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Seasonal Distributions of Atka Mackerel *(Pleurogrammus monopterygius)* in Commercially-fished Areas of the Aleutian islands and Gulf of Alaska

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U.S. DEPARTMENT OF COMMERCE
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Abstract

Analyses of the haul locations, and sex and length composition of Atka mackerel *(Pleurogrammus monopterygius)* caught by the commercial fishery in four areas in the Aleutian Islands and Gulf of Alaska from 1984 to 1994 revealed seasonal and small-scale spatial distribution patterns of the species related to its reproductive behavior and life history. In winter, fishery hauls were generally conducted in deeper water than in summer, and the exploited population was well-mixed by sex in each of the four areas. In summer, when spawning and nest-guarding by males occurs, commercial hauls had higher percentages of females, had fewer mature males greater than 35 cm in length, and occurred in the relatively shallow inshore waters in "spawning" areas of Seguam Pass, Amchitka Island, and Umnak Island. At a "feeding" area on Petrel Bank, the only difference between winter and summer fishery catches was an under-representation of Atka mackerel of both sexes greater than 35 cm in length in summer, suggesting that they abandoned this area to spawn elsewhere. Knowledge of the seasonal and small-scale spatial distributions of Atka mackerel will be useful in designing better surveys to assess abundance and for long-term management of the fishery.

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INTRODUCTION

Atka mackerel *(Pleurogrammus monopterygius)*, a member of the greenling family Hexagrammidae, is distributed from the Gulf of Alaska off the United States and Canada to the Kamchatka Peninsula of Russia (Rutenberg 1962). A fishery for Atka mackerel has operated in the Aleutian Islands area and Gulf of Alaska since the early 1970s (Lowe and Fritz 1997). Annual landings off Alaska ranged between about 20,000 and 40,000 metric tons (t) from the late 1970s through 1991, increased to an average of about 75,000 t between 1992 and 1995, exceeded 105,000 t in 1996, and declined to approximately 65,000 t in 1997 and 1998. Processed Atka mackerel products were worth $44 million in 1995 and $69 million in 1996 (Kinoshita et al. 1998). The species is also an important member of the nearshore fish community in the Aleutian Islands area and the Gulf of Alaska, where it is preyed upon by commercially valuable groundfish (Livingston et al. 1993; Yang 1997), some seabirds (Byrd et al. 1992), and marine mammals, one of which, the Steller sea lion *(Eumetopias jubatus)*, is listed as endangered under the U.S. Endangered Species Act (Fritz et al. 1995; Fritz and Ferrero, in press). Adult Atka mackerel primarily consume zooplankton, including copepods and euphausiids, but may also eat small fish (Gorbunova 1962; Yang 1997).

Many of the details of Atka mackerel biology, ecology, and life history are poorly understood. It has been reported that Atka mackerel occur in large localized aggregations, usually at depths less than 200 m, and generally over rough, rocky and uneven substrates near areas where tidal currents are swift (Gorbunova 1962; Zolotov 1993). In Russian waters, the species is distributed offshore during much of the year, but moves to shallow waters each summer to spawn (Gorbunova 1962). Spawning peaks in summer throughout most of the species' range (Zolotov 1993), and extends into early fall in U.S. waters (McDermott and Lowe 1997). In Russian waters, spawning Atka mackerel have been observed to deposit batches of adhesive eggs in nests built and guarded by males on rocky substrates or on kelp in shallow water (Gorbunova 1962). No spawning or nesting areas have been identified in U.S. waters. Hatching occurs 40-45 days after the eggs are deposited, releasing planktonic larvae which can

be dispersed great distances by currents (Gorbunova 1962; Zolotov 1993). Little is known of the life history of young Atka mackerel prior to their appearance in trawl surveys and the fishery at about age 2-3 years. The age at 50% maturity is 3.6 years in the Aleutian Islands area (McDermott and Lowe 1997).

There are two data sources that can be used to describe seasonal Atka mackerel distributions in U.S. waters. First, bottom trawl surveys of the narrow continental shelf off the Aleutian Islands have been conducted about every 3-5 years since 1980 by the U.S. National Marine Fisheries Service (Harrison 1993; Ronholt et al. 1994). These surveys, conducted during the summer, were designed to assess the groundfish complex as a whole, and did not target on any one particular species. Consequently, much of the habitat preferred by Atka mackerel has not been surveyed because the substrate is unsuitable for trawling with the standard survey gear. Furthermore, since Atka mackerel exist in dense local aggregations and may be segregated by size and sex during the summer spawning season, large portions of the population may not be sampled by the survey.

The second database has information obtained by fishery observers, who have collected detailed data on the composition (e.g., species, length, sex), amounts, and locations (latitude, longitude, and depth) of catches. These data have been collected annually, at various times throughout the year, and at every location utilized by the Atka mackerel fishery. The geographic and seasonal distribution of fishing effort, however, is not only affected by the distribution of the target species, but also by U.S. fishing regulations. There were few management actions that affected the distribution of the Atka mackerel fishery in the Aleutian Islands and Gulf of Alaska prior to 1992. In that year, trawl exclusion zones around Steller sea lion rookeries were created, and these excluded the Atka mackerel fishery (among others) from some areas they had fished previously. [Trawl exclusion zones around all Steller sea lion rookeries west of long. 15O°W were created in January 1992. Zones with a radius of 10 nautical miles (nmi) (18.3 km) are in place year-round while larger, 20 nmi (36.6 km) radius zones exist around six rookeries in the eastern Aleutian Islands from 1 January-l5 April, including two in the Seguam Pass area (Fritz et al. 1995)].

For our study, we used data collected by fishery observers to describe seasonal, small-scale spatial distributions of Atka mackerel in the commercially fished areas of the Aleutian Islands area and the Gulf of Alaska. Compared to the fishery data, survey data are relatively sparse in a given area, and have only a single season of coverage (summer), precluding their use alone in an analysis of the spatial and temporal distribution patterns of Atka mackerel. Of particular importance in this analysis are the haul depth and location by month or season, and the sex and length compositions of Atka mackerel in the haul. Increased understanding of the spatial and temporal distribution patterns of Atka mackerel in U.S. waters is important for proper long-term management of the fishery, could reveal differential habitat utilization by the species, and will aid in designing a survey to better assess the species' abundance.

MATERIALS AND METHODS

All fishery data utilized in this analysis were collected by observers aboard commercial vessels fishing for Atka mackerel in the Gulf of Alaska and near the Aleutian Islands from 1984 to 1994. Observers collected data on location, depth, and date of the haul (haul data); species composition and weight of the catch (catch composition); and sex and length of the targeted species (length-frequency). Observer protocols for collecting data on catch composition and length-frequency have been described by Nelson et al. (1981) and by the NMFS (NMFS 1996).

Atka mackerel fishery data collected in four commercially exploited areas were utilized in this analysis (Fig. 1). From west to east, the four areas and corresponding coordinates were:

1. Amchitka Island - between long. 177°55'E and 179°50'E and between lat. 51°N and 5l°40'N;
2. Petrel Bank - between long. 179°W and 18O°W and between lat. 52°N and 53°N;
3. Seguam Pass - between long. 171°3O'W and 173°W and between lat. 51°30'N and 52°30'N;
4. Umnak Island - between long. 167°3O'W and 169°W and between lat. 52°30'N and 53°30'N.

These four areas were chosen because the Atka mackerel fishery used them for many years, and during different months (Table 1). At Seguam Pass, data collected aboard foreign and joint-venture vessels in the 1980s were considered separately from those collected in domestic

fisheries in the 1990s because, as will be shown, the two fleets fished in slightly different regions.

Hauls in which Atka mackerel was targeted were identified in the observer database using the species composition of the catch samples and a series of hierarchical target definitions (J. Berger, NMFS, Alaska Fisheries Science Center, 7600 Sand Point Way, NE, Seattle, WA 98115. Personal commun., March 1992). Atka mackerel was assumed to be a target species if it made up at least 20% of the retained groundfish by weight. Hauls in which other species comprised between 20% and 95% of the retained groundfish were removed from consideration prior to assigning an Atka mackerel target to those satisfying the above criterion. Depth, location and date of the Atka mackerel fishery hauls were utilized to analyze seasonal and depth distributions of the exploited populations by area (Table 1).

Observers typically measured up to 150 specimens of Atka mackerel each day that the vessel fished. The length-frequency sample from any one haul was randomly selected and reflects both the length and sex composition of the entire haul. Only data from sampled hauls in which more than 30 fish were measured, and no more than 1 fish was unsexed, were further aggregated by month and area for analysis of seasonal length frequency and sex composition of Atka mackerel fishery hauls (Table 2).

RESULTS

Haul Location and Depth

Within two areas exploited by the fishery (Seguam Pass in the 1980s and Umnak Island), commercial fishing occurred in deeper water during winter (January-April) than in summer (May-October; Table 1; Figs. 2-5). Data collected in the 1980s from the Seguam Pass area ranged in months only from April to October, but revealed a gradual decline in modal depth range (and mean depth) fished from 175-200 m (mean = 193 m) in April to 125-150 m (mean = 134 m) in August-September, and an increase to 150-175 m (mean = 163 m) in October-November as the spawning period ended (Table 1). There was little seasonality to the depths fished at Seguam Pass in the 199Os, with the modal depth range in all months at 125-150 m

(monthly means ranged from 132 to 162 m). While data from Umnak Island do not span the entire year, the modal depth range shoaled from 100- 125 m (mean = 141 m) in January-February to 75-100 m (mean = 88 m) in May, and increased in depth to l00-125 m (mean = 136 m) in September-October. At the two westernmost areas, Amchitka Island and Petrel Bank (Table 1; Figs. 2, 6, and 7), there was little seasonality in the depths fished. The modal depth range each month at Amchitka Island was either 125-150 m or 150-l75 m (monthly means ranged from 141 to 164 m) and slightly shallower at Petrel Bank (l00- 125 m or 125- 150 m, with monthly means ranging from 110 to 153 m). At Amchitka Island (Fig. 6), while the monthly mean and modal depth ranges had little seasonal pattern, haul locations tended to be more concentrated in summer (May-August) than during the remainder of the year.

