Observations on the Biology and Distribution of Pacific Hake, Walleye Pollock, and Spiny Dogfish in the Strait of Georgia, February 20 - May 2, and July 3, 1981

G. A. McFarlane, W. Shaw, and R. J. Beamish

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

November 1983

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1722

nt of Canada
nd Oceans
Gouvernement du Canada
Pêches et Océans

Canadian Manuscript Report of

Fisheries and Aquatic Sciences No. 1722

November 1983

OBSERVATIONS ON THE BIOLOGY AND DISTRIBUTION OF PACIFIC HAKE, WALLEYE POLLOCK, AND SPINY DOGFISH IN THE STRAIT OF GEORGIA FEBRUARY 20 - MAY 2 AND JULY 3, 1981

by

G. A. McFarlane, W. Shaw, and R. J. Beamish

Department of Fisheries and Oceans

Fisheries Research Branch

Pacific Biological Station

Nanaimo, British Columbia V9R 5K6

Cat. No. Fs 97-4/1722 ISSN 0706-6473

ABSTRACT

McFarlane, G. A., W. Shaw, and R. J. Beamish. 1983. Observations on the biology and distribution of Pacific hake, walleye pollock, and spiny dogfish in the Strait of Georgia--February 20 - May 2 and July 3, 1981. Can. MS Rep. Fish. Aquat. Sci. 1722: vi + 109 p.

A total of 192 midwater and 5 bottom sets were completed during the survey, 73 during February 20-March 3, 52 during March 24-April 3, 17 during April 9-12, 54 during April 22-May 2, and 1 on July 3. Pacific hake (Merluccius productus) was the principal species captured. Walleye pollock (Theragra chalcogramma) and spiny dogfish (Squalus acanthias) were common in the catches but were less abundant.

During all cruises, two distinct midwater layers were present throughout the study area. Hake, pollock and spiny dogfish comprised nearly all catches made in these layers.

Pacific hake ranged in length from 7-80 cm and age from 1-19 yr. The majority of hake ranged from 40-48 cm in length and 4-11 yr in age. Hake growth is rapid to age 4 and then is reduced. Both males and females have similar growth patterns up to age 4 or 5, after which mean length for females is 2-3 cm larger than for mature males.

Females predominated in the shallow layer (67-78%) and males in the main concentration (57-87%). Maturity studies in the central Strait indicated that, during February-March, males were in a more advanced stage of maturity and that after peak spawning during mid-March to mid-April, spent and recovering fish predominated in the shallow layer.

Length and age at 50% maturity was 33.1 cm and 3+ for males and 37.1 cm and 3+ for females indicating that hake in these samples matured in their 4th year of age.

Strong year-classes were evident in the population. Change in relative abundance of these strong year-classes from 1975-1981 indicated total annual mortality ranged from A = 0.15-0.25.

Walleye pollock were present in most sets. The largest catches were made during March 24-April 3 off Halibut Bank at depths of 155-183 m. Pollock concentrations were found in the midwater and on-bottom between Active Pass and Point Roberts.

Pollock males were in spawning condition sooner than females. Spawning males and females were more common in samples collected in the lower third of the water column.

Spiny dogfish were present but not abundant in most sets. Juvenile dogfish (<60 cm) were predominant in sets made off Sand Heads and Oyster River during February 20-March 3 and were distributed throughout the midwater. During later cruises, juveniles predominated in catches from shallow sets (<150 m). Juvenile dogfish were more abundant on the Vancouver Island land side of the Strait of Georgia.

Key words: Pacific hake, walleye pollock, spiny dogfish, biology, distribution, Strait of Georgia

RÉSUMÉ

McFarlane, G. A., W. Shaw, and R. J. Beamish. 1983. Observations on the biology and distribution of Pacific hake, walleye pollock, and spiny dogfish in the Strait of Georgia -- February 20 - May 2 and July 3, 1981. Can. MS Rep. Fish. Aquat. Sci. 1722: vi + 109 p.

Un total de 192 traits mésopélagiques et de 5 traits de fond ont été réalisés au cours de l'étude, soit 73 du 20 février au 3 mars, 52 du 24 mars au 3 avril, 17 du 9 au 12 avril, 54 du 22 avril au 2 mai et 1 le 3 juillet. Le merlu du Pacifique (Merluccius productus) a été la principale espèce capturée. La morue du Pacifique occidental (Theragra chalcogramma) et l'aiguillat commun (Squalus acanthias) se retrouvaient fréquemment dans les prises mais étaient moins abondants.

Au cours de toutes les expéditions, deux couches mésopélagiques distinctes ont été observées dans tout le secteur à l'étude. Le merlu du Pacifique, le morue du Pacifique occidental et l'aiguillat commun constituaient presque toutes les prises effectuées dans ces couches.

La longueur des merlus du Pacifique variait de 7 à 80 cm et leur âge de 1 à 19 ans. Le plus grande partie d'entre eux mesuraient entre 40 et 48 cm et étaient âgés de 4 à 11 ans. La croissance des merlus est rapide jusqu'à l'âge de 4 ans, et est réduite par après. Les mâles et les femelles ont des régimes de croissance similaires jusqu'à l'âge de 4 ou 5 ans, après quoi la longueur moyenne des femelles est de 2 à 3 cm supérieure à celle des mâles adultes.

Les femelles étaient les plus nombreuses dans la couche peu profonde (67 à 78 %) et les mâles dans la concentration principale (57 à 87 %). Des études sur la maturité dans la partie centrale du détroit ont montré que, de février à mars, les mâles étaient dans un stade plus avancé de maturité et qu'après la période maximale de la fraie de la mi-mars à la mi-avril les poissons vides et en train de se rétablir étaient les plus nombreux dans la couche peu profonde.

La longueur et l'âge à une maturité de 50 % étaient de 33,1 cm et de 3+ pour les mâles et de 37,1 cm et de 3+ pour les femelles, ce qui indique que les merlus dans ces échantillons devenaient matures à leur quatrième année.

Des classes d'âge marquées étaient évidentes dans la population. Le changement dans l'abondance relative de ces classes d'âge importantes entre 1975 et 1981 a montré que la mortalité annuelle totale a varié de A=0, 15 à A=0, 25.

La morue du Pacifique occidental était présente dans la plupart des traits. Les prises les plus importantes ont été effectuées entre le 24 mars

et le 3 avril au large d'Halibut Bank à des profondeurs de 155 à 183 m. Des concentrations de morues ont été trouvées dans la zone mésopélagique et au-dessus du fond entre Active Pass et Point Roberts.

Les mâles de morue du Pacifique occidental étaient prêts à frayer plus tôt que les femelles. Les mâles et les femelles en fraye étaient plus nombreux dans les échantillons recueillis dans le tiers inférieur de la colonne d'eau.

Les aiguillats communs étaient présents mais moins abondants dans la plupart des traits. Les jeunes aiguillats ($\leq$ 60 cm) étaient les plus nombreux dans les traits effectués au large de Sand Heads et d'Oyster River entre le 20 février et le 3 mars et étaient distribués dans toute la zone mésopélagique. Au cours d'expéditions subséquentes, les jeunes prédominaient dans les prises provenant de traits peu profonds (< 150 m). Les jeunes aiguillats étaient plus abondants du côté du détroit de Géorgie situé près de l'île Vancouver.

Mots-clés: merlu du Pacifique. morue du Pacifique occidental, aiguillat commun, biologie, distribution, détroit de Géorgie.

INTRODUCTION

Earlier studies in the Strait of Georgia have shown that there is a resident population of Pacific hake that is capable of supporting a commercial fishery. Little was known about the biology of Pacific hake and the less abundant but commercially important walleye pollock. In anticipation of a commercial fishery, an intensive research program was established to study the biology and population dynamics of Pacific hake and walleye pollock (Beamish et al. 1976a,b and c; Barner and Taylor 1976; Beamish et al. 1978; Weir et al. 1978; Cass et al. 1978; Thompson and Beamish 1979; Cass et al. 1980; McFarlane et al. 1982a; Beamish et al. 1982)

The primary objective of the survey reported upon in this report was to study the biology, distribution and abundance of hake and pollock in the Strait of Georgia. The survey involved four cruises aboard the M/V ARCTIC HARVESTER during February 20-March 3, March 24-April 3, April 9-12, and April 22-May 2, 1981 and a 1-day cruise, July 3, 1981 aboard the R/V G.B. REED. This report summarizes the preliminary analysis of biological data, collected during the cruises as part of the continuing program to examine hake and pollock stocks in the Strait of Georgia. A separate report (Thompson and McFarlane 1982) summarizes the results of abundance studies.

METHODS

Catch composition and detailed biological data on which this report is based are presented by McFarlane et al. (1982b).

The ARCTIC HARVESTER is a 44.5 m commercial stern trawler. A Simrad 38A scientific sounder was used to locate fish concentrations while the depth of the net and the net opening were determined with an ELAC LAS 17 netsounder.

During the February cruise a Canadian Diamond 7 midwater trawl equipped with a 3 cm herring codend was used for all tows. A Canadian Diamond 5-B midwater trawl, equipped with a 3 cm herring codend was used on all other cruises. An Engel high-lift bottom trawl was used on 5 tows carried out in the southern portion of the Strait on April 12. A detailed description of vessel and net specifications is included in McFarlane et al. (1982b).

Fishing sites were selected such that tows were distributed throughout the Strait in areas in which echograms indicated concentrations of fish. Tows were also made to identify species composition of targets in the midwater and to estimate catch rates where the sounder indicated regions of varying densities. At many stations a series of horizontal tows were made to examine the species composition of the various layers.

At two locations in February and one in March a series of tows were made at various depths during day and night to examine species composition.

The catch from each set was sorted by species into 55 L (12 gal) galvanized tubs. Each tub was weighed to obtain total catch. Small catches were sampled in their entirety, while a representative subsample was taken from large catches by selecting 2 tubs of fish from each of the front, middle and end of the catch.

Hake and pollock were measured for fork length and stratified random or random samples of fish were sampled for weight, sex, maturity, stomach contents, and otoliths and fins. Dogfish were measured for total length from the tip of the snout to the tip of the upper lobe of the caudal fin when depressed in a line horizontal with the body. Random samples of dogfish were selected for sex, maturity, and stomach contents.

Other species were noted as being present and estimates of catch were recorded.

RESULTS AND DISCUSSION

GENERAL CRUISE SUMMARY

A total of 192 midwater sets and 5 bottom sets were completed during the survey (Fig. 1,2,3,4). Seventy-three from February 20-March 3, 52 from March 24-April 3, 17 from April 9-12, 54 from April 22-May 2, and 10 on July 3. Pacific hake was the most common species captured (McFarlane et al. 1982b; Table 2). Pollock and dogfish were common in the catches but were less abundant.

Echograms revealed two distinct midwater layers during all cruises. These layers have been reported in earlier studies of the Strait of Georgia (Beamish et al. 1982; and McFarlane et al. 1982a). The shallower layer appeared at about 50-110 m. The deeper layer ranged from 110-320 m but was densest between 150-225 m. A pattern of discrete relatively large spots which comprised most of the shallow layer was not present in the deep layer, where echograms appeared as a pattern of smaller scatters. A concentrated scattering layer, thought to be plankton, was common throughout the Halibut Bank region in the April cruises, but not during March. This layer appeared at about 120-130 m. A similar very dense layer appeared in the Strait from Winchelsea Island northwards, near bottom, during April. Tows through these layers produced few fish. For a more complete description of appearance and distribution of midwater targets in the Strait of Georgia during this survey see Thompson and McFarlane (1982).

Fish present in the shallower layer tended to disperse at night (Fig. 5,6). During darkness they scattered throughout the upper 100 m of the water column. By dawn the fish regrouped into the discrete schools. Fish in the deeper layer did not disperse at night.

Detailed discussions of the results are included in the following summary by species.

PACIFIC HAKE

Catch rates

Pacific hake were present in 190 of the 196 sets made between February 20-May 2 and in the 1 set made July 3 (McFarlane et al. 1982b). Catch rates averaged 671, 2991, 191 and 2380 kg/h during the four cruises respectively (Table 1). The largest catches were made during March 24-April 3 and April 22-May 2 when the net was towed through the heavy (H) to very heavy (VH) main concentration off Halibut Bank. Catches through these layers averaged 3905-9185 kg/h.

A total of 55,604 Pacific hake were sampled from 176 sets. No Pacific hake were sampled during the April 9-12 cruise.

Length distribution

Pacific hake ranged in length from 7-80 cm (Fig. 7). The modal length of mature males and females was 44 cm and 45 cm, respectively. The largest male sampled was 63 cm but less than 0.5% were larger than 50 cm. The largest female was 80 cm but only 3.1% (636 fish) were larger than 50 cm.

During February 20-March 3, the length frequency of males and females, combined, showed modes at approximately 11, 22 and 35 cm which represent the modal lengths of hake that have completed 1, 2, and 3 yr of growth, respectively (Fig. 7). Hake older than age 3 were not distinguishable from a length frequency analysis.

The frequency distributions in Fig. 8-11, have been separated by cruise and by depth interval. During February 20-March 3 fish age-1 using length frequency analysis were captured throughout the water column (Fig. 8) but the majority were caught in sets where the average net depth was less than 200 m. Previous cruises have reported segregation of hake by depth with age-1 hake occupying the upper strata at this time of year (Cass et al. 1978; McFarlane et al. 1982a). During March 24-April 3 and April 22-May 2, few age-1 hake were captured (Fig. 9,10), but the net depth of sets in which these fish were caught averaged less than 180 m. At this time young hake appeared to be associated with the concentrated scattering plankton layer present between 100-150 m but densest at about 120-130 m (Thompson and McFarlane 1982). Previous studies have reported this association of hake with a concentrated scattering layer occurring at a depth of approximately 100-170 m (Beamish et al. 1976c; Beamish et al. 1978; Cass et al. 1980). The modal lengths of age-1 hake from these cruises (Fig. 8-10) of 11, 12 and 13 cm indicate a temporal growth increment of 1 cm for February, March and April, respectively. These modal lengths coincide with those documented in previous studies (Weir et al. 1978; Cass et al. 1980; McFarlane et al. 1982a).

Age and growth

Hake, estimated to be age-2 and age-3 from the length frequency histogram, were relatively abundant (27%) in the catches only during the February 20-March 3 cruise. These fish were captured in water deeper than 200 m and were not caught with adults, although catches were often made at depths where adults were also taken. During the March 24-April 3 and April 22-May 2 cruises, few age-2 and age-3 fish were captured. Sets were directed on spawning concentrations, hence the absence of these fish is not unusual. Previous studies (Beamish et al. 1976a,b,c; McFarlane et al. 1982a) have reported that age-2 and age-3 fish segregate from the rest of the population in the open Strait.

Hake ages were determined using both sections of otoliths (Beamish 1979) and the break and burn technique (Chilton and Beamish 1982). Ages determined independently using both techniques produced similar results (Table 2). Hake ranged in age from 1-20 yr, most hake (83%) were aged 4-11 yr (Table 3-8). Hake aged 1, 2 and 3 yr had modal lengths which correspond to similar modes in the length frequency (Fig. 12).

Mean lengths at age (Fig. 13-16) are consistent with those observed during previous studies (Beamish et al. 1978; Cass et al. 1978; McFarlane et al. 1982a) in the Strait and show a constant relatively rapid growth to age-4 and a subsequent flattening of the curve thereafter indicating a pronounced reduction in growth in length of older fish.

Male and female hake have similar annual growth in length up to age-4 or 5 after which mean lengths for females are significantly larger (t-test $p \leq 0.05$), with mature males averaging 2-3 cm smaller than mature females.

Mortality

Total annual mortality and total instantaneous mortality can be estimated (Jackson 1939) from the slope of the right-hand limb of the catch curves (Fig. 17). The shape of the catch curves indicates that annual recruitment is not constant and that at least one of the assumptions required by the method has been violated. Estimates obtained from the age frequencies in Tables 4 to 9 for ranges of ages from 7-15 yr ranged from $A = 0.21$-0.74 which corresponds to instantaneous mortality rates of $Z = 0.24$-1.35. These estimates encompass the range of estimates for the Strait of Georgia as reported previously (Beamish et al. 1976a,b and c; Beamish et al. 1978; Thompson and Beamish 1979; and McFarlane et al. 1982a). The highest mortality rate of $A = 0.74$ was calculated for ages 11-15 yr and is a result of apparent weak recruitment of the 1966-1969 year-classes.

Previous reports (Beamish et al. 1982; McFarlane et al. 1982a) have indicated that strong year-classes are an important component of this population. Comparing the change in relative abundance of the 1967, 1969, 1970 and 1972 year-classes from age frequency distributions for 1975, 1978, 1979 (McFarlane et al. 1982a), 1976 (Beamish et al. 1982), and 1981, using simple linear regression (Ricker 1975), gave total annual mortality estimates

ranging from A = 0.15-0.25 which correspond to instantaneous mortality rates of Z = 0.16-0.29. The lower estimate of A = 0.15 was determined for the relatively weak 1967 year-class and may be indicative of differential mortality rates between year-classes. Several consecutive years of age samples will be required to calculate accurate age, sex and year-class mortality rates.

Catch curves from samples collected during February from the major fishing areas are presented in Fig. 18. The lack of older mature fish aged 6-11 yr in the Malaspina Strait sample appears to be indicative of migration of these age-classes during this time to the spawning area in the central Strait.

Length-weight relationship

Individual weights were collected from 942 hake during three of the cruises, February 20-March 3, April 22-May 2 and July 3 (McFarlane et al. 1982b). A summary of the length-weight parameters is presented by cruise in Table 9. These length-weight parameters reflect pre-spawning and post-spawning differences in the fish. The relationship is exponential (Fig. 19a,b) and can be expressed by the equation:

$$W = aL^b$$

where W = round weight (gm), L = fork length (cm), and a and b are constants. The relationship for both male and female hake can be expressed as

(1) $W = .0065L^{2.9969}$ (February 20-March 3)

(2) $W = .0074L^{2.8923}$ (April 24-May 2)

(3) $W = .5134L^{1.7791}$ (July 3)

Sex ratio

Males composed 54% and females 46% (Table 1) of the fish sampled during February 20-March 3 from set locations throughout the Strait (Fig. 1). During March 24-April 3, males predominated (75%) in sets made in the south central Strait (Fig. 2) near Halibut Bank. Sets in the same area in March 1975 (Cass et al. 1978) and March 1979 (McFarlane et al. 1982a) were also predominated by males. During April 22-May 2 in sets sampled throughout the Strait (Fig. 4) the male/female ratio was 59 and 41%. There was an obvious difference between sex ratio and mean net depth of set (Table 1). During pre-spawning, spawning and post-spawning cruises the shallow layer (<150 m) was predominated by females, 78 and 74% during the February-March and March-April cruises, respectively, and 67% during the April-May cruise. The main concentration (>150 m) was predominated by males (57-87%). It is difficult to interpret the sex ratio from the deepest sets (Table 1). As

there was no method of opening and closing the net, there could be a bias towards males in the catch as the net moved through the main concentrations. However, it appears that hake are segregatd by sex and depth during pre-spawning, spawning and post-spawning activity.

Maturity

A total of 13,975 hake were examined for maturity states during all cruises (McFarlane et al. 1982b). A description of Pacific hake maturity states is presented in Appendix Table 1 and Weir et al. (1978). During February 20-March 3, 18% and 26% of the males and females, respectively, were immature; 10% of the males and 11% of the females were in early stages of development (R_1), and 59% (male) and 62% (female) were in the more advanced stages (R_2, R). No spawning females (RR) were sampled and only 5 fish were approaching spawning (1R, 2R). Thirteen percent of males were in spawning condition (RR) (McFarlane et al. 1982b).

During March 24-April 3, Pacific hake sampled in the south Central portion of the Strait in the vicinity of Halibut Bank were in a more advanced state of maturity and a higher percentage of males (75%) were captured (Table 1), indicating earlier ripening and subsequent movement of mature males to the spawning area. Other studies (Beamish et al. 1978; McFarlane et al. 1982a) found that male hake were in a more advanced state of maturity than females during January and February. During this period more than 98% of males and 97% of females were mature (McFarlane et al. 1982b). Fifty-eight percent of the males were ripe, 32% were in spawning condition (RR) and 8% were spent or recovering. Fifty-four percent of the females were ripe or ripening (R_1, R_2, R). Seventeen percent were in advanced stages of maturity (1R, 2R, RR), and 26% were spent or recovering.

During April 22-May 2, 84% of the males and 82% of the females sampled were spent or recovering (McFarlane et al. 1982b), indicating that spawning was complete. By July 3, 100% of mature fish sampled were recovering or resting (McFarlane et al. 1982b).

Maturity states by sex, depth interval, and cruise are presented in Fig. 20-23. Examination of these figures indicates that during pre-spawning (February 20-March 3) ripe males and females were found throughout the water column. During March 24-April 3, the percentage of ripe fish remained constant, however, there was a marked increase in the advanced stages of both males (RR and Sp) and females (1R, 2R, RR, Sp) in the deeper water.

