia*	1	
possible *Diphyllobothrium*		1
Unidentified helminth		1

The addition of 33 new females (exclusive of pups) photographed in the Muskeget spring haulout, and six from Monomoy, brings to 112 the number of photographed females seen once in Nantucket Sound. The number of females seen more than once, but not with pups, is 11. The total number of females in the Nantucket Sound catalog is 183 (V. Rough, unpub. data).

Entanglements.

Two females with severe constrictions of the neck caused by entanglement in wire, twine, or plastic were observed at Muskeget. These were: an adult with a pup, and an adult, seen on 6 March, not recognized from previous sightings. Plastic packing band material was visible on the neck of the latter seal. A third female, with a less severe neck constriction, was photographed at Monomoy on 6 March by staff of Massachusetts Audubon Society.

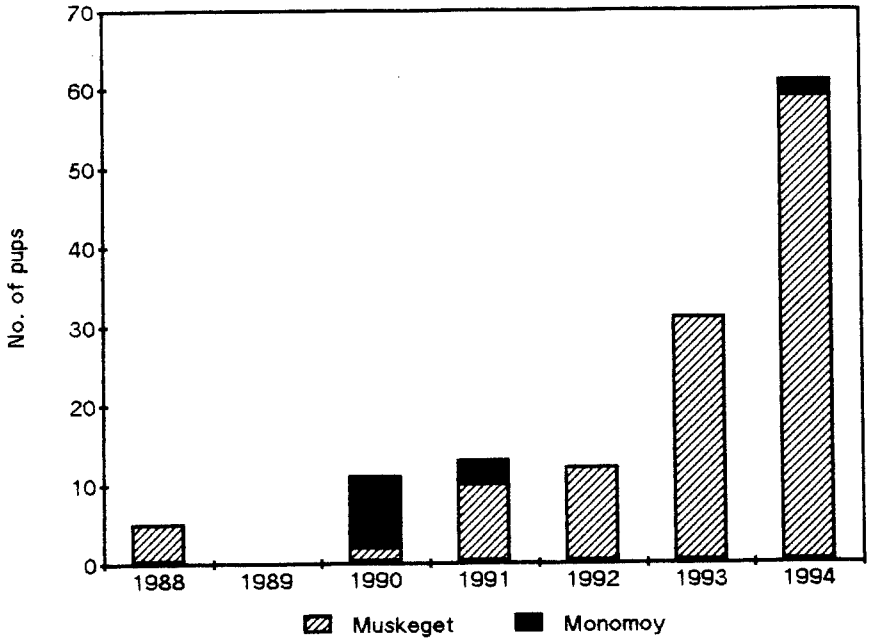
Scat analysis.

Twenty-six scat samples were collected in 1994. Identified prey item parts include otoliths of sandeel, winter flounder, silver hake, and Urophycis spp. hakes; the toothplate of a hagfish; and skate thorns (Table 2). Parasites include codworm, acanthocephalans, and unidentified annelids.

DISCUSSION

The 1994 study confirmed recent rapid growth in the southern New England gray seal population. The most direct evidence of growth was an increase in the number of pups born at Muskeget, from 30-32 in 1993 (V. Rough, unpub. data) to 59 in 1994. There were no births at Monomoy in 1993 and probably two in 1994. The Muskeget and Monomoy groups are a single breeding group, based on the observation of known individuals at both sites. Four of eight identified females which pupped at Monomoy have later pupped at Muskeget (V. Rough, unpub. data). However no identified females that pupped at Muskeget have later pupped at Monomoy, suggesting that Muskeget is a preferred breeding site. Combined pup counts for Muskeget and Monomoy 1988-1994 (Figure 8) show that after reestablishment of pupping in 1988, production was level at 11-13 during 1990-1992, then increased sharply in 1993 and again in 1994.

Figure 8. Pup counts, Muskeget and Monomoy, 1988-1994.



Sightings of brands and tags among females that gave birth at Muskeget in 1994, and at Muskeget and Monomoy in previous years (V. Rough, unpub. data), indicate that the the expanding gray seal stock at Sable Island has supplied recruits to the breeding population in the study area. The population dynamics of the southern New England gray seal population may be similar to those of the Sable Island population. For comparison, information on the Sable Island population is presented below, as is some of the author's unpublished data collected in the Massachusetts study area for years prior to 1994.

Timing of births.