Within three of the four areas, fishery trawl locations were further clustered into smaller regions. South of Umnak Island (Fig. 3), two fished regions were separated by a distance of between 40 and 50 km, due principally to the trawl exclusion zone around a nearby Steller sea lion rookery. In Seguam Pass (Figs. 4 and 5), trawl locations were clumped together in the northern pass west of Seguam Island in the 198Os, and either in the southern pass east of Amlia Island or on the bank southeast of Seguam Island in the 199Os, a distance of between 40 and 70 km. The 20 nmi trawl exclusion zones removed access to the entire pass during the first third of the year after 1992. However, some portion of the domestic fleet utilized the region outside the trawl exclusion zone in winter even prior to 1992. In the Amchitka Island area (Fig. 6), there were three groups of haul locations separated by as much as 100 km: one west of Rat Island, one west of the northwest tip of Amchitka Island, and one south of the east end of Amchitka Island. Trawl exclusion zones removed fleet access to some areas, particularly south of the east end and west of the northwest end of Amchitka Island. On Petrel Bank (Fig. 7), there was no spatial separation of hauls within the area, nor did trawl exclusion zones affect the distribution of the fleet.

Length-frequency by Month

In three of the four areas studied, commercial fishery catches were composed of similar numbers and sizes of male and female Atka mackerel during the non-reproductive seasons

(winter, spring, and fall). This was observed in the months of March-April and September-October at Amchitka Island, January-April at Seguam Pass, and March and September-October at Umnak Island (Table 2; Figs. 8-11). However, the January and February distributions at Umnak did not fit this pattern. The general pattern suggests that the Atka mackerel populations in these three areas were well-mixed by sex during the non-reproductive seasons and equally available to commercial gear in the areas fished. At these same areas during the summer, females were caught more frequently than males, and large males were less abundant than expected given the similarity in female and male length-frequency distributions in the non-reproductive seasons. This is evident in May-August at Amchitka, May-October at Seguam, and April-May at Umnak Island (Table 2; Figs. 8-l 1).

The pattern of length-frequency by sex and month at Petrel Bank (Fig. 12) is different than that described above for Amchitka Island, Seguam Pass, and Umnak Island (hereafter, referred to as spawning areas). In February-April, approximately equal numbers of males and females were caught, and they each had similar modes, a pattern similar to that observed in the spawning areas. Modal lengths of males and females were either 37 or 38 cm during these three months aggregated over as many as 5 years (for April; Table 2). In May-July, the numbers of males and female caught were similar (Table 2), and commercial catches were not dominated by females nor were large males disproportionately under-represented. However, in these 3 months, larger individuals of both sexes were absent from the catches; modal lengths decreased to between 30 and 34 cm and very few Atka mackerel larger than 40 cm were caught. Larger fish reappeared at Petrel Bank in August through October as evidenced by the increase in the modal length for both sexes to 37 cm. It appears that Atka mackerel of both sexes larger than 35 cm were less abundant in the area exploited by the fishery in summer than during the non-reproductive seasons. Hereafter, Petrel Bank will be referred to as a non-spawning area.

Sex Ratio of Catches by Season

At Amchitka, the distribution of haul sex ratios was centered at 50% females and 50% males in September-April; hauls with between 41-60% females and 40-59% males were the most

commonly observed (Fig. 13). From May to August, however, sex ratios were skewed toward greater numbers of females in each haul. The exploited population, principally females, also appeared to be more locally aggregated in May-August than during the remainder of the year, particularly south of the east end of Amchitka Island (Fig. 6). Less than 5% of the hauls were composed of greater than 59% males (with none greater than 79%) during the summer at Amchitka, suggesting that nesting areas were not subjected to commercial exploitation.

The distribution of haul sex ratios and locations of commercial Atka mackerel hauls at Seguam Pass (Figs. 4, 5, and 13) were similar to those described above for Amchitka Island. From January to April, the distribution of haul sex ratios was distributed evenly around the mode at 5l-60% female and 40-49% male, with the second most commonly observed ratios in the range of 41-50% female and 50-59% male. During the reproductive months (May-October), the modal sex ratio was the same as in January-April, but the distribution was heavily skewed toward females; 57% of the hauls sampled were composed of 60% or more female Atka mackerel, while only 4% were composed of 60% or more males. Haul locations tended to more dispersed throughout the entire Seguam Island area in the non-reproductive seasons than in summer, just as at Amchitka Island. In January-April, the fishery worked both within the pass between Seguam and Amlia Islands, as well as on the bank southeast of Seguam Island, while in the rest of the year, hauls were much more concentrated within the pass. The recent domestic fishery at Seguam Pass worked in the shallower areas east of Amlia in both seasons much more than the foreign and joint venture fisheries in the 1980s. This resulted in the different depth distributions of the two fisheries (Fig. 2). In the non-reproductive months, there were a small percentage of hauls that had more than 80% males (1%) or females (2%), each dispersed throughout the pass region. In the reproductive months, however, there was a much larger percentage of hauls that had more than 80% females (13%) concentrated primarily in the deeper areas of the pass. Those hauls with more than 80% males (1%) were not dispersed throughout the pass, but located in the shallower areas worked by the foreign and joint-venture (Fig. 5, top) and domestic fisheries (Fig. 5, bottom),

At Umnak, there were no commercial data collected from June-August, which is assumed to be the peak spawning period for Atka mackerel. There was little difference in the distribution

of haul sex ratios between the September-March and April-May periods (Fig. 13). During both periods, hauls with slightly more females (5l-60%) than males (40-49%) were more commonly observed, and resulted in the monthly aggregate length-frequencies shown in Figure 11. Locations in April and May were shallower than those fished in September-March (Figs. 2 and 3).

At Petrel Bank, there was little difference between the winter and summer haul sex-ratio distributions (Fig. 13). Both were symmetrically distributed about the 50:50 female:male ratio. There was also little difference in the locations fished in each season (Fig. 7). Fishing locations in both seasons were concentrated on the northeast corner of Petrel Bank, approximately 50-100 km northeast of Semisopochnoi Island (Fig. 1). At this "non-spawning" area, there was also little difference in the aggregate numbers of males and females caught (Fig. 12) and in the depths fished by month (Fig. 2). This is in contrast to the "spawning" areas of Amchitka and Seguam Islands (and possibly Umnak Island) where there tended to be more females caught and shallower depths fished in the summer spawning period than during the rest of the year.

DISCUSSION

Analyses of fishery data collected by observers suggests that the seasonal distribution of Atka mackerel in the Aleutian Islands area and western Gulf of Alaska is similar to that described for Russian waters (Gorbunova 1962, Zolotov 1993), and consistent with recent data on female reproductive cycles in U.S. waters (McDermott and Lowe 1997). In spawning areas (i.e., Seguam, Amchitka, and Umnak Islands), the population in commercially exploited regions appeared to be well-mixed by sex, more dispersed, and in deeper waters in winter (November-April) than in summer (May-October). Beginning in May and June, Atka mackerel of both sexes appeared to move to shallower, inshore waters, presumably in preparation for spawning in summer. This coincided with the first appearance of vitellogenic and early hydrated eggs in females (McDermott and Lowe 1997). Large males were under-represented in commercial catches during the summer, possibly because they were guarding nests of eggs in untrawlable areas near shore. Exploited aggregations of females and small males in summer may have been

in feeding areas near nesting/spawning habitat. Females could transit between the feeding and spawning areas to release their series of egg batches throughout the summer (Zolotov 1993). Feeding areas near nests where the fishery operates may have both trawlable bottom and characteristics that attract or aggregate Atka mackerel forage. Only when the fishery worked in certain shallow areas in summer (i.e., east of Amlia Island) did samples reveal high percentages of male Atka mackerel, possibly indicating the location of nesting sites.

The pattern of length-frequency by month, haul sex ratios, depth of hauls, and fishery haul locations by season was different at Petrel Bank than at the other areas frequented by the fishery. At Petrel Bank there was little difference in the proportion of females and males each month in aggregated length-frequencies, no seasonal deviation from a 50:50 female:male haul sex ratio, and no differences in the depth or areal distribution of hauls by season. The only seasonal difference in the exploited population at Petrel Bank was the under-representation of both males and females greater than 35 cm in length, the sexually mature portion of the population (Lowe and Fritz 1997; McDermott and Lowe 1997), from commercial catches in summer compared with winter. The commercially exploited region on Petrel Bank may be an important feeding area for the entire population in winter, but apparently only for the juvenile, non-reproductive fraction in summer. Of all the areas analyzed in this study, Petrel Bank was the farthest from near-shore habitat, despite having haul depths shallower than those at nearby Amchitka Island. Perhaps this feeding area is too far from nesting areas to be used by reproductive females in summer. Differential habitat utilization by Atka mackerel has also been observed in Russian waters off Kamchatka and the Kuril Islands (0. Zolotov, Laboratory of Pelagic Fish, Pacific Research Institute of Fisheries and Oceanography, Kamchatka Branch, 18, Naberezhnaya, Petropavlovsk-Kamchatsky, 683602, Russia. Personal commun., October 1996).