During April 22-May 2, 84% of the males and 82% of the females were spent or recovering with the majority of females present in the shallow layer (<150 m).

In summary, pre-spawning fish (R_1, R_2, and R) were present throughout the water column during February-March. During late March-April, the percentage of pre-spawning fish remained constant with females occupying the shallow layer (75%) and males occupying the upper portion of the deep concentration. At this time there was a marked increase of actively spawning males and females in the lower portion of the deeper concentration. The

greatest percentage of actively spawning fish was below 220 m. By late April-early May, 85% of the males and females have completed spawning and are aggregating in the shallow layer (50-80 m).

Examination of maturity states by area during February 20-March 3 (Fig. 24) indicates that fish in spawning condition were present throughout the Strait but were densest at two locations: a large, heavy concentration found south and west of Halibut Bank; and a smaller heavy concentration off Montgomery Bank (Fig. 25). Although ripe males and females were found in Malaspina Strait and Sabine Channel at this time it is likely that they were migrating to the Halibut Bank area as no heavy concentrations were encountered and few actively spawning fish (RR) were captured in these areas. These trends are similar to those suggested from egg and larval plankton surveys carried out in the Strait in 1979-80-81 (Dr. J. C. Mason, pers. comm). Eggs were common throughout the Strait south of Texada Island, and were densest off Halibut Bank; a smaller dense concentration was present northwest of Texada Island, near Montgomery Bank.

The lengths of mature fish ranged from 30-63 cm for males and 34-80 cm for females. The length of 50% maturity determined by probit analysis (Beacham 1983) was 33.1 m and 37.1 m for male and females, respectively. More than 50% of both males and females spawned as age 3+ fish (Fig. 13-16, 26).

Stomach analysis

A total of 2,072 hake were examined for stomach contents from February 20-May 2 (Table 10). Of the 1,102 fish examined from February 20-March 3, 499 (45%) were empty, 328 (30%) had everted stomachs and 275 (25%) contained a variety of food organisms. The average volume for all fish including empty but excluding everted stomachs was 1.2 cc. Euphausids comprised 60.9% of the total volume, unidentified fish remains comprised 31.4%, squid 4.2% and glass shrimp 3.5%. During the March 24-April 3 cruise 310 stomachs were examined of which 139 (45%) were empty and 31 (10%) everted. Euphausids again comprised the major portion of the diet by volume (82%). Unidentified fish remains, Leuroglossus sp., and glass shrimp made up 15.5, 1.9 and 0.6%, respectively. During the post-spawning survey, April 24-May 2, 660 stomachs were examined, 169 (26%) were empty and 108 (16%) everted. Euphausids comprised 74.3%, Pacific herring 14%, glass shrimp 8.3% and eulachon, amphipods, unidentified fish remains and Leuroglossus were present in small amounts. The average volume for all fish including empty stomachs was 1.1 cc in March-April and 1.9 cc in April-May.

WALLEYE POLLOCK

Catch rates

Pollock were not as abundant as Pacific hake but were present in most sets made from February 20-May 2 and in the set made July 3 (McFarlane

et al. 1982b). Catch rates averaged 111, 324, 243 and 69 kg/h during the four cruises, respectively (Table 11).

During February 20-March 3, catches were large (>300 kg/h) in only 2 areas: Sand Heads (Fig. 1; sets 7, 8, 9, 12) and south Malaspina Strait (set 40). Net depth for these sets ranged from 126 to 181 m.

The largest catches were made during March 24-April 3 off Halibut Bank (Fig. 2; sets 6, 24) at depths of 165-183 m and 155-165 m, respectively. Catch-per-unit-effort for these sets was 2227 and 2268 kg/h, respectively.

Bottom trawl sets between Active Pass and Point Roberts during April 9-12 (Fig. 3; sets 13-17) produced an average of 104 kg/h and midwater sets averaged 301 kg/h. During a survey of the same area in 1978 bottom trawl catches averaged 637 kg/h during April 5-7 and 60 kg/h during April 11-13 (Thompson and Beamish 1979).

During April 22-May 2 catches were very small. Only 3 sets produced large catches (Fig. 4; sets 28, 45, 46). All three sets were in the northern portion of the Strait. Catch rates were 560, 1043, and 656 kg/h, respectively, at depths between 102-143 m.

During all cruises largest catches were made between 100-200 m (Table 11). Two sets made between 246-300 m during the March 24-April 3 cruise (peak spawning period--Thompson 1981) yielded 1,105 kg/h and may be a reflection of spawning activity.

Length distribution

Length frequencies collected from pollock catches in the central strait during the survey period ranged from 14-63 cm (n = 16,106) with 97.5% between 32-52 cm (McFarlane et al. 1982b). Relatively more young pollock (19%) ranging from 14-30 cm were captured off E. Saturna Island (Fig. 3; sets 2, 3, 4) during the April 9-12 cruise. One age-1 pollock, as identified by its small size (14 cm) was captured in set 3. Age-2 pollock, with a mode at 30 cm, could be identified from the length frequency (Fig. 27). In general, this area produced the only significant catches of juveniles. These observations are similar to previous ones made during the same time period (Beamish et al. 1978; Cass et al. 1980). Few age-2 fish were evident among the spawning adults.

Sex ratio

The sex ratio was dominated by males (Table 11; Fig. 27-30). The ratio was more equal during the February 20-March 3 and April 22-May 2 period (59 and 57% male, respectively), than during the other cruises; 65 and 73% during March 24-April 3 and April 9-12, respectively.

Maturity

A total of 10,029 males and 5,892 females were examined for maturity condition (Fig. 31-34). A description of walleye pollock maturity states is presented in Appendix Table 2. These observations indicate that during February 20-March 3, 81 and 87% of males and females, respectively, were ripe (R) and 9 and 3%, respectively, were in advanced maturity states (1R, 2R, RR). Maturity data by set number and cruise are presented in McFarlane et al. (1982b). During March 24-April 3, 18 and 13% of males and females were ripe, with the majority, 66 and 57%, in advanced stages (1R, 2R) or actively spawning (RR). Fewer pollock were captured in the deeper sets (>200 m) but a greater proportion at these depths were in spawning condition (RR), 88% males and 13% females. At this time a greater percentage of spent, recovering or resting fish were captured in the shallower sets (<200 m). The majority at these maturity stages for both males and females were captured between 80 and 135 m. During April 22-May 2 most of the pollock caught had completed spawning, 83% of both male and female fish were spent, recovering or resting, 9 and 7% of males and females, respectively, were in advanced maturity stages and 5 and 7% were ripe.

As with hake, the predominance of fish in spawning condition in the deeper sets (>200 m) and spent or recovering fish in the shallower sets indicates spawning occurs in the lower portion of the water column.

During April 9-12 in sets made between Active Pass and Point Roberts the majority of fish were in advanced stages of maturity, 55 and 37% male and female, respectively, with 30 and 25% spent or recovering.

Length-weight relationship

Individual weights were collected from 652 pollock during the February 20-March 3, March 24-April 3 and April 9-12 cruises. A summary of the length-weight parameters is presented by cruise in Table 13. The relationship is exponential (Fig. 35) and can be expressed by the equation

$$W = aL^b$$

The length-weight relationship for male and female pollock can be expressed as:

(1) $W = .0071 \times 10^{-3} L^{3.0445}$ February 20-March 3

(2) $W = .0534 \times 10^{-2} L^{2.4406}$ March 24-April 3

(3) $W = .0198 \times 10^{-2} L^{2.7134}$ April 9-12

Stomach analysis

A total of 1,513 pollock were examined for stomach contents during the survey. The proportion of empty stomachs was 30, 36 and 6% during February-March, March-April and April-May, respectively. The average volume for all fish including empty but excluding everted stomachs was 1.4, 1.0 and 2.7 cc for the three cruises. Euphausiids and amphipods were the dominant prey items during all survey times comprising 70, 75 and 96% by volume of the diet in pollock during the three cruises, respectively (Table 12).

SPINY DOGFISH

Catch rates

Dogfish were common but not abundant relative to Pacific hake catches made during February 20-May 2 and in 1 set made July 3 (McFarlane et al. 1982b). During February 20-March 3 large numbers were captured in the central Strait off Sand Heads (Fig. 1; set 8, 10) and in the northern Strait off Oyster River (set 52). These fish were primarily juveniles measuring less than 60 cm and represented 100% of all dogfish sampled. Eighty-one percent of dogfish sampled in all areas of the Strait at this time were $\leq$60 cm. It is apparent that at this time of the year the majority of juvenile dogfish are congregated in these areas and are evenly distributed throughout the midwater (Fig. 36).

During March 24-April 3 only the central portion of the Strait was fished. Large numbers of dogfish were captured off Halibut Bank, Entrance Island, Gower Point and Cape Roger Curtis (McFarlane et al. 1982b). Of the fish sampled 67% were <60 cm and 68% of these were captured in shallow water (average net depth <150 m) (Fig. 37).

Sets made from April 9-12 between Point Roberts and Active Pass produced relatively few dogfish, however 3 bottom trawls in the area had catch rates of >200 kg/h.

During April 22-May 2 dogfish were present in minor quantities throughout the Strait. Largest catches (>100 kg/h) were made off Halibut Bank. Juvenile dogfish represented 66% of the total catch with the largest proportion present in catches made off Cape Lazo indicating that the Vancouver Island side of the northern Strait remained a principal site for juvenile dogfish. Again a large proportion of fish captured in sets with an average net depth of less than 150 m were juveniles (88%) (Fig. 38).

Significant numbers of young of the year dogfish were captured during the survey and accounted for 18, 13, and 24% respectively of the dogfish sampled during February-March, March-April and April-May.

Stomach analysis

A total of 1030 dogfish were examined for stomach contents (Table 14). Of these, 572 were juveniles and 46% had empty stomachs. The average volume of stomach contents in juveniles including fish with empty stomachs was 1.7 cc compared to 24.6 cc for adults. Dominant food items found in juvenile dogfish with respect to volume were: fish remains and zooplankton (principally euphausiids and amphipods). Adult dogfish contained principally Pacific hake, squid and unidentified fish remains. As Pacific hake was the major component of the catches, and because dogfish are opportunistic feeders, their presence in the stomach contents of dogfish is expected.

ACKNOWLEDGMENTS

The authors would like to thank Captain J. Trimm and the crew of the ARCTIC HARVESTER for their cooperation and assistance during the surveys and for sharing their knowledge with us. We appreciate the technical assistance of K. Best, M. Hamer, T. Hoyt, K. Robinson, J. Scarsbrook, and M. Smith. Karen Charles and Shayne MacLellan estimated the ages of Pacific hake.

REFERENCES

Barner, L. W. and F. H. C. Taylor. 1976. Midwater trawl tows and catches made on G. B. REED cruises GBR 75-1, -2, and -3, and GBR 76-1 and -2 in the Strait of Georgia. Fish. Mar. Serv. Data Rec. 19: 45 p.

Beacham, T. D. 1983. Variability in median size and age of sexual maturity of cod (Gadus morhua) on the Scotian shelf in the northwest Atlantic Ocean. In press.

Beamish, R. J., J. R. Scarsbrook, and F. P. Jordan. 1976a. A bottom trawl study of Pacific hake and walleye pollock along the inshore areas and adjacent to Vancouver Island in the Strait of Georgia. Fish. Mar. Serv. Data. Rec. 4: 67 p.

Beamish, R. J., D. Eftoda, R. Scarsbrook, and M. Smith. 1976b. Pacific hake and walleye pollock study, Strait of Georgia cruise, A.P. KNIGHT, April 7-18, 1975. Fish. Res. Board Can. MS Rep. 1380: 40 p.

Beamish, R. J., M. Smith, R. Scarsbrook, and C. Wood. 1976c. Hake and pollock study, Strait of Georgia cruise G.B. REED, June 16-27, 1975. Fish. Mar. Serv. Data Rep. 1: 174 p.

Beamish, R. J., M. Smith, and R. Scarsbrook. 1978. Hake and pollock study, Strait of Georgia cruise, G.B. REED, January 6- February 21, 1975. Fish. Mar. Serv. Data Rep. 48: 206 p.

Beamish, R. J. 1979. Differences in the age of Pacific hake (Merluccius productus) using whole otoliths and sections of otoliths. J. Fish. Res. Board Can. 36: 141-151.

Beamish, R. J. and D. E. Chilton. 1982. Preliminary evaluation of a method to determine the age of sablefish (Anoplopoma fimbria). Can. J. Fish. Aquat. Sci. 39: 277-287.

Beamish, R. J., G. A. McFarlane, K. R. Weir, M. S. Smith, J. R. Scarsbrook, A. J. Cass, and C. C. Wood. 1982. Observations on the biology of Pacific hake, walleye pollock, and spiny dogfish in the Strait of Georgia, Juan de Fuca Strait, and off the west coast of Vancouver Island and the Unit States, ARCTIC HARVESTER, July 13-24, 1976. Can. MS Rep. Fish. Aquat. Sci. 1651: 150 p.

Cass, A. J., R. J. Beamish, M. S. Smith, and J. R. Scarsbrook. 1978. Hake and pollock study, Strait of Georgia Cruise, G.B. REED, March 27-24, 1975. Fish. Mar. Serv. Data Rep. 50: 66 p.

Cass, A. J., R. J. Beamish, M. S. Smith, and K. Weir. 1980. Hake and pollock study, Strait of Georgia Cruise G.B. REED, January 13-28, 1976. Can. Data Rep. Fish. Aquat. Sci. 225: 88 p.

Chilton, D. E. and R. J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60: 102 p.

Jackson, C. H. N. 1939. The analysis of an animal population. J. Anim. Ecol. 8: 238-246.

McFarlane, G. A., R. J. Beamish, and K. R. Weir. 1982a. Study of the biology and distribution of Pacific hake during the first commercial fishery conducted in the Strait of Georgia by the M/V CALLISTRATUS. February 16-17, March 10-April 3, and May 12, 1979. Can. MS Rep. Fish. Aquat. Sci. 1650: 111 p.

McFarlane, G. A., W. Shaw, J. M. Thompson, J. R. Scarsbrook, M. S. Smith, and K. L. Best. 1982b. Hake and pollock study, Strait of Georgia cruises, February to May 1981, M/V ARCTIC HARVESTER. Can. Data Rep. Fish. Aquat. Sci. 339: 456 p.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull. 191: 382 p.

Thompson, J. M. and R. J. Beamish. 1979. An examination of the biology and distribution of walleye pollock in Dixon Entrance, Hecate Strait, the mainland inlets off Queen Charlotte Sound, and the Strait of Georgia during March 14-April 21, 1978. Can. Data Rep. Fish. Aquat. Sci. 173: 188 p.

Thompson, J. M. 1981. Preliminary report on the population biology and fishery of walleye pollock (Theragra chalcogramma) off the Pacific coast of Canada. Can. Tech. Rep. Fish. Aquat. Sci. 1031: v + 157 p.

Thompson, J. M. and G. A. McFarlane. 1982. Distribution and abundance of Pacific hake and walleye pollock in the Strait of Georgia, March 24-May 2, 1981. Can. MS Rep. Fish. Aquat. Sci. 1661: 79 p.

Weir, K. R., R. J. Beamish, M. S. Smith, and J. R. Scarsbrook. 1978. Hake and pollock study, Strait of Georgia bottom trawl cruise G.B. REED, February 25-March 13, 1975. Fish Mar. Serv. Data Rep. 71: 153 p.

Table 1. Summary of catch, catch per unit effort and sex ratio by depth interval for Pacific hake, February 20-May 2, 1981.

Cruise	Depth interval (m)	Number of hauls	Catch (kg)	CPUE kg/hr	Sample size	% Male	% Female
February 20 - March 3	64-117	14	1068	168	996	22	78
	118-171	14	6403	1035	4200	66	34
	172-226	24	10174	761	10008	57	43
	227-282	18	5437	661	8711	49	51
	Total	70	23082	671	23915	54	46
March 24 - April 3	82-136	11	2679	321	1964	26	74
	137-190	29	35031	2893	8112	87	13
	191-245	7	14558	6932	1436	78	22
	246-300	2	2754	5297	615	78	22
	Total	49	55022	2991	12127	75	25
April 9-12	64-117	3	195	68	-	-	-
	118-171	9	1326	235	-	-	-
	Bottom	5	533	185	-	-	-
	Total	17	2054	191	-	-	-
April 22 - May 2	0-63	2	1030	1026	277	44	56
	64-117	12	14736	1716	3433	33	67
	118-171	14	18353	4047	4609	43	57
	172-226	22	21238	1946	7081	82	18
	227-282	4	2522	1590	1417	63	37
	Total	54	57879	2380	16863	59	41
July 3	102-113	1	159	212	461	70	30

Table 2. Mean size of Pacific hake for each age-group from set 12 (March 28) and sets 19 and 22 (April 26 and 27) combined using section ages and ages determined from the break and burn technique.

	Section									Break and burn								
	Male			Female			Total			Male			Female			Total		
Age	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n
3	36.0	0.27	8	37.6	0.68	5	36.6	0.37	13	36.0	0.27	8	37.0	0.41	4	36.3	0.26	12
4	40.1	0.71	16	40.8	0.26	20	40.5	0.35	36	39.9	0.73	15	41.0	0.30	21	40.6	0.36	36
5	41.7	1.06	7	42.4	0.65	9	42.1	0.58	16	42.5	1.18	6	41.4	0.48	7	41.9	0.59	13
6	42.0	0.67	11	44.6	0.32	16	43.5	0.41	27	41.2	0.54	6	44.4	0.35	16	43.5	0.43	22
7	42.9	0.60	14	44.6	0.84	17	43.9	0.55	31	42.9	0.63	16	46.3	0.80	8	44.0	0.59	24
8	43.2	0.62	13	46.1	0.53	12	44.6	0.50	25	42.7	0.57	11	44.8	1.02	14	43.9	0.65	25
9	43.3	0.74	12	45.6	0.46	22	44.8	0.44	34	43.3	0.64	16	45.6	0.61	16	44.4	0.48	32
10	43.4	0.34	11	46.2	0.58	17	45.1	0.45	28	44.0	0.26	6	45.4	0.47	16	45.0	0.37	22
11	44.6	0.26	18	47.2	0.50	18	45.9	0.35	36	44.2	0.34	12	46.9	0.45	21	45.9	0.39	33
12	46.3	0.67	3	46.5	2.50	2	46.4	0.87	5	44.4	0.40	5	47.5	0.85	6	46.1	0.68	11
13	46.5	1.50	2	49.3	3.38	3	48.2	2.03	5	46.3	0.88	3	46.6	0.51	5	46.5	0.42	8
14	45.0	-	1	-	-	0	45.0	-	1	-	-	0	50.0	-	2	50.0	-	2
15	-	-	0	50.0	-	2	50.0	-	2	44.3	0.67	3	-	-	0	44.3	0.67	3
16	43.0	-	1	48.5	0.50	2	46.7	1.86	3	-	-	0	-	-	0	-	-	0
17	-	-	0	47.0	-	2	47.0	-	2	-	-	0	53.0	3.0	2	53.0	3.0	2
18	-	-	0	-	-	0	-	-	0	-	-	0	47.0	-	2	47.0	-	2
19	-	-	0	-	-	0	-	-	0	-	-	0	49.0	-	1	49.0	-	1
Total			117			147			264			107			141			248

Table 3. Mean size of hake for each age-class for sets 1, 4, 8, 12, 13, and 17 in the Strait of Georgia. M/V ARCTIC HARVESTER, February 20 - March 3, 1981.

Age (years)	Male			Female			Total		
	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n
1	-	-	0	-	-	0	11.5	1.78	12
2	22.2	2.14	6	21.6	1.90	7	21.8	1.95	13
3	33.4	4.23	33	35.9	9.55	27	34.5	7.17	60
4	40.4	2.78	38	40.0	3.09	22	40.3	2.88	61
5	40.2	2.18	22	41.1	4.09	13	40.5	3.00	35
6	42.4	1.38	35	45.3	3.06	17	43.4	2.52	54
7	42.7	1.86	59	45.8	1.51	28	43.7	2.25	87
8	43.3	1.83	53	45.1	4.35	29	44.0	3.09	83
9	43.3	1.85	46	48.2	3.61	21	45.2	3.70	72
10	44.4	1.89	25	46.7	3.34	19	45.4	2.84	45
11	44.7	1.43	52	50.1	8.55	33	46.9	6.16	88
12	44.5	1.31	8	51.3	4.31	5	47.7	4.59	15
13	45.2	3.27	5	50.3	4.04	2	47.1	4.22	8
14	45.0	2.16	4	53.0	-	1	46.6	4.04	5
15	45.0	-	1	47.0	-	1	46.0	1.41	2
16	- 0	-	0	-	-	0	-	-	0
17	- 0	-	0	48.0	-	1	48.0	-	1
18	44.0	-	1	45.5	2.12	2	45.0	1.73	3
Total			388			228			628

Table 4. Mean size of hake for each age-class for sets 4, 8, 11, 12, 14, and 21 in the Strait of Georgia. M/V ARCTIC HARVESTER, March 24-April 3, 1981.