At Sable Island, 99% of the pups are born by 20 January, while none have yet left the island by that date; this is the optimal date for aerial census of pup production (B. Beck, pers. comm.). Muskeget pup counts for 1992, 1993, and 1994 (Fig. 5), show a later peak, between 26 and 31 January. At Monomoy in 1991, the maximum pup count of three occurred 29 January-5 February, while in 1990 the maximum count of six occurred on 19 January. However, 13-15 days after the sixth pup was born

in 1990, three more were born on 1-3 February. Discontinuous, late pupping was also seen at Muskeget in 1993 with two births 6-9 February, about two weeks after the last of the previous births; and in 1994, with a birth on or about 6 February, about 10 days after the last of the previous births, based on limited observations of pup stages.

The shape and position in time of the pupping curve, or ogive, is a result of the parturition dates of individual females. Table 1 gives estimated birth dates in prior years for the eight identified females who were repeat puppers in 1994. Four pupped within five days of the previous year's date; three others have a variable range of one to eight days; and one pupped 13 days earlier in 1994 than in 1993.

Pup mortality.

Preweaning pup mortality based on pups found dead at Muskeget in 1994 was 1 out of 59, or 1.7%, far lower than Sable Island preweaning mortality of 6.1-15.6% (Stobo and Zwanenburg 1990). At Muskeget, single dead pups were found each year in 1988, 1991, and 1993; therefore the effective mortality was higher: 20%, 9% and 3%, respectively, in those years than in 1994.

For the Canadian gray seal stocks postweaning mortality is not precisely known, because the pups disperse widely and an unknown portion return to breeding grounds as yearlings. Mansfield and Beck (1977) gave an estimated first year mortality of 49% for females and 55% for males. Beck (pers. comm.) estimates that 11% of weaned pups at Sable Island die within two months due to low weaning weight of 30 kg or less. Optimal weaning weight is 50+ kg. Those of 30-35 kg are marginal (B. Beck, pers. comm.) and probably contribute significantly to strandings. Boness et al (1995) found females that gave birth late (i.e., 13-24 January) in the pupping season at Sable Island weaned pups lighter in weight than those that pupped earlier, likely resulting in lower survival of late-born pups. No pups have been weighed at Muskeget; differences in weaned condition, or fatness, have been noted, and qualitatively it appears late born pups there are smaller at weaning.

Other vital parameters.

Mansfield and Beck (1977) derived juvenile and adult survival rates, and fecundity rates for the Canadian stock

using seals taken by rifle, aged by methods described in Hewer (1964). Zwanenburg and Bowen (1990) modified Mansfield and Beck's life table parameters to reflect the present annual rate of increase at Sable Island, as indicated by total cohort tagging 1977-1989, of 12.6%. They indicated that the observed rate of increase would result from a juvenile survival rate of 79%, an adult survival rate of 96%, and pregnancy rates at ages 4, 5 and 6 of 16%, 71% and 91%, respectively.

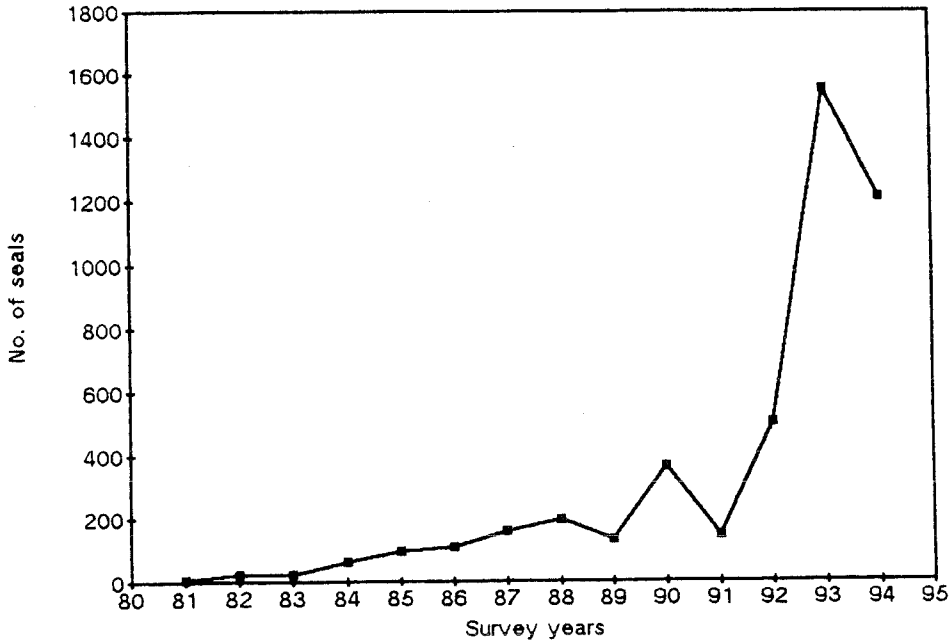
Population estimates and census results.