Monthly length-frequency summaries were aggregates of as many as 6 years of measurements (Table 2). There was a strong similarity in the sizes of Atka mackerel caught by the fishery from year-to-year, with modal lengths between 35 and 50 cm in all commercially fished areas in the Aleutian Islands. This length-range corresponds with 3+ year-old Atka mackerel (Lowe and Fritz 1997). Some monthly length-frequencies were collected in a single year, and as such, would reflect only that year's population length distribution (e.g., February,

March, September and October at Petrel Bank, and June 1990s and September 1980s at Seguam Pass). However, when these single-year monthly distributions are compared with neighboring months during which data were collected in more than one year, the seasonal patterns at each type of area, spawning or non-spawning, remain. Consequently, the mixing and segregation of the sexes in the exploited population during the non-reproductive and reproductive seasons in spawning areas appears to be independent of variations in year-class strength. Similarly, at Petrel Bank, which we consider a non-spawning area, the lack of large Atka mackerel in the late spring and early summer commercial catches, and their reappearance in late summer, fall and winter, appear to be independent of annual variation in population length distributions.

Food habits of Steller sea lions in the Aleutian Islands tend to support the observation of summer inshore and winter offshore movements of Atka mackerel. Atka mackerel form a large proportion of the diet of Steller sea lions during summer in the Aleutian Islands (NMFS 1995), when the latter are congregated on rookeries for pupping and breeding. During this time, adult females have more restricted foraging ranges than they do in winter, since they must return to the rookery frequently to nurse their newborn pup. During the winter, however, when populations of both species are more dispersed, the proportion of Atka mackerel in the sea lion diet decreases. While specific Atka mackerel nesting areas have not been identified, it is interesting to note the association of Steller sea lion rookeries and the Atka mackerel fishery in the Aleutian Islands. When the fishery occurred primarily in the summer and prior to the establishment of trawl exclusion zones (from 1982 to 199l), an average of two-thirds (66.7%) of the Atka mackerel caught in the Aleutian Islands area was caught within 10 nmi of Steller sea lion rookeries (L. W. Fritz, AFSC, NMFS, unpublished data). While most of these Atka mackerel were caught in Seguam Pass (near the rookeries on Seguam and Agligadak Islands), several other rookeries have had large catches of Atka mackerel nearby, including those on Kiska Island and in the Delarof Islands. Trawl exclusion zones may not only create a refuge within which Steller sea lions can forage separate from trawl fisheries, but may also exclude the fishery from important Atka mackerel spawning and nesting habitat.

For long-term management of the fishery, we must obtain more accurate and precise abundance estimates for the species, which will require a change from the stratified-random,

general groundfish bottom trawl survey currently being used. One alternative, an index site survey, would take advantage of both the locally aggregative nature of the fishery and the species. In this type of survey, several relatively small areas would be intensively sampled each year. For such surveys to be useful, however, changes in the population sampled at each index site should reflect changes in the population as a whole. Furthermore, Atka mackerel behavior and habitat utilization within each index site must be known. For instance, the index area sampled should encompass the entire local range of Atka mackerel; during summer, this would include shallow, nearshore nesting areas which have not been sampled on past surveys. Similarly, the design should account for large segments of the population being absent from areas such as Petrel Bank during the summer, when mature individuals apparently leave the area for spawning elsewhere. Increased understanding of the life history and behavior of Atka mackerel will help improve survey design and management of the fishery.

While it might be assumed that the fishery tracks large concentrations of the target species, there are logistical, safety, and weather considerations as well as fishery regulations that affect where the fishery operates. These may limit the ability of the fishery to exploit all areas occupied by the target species in all seasons. The analysis of fishery data must be interpreted within the constraints of these various factors. In this paper, we have shown that small-scale spatial-temporal distribution patterns can be revealed through analysis of fishery data. The broad temporal and fine-scale spatial distribution of commercial fishery operations provides an important source of data to supplement those obtained on general groundfish surveys.

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Table 1 .--Mean bottom depth and numbers of Atka mackerel fishery hauls sampled by fishery observers each month in each area. Years sampled and total number of years for each area are also indicated.

Area	Month	Number of Hauls	Mean Depth	Number of Years	Years
Amchitka Island	Mar	29	141 m	4	91-94
	Apr.	123	154	6	84-86,92-94
	May	180	156	5	84-87,94
	Jun	230	164	4	85-88
	Jul-Aug	52	158	4	87,88,93,94
	Sep-Oct	27	147	1	93
Petrel Bank	Jan-Mar	254	130	4	91-94
	Apr	271	153	7	84-86,91-94
	May	230	148	7	84-87,90,92,94
	Jun	328	129	7	84-88,90,91
	Jul	223	121	4	85,87,88,94
	Aug-Dee	377	110	3	87,90,93
Seguam Pass 1980s	Apr	81	193	2	84,85
	May	324	182	4	84-87
	Jun	217	160	5	84-88
	Jul	487	158	4	84-87
	Aug-Sep	57	134	3	84,86,87
	Oct	75	163	2	84,87
Seguam Pass 1990s	Jan	234	162	4	91-94
	Feb	473	147	4	91-94
	Mar	937	144	5	90-94
	Apr	451	157	5	90-94
	May	77	162	3	90-92
	Jun	236	132	1	90
Umnak Island	Jan-Feb	81	141	1	92
	Mar	101	105	2	93,94
	Apr	171	100	2	92,93
	May	59	88	1	92
	Sep-Oct	65	136	1	91

Table 2. --Numbers of male and female Atka mackerel measured for length each month in each area by fishery observers. Years sampled and total number of years for each area are also indicated.

Area	Month	Males	Females	Number of Years	Specific Years
Amchitka Island	Mar-Apr	4,012	4,198	6	84-86,91,92,94
	May	6,343	8,213	5	84-87,94
	Jun	10,417	15,466	5	85-88,94
	Jul-Aug	2,435	4,428	4	87,88,93,94
	Sep-Oct	890	846	1	93
Petrel Bank	Feb	1,365	1,449	1	94
	Mar	2,213	2,148	1	94
	Apr	7,968	7,442	5	84-86,92,94
	May	7,404	8,268	6	84-87,90,94
	Jun	13,405	14,963	6	84-88,90
	Jul	8,681	9,916	5	85,87,88,92,94
	Aug	1,914	2,083	2	87,93
	Sep	916	1,226	1	93
	Oct	1,260	1,816	1	93
Seguam Pass 1980s	Apr	4,274	4,136	3	84-86
	May	19,087	27,615	4	84-87
	Jun	21,239	32,690	5	84-88
	Jul	23,954	48,992	5	84-88
	Aug	2,510	5,818	3	84,86,87
	Sep	385	1,577	1	87
	Oct	1,867	4,369	2	84,87
Seguam Pass 1990s	Jan	8,670	8,437	4	91-94
	Feb	16,270	15,968	4	91-94
	Mar	24,113	24,493	5	90-94
	Apr	10,024	11,696	4	90,92-94
	May	3,335	5,406	2	90,92
	Jun	4,521	7,874	1	90
Umnak Island	Jan	1,562	2,335	1	92
	Feb	883	1,549	1	92
	Mar	1,161	1,169	2	92,94
	Apr	4,754	5,461	1	92
	May	1,883	2,268	1	92
	Sep-Oct	2,769	2,713	1	91

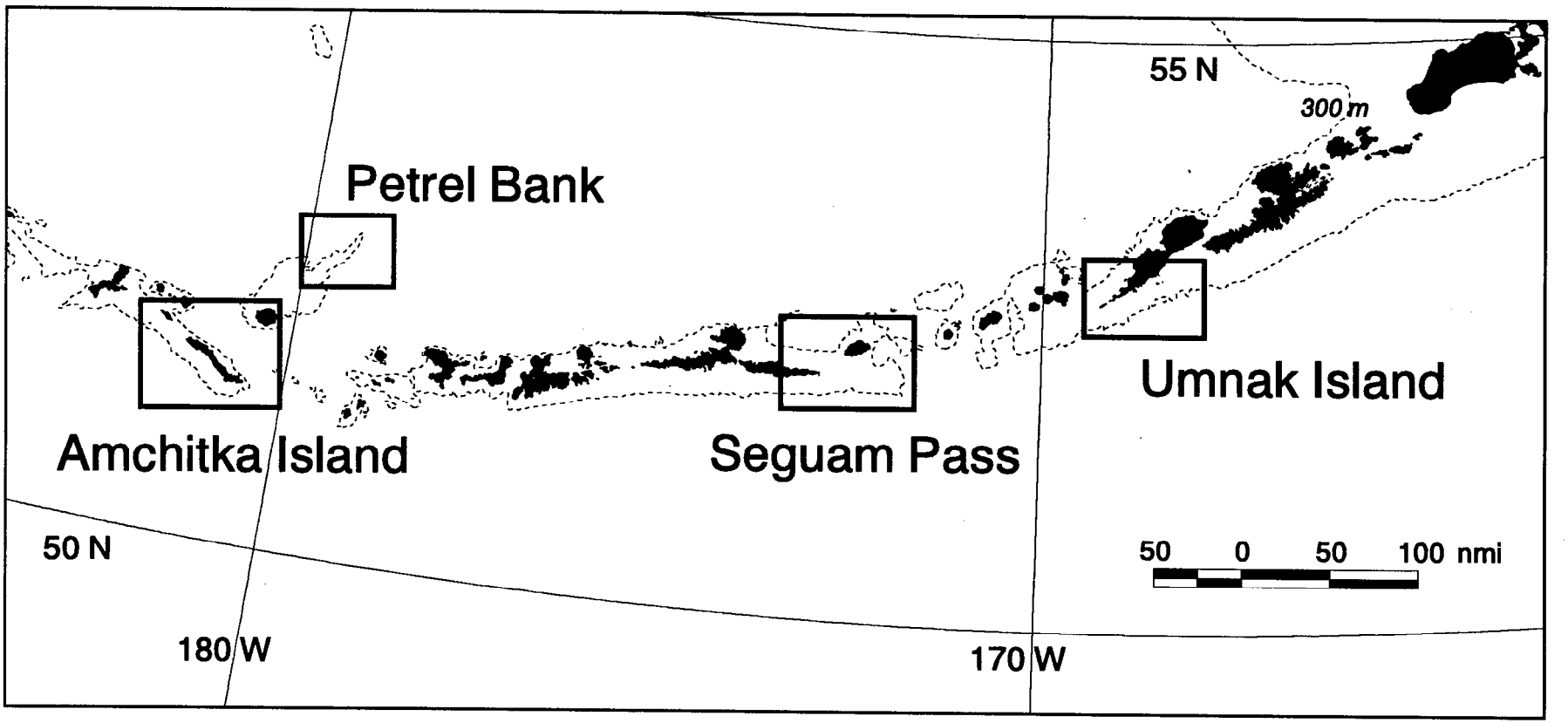

Figure 1 .--The Aleutian Islands and western Gulf of Alaska showing areas where Atka mackerel fishery data were collected. See Table 1 for months and years of data collection at each area.