Age (years)	Male			Female			Total		
	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n
1	-	-	0	-	-	0	12.0	1.41	2
2	-	-	0	-	-	0	-	-	0
3	37.0	2.48	15	32.0	8.48	2	36.4	3.55	17
4	39.2	1.76	43	40.9	1.41	17	39.7	1.82	60
5	41.5	2.68	12	42.5	2.41	14	42.0	2.54	26
6	42.0	2.32	37	43.9	2.23	32	42.9	2.45	69
7	42.1	2.69	32	45.3	1.97	41	43.9	2.80	73
8	43.4	1.62	27	46.0	1.70	21	44.5	2.07	48
9	43.5	1.55	30	45.8	2.10	39	44.8	2.20	69
10	44.0	1.73	22	45.8	2.79	28	45.0	2.54	50
11	44.8	1.69	48	47.0	2.31	46	45.9	2.30	94
12	45.6	1.34	5	47.3	1.53	3	46.2	1.58	8
13	45.2	1.64	5	49.6	4.16	5	47.4	3.78	10
14	-	-	0	45.7	2.08	3	45.7	2.08	3
15	46.0	-	1	50.0	-	2	48.7	2.31	3
16	43.0	-	1	48.5	0.70	2	46.7	3.21	3
17	42.0	-	1	48.0	1.00	3	46.5	3.11	4
18	46.0	-	1	49.5	0.70	2	48.3	2.08	3
Total			280			260			542

Table 5. Mean size of hake for each age-class for sets 6, 11, 13, 19, and 22 in the Strait of Georgia. M/V ARCTIC HARVESTER, April 22-May 2, 1981.

Age (years)	Male			Female			Total		
	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n
2	-	-	0	25.0	-	1	25.0	-	1
3	37.0	3.82	24	36.6	1.99	27	36.8	2.97	51
4	39.5	2.04	51	40.6	1.91	64	40.1	2.03	115
5	40.9	2.67	23	42.7	1.83	22	41.8	2.46	45
6	42.6	2.43	36	44.5	1.59	39	43.6	2.25	75
7	43.4	1.92	41	44.1	3.02	37	43.7	2.51	78
8	43.0	1.70	37	45.5	3.06	33	44.2	2.74	70
9	43.7	1.74	47	45.5	2.22	40	44.5	2.15	87
10	44.0	1.47	30	46.5	2.20	21	45.0	2.16	51
11	44.4	1.89	45	46.4	1.59	29	45.2	2.02	74
12	46.0	1.15	4	45.5	0.71	2	45.8	0.98	6
13	46.5	2.12	2	46.0	-	1	46.3	1.53	3
14	45.0	-	1	-	-	0	45.0	-	1
15	47.0	-	1	-	-	0	47.0	-	1
16	-	-	0	-	-	0	-	-	0
17	-	-	0	51.0	5.66	2	51.0	5.66	2
Total			342			318			660

Table 6. Mean size of hake for each age class for set 1 in the Strait of Georgia. R/V G.B. REED, July 3, 1981.

Age (years)	Male			Female			Total		
	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n
3	35.7	2.06	19	35.4	2.77	8	35.6	2.24	27
4	38.2	2.32	26	40.5	1.39	13	38.9	2.31	39
5	39.8	1.92	5	42.0	-	1	40.2	1.94	6
6	42.3	1.16	8	43.1	2.75	8	42.7	2.09	16
7	42.6	2.21	14	44.3	1.91	8	43.2	2.22	22
8	43.8	1.46	19	45.5	2.52	4	44.1	1.74	23
9	43.3	1.42	43	45.6	1.91	11	43.8	1.79	54
10	43.4	1.69	11	45.7	1.70	7	44.3	2.00	18
11	44.4	1.74	34	46.1	1.46	8	44.7	1.81	42
12	44.7	1.73	9	47.5	0.71	2	45.2	1.94	11
13	45.0	1.41	2	-	-	0	45.0	1.41	2
14	45.0	-	1	-	-	0	45.0	-	1
15	45.0	-	1	-	-	0	45.0	-	1
16	-	-	0	-	-	0	-	-	0
17	46.0	-	1	46.0	-	1	46.0	-	2
18	-	-	0	-	-	0	-	-	0
19	-	-	0	45.0	-	1	45.0	-	1
Total			193			72			265

Table 7. Mean size of hake for each age-class for sets 47, 48, 49, 54, 55, 57 and 58 from the northern Strait area. M/V ARCTIC HARVESTER, February 20-March 3 and April 22-May 2, 1981.

Age (years)	Male			Female			Total		
	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n
1	-	-	0	-	-	0	11.9	1.17	14
2	22.4	2.35	26	22.9	1.88	16	22.6	2.17	42
3	33.5	2.81	81	33.9	3.47	69	33.7	3.12	150
4	39.1	2.18	97	40.6	2.45	96	39.9	2.44	193
5	41.3	2.62	28	42.3	2.58	43	41.9	2.62	71
6	42.8	1.94	38	44.4	2.81	68	43.8	2.64	106
7	42.9	2.11	55	45.6	2.26	68	44.3	2.57	123
8	44.1	1.68	41	45.8	2.17	64	45.1	2.16	105
9	44.0	1.87	53	47.1	3.43	84	45.9	3.30	137
10	45.7	2.96	32	46.8	3.29	52	46.4	3.19	84
11	45.3	2.07	66	48.0	2.53	85	46.8	2.71	151
12	45.3	2.50	15	47.7	1.93	13	46.4	2.52	28
13	45.2	1.92	5	51.2	4.60	5	48.2	4.59	10
14	50.0	4.24	2	49.0	1.41	4	49.3	2.25	6
15	45.0	-	1	51.0	1.41	2	49.0	3.61	3
16	46.0	-	1	47.3	2.52	3	47.0	2.16	4
17	45.0	2.83	2	-	-	0	45.0	2.83	2
18	45.5	2.12	2	47.0	-	3	46.4	1.34	5
19	-	-	0	49.0	-	1	49.0	-	1
20	-	-	0	48.0	-	1	48.0	-	1
Total			545			677			1236

Table 8. Mean size of hake for each age-class for sets 37, 38, 40, 44, and 45 from Malaspina Strait. M/V ARCTIC HARVESTER February 20 - March 3, 1981.

Age (years)	Male			Female			Total		
	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n	$\bar{x}$	S.D.	n
1	-	-	0	-	-	0	11.8	0.96	4
2	26.3	1.75	6	26.4	3.36	7	26.4	2.63	13
3	34.3	3.14	133	35.3	3.04	131	34.8	3.12	264
4	38.8	1.91	125	39.6	2.20	126	39.2	2.09	251
5	40.6	2.27	41	41.8	3.04	31	41.1	2.68	72
6	41.7	2.01	27	42.8	2.34	26	42.3	2.23	53
7	42.6	2.29	15	44.2	2.07	18	43.4	2.28	33
8	43.9	0.90	7	45.1	2.46	16	44.7	2.16	23
9	43.2	1.59	12	47.8	8.39	12	45.5	6.37	24
10	43.5	2.35	6	45.3	2.52	3	44.1	2.42	9
11	44.6	1.97	17	46.3	2.69	7	45.1	2.28	24
12	44.5	0.71	2	49.0	-	2	46.8	2.63	4
13	46.0	1.73	3	-	-	0	46.0	1.73	3
14	45.5	0.71	2	-	-	0	45.5	0.71	2
15	47.0	-	1	-	-	0	47.0	-	1
16	48.0	-	1	-	-	0	48.0	-	1
17	-	-	0	-	-	0	-	-	0
18	-	-	0	48.0	-	1	48.0	-	1
Total			398			380			782

Table 9. Summary of hake length-weight parameters estimated using geometric regression ($W = aL^b$) by cruise.

Cruise	Male				Female				Total			
	n	a	b	r	n	a	b	r	n	a	b	r
Feb. 20 - March 3	160	0.0155	2.7412	-	219	0.0056	3.029	-	379	0.0065	2.9969	-
April 22 - May 2	142	0.1406	2.1103	0.88	143	0.0619	2.337	0.83	326	0.0074	2.8923	0.97
July 3	137	1.0882	1.5712	0.83	99	0.2586	1.9693	0.91	237	0.5134	1.7791	0.87
Means (weighted)			2.172				2.5867				2.6543	
Total	439				461				942			

Table 10. Stomach contents of Pacific hake by cruise. M/V ARCTIC HARVESTER, February 20 - May 2, 1981. Percent by volume in brackets.

Cruise	February 20 - March 3	March 24 - April 3	April 22 - May 2
Numbered examined	1102	310	660
Number empty	499	139	169
Number everted	328	31	108
Food Items	Volume (cc)	Volume (cc)	Volume (cc)
Herring	-	-	143 (14.0)
Leuroglossus	-	6 (1.9)	4 (0.4)
Eulachon	-	-	19 (1.8)
Fish remains	295 (31.4)	49 (15.5)	6 (0.6)
Euphausiid	571 (60.9)	260 (82.0)	759 (74.3)
Amphipod	-	-	6 (0.6)
Glass shrimp	33 (3.5)	2 (0.6)	85 (8.3)
Squid	39 (4.2)	-	-
Total	938 (100)	317 (100)	1022 (100)

Table 11. Summary of catch, catch per unit effort and sex ratios by depth interval for walleye pollock. M/V ARCTIC HARVESTER, February 20 - May 2, 1981

Cruise	Depth interval (m)	Number of hauls	Catch (kg)	CPUE kg/hr	Sample size	% Male	% Female
February 20 - March 3	64-117	15	1105	93	1619	49	51
	118-171	14	1818	265	2295	68	32
	172-226	23	706	54	989	62	38
	227-282	18	1504	81	1071	51	49
	Total	70	5133	111	5974	59	41
March 24 - April 3	82-136	11	966	125	1795	54	46
	137-190	29	4247	369	4579	69	31
	191-245	7	426	229	692	54	46
	246-300	2	580	1105	636	76	24
	Total	49	6219	324	7702	65	35
April 9 -12	64-117	3	437	186	518	59	41
	118-171	9	1626	340	1612	85	15
	Bottom	5	533	104	420	44	56
	Total	17	2596	243	2550	73	27
April 22 - May 2	0-63	1	11	22	19	42	58
	64-117	12	736	106	1409	59	41
	118-171	14	554	132	974	54	46
	172-226	17	75	10	122	66	34
	227-282	4	8	5	-	-	-
	Total	48	1384	69	2524	57	43
July 3	56-62	1	23	31	-	-	-

Table 12. Stomach contents of walleye pollock by cruise. M/V ARCTIC HARVESTER, February 20 - May 2, 1981. Percent by volume in brackets.

Cruise	February 23 - March 3	March 24 - April 3	April 22 - May 2
Number examined	717	470	326
Number empty	221	175	22
Number everted	3	3	1
Food items	Volume (cc)	Volume (cc)	Volume (cc)
Pacific hake	22.0 (2.1)	-	-
Leuroglossus	29.5 (2.8)	-	-
Myctophid	5.0 (0.1)	-	-
Flatfish (unid.)	-	1.0 (0.2)	-
Fish remains	9.0 (0.9)	5.0 (1.1)	-
Euphausiid	401.25 (38.9)	266.5 (57.6)	749.25 (85.9)
Amphipod	316.5 (30.6)	78.25 (16.9)	89.0 (10.2)
Glass shrimp	63.25 (6.1)	20.0 (4.4)	18.0 (2.1)
Shrimp	8.0 (0.8)	5.0 (1.1)	-
Squid	10.5 (1.0)		-
Isopod	1.0 (0.1)		-
Zooplankton	117.25 (11.4)	60.25 (13.0)	15.25 (1.7)
Eggs (Unid.)	-	5.5 (1.2)	-
Polycheate	-	1.0 (0.2)	-
Digested Matter	49.25 (4.8)	20.0 (4.3)	1.0 (0.1)
Total	1032.5 (100)	463 (100)	872.5 (100)

Table 13. Summary of pollock length-weight parameters estimated using geometric regression ($W = aL^b$) by cruise.

	Male				Female				Total			
Cruise	n	a	b	r	n	a	b	r	n	a	b	r
Feb. 20 - March 3	191	0.0076	3.0302	0.96	194	0.0069	3.057	0.98	385	0.0071	3.0495	0.97
March 24 - April 3	116	0.0606	2.4097	0.95	92	0.0221	2.6698	0.92	208	0.0534	2.4406	0.94
April 9 - 12	-	-	-	-	-	-	-	-	59	0.0198	2.7134	0.98
Means (weighted)			2.796				2.932				2.825	
Total	307				286				652			

Table 14. Stomach contents of spiny dogfish ≤ 60 cm and >60 cm by cruise. M/V ARCTIC HARVESTER, February 20 - May 2, 1981.

a) February 20 - March 3	≤ 60 cm	> 60 cm	Total
Number examined	323	124	447
Number empty	212	52	264
Food items	Volume (cc)	Volume (cc)	Volume (cc)
Pacific hake	605	133	738
Walleye pollock	-	15	15
Leuroglossus	-	2	2
Fish remains	60	699	759
Euphausiids	33	5	38
Squid	65	505	570
Jellyfish	5	-	5
Total	768	1359	2127

b) March 24 - April 3	≤ 60 cm	> 60 cm	Total
Number examined	168	200	368
Number empty	35	46	81
Food items	Volume (cc)	Volume (cc)	Volume (cc)
Pacific hake	-	50	50
Fish remains	70	79	149
Euphausiids	58	-	58
Amphipod	12	-	12
Total	140	129	269

Table 14 (cont'd).

c) April 22 - May 2	≤ 60 cm	> 60 cm	Total
Number examined	81	134	215
Number empty	14	41	55
Food items	Volume (cc)	Volume (cc)	Volume (cc)
Pacific hake	4	8490	8494
Leuroglossus	-	15	15
Ratfish	-	5	5
Fish remains	31	1007	1038
Euphausiids	40	-	40
Squid	-	235	235
Crab	10	-	10
Prawn	-	2	2
Ctenophore	-	5	5
Total	85	9759	9844

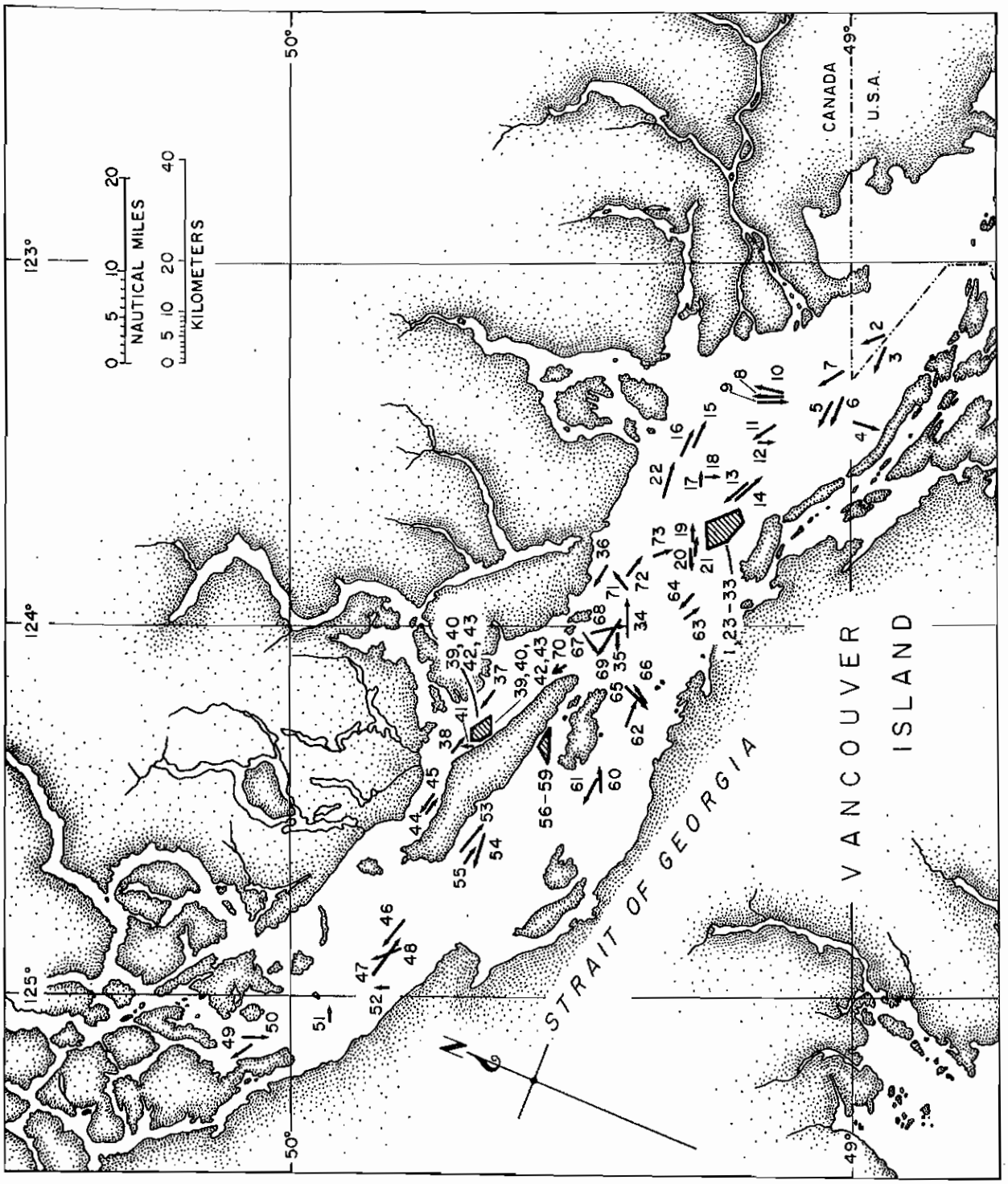

Fig. 1. Set locations in the Strait of Georgia, M/V ARCTIC HARVESTER, February 20-March 3, 1981.

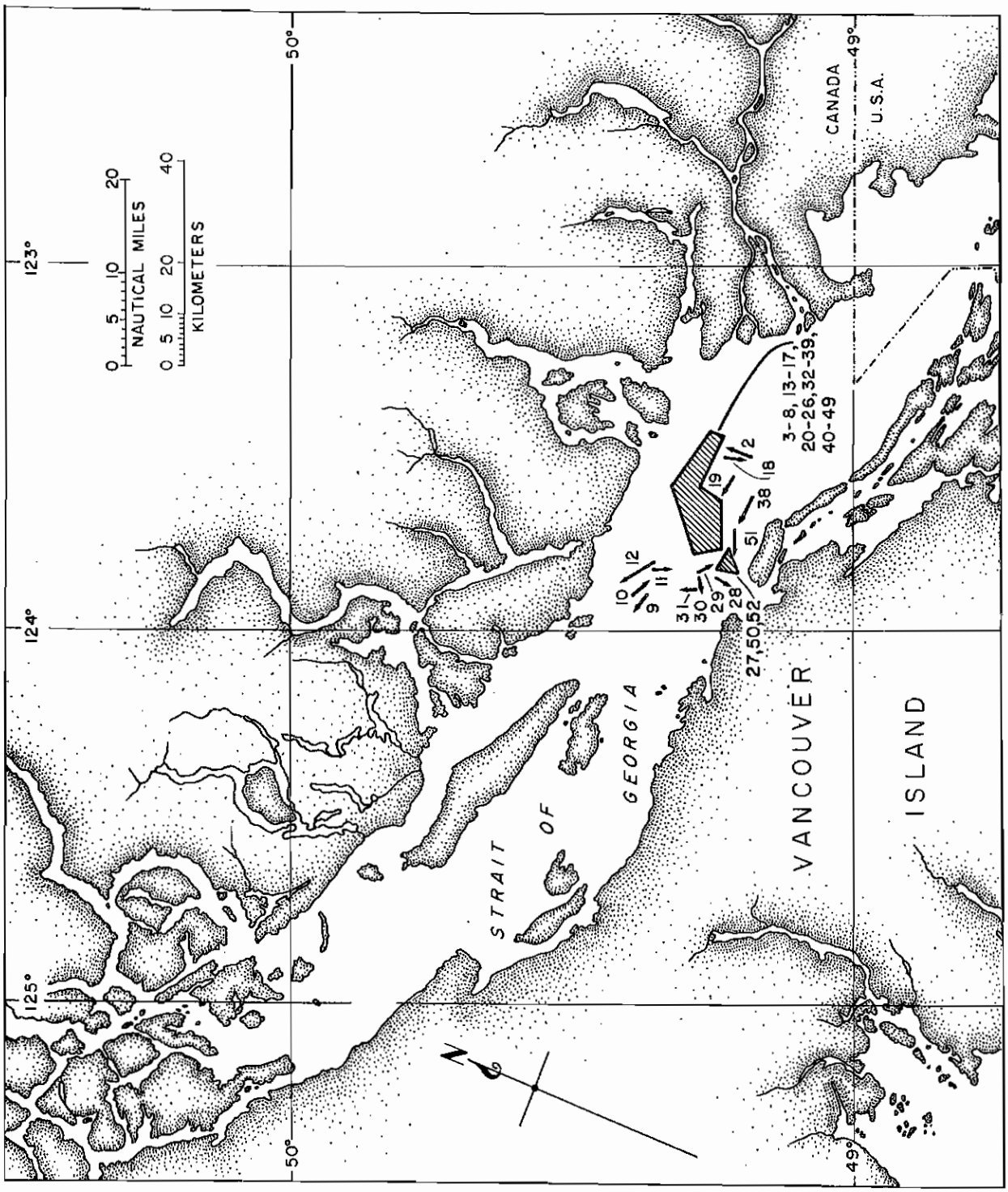

Fig. 2. Set locations in the Strait of Georgia, M/V ARCTIC HARVESTER, March 24-April 3, 1981.