In the stable age distribution proposed for Sable Island by Zwanenburg and Bowen (1990) the ratio of nonpup to pup gray seals is 5.7. Applying this ratio to the estimated Sable Island pup production of 14,300 in 1993 (B. Beck, pers. comm.) yields a nonpup population estimate in 1993 of 81,510. If the same ratio exists in the Muskeget population, then the non-pup population consisted of about 336 in 1994. Actual counts of nonpup seals from the five January aerial surveys at Muskeget in 1994 ranged from 311 to 369, and averaged 338.

However, every spring, before and during the molt, the nonpup gray seal population of Nantucket Sound swells to much greater numbers than during the breeding season, suggesting a major influx from other areas. Figures 6 and 7 show the springtime increase in gray seal numbers noted in aerial surveys at Muskeget and Monomoy in 1994. The number of seals counted in spring has increased in recent years (Fig. 9) in parallel with the increase in pupping rate. There were fewer gray seals at Muskeget in 1994 than in 1993, but more at Monomoy in 1994 (563-892 in April-May) than in 1993 (50 in April, S. Ware, pers. comm.). Persistent east winds in spring 1993 likely made the exposed east shore of South Monomoy undesirable for gray seals, which adopt heat conserving behavior when molting. Winds were generally westerly in spring 1994 through early May, and counts were high at both sites. On 9 May 1994 the combined count was 2010, exceeding the probable combined total for 1993 if both sites had been censused on the same day.

In mid-May 1994 a persistent easterly wind flow developed and on 21 May the Monomoy gray seal count had dropped to 150, all on South Beach (B. Nikula, pers. comm.). Meanwhile at Muskeget fewer than 100 gray seals were on shoals north of Muskeget on 24 May (A. Costa, pers. comm.); disturbance by boating activity may have

Figure 9. Maximum gray seal counts from aerial surveys at Muskeget and Wasque Shoal, 1980-1994.



reduced the size of the haulout. J. Sones (pers. comm.) reported 200 gray seals at Monomoy's South Beach Bars in mid July 1994.

Although two branded seals were sighted at Monomoy, none were seen in the spring haulout at Muskeget compared to three there in 1993. Fewer branded seals in the molting haulout may reflect a) increasing production at Sable Island, swamping a relatively small number of brands; b) a Sable Island component weighted towards animals younger than 5 years, none of which would have brands; and/or c) animals coming from areas other than Sable Island.

Scat analysis.

The scat analyses suggest a varied diet, and different prey composition in 1988 and 1994 (Table 2), possibly reflecting a change in relative abundance of fish stocks. Otoliths common to both years are those of windowpane flounder and silver hake. Sandeel otoliths, which occurred in 38% of 1988 samples, with abundance of up to

33 in one sample, were not found in 1994. Otoliths of winter flounder and Urophycis spp. hakes, and a hagfish toothplate, were present in 1994 samples but absent in 1988. Skate thorns were more frequent in 1988 than in 1994.

Overall, gadids, the hakes of various species, were better represented in 1994, both in frequency and abundance. The same is true for parasitic worms, including codworm. One 1994 sample contained 20 codworms. Possible echinoderm plates were observed to be relatively frequent in both years, however these have not been positively identified; they may be ingested stomach contents of prey fish.

There may be differences in the potential codworm burden of various fish species. For example McClelland et al. (1990) found codworms relatively prevalent in windowpane flounder compared to winter flounder, and a greater prevalence of codworm in cod (Gadus morhua) than in silver and Urophycis spp. hakes, on the Sable Island Bank. At present there does not seem to be information on occurrence of codworm in various fish species in U.S. waters.

Harbor seals.