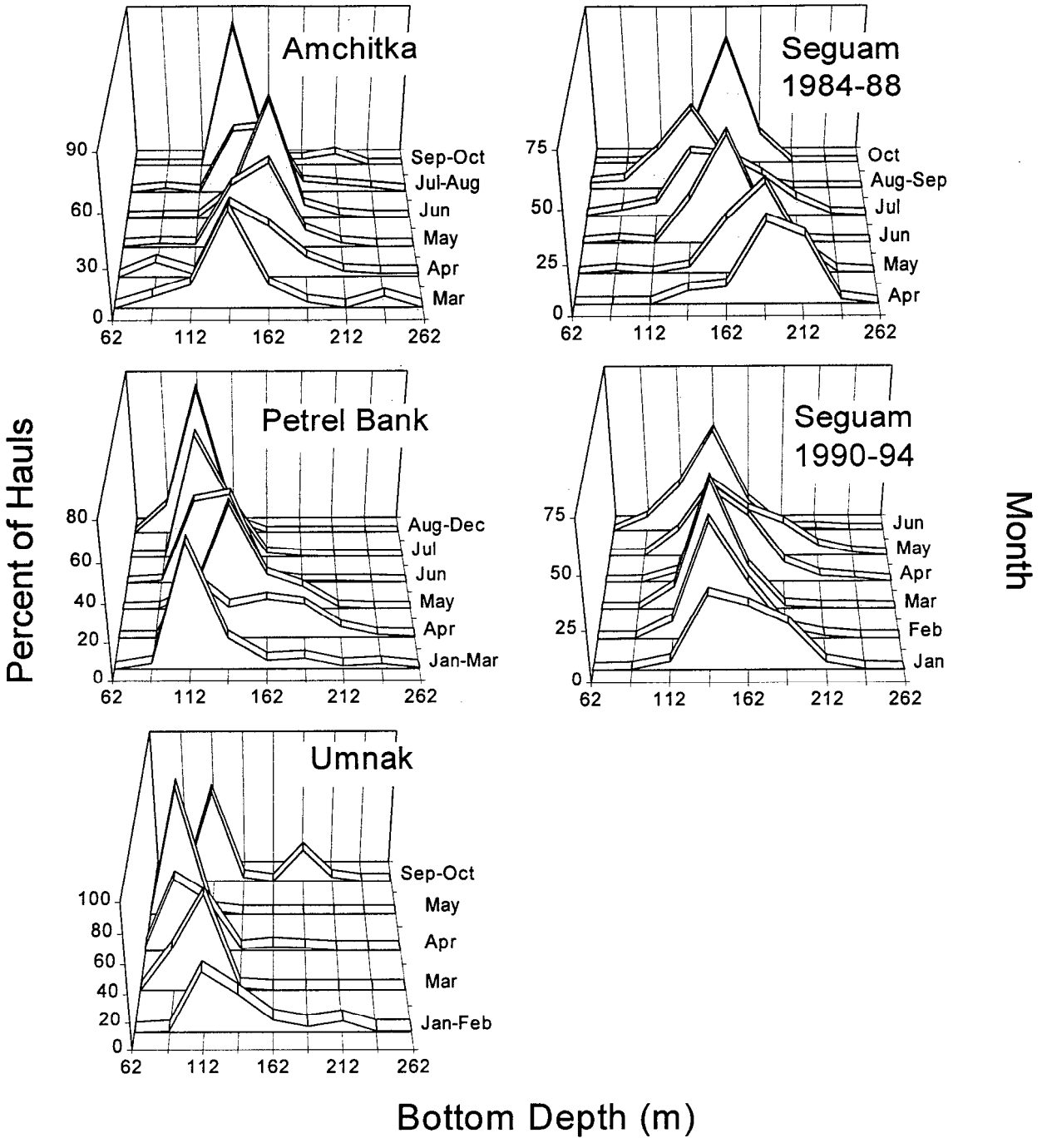

Figure 2.-- Depth distribution of Atka mackerel fishery hauls by month (or groups of months) in each of four areas in the Aleutian Islands and Gulf of Alaska from 1984 to 1994. Data were grouped into 25 m depth bins for display. X-axis labels are midpoints of depth bins. Data for Seguam is divided into two time periods, 1984-88 and 1990-94, representing the foreign-joint venture and domestic fleets, respectively.

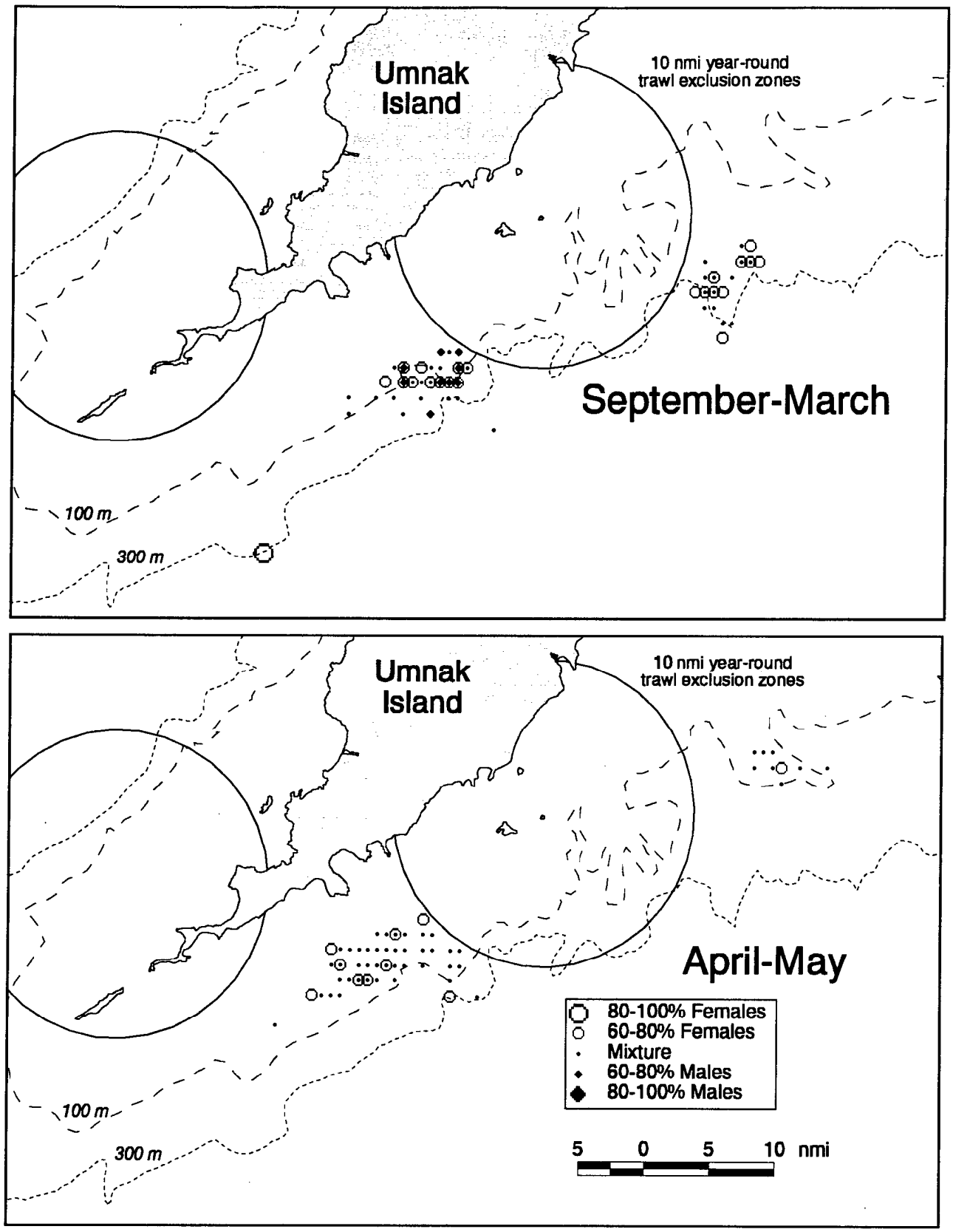

Figure 3.- -Location and sex ratio of Atka mackerel fishery hauls near Umnak Island in winter (September-March) and spring (April-May).