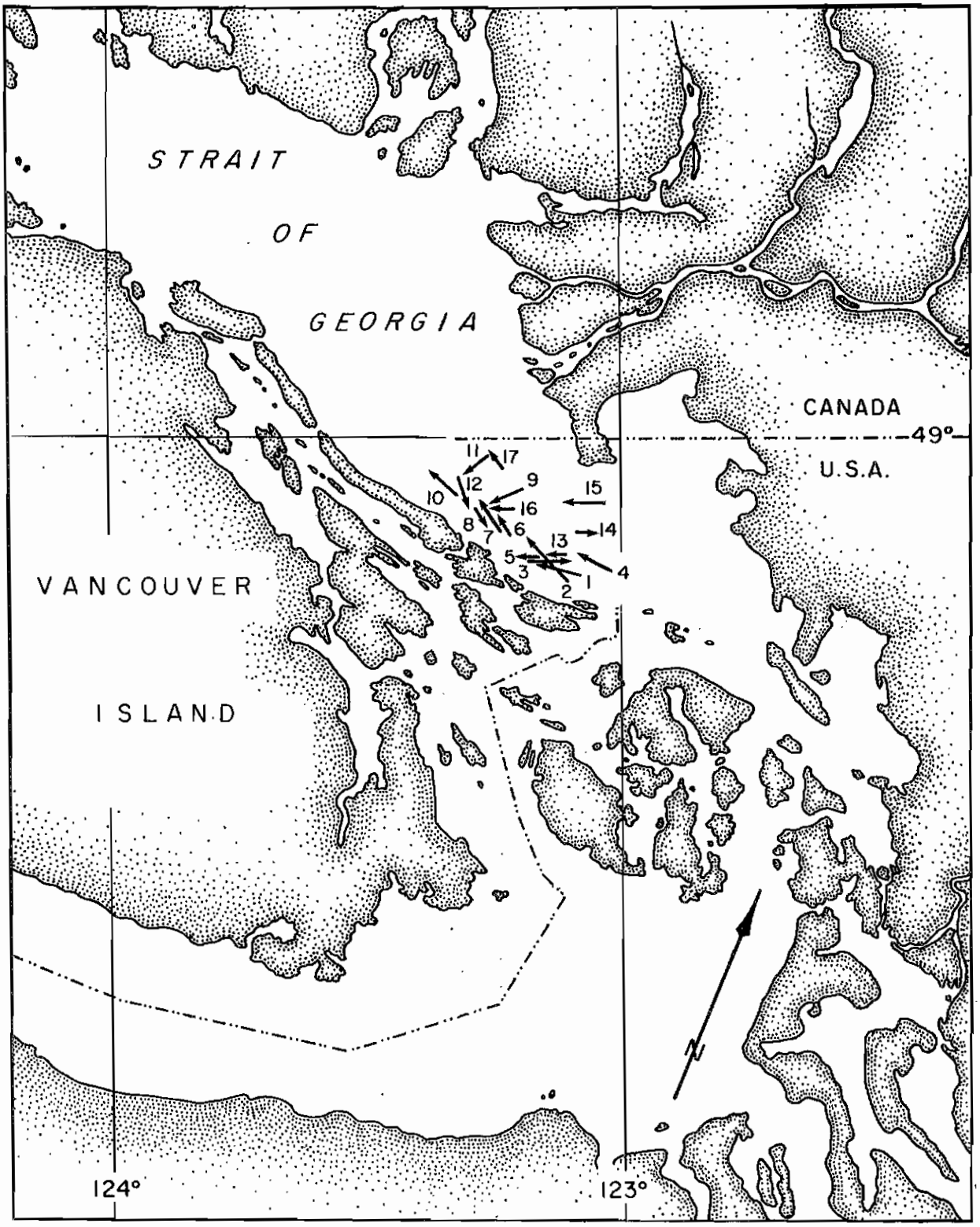

Fig. 3. Set locations in the Strait of Georgia, M/V ARCTIC HARVESTER, April 9-12, 1981.

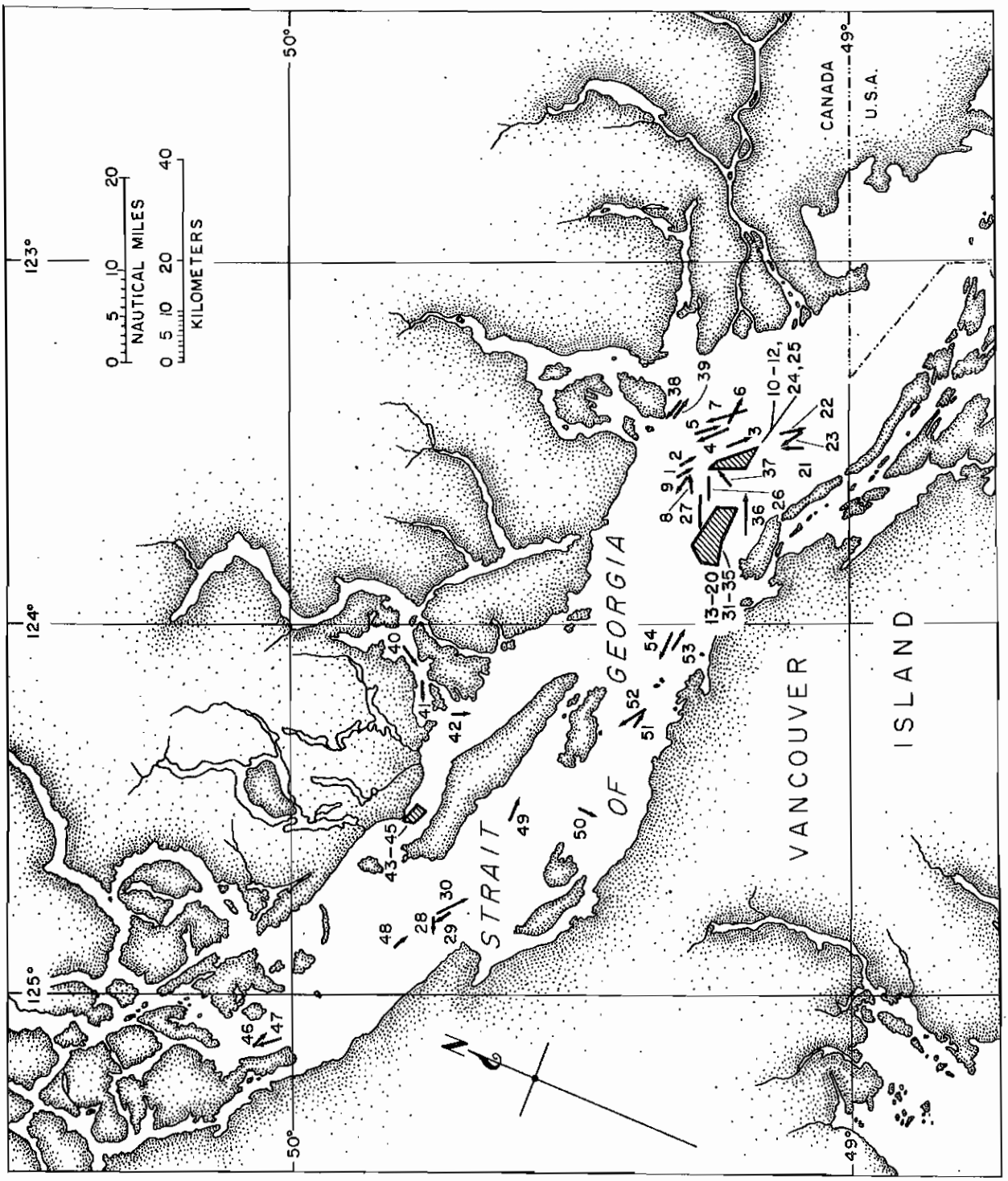

Fig. 4. Set locations in the Strait of Georgia, M/V ARCTIC HARVESTER, April 22-May 2, 1981.

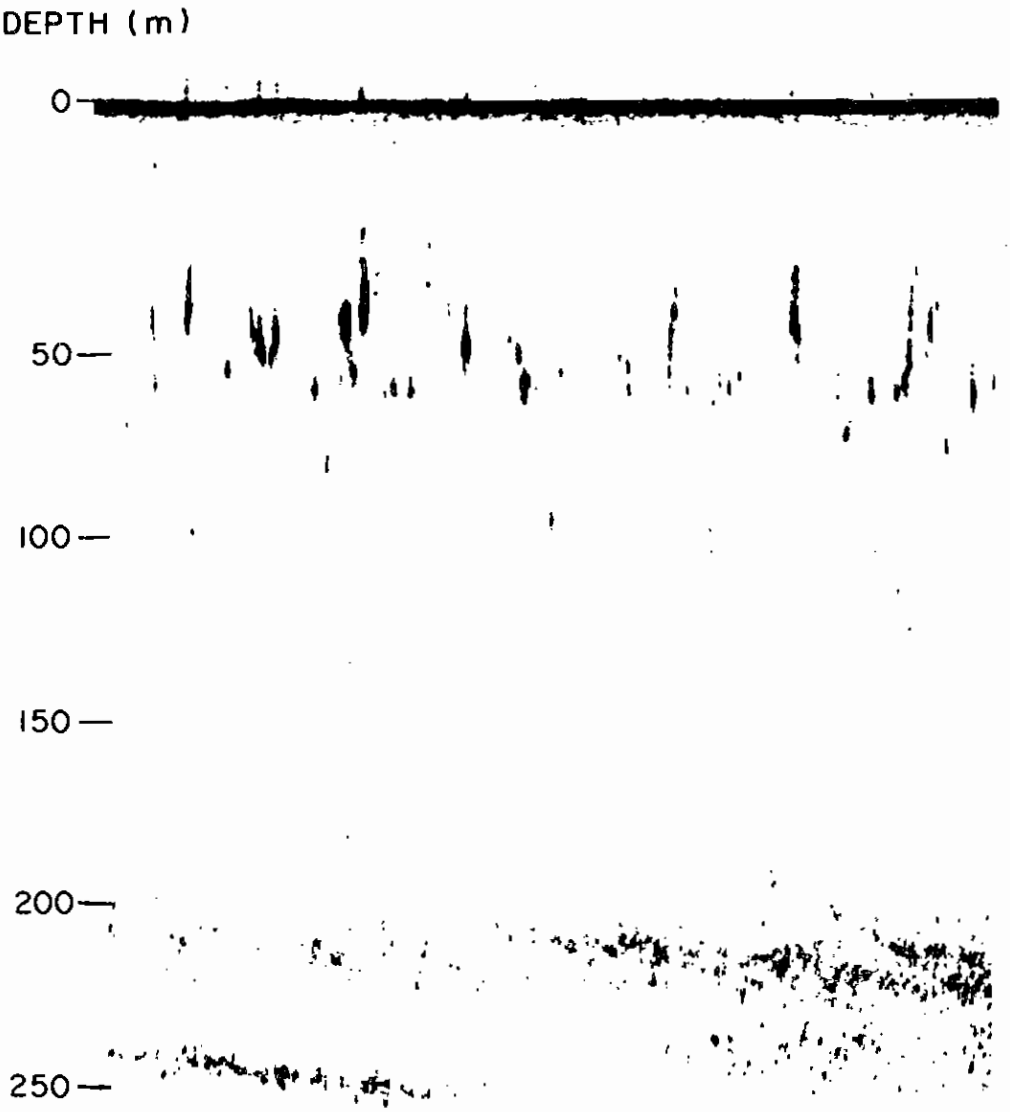

Fig. 5. Echogram showing concentrations of midwater fishes during daylight hours in the Strait of Georgia, March-April 1981. Shallow layer (30-70 m) of heavy spotting comprised mainly of hake and some pollock.

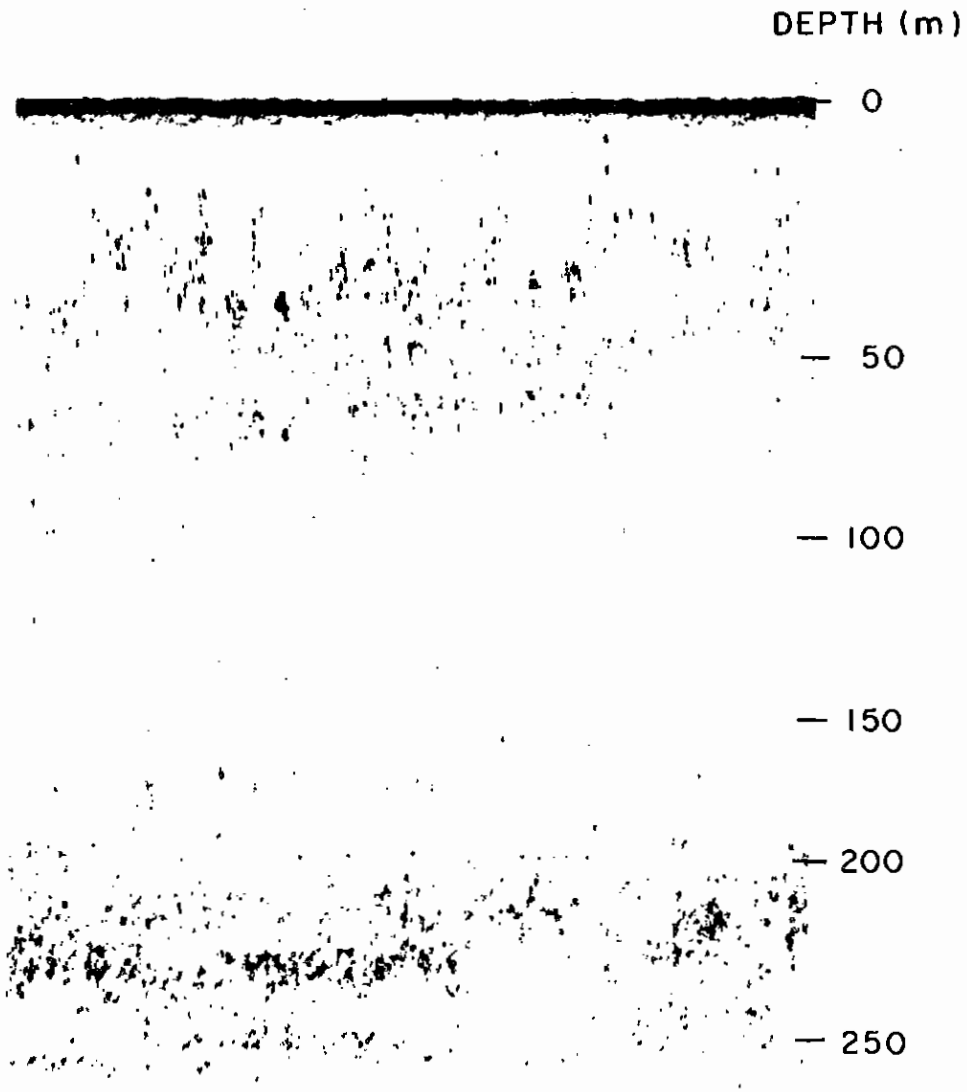

Fig. 6. Echogram showing concentrations of midwater fishes during night in the Strait of Georgia, March-April 1981. Shallow layer dispersed throughout the upper 100 m.

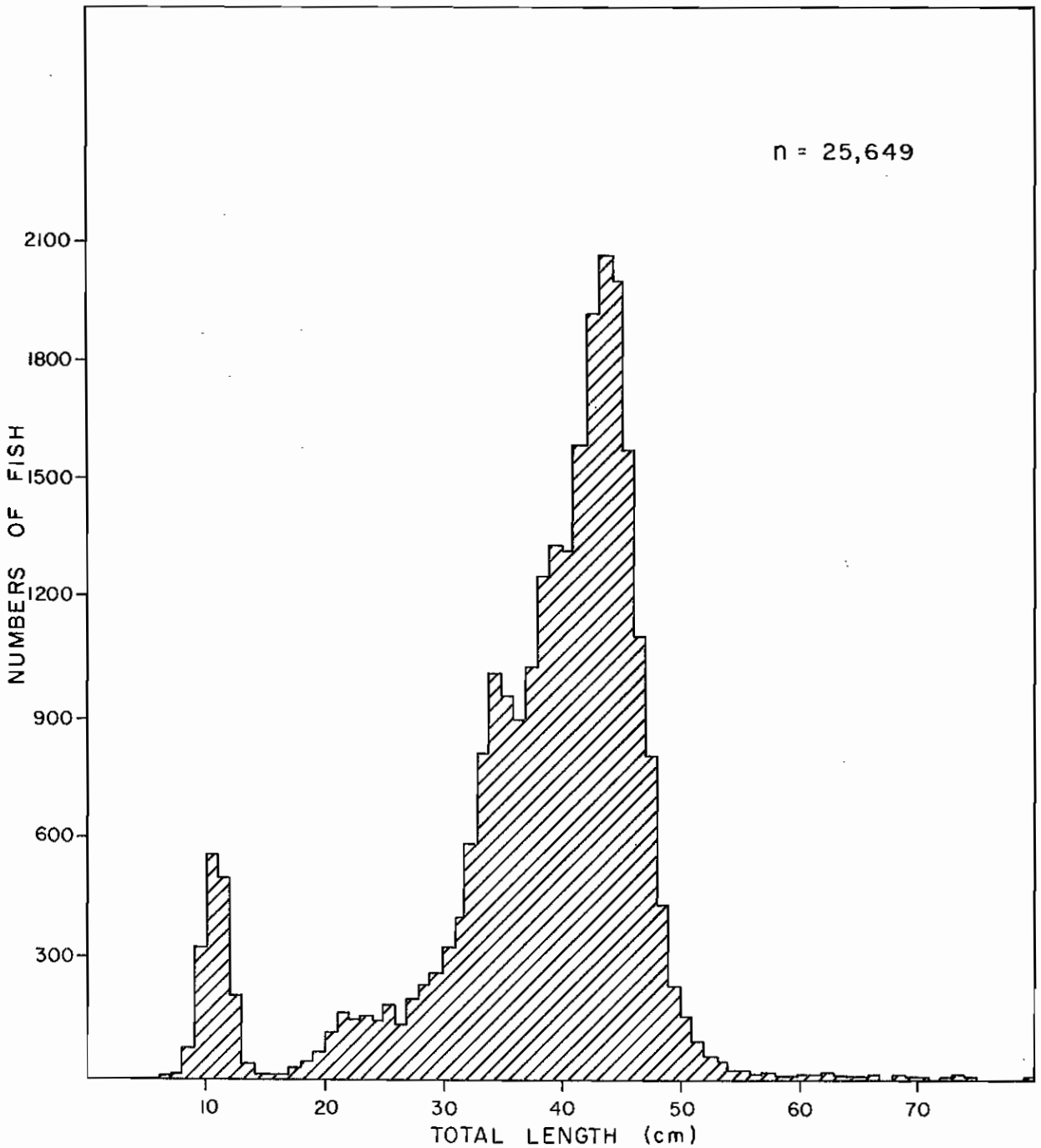

Fig. 7. Pacific hake length frequency, Strait of Georgia, February 20-March 3, 1981.