Harbor seals were aerially censused in the course of censusing gray seals; counts are shown in Figures 6 and 7. The data show that harbor seals were absent from the Nantucket area in the first three weeks of January, possibly because of harsh weather conditions and extensive sea ice during that time. They also show a decline at Nantucket to very low numbers in late April, consistent with observations in previous years (V. Rough, unpub. data). This decline, and the concurrent buildup in numbers at Monomoy, probably reflect the return migration of harbor seals from wintering areas in southern New England and New York en route to northern parts of New England where breeding occurs. Harbor seals do not now pup in Massachusetts, therefore the presence of over 3,000 at Monomoy on 9 May, the beginning of the harbor seal pupping season, is noteworthy. Possibly most of the seals were juveniles. B. Nikula (pers. comm.) reported 1,000-1,500 harbor seals at South Beach on 21 May 1994.

Future research.

Because the Marine Mammal Protection Act prohibits killing marine mammals except for specific purposes, killing gray seals for life history studies may not be feasible. Instead, photoidentification may be used to follow fecundity and survival in certain individuals. For example, females photographed at Muskeget as yearlings, when natural marking patterns have become distinct, could be recognized if they later return to the island to pup. Older juveniles may be aged to within a year by visual estimate. The age of branded seals, and some tagged seals, is known for certain. In 1989, the final year of branding at Sable Island, 490 females were permanently marked, and these will be fully recruited to the breeding stock in 1995. Three individually branded females have pupped at Muskeget or Monomoy to date, including E494 at Muskeget in 1994. None of these have returned to Sable Island since birth, according to Department of Fisheries and Oceans personnel who conduct dedicated resighting efforts on the island. A fourth female, that pupped at Muskeget four consecutive years, including 1994, has a generic 1978 brand. Its age is known, however its sighting history at Sable Island is not.

The application of brands or tags to pups may cause disturbance and alter natural behavior, and is probably not advisable in the near future. It may be feasible to apply a long lasting paint to the coats of newly molted pups, that are usually quite lethargic before going to sea. In theory paint would not influence survival, and would last until the following year's molt. In the case of a female, for example, this would allow individual tracking from pup stage, when coat patterns appear diffuse, to yearling stage when the pattern becomes more defined and recognizable.

There is potential for use of Sable Island brands and unique coat patterns to distinguish individuals for life history studies. The logistics of this approach are still at a manageable stage, and the potential can be realized over the next 10 years if most or all breeding females are photographed annually.

Photoidentification studies may become less effective as the population grows beyond the point where most individuals can be identified. Branding and flipper tagging might then be used to track individuals; however these methods may be unacceptable for humane reasons. The

feasibility of radio and satellite tagging studies, which might provide valuable information on movements and foraging locations, should be investigated.

The Nantucket Sound gray seal population has just become reestablished as a breeding colony. It will likely grow exponentially in the next decade, and the species' role in the marine community of the area will become more important. Abundance, distribution, birth rates, survival rates, and diet should be monitored for their basic scientific value, and for their relevance to the species' potential impact on fisheries. Abundance and distribution can be determined from aerial surveys. Pup production can be monitored by aerial and ground counts. Survival and fecundity of individual females can be monitored using photoidentification, and paint marking may be used to track survival of some pups, perhaps to compare the influence of early versus late birth. Further scat collection and analysis will elucidate the local gray seal diet, and can be used to follow any changes through time (although sample sizes would need to be substantially larger than in the present study).

At the present rate of increase observed at Muskeget, density related pup mortality may become significant in 4-5 years. Monomoy has more space but may be less attractive to the seals; this site should be monitored also. These incipient colonies, at or near the periphery of the species' present range, provide unique opportunities to study in detail various aspects of life history and ecology, that would be obscured in larger stocks.

CONCLUSIONS

The 1994 study of gray seals at two sites in Nantucket Sound, Massachusetts, indicated that pup production was nearly twice that observed in 1993; and that the size of the spring molting assembly, as measured by aerial surveys, was equal to or larger than that observed in 1993. The analysis of photographs of 24 of 58 gray seal females with live pups at Muskeget in 1994 showed that 33% were pupping for at least the second time, and one was pupping for the fourth time, in the Nantucket Sound area.

An exponential growth trend was identified in this group in the last two years and is likely to continue.

The population size is now equal to or greater than its historically known level prior to reduction and near elimination by bounty killing. Protection efforts have thus been succesful. However the increasing population here and elsewhere in New England may impact commercial fishery interests if it causes increased incidence of codworm in groundfish, as has occurred in eastern Canada.

This report contains suggestions for non-disruptive research on the Nantucket Sound breeding colony, which should be undertaken in 1995 to maintain continuity with previous studies. Population trends of the gray seal should be monitored in Massachusetts, and in Maine, where another breeding site has been found.

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