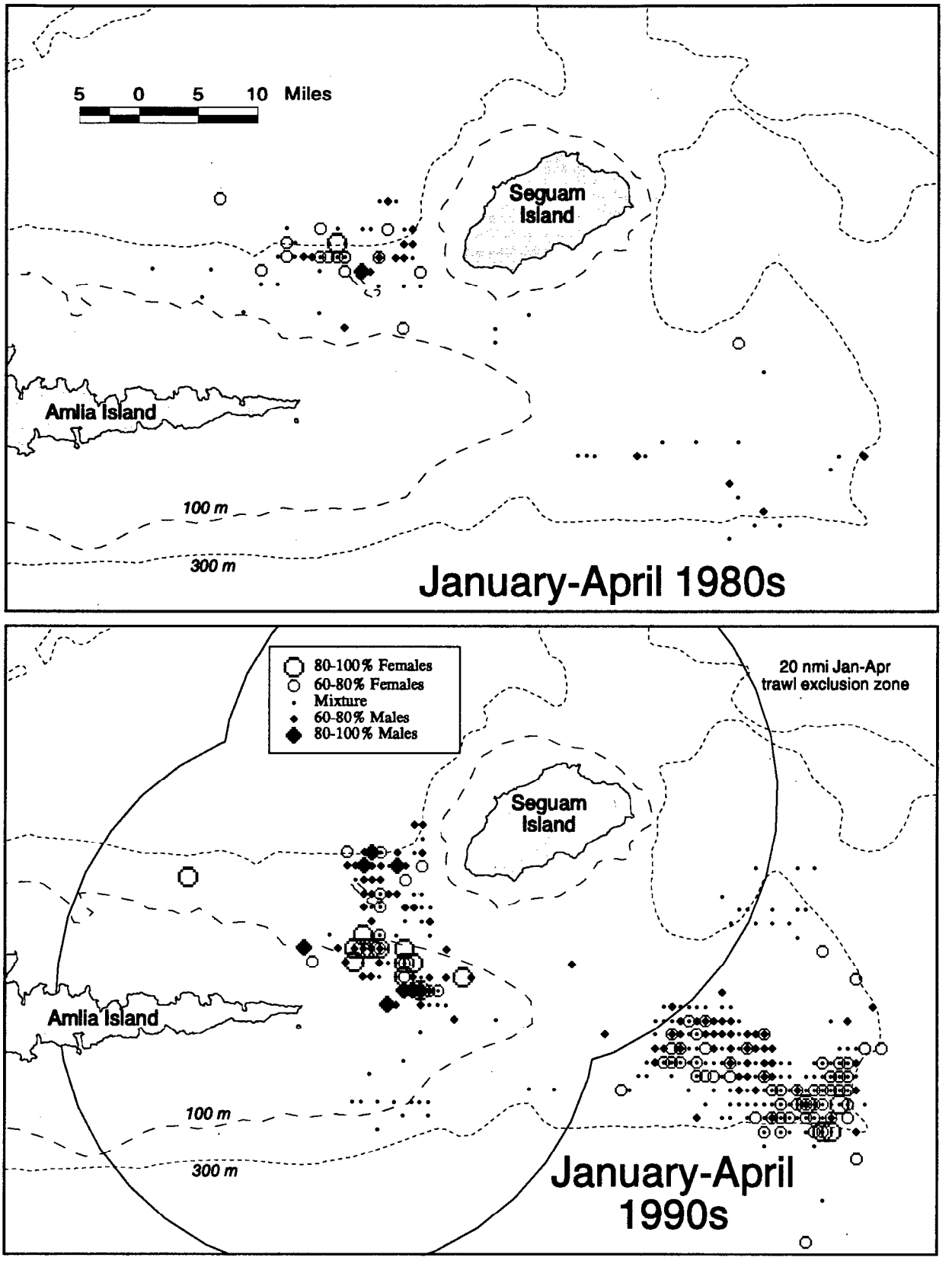

Figure 4.-- Location and sex ratio of Atka mackerel fishery hauls taken near Seguam Island in winter in the 1980s and 1990s.

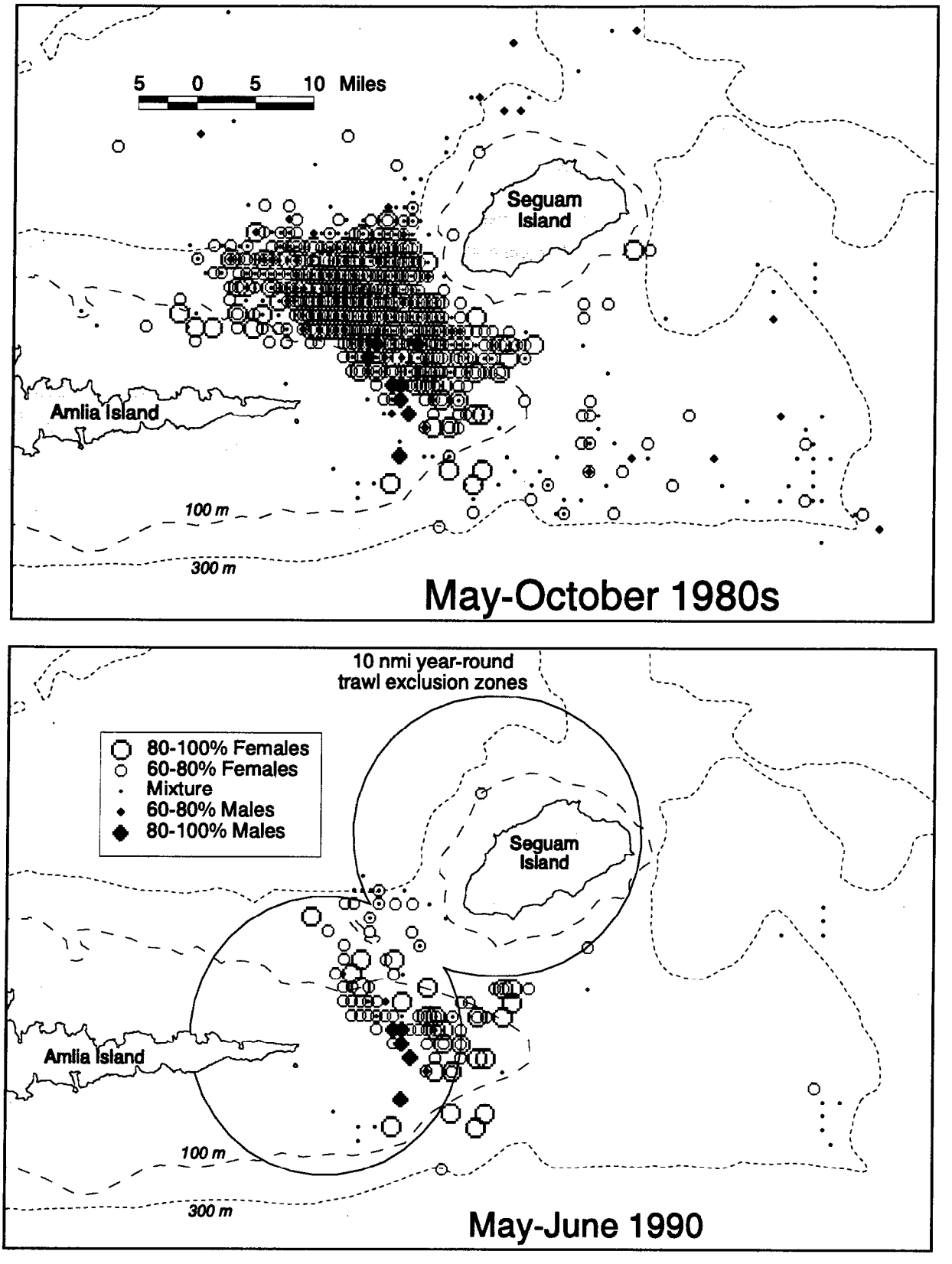

Figure 5. -Location and sex ratio of Atka mackerel fishery hauls taken near Seguam Island in summer in the 1980s and in 1990.

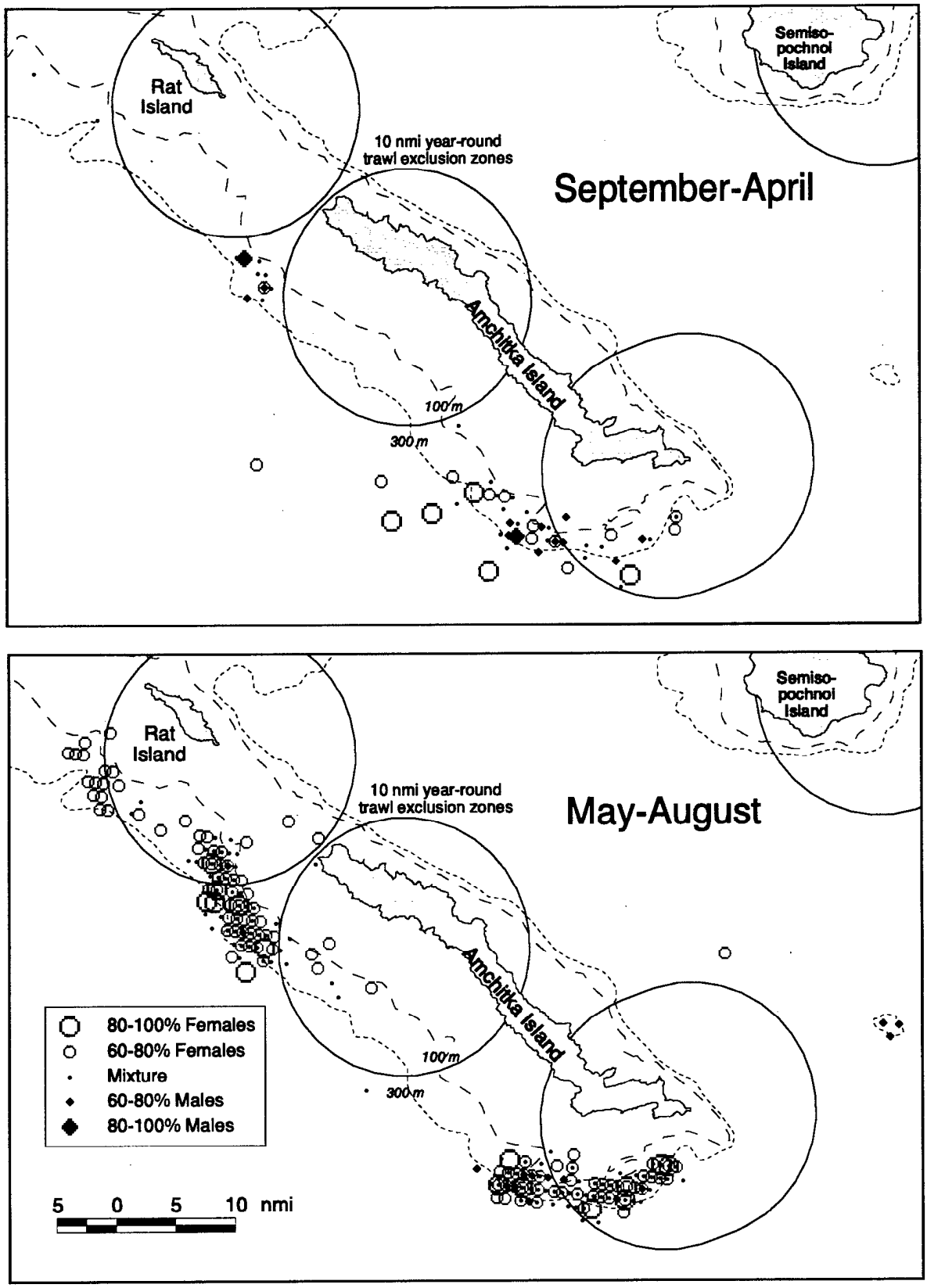

Figure 6.- Location and sex ratio of Atka mackerel fishery hauls taken near Amchitka Island in winter (September-April) and summer (May-August).