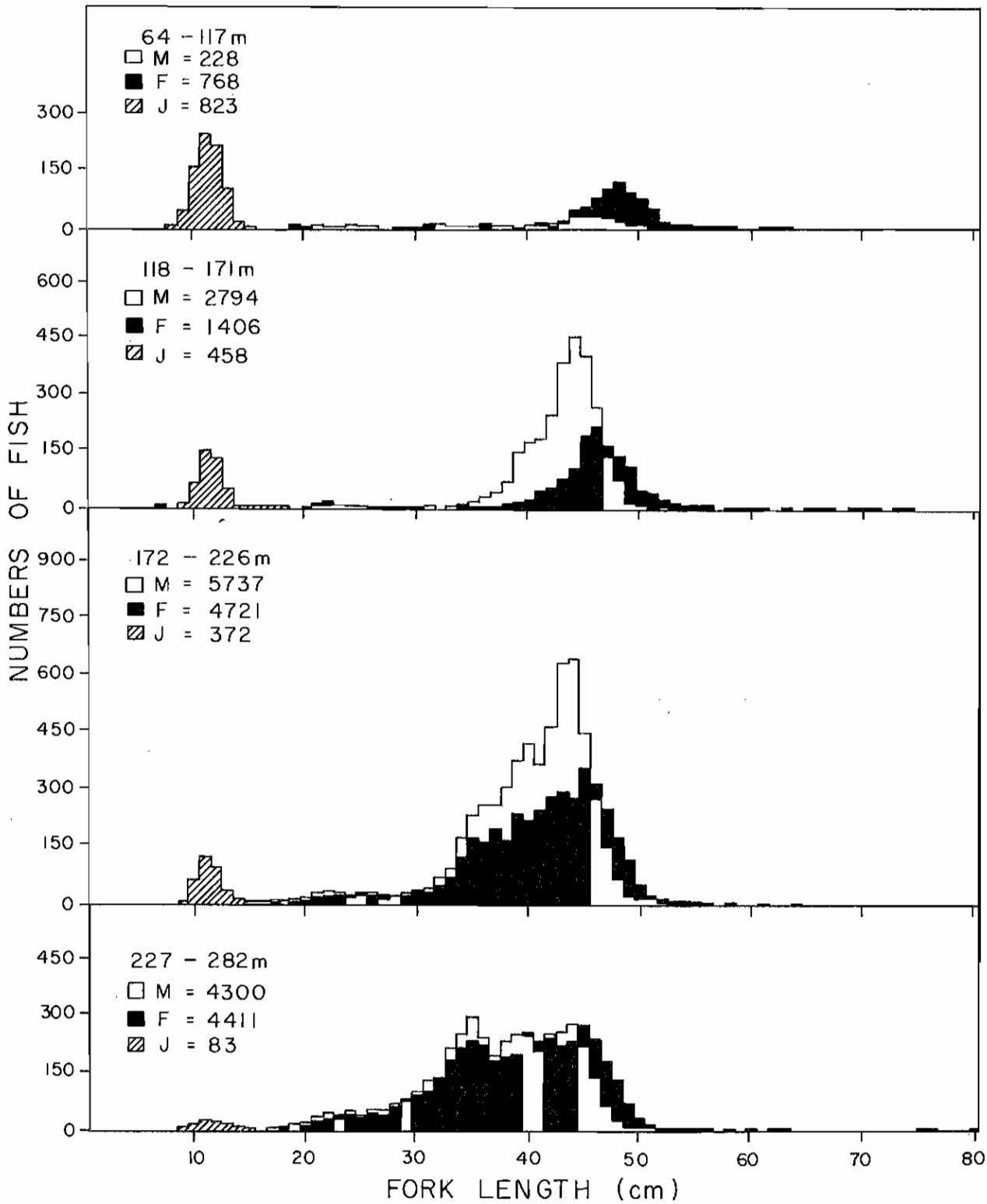

Fig. 8. Length frequency of Pacific hake, by depth interval, Strait of Georgia, February 20-March 3, 1981.

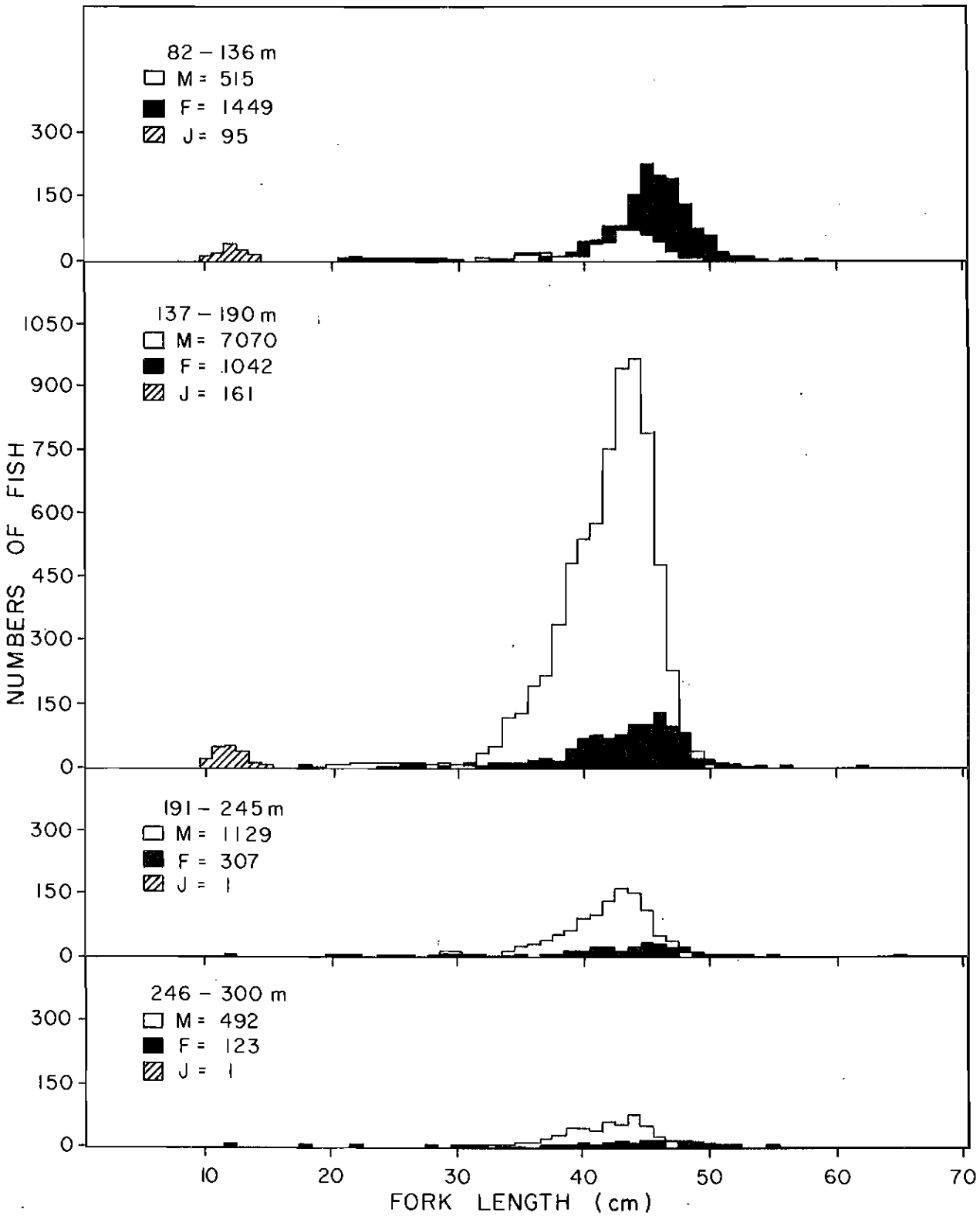

Fig. 9. Length frequency of Pacific hake, by depth interval, south central Strait of Georgia, March 24-April 3, 1981.

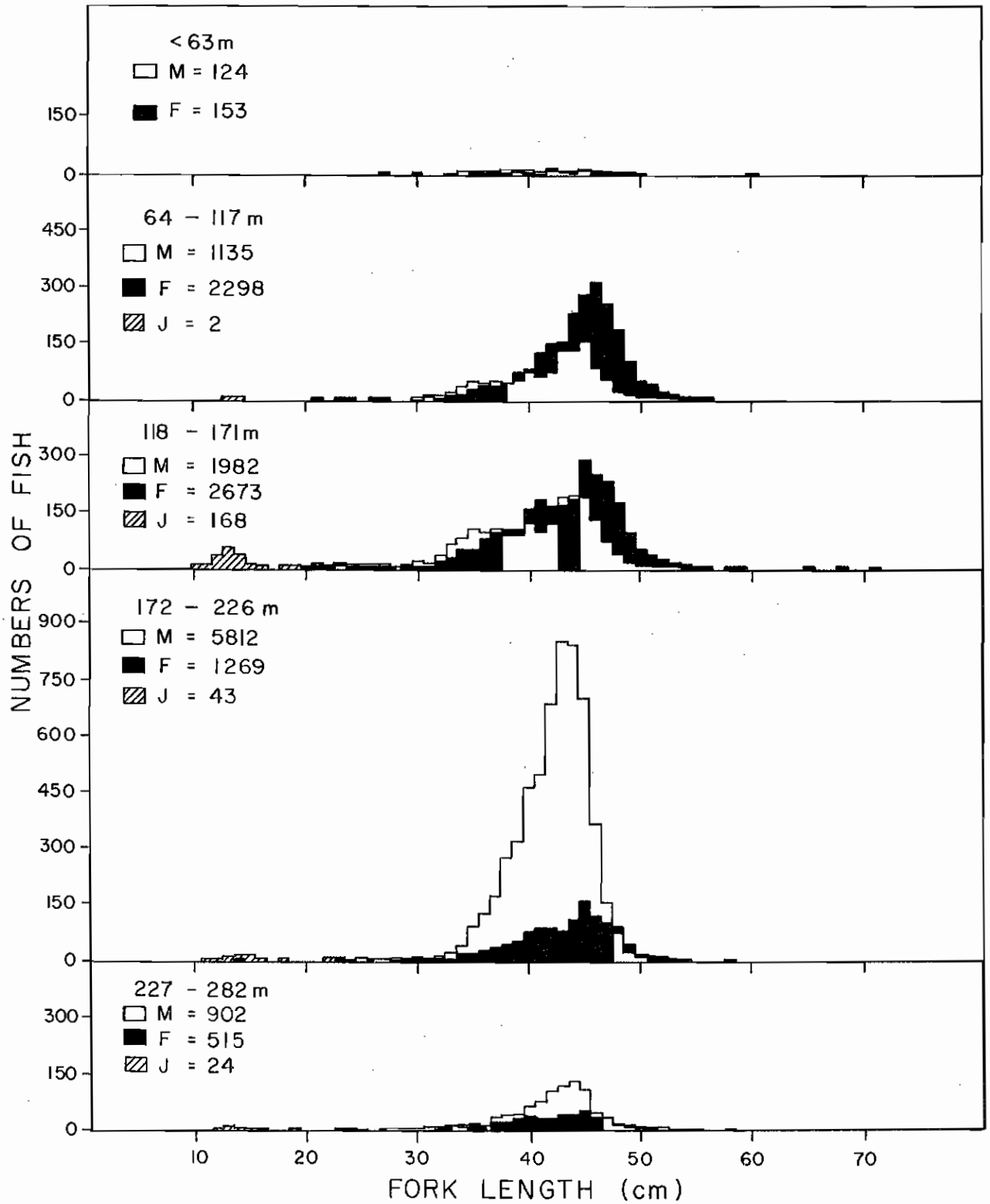

Fig. 10. Length frequency of Pacific hake, by depth interval, Strait of Georgia, April 22-May 2, 1981.

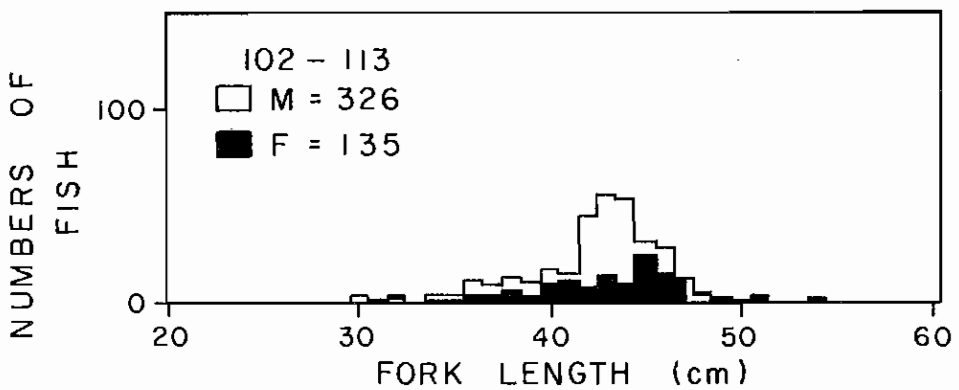

Fig. 11. Length frequency of Pacific hake off Entrance Island, July 3, 1981.

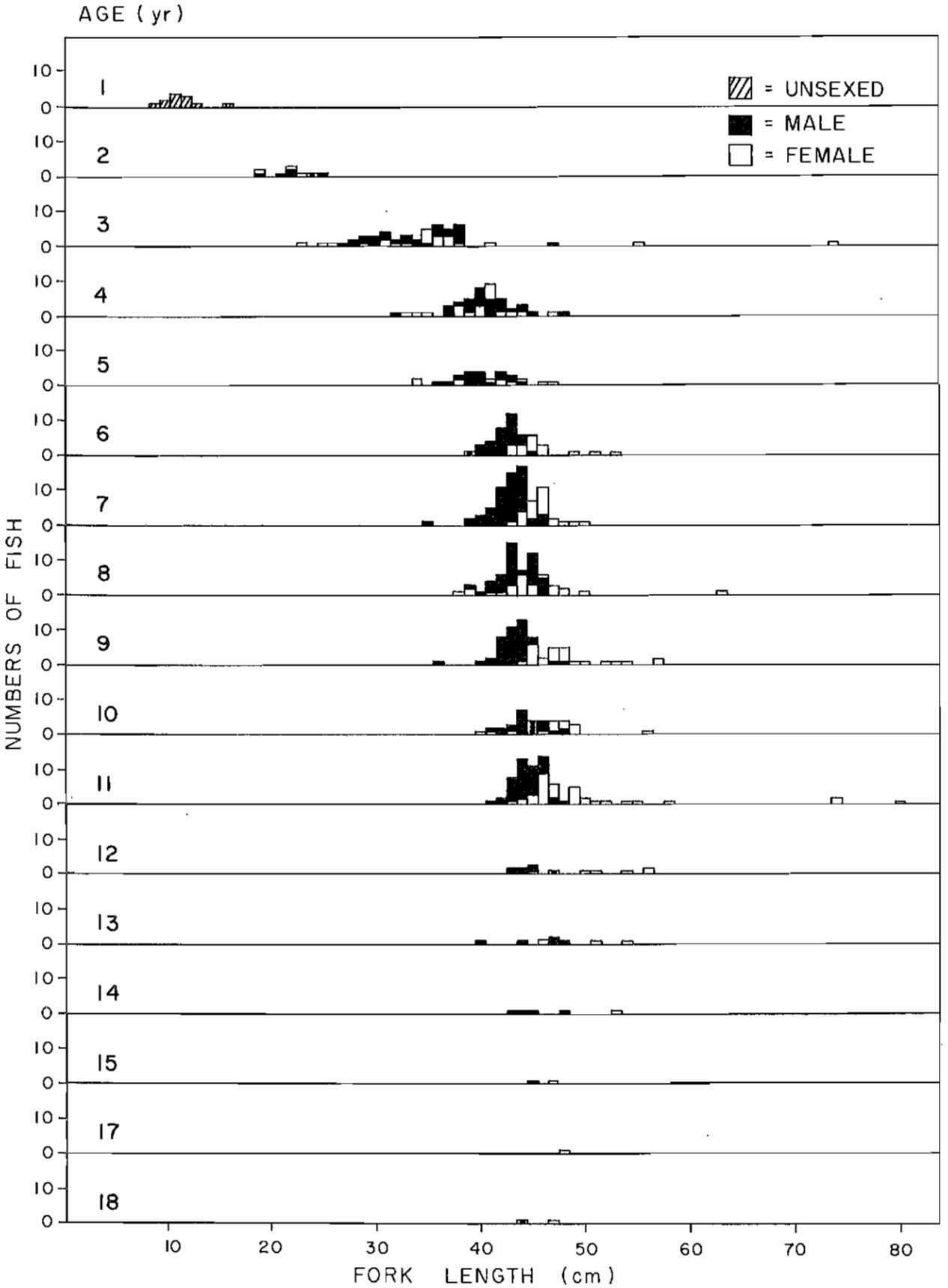

Fig. 12. Length frequencies of Pacific hake by age-class, February 20-March 3, 1981 (set nos. 1, 4, 5, 8, 12, 13, 14, 16, and 17).

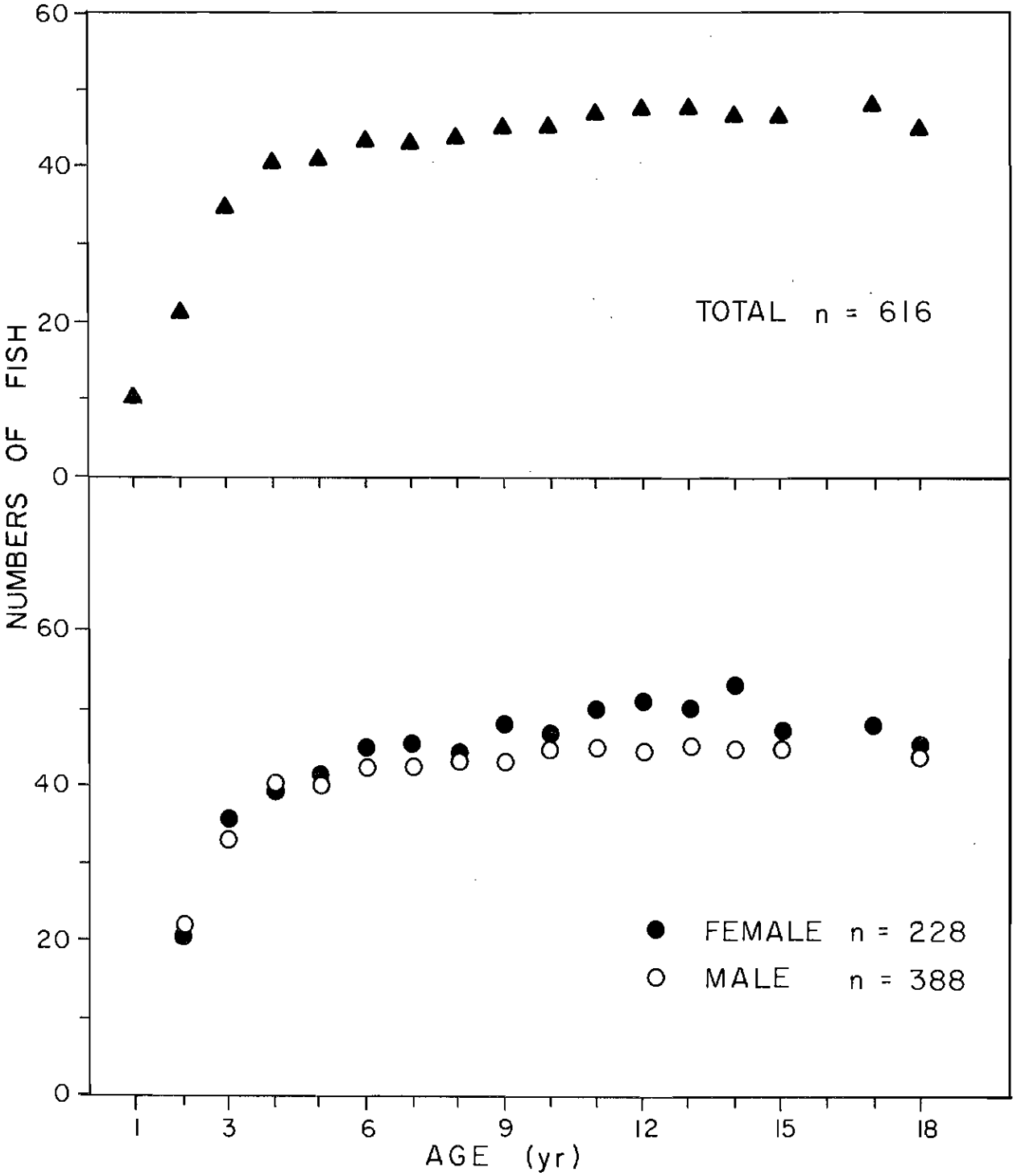

Fig. 13. Mean lengths at age for Pacific hake, February 20-March 3, 1981 (set nos. 1, 4, 8, 12, 13, and 17).