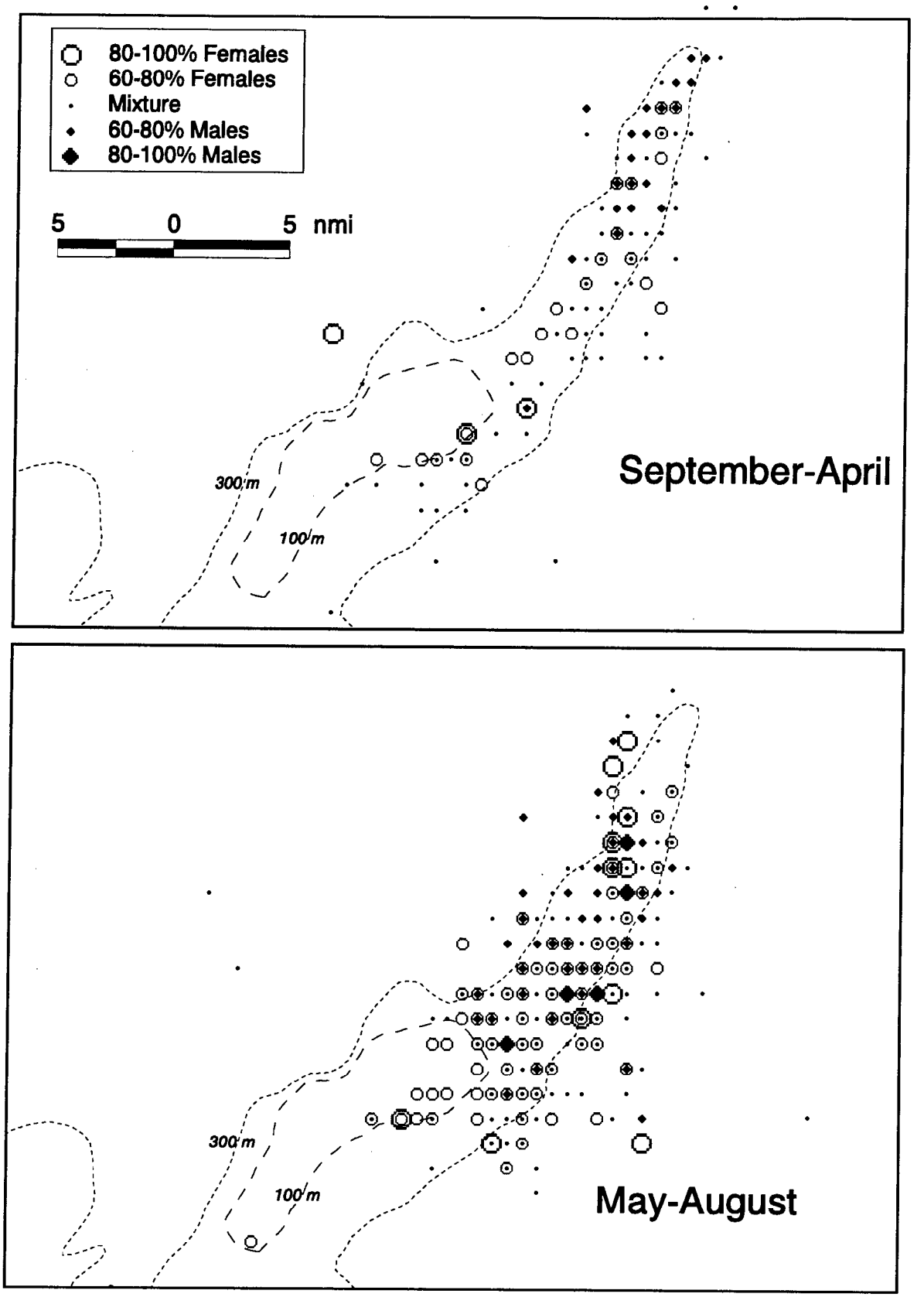

Figure 7. -Location and sex ratio of Atka mackerel fishery hauls taken on Petrel Bank in winter (September-April) and summer (May-August).

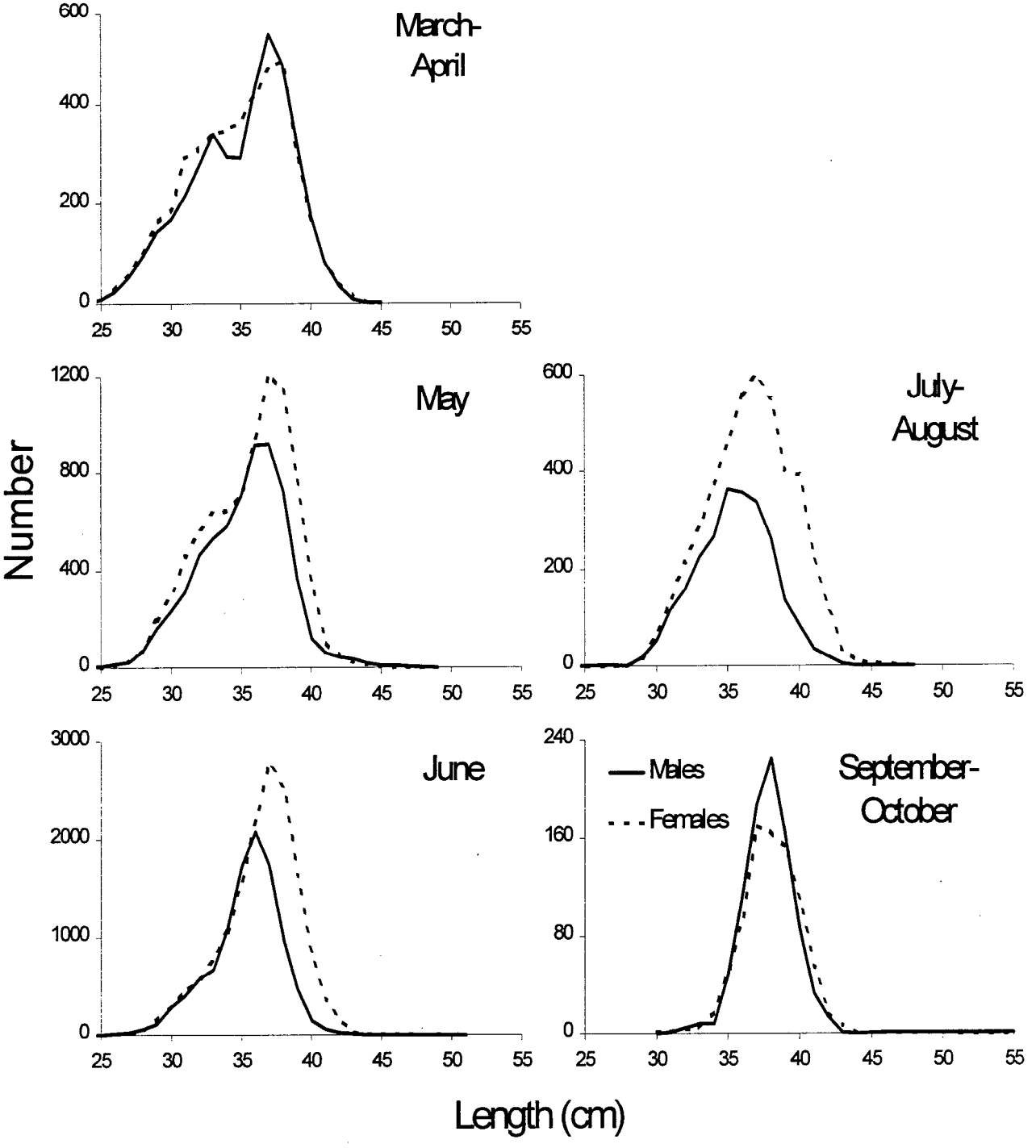

Figure S.--Length-frequencies of female (dashed line) and male (solid line) Atka mackerel sampled from fishery hauls near Amchitka Island aggregated by month or groups of months (see Table 1 for sample sizes and years).