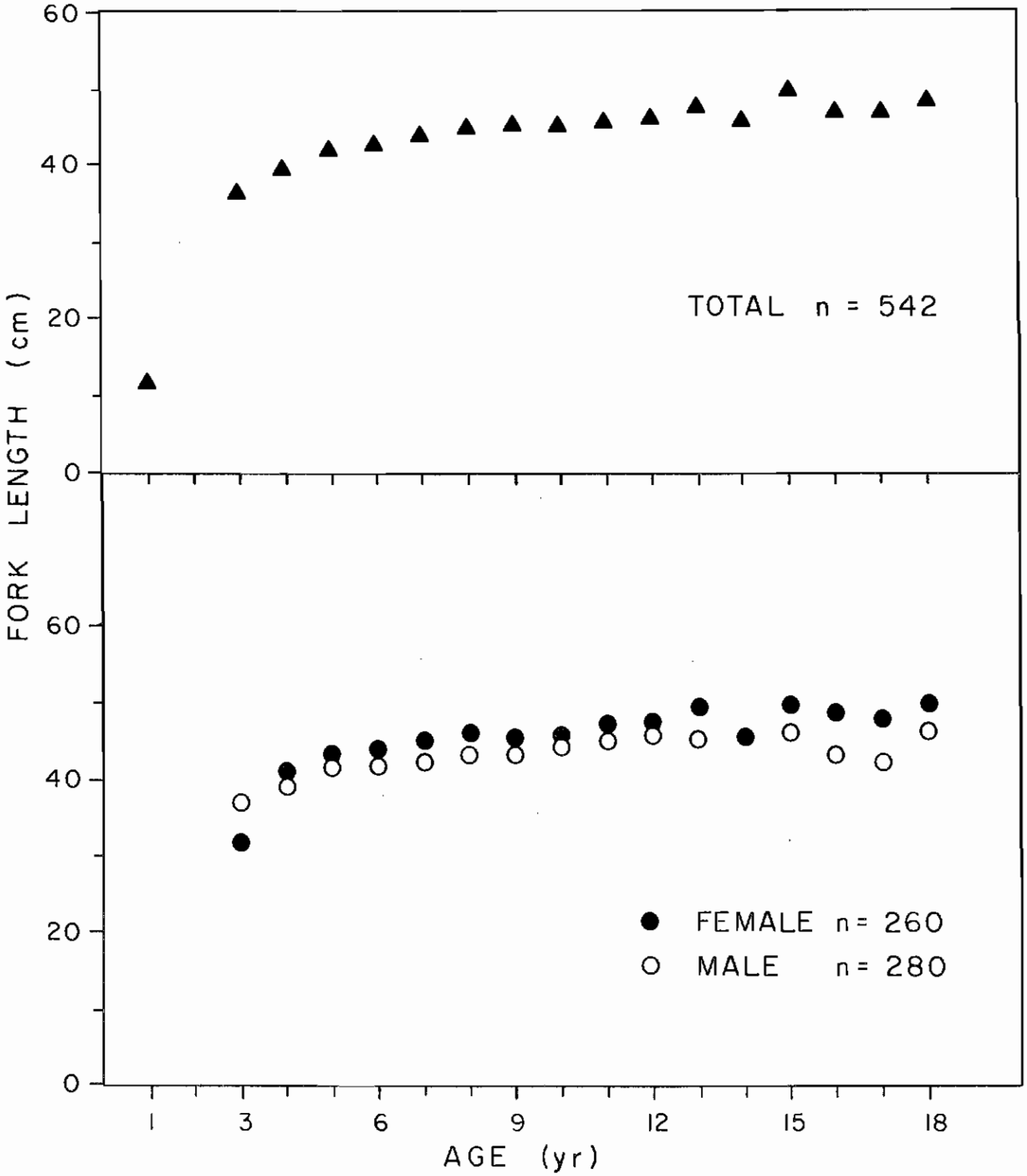

Fig. 14. Mean lengths at age for Pacific hake, March 24-April 3, 1981 (set nos. 4, 8, 11, 12, 14, and 21).

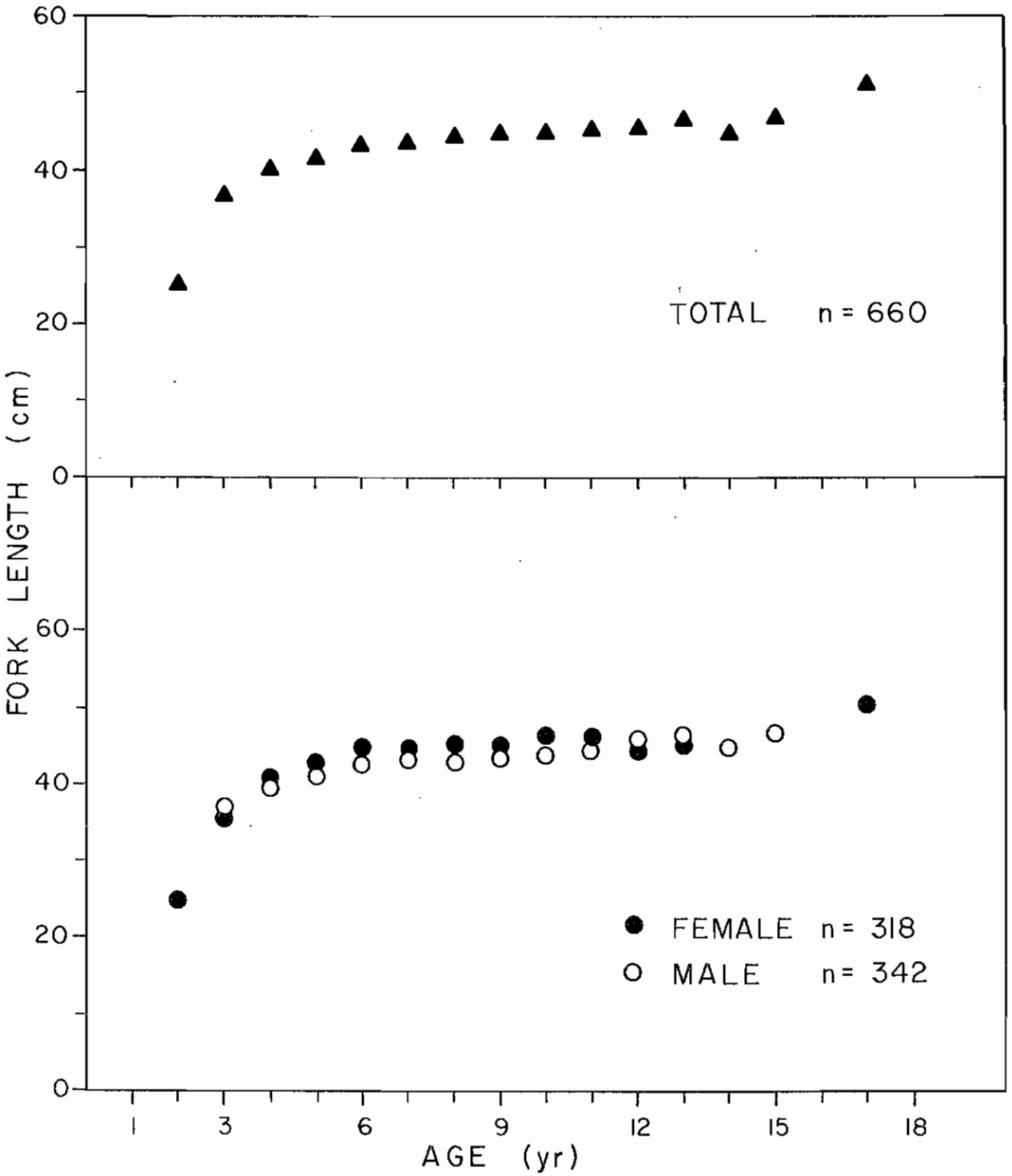

Fig. 15. Mean lengths at age for Pacific hake, April 22-May 2, 1981 (set nos. 6, 11, 13, 19, and 22).

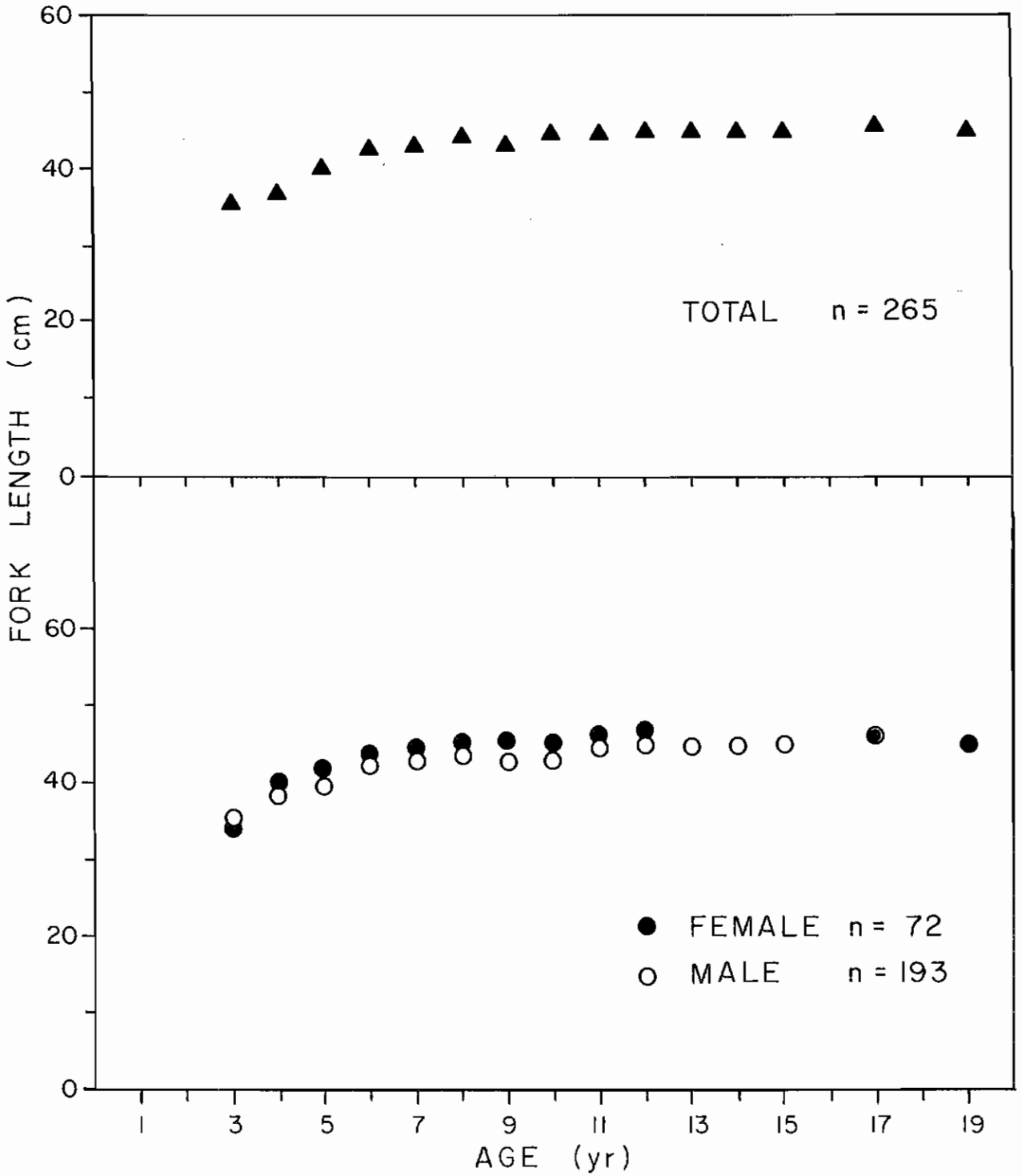

Fig. 16. Mean lengths at age for Pacific hake, July 3, 1981.

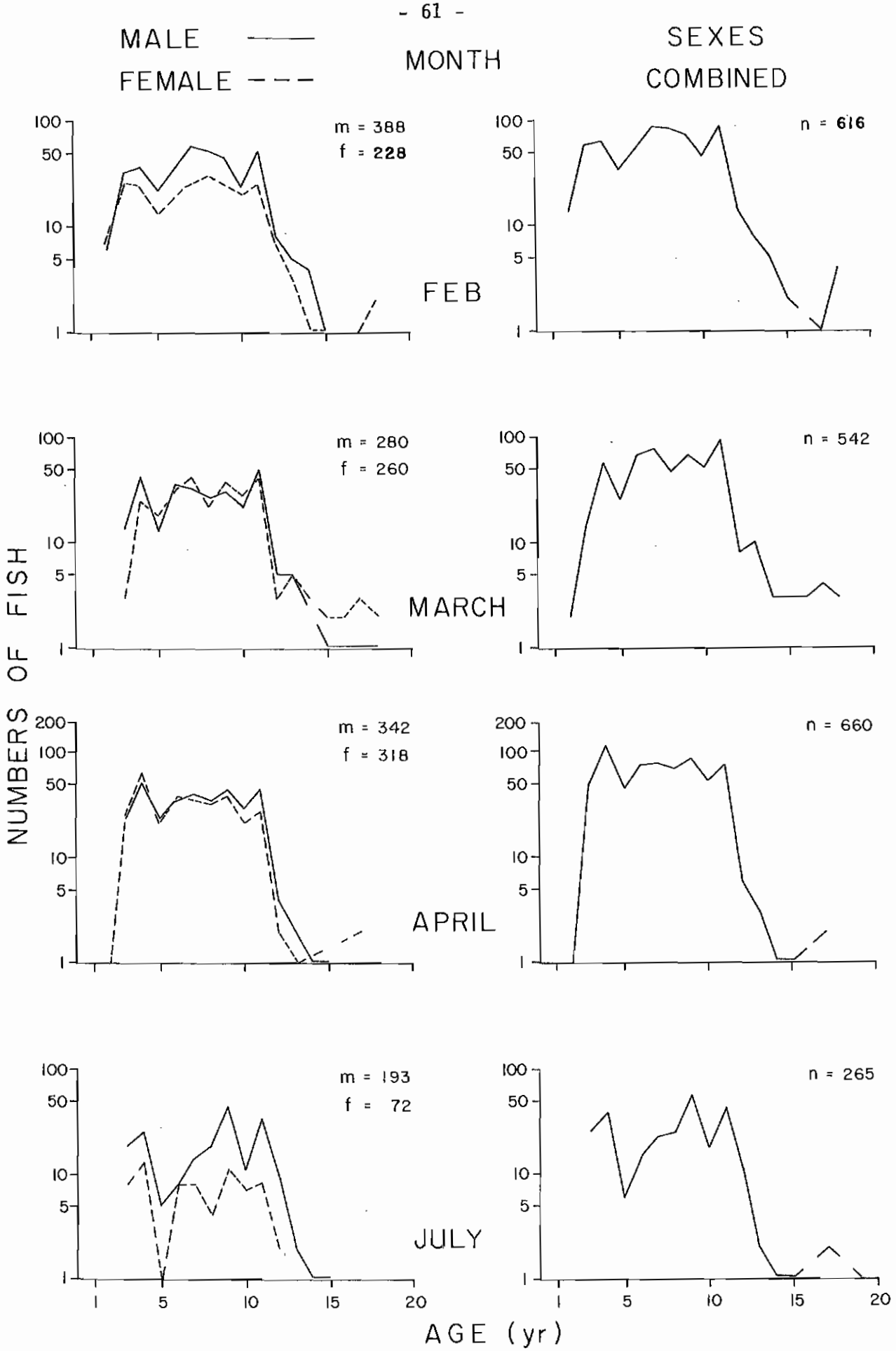

Fig. 17. Age compositions by month and by sex for Pacific hake collected in the south central Strait of Georgia, February-July, 1981.

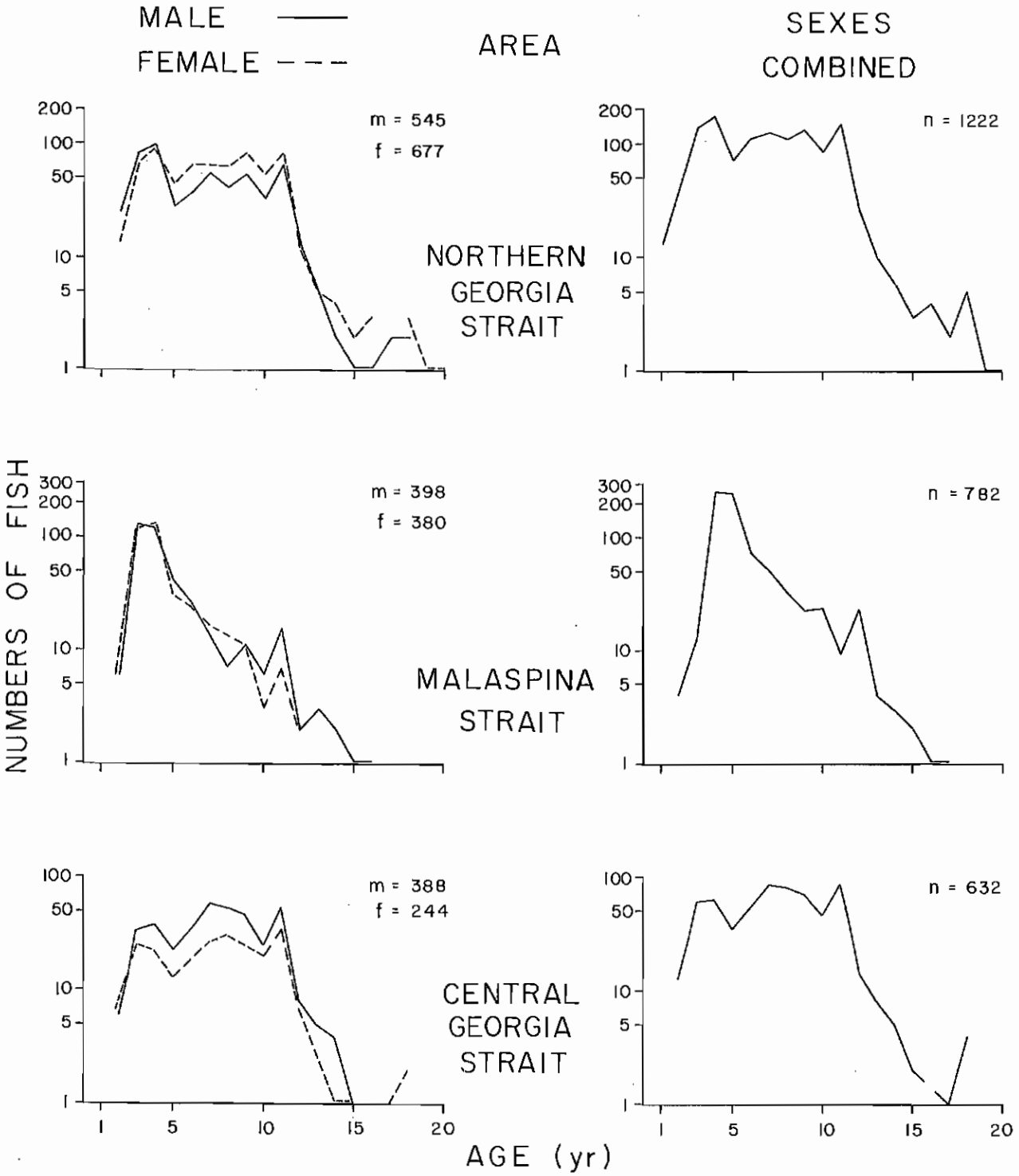

Fig. 18. Age compositions by sex and by area for Pacific hake collected in the Strait of Georgia, February 20-March 3, 1981.

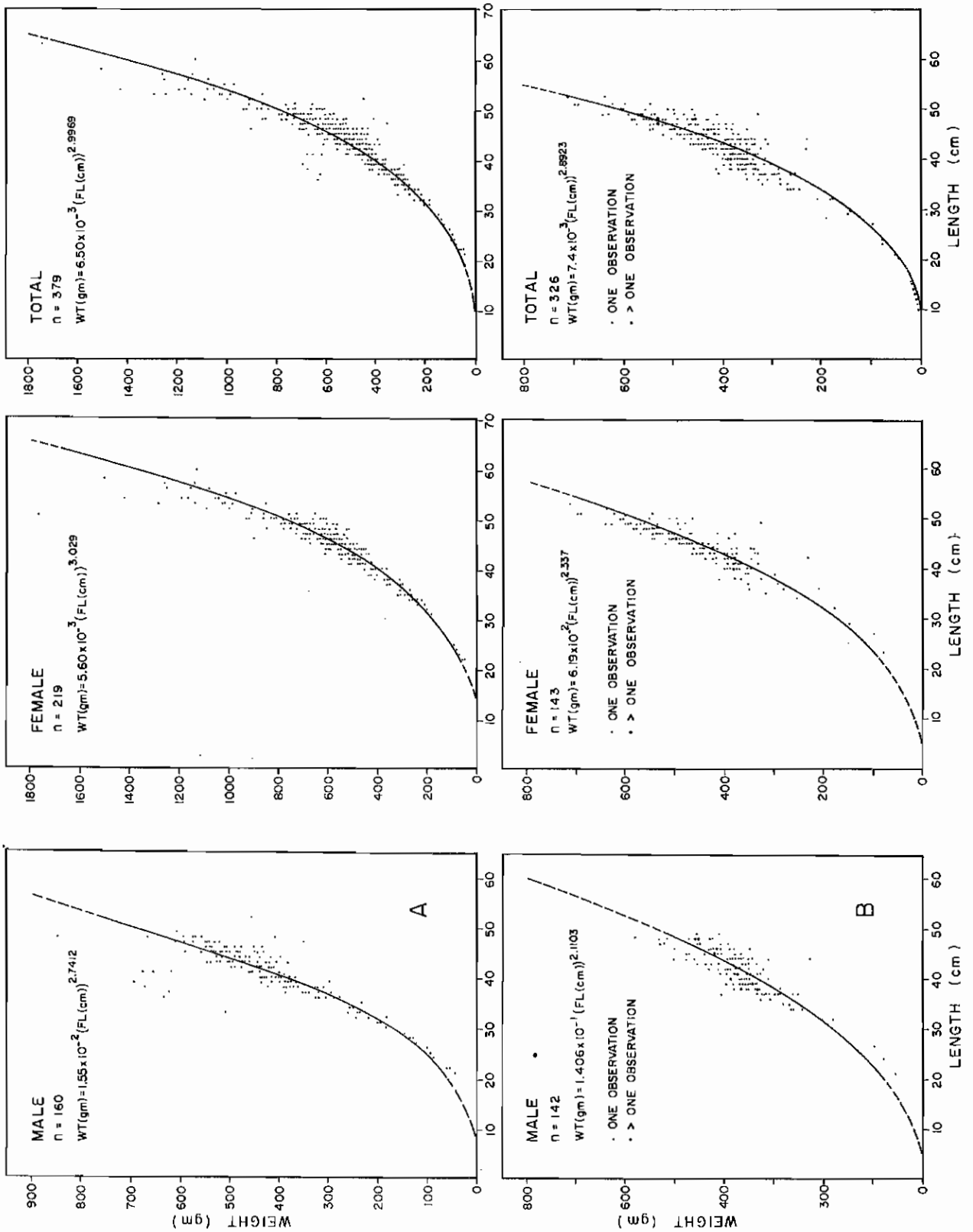

Fig. 19a. Length-weight relationships for Pacific hake collected in the south central Strait of Georgia. A. February 20-March 3, 1981. B. April 24-May 2, 1981.

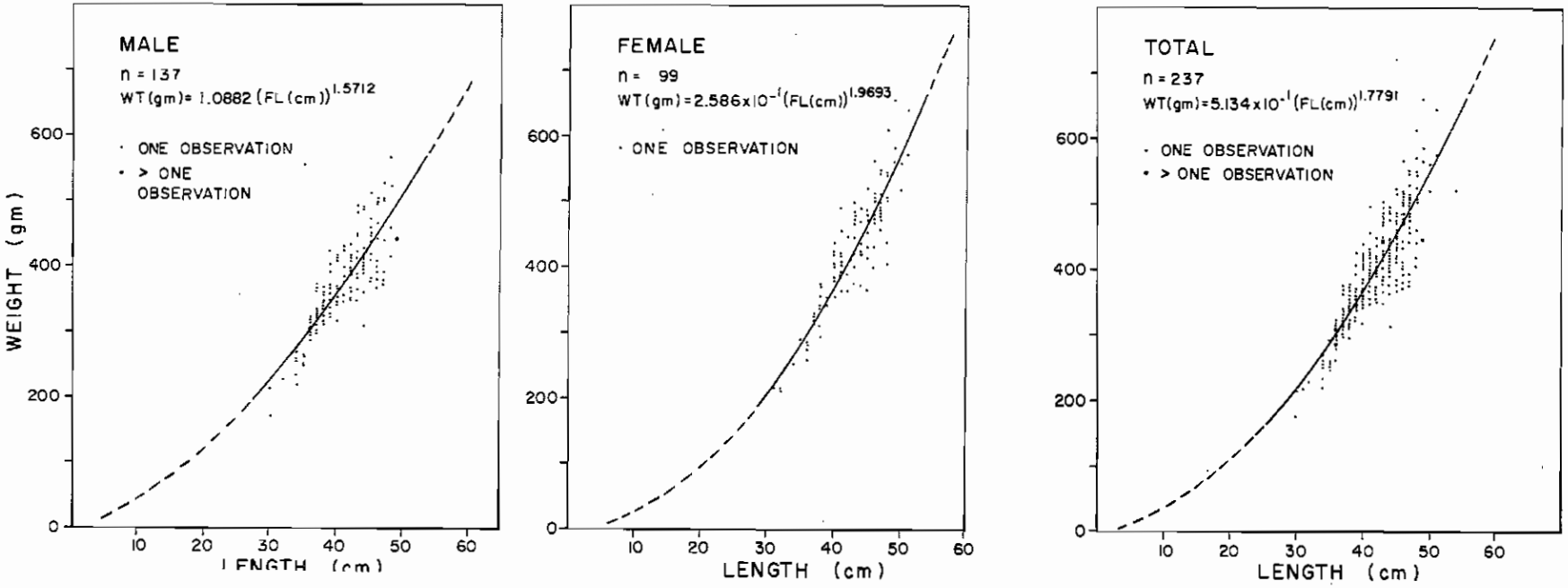

Fig. 19b. Length-weight relationships for Pacific hake collected in the south central Strait of Georgia, July 3, 1981.

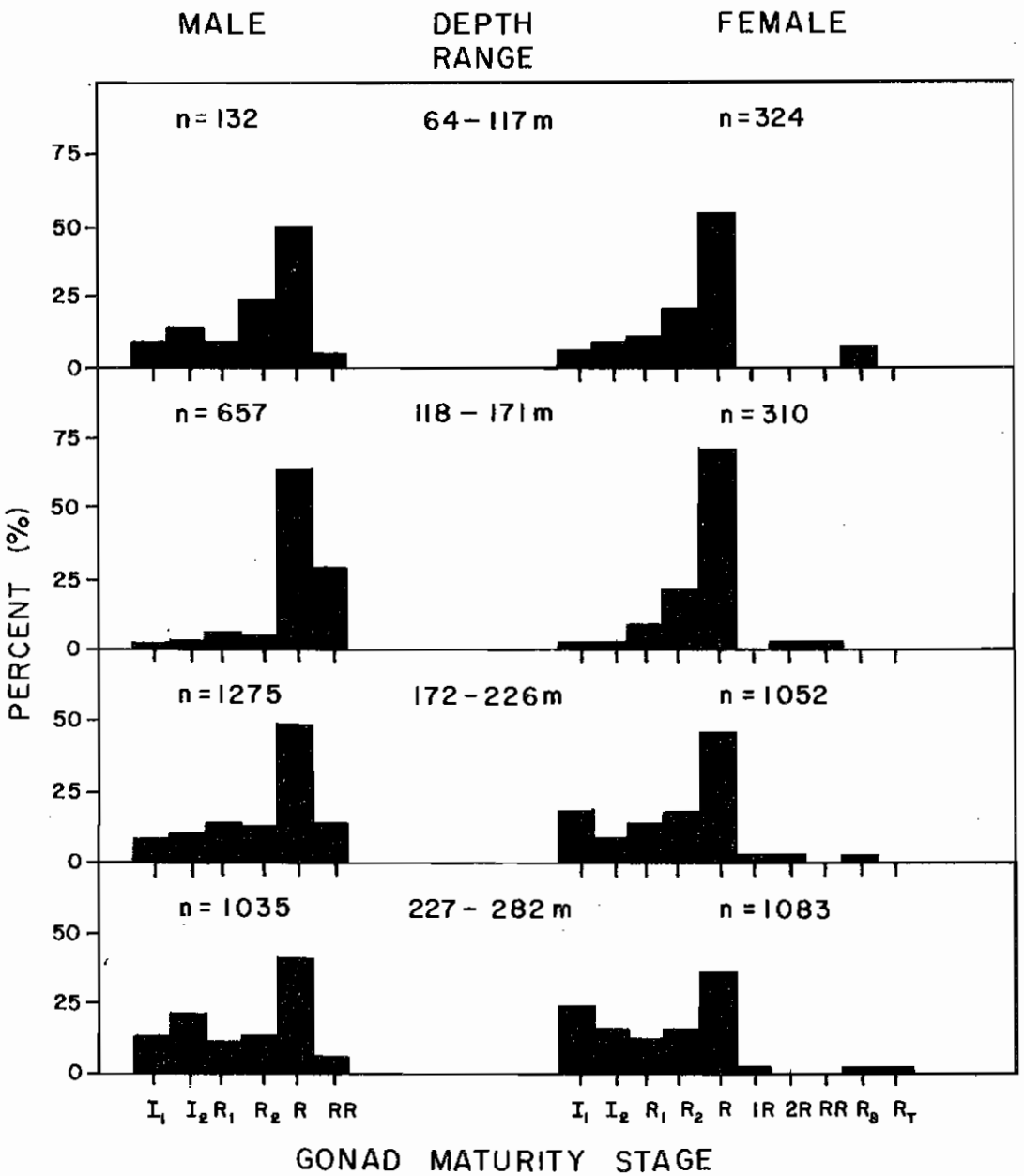

Fig. 20. Pacific hake gonad maturity stages, by depth interval, collected throughout the Strait of Georgia, February 20-March 3, 1981.

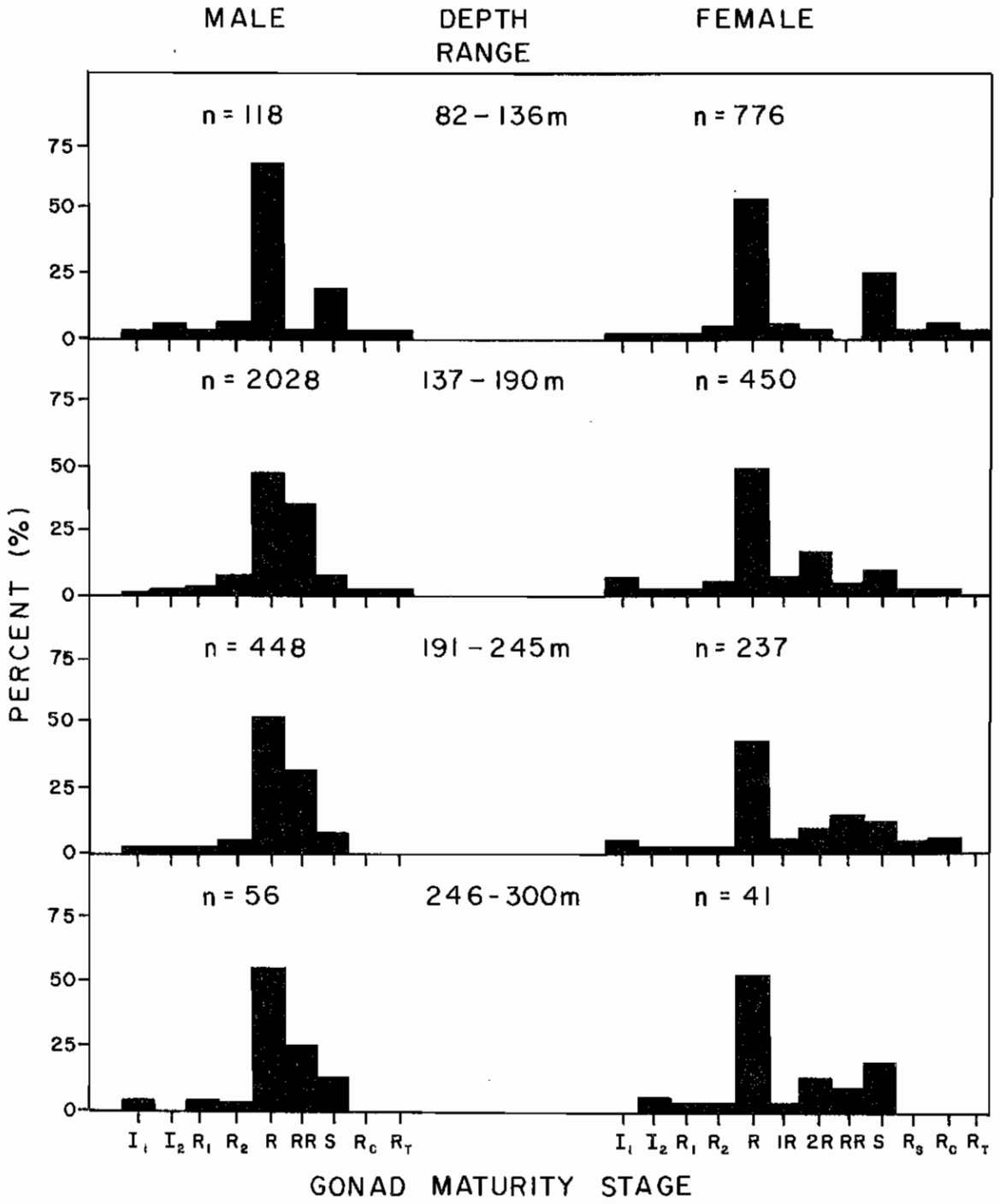

Fig. 21. Pacific hake gonad maturity stages, by depth interval, collected in the south central Strait of Georgia, March 24-April 3, 1981.

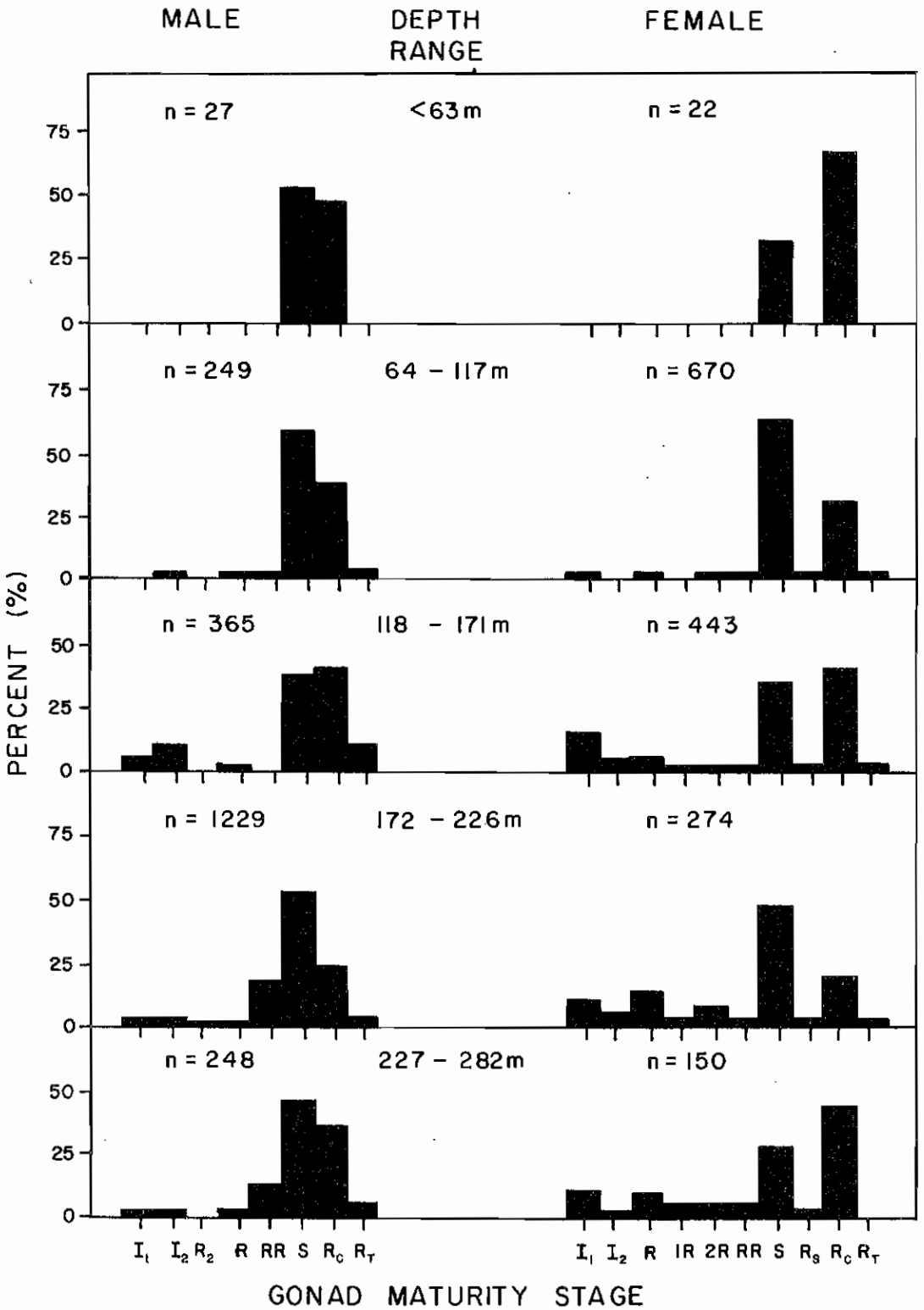

Fig. 22. Pacific hake gonad maturity stages, by depth interval, collected throughout the Strait of Georgia, April 22-May 2, 1981.

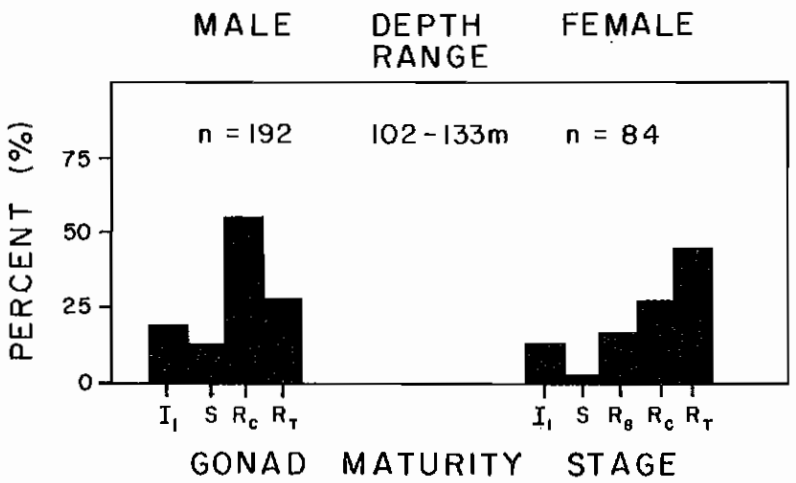

Fig. 23. Pacific hake gonad maturity stages collected off Entrance Island, July 3, 1981.

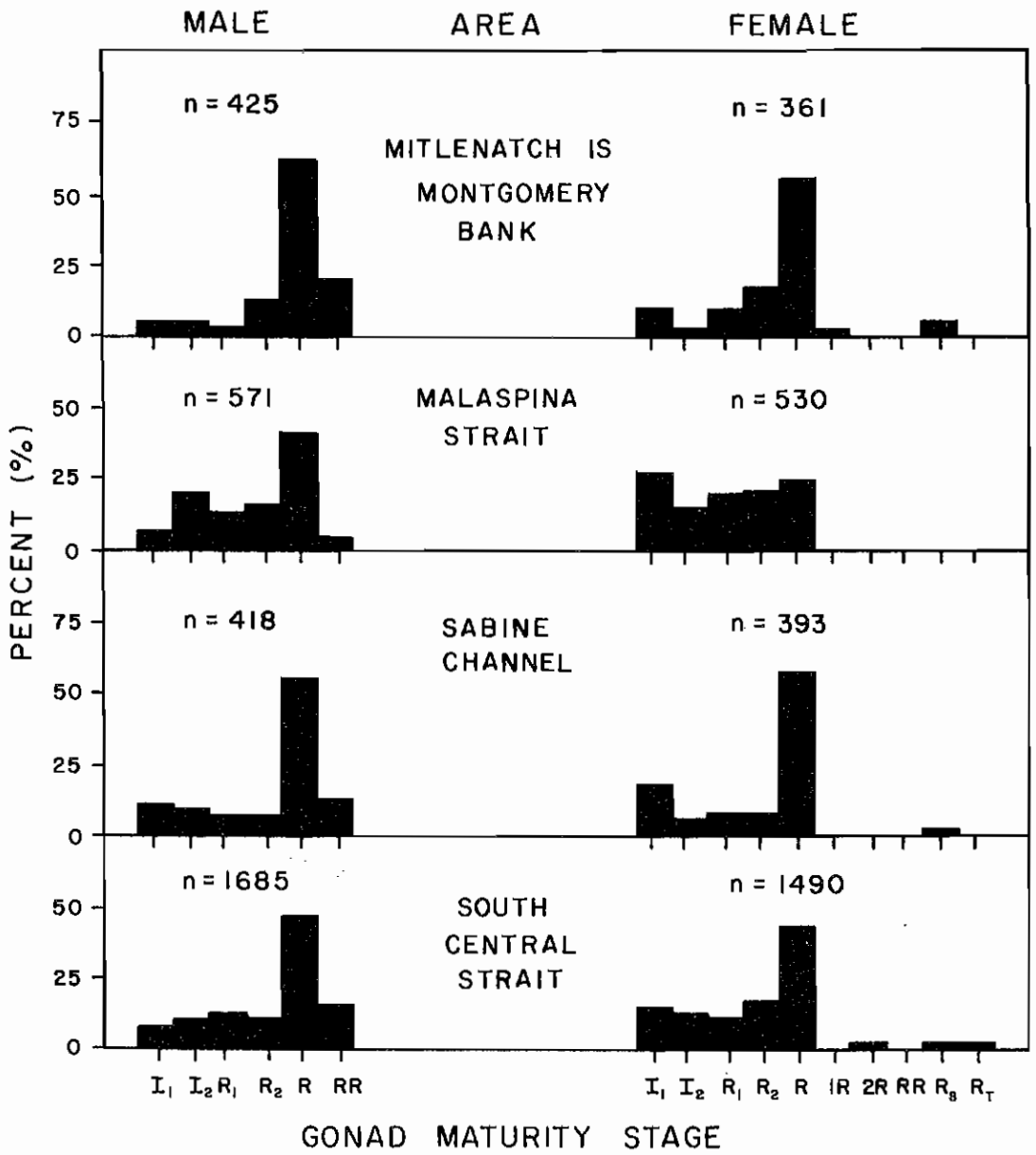

Fig. 24. Pacific hake gonad maturity stages, by area, collected in the Strait of Georgia, February 20-March 3, 1981.