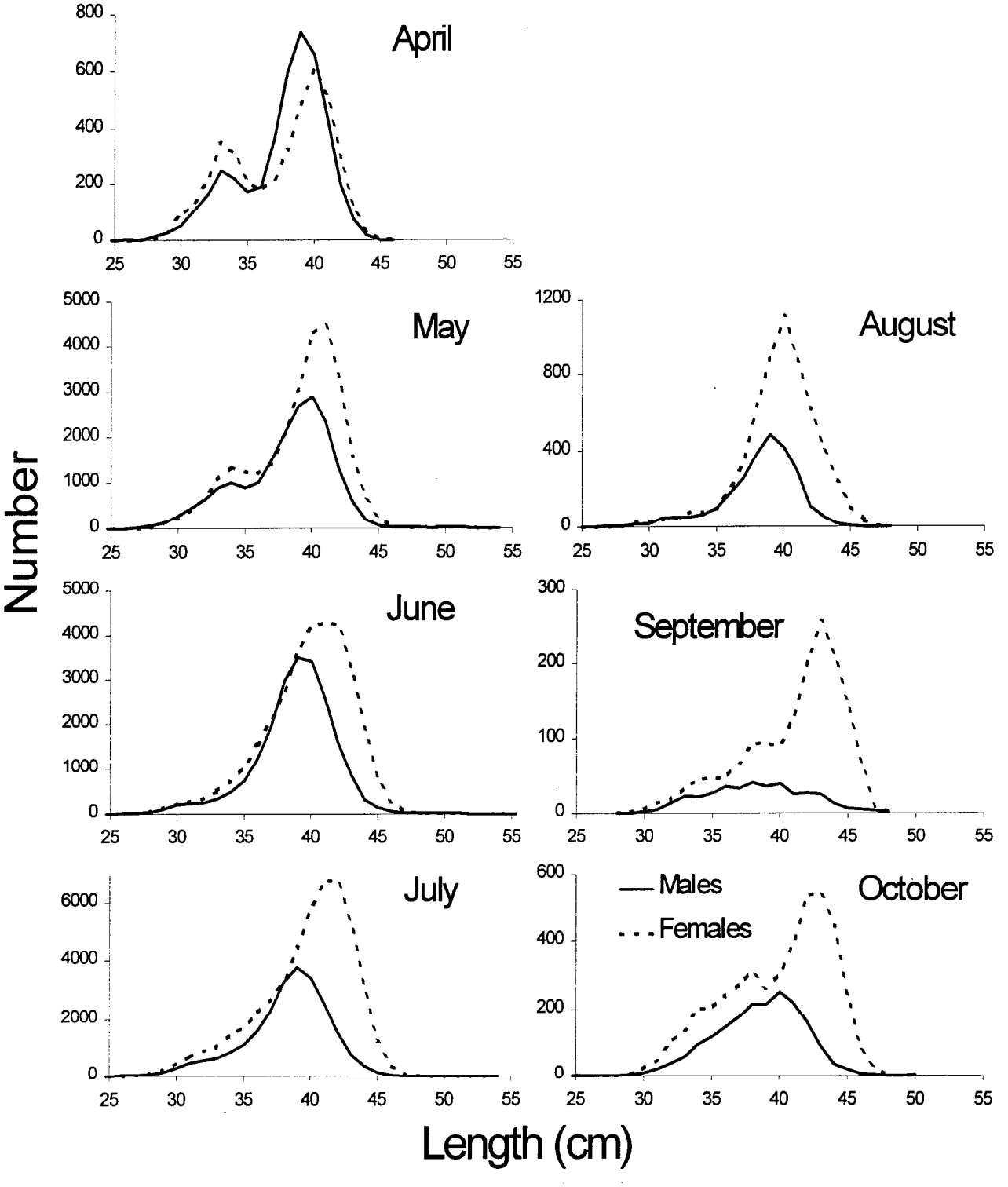

Figure 9. --Length-frequencies of female (dashed line) and male (solid line) Atka mackerel sampled from foreign and joint-venture fishery hauls near Seguam Island in the 1980s aggregated by month (see Table 1 for sample sizes and years).

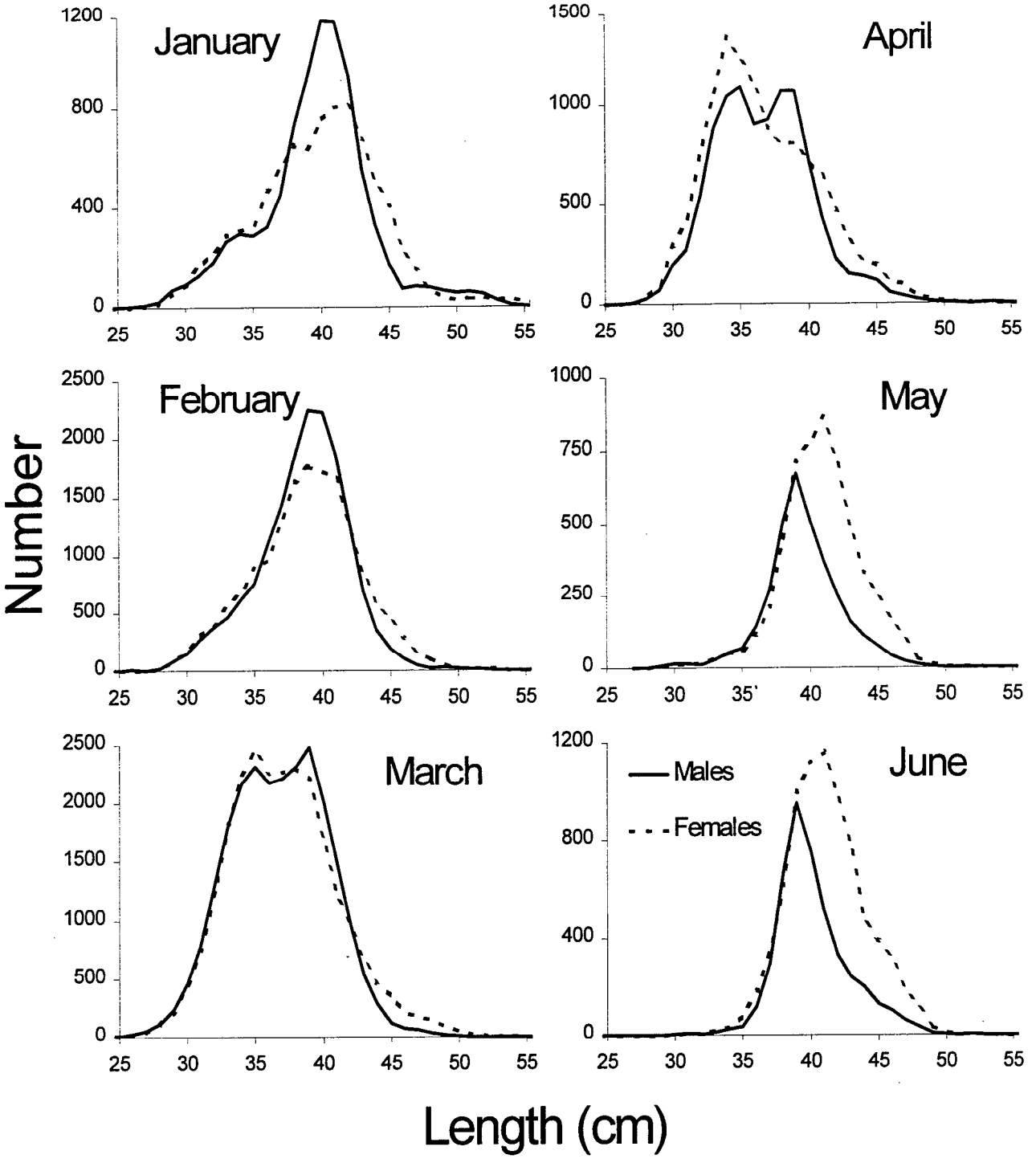

Figure l0 .--Length-frequencies of female (dashed line) and male (solid line) Atka mackerel sampled from domestic fishery hauls near Seguam Island in the 1990s aggregated by month (see Table 1 for sample sizes and years).

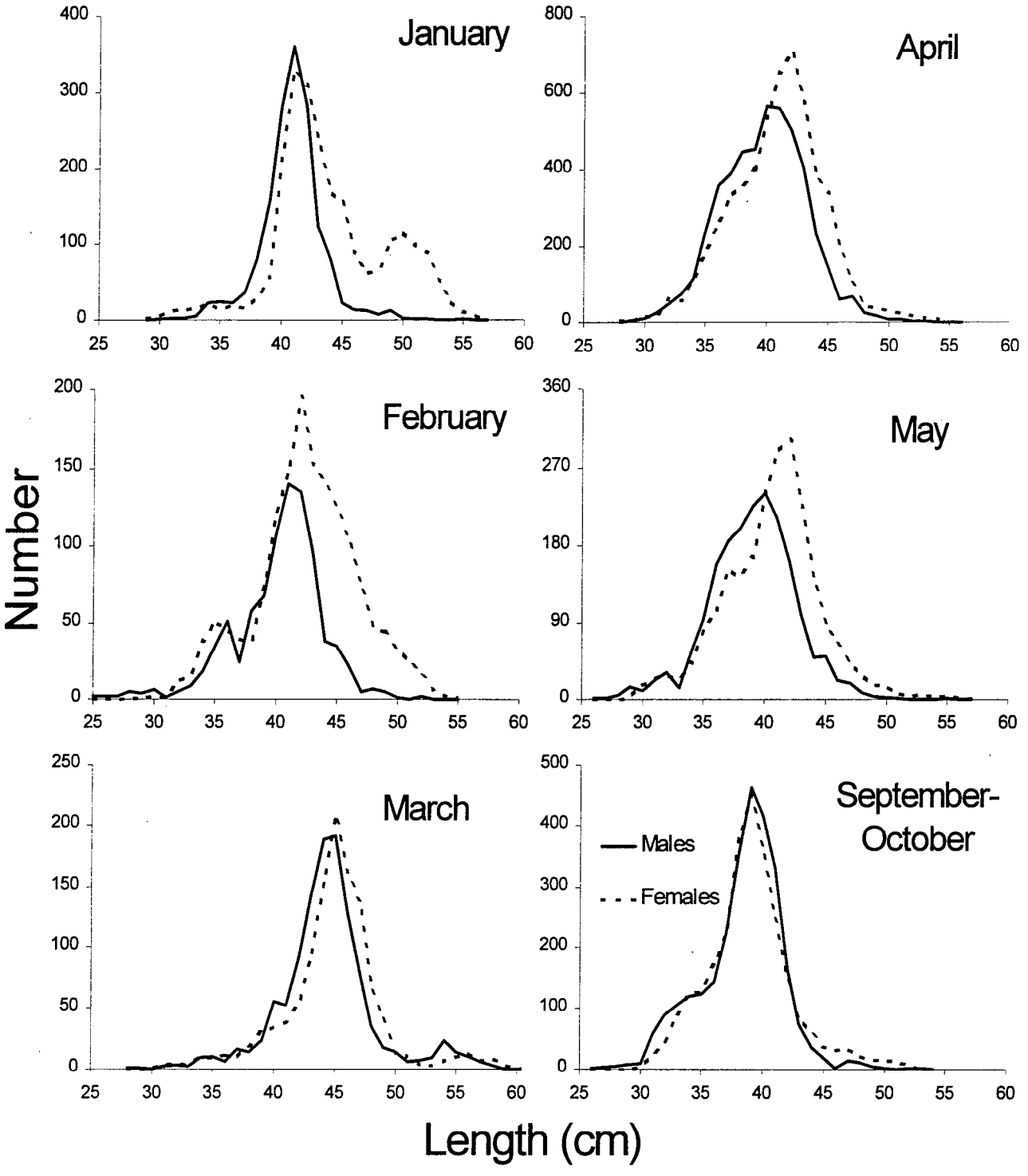

Figure 11 .--Length-frequencies of female (dashed line) and male (solid line) Atka mackerel sampled from fishery hauls near Umnak Island aggregated by month or groups of months (see Table 1 for sample sizes and years).

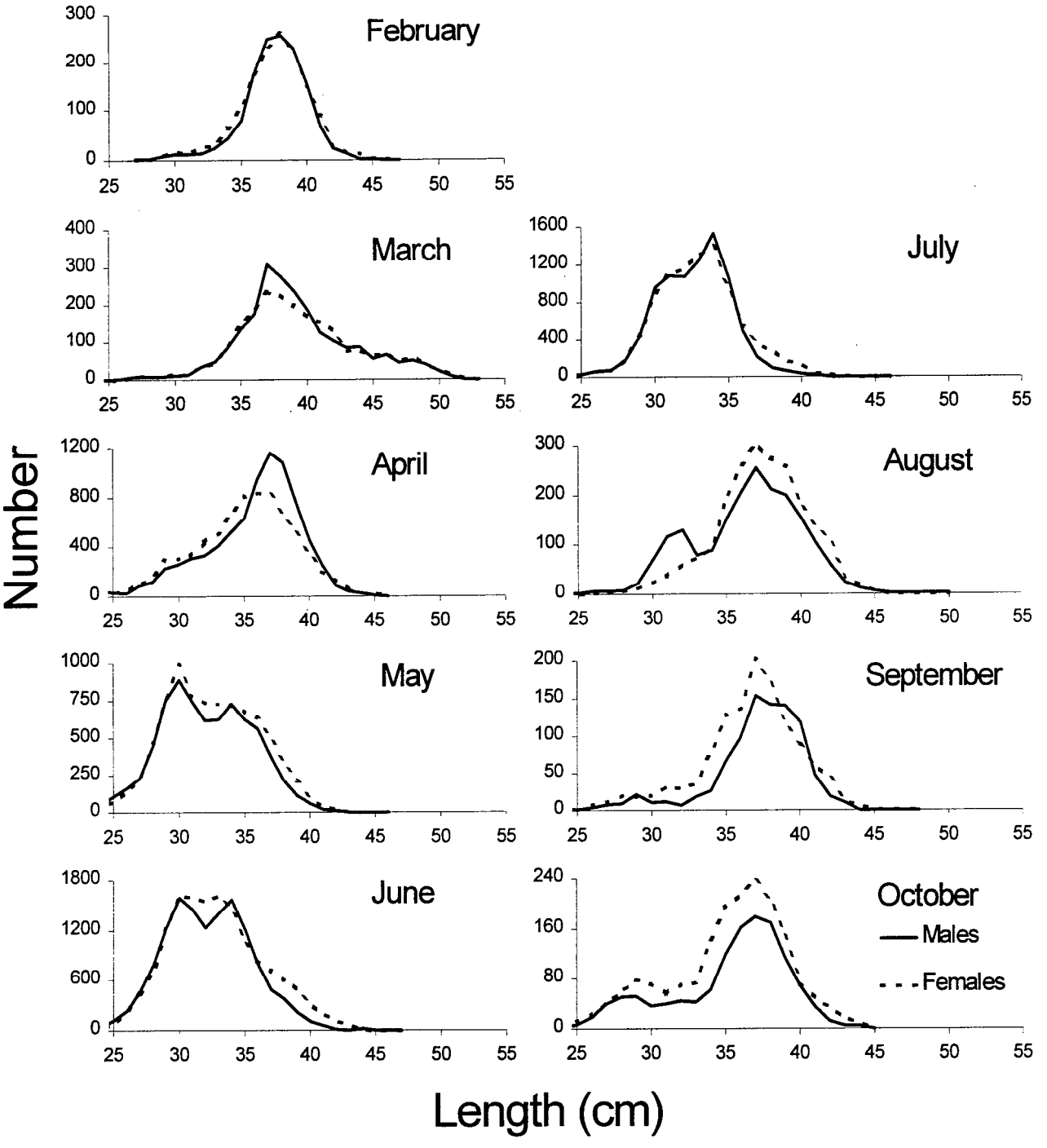

Figure 12 .--Length-frequencies of female (dashed line) and male (solid line) Atka mackerel sampled from fishery hauls on Petrel Bank aggregated by month (see Table 1 for sample sizes and years).

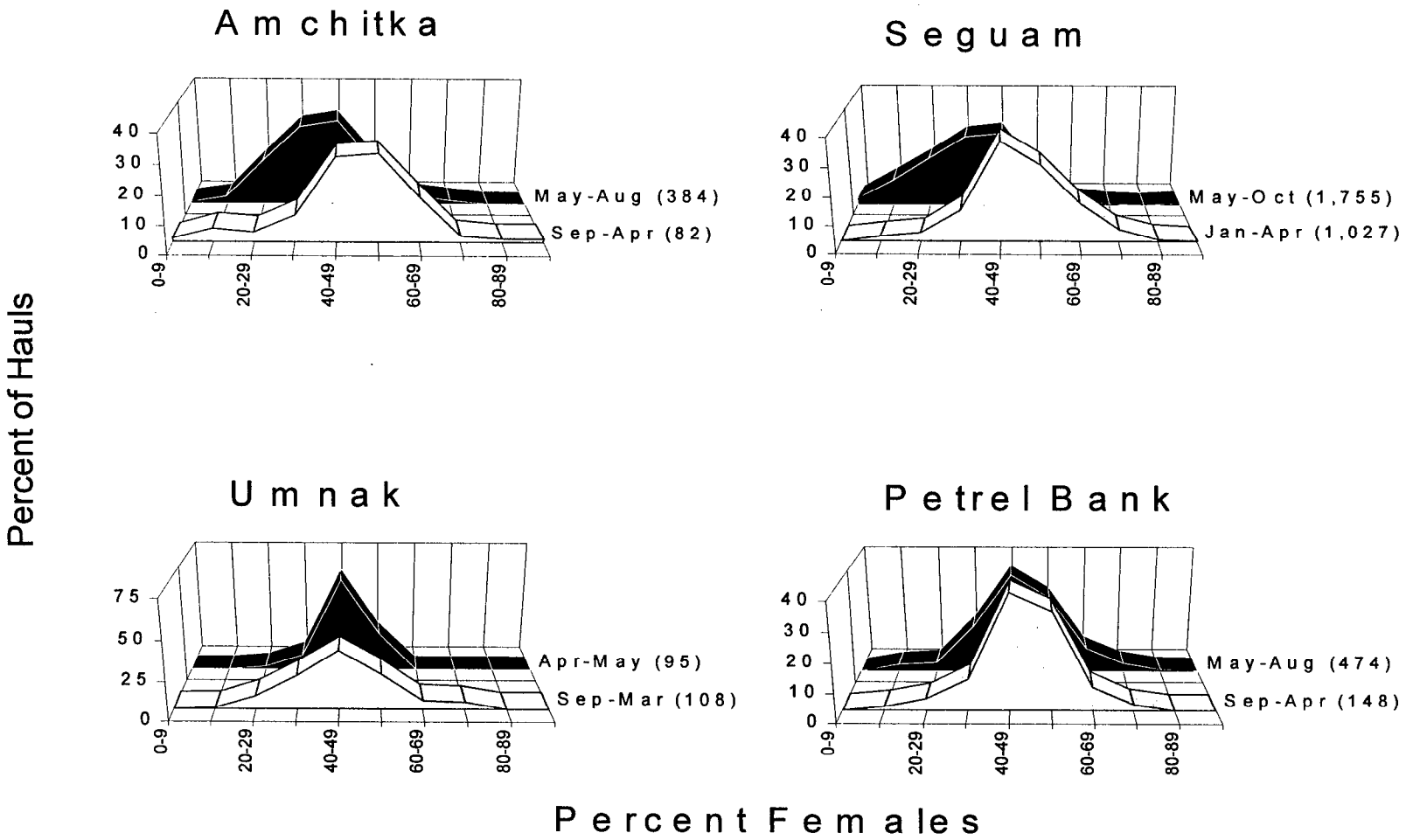

Figure 13 .--Percent frequency distribution of Atka mackerel sex ratios in fishery hauls taken in each of four areas aggregated by season (winter=light shading; summer=dark shading). The number of observed hauls in each season and area is listed in parentheses. X-axis labels: percentage of females in the haul, aggregated into bins of 10%.

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