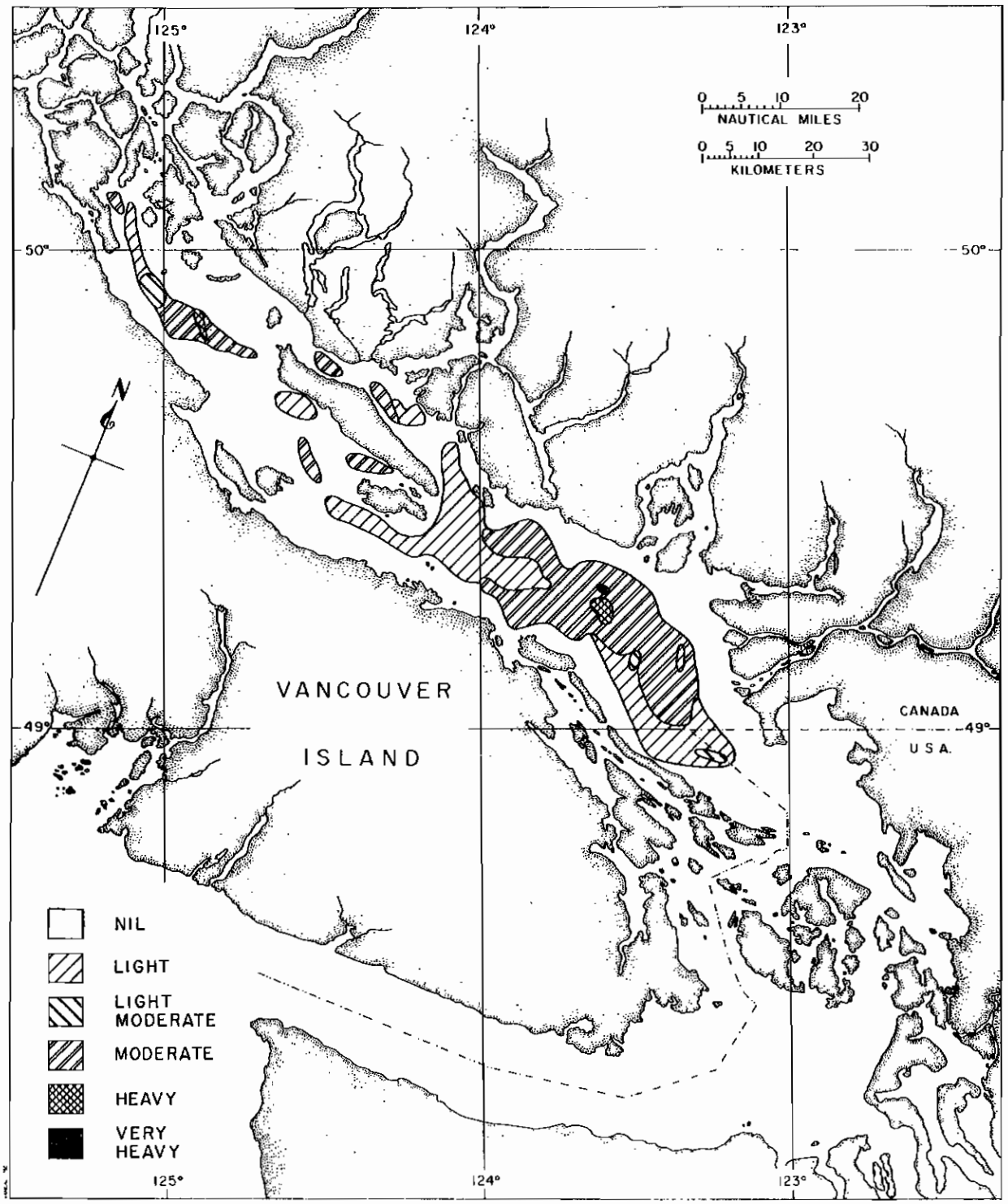

Fig. 25. Distribution of Pacific hake and walleye pollock in the Strait of Georgia, February 20-March 3, 1981.

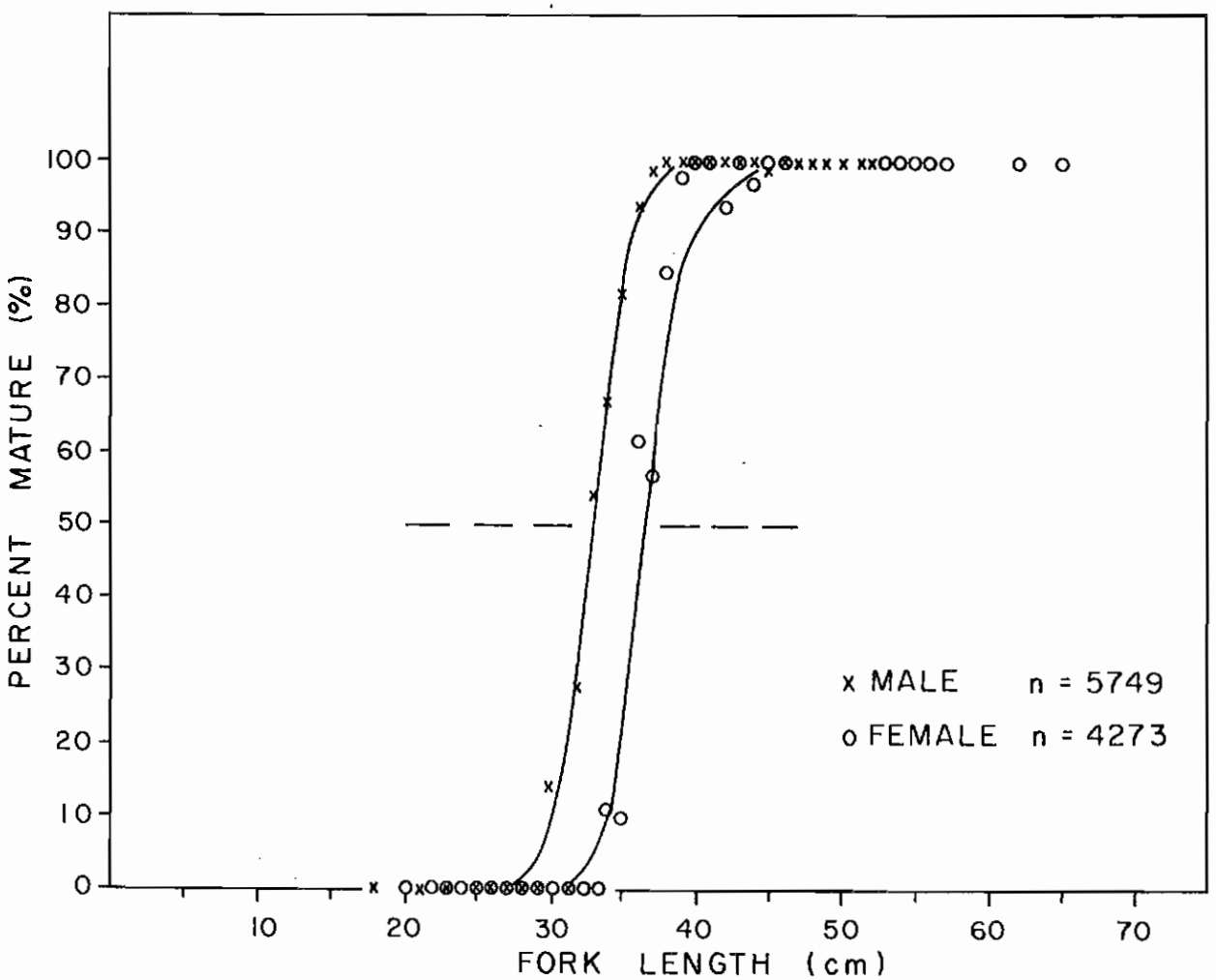

Fig. 26. Pacific hake length at 50% maturity, Strait of Georgia, February 20-April 3, 1981.

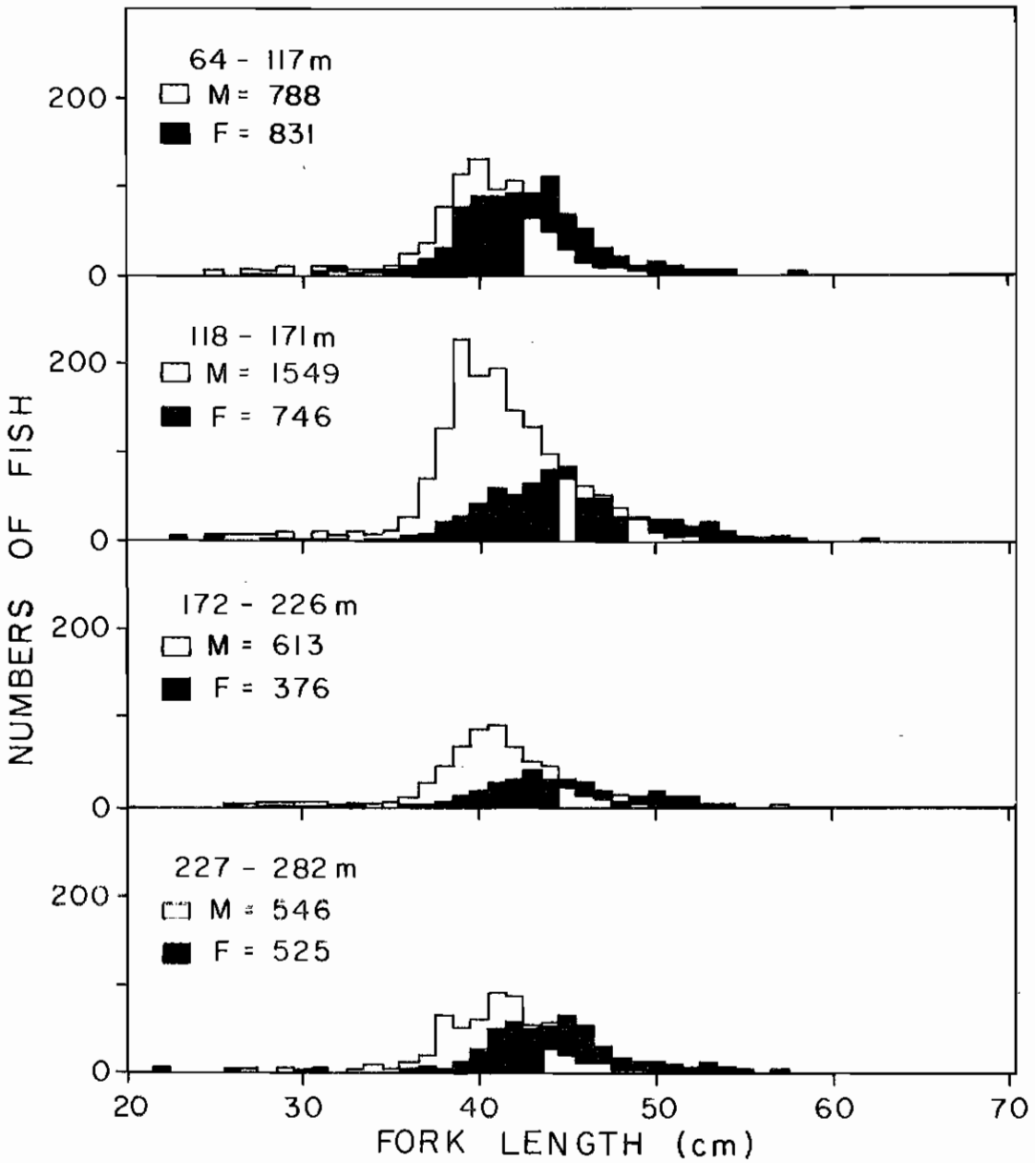

Fig. 27. Length frequency of walleye pollock, by depth interval, Strait of Georgia, February 20-March 3, 1981.

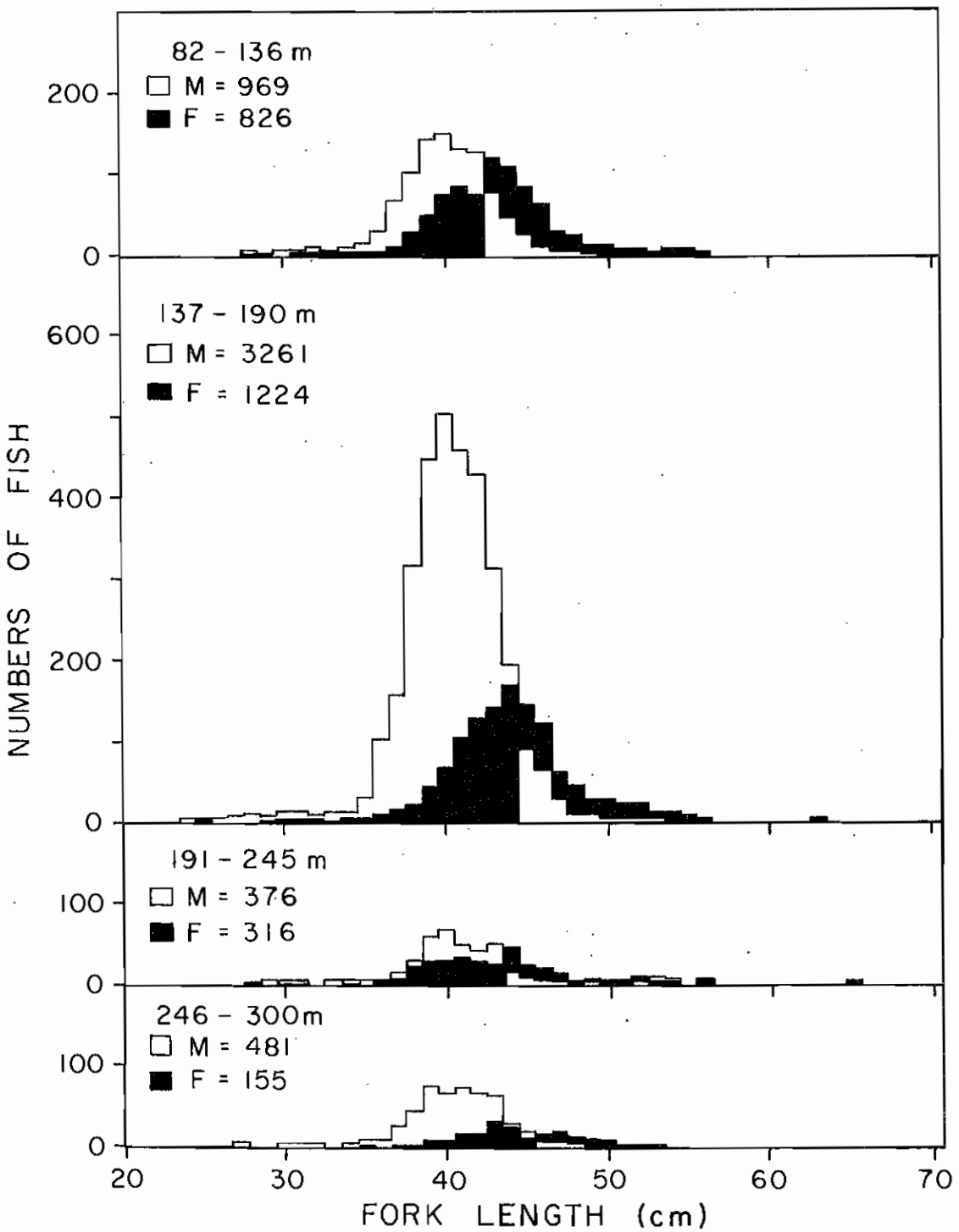

Fig. 28. Length frequency of walleye pollock, by depth interval, south central Strait of Georgia, March 24-April 3, 1981.

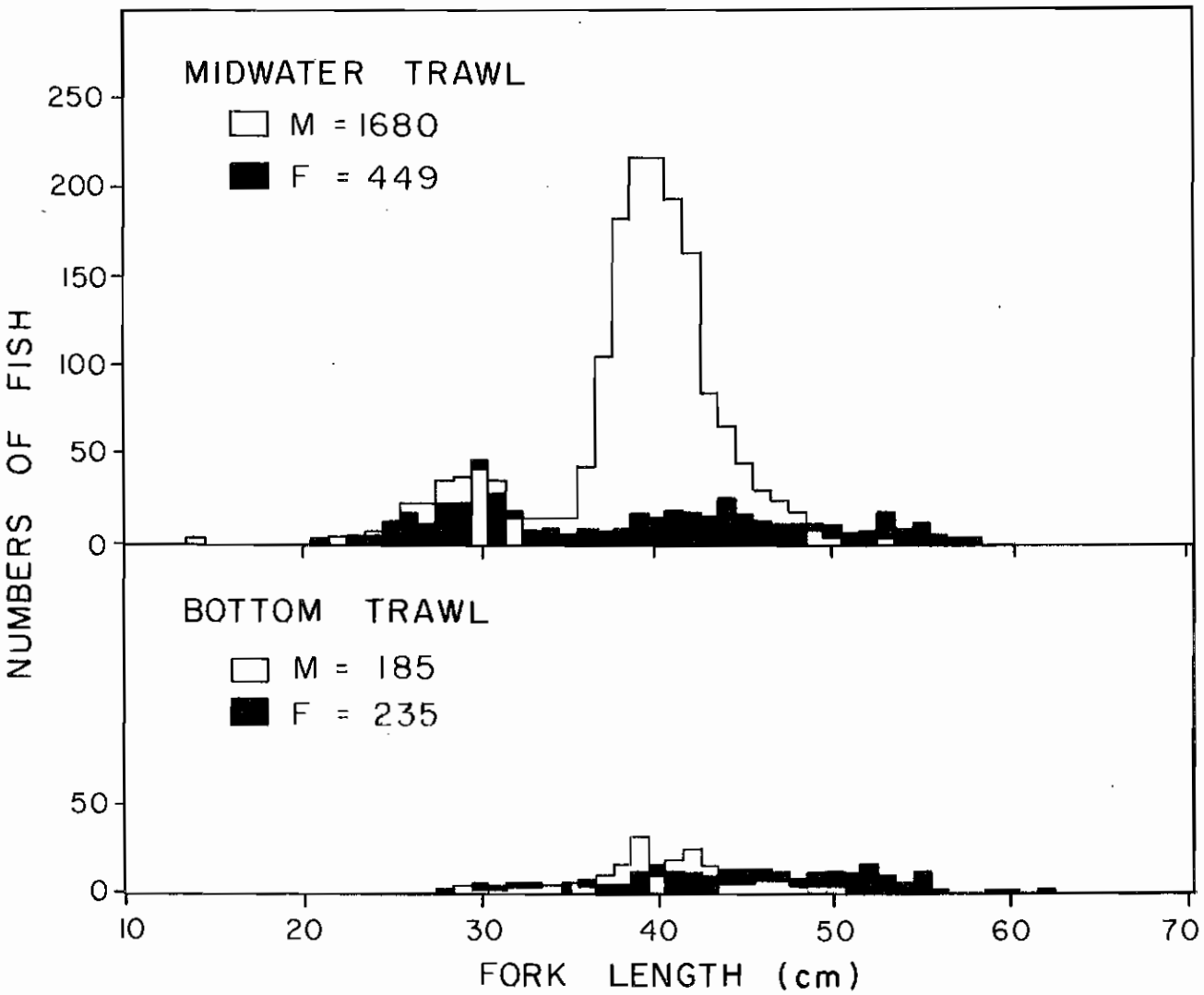

Fig. 29. Length frequency of walleye pollock, for midwater and bottom trawl samples collected in the Active Pass-Point Roberts area, April 9-12, 1981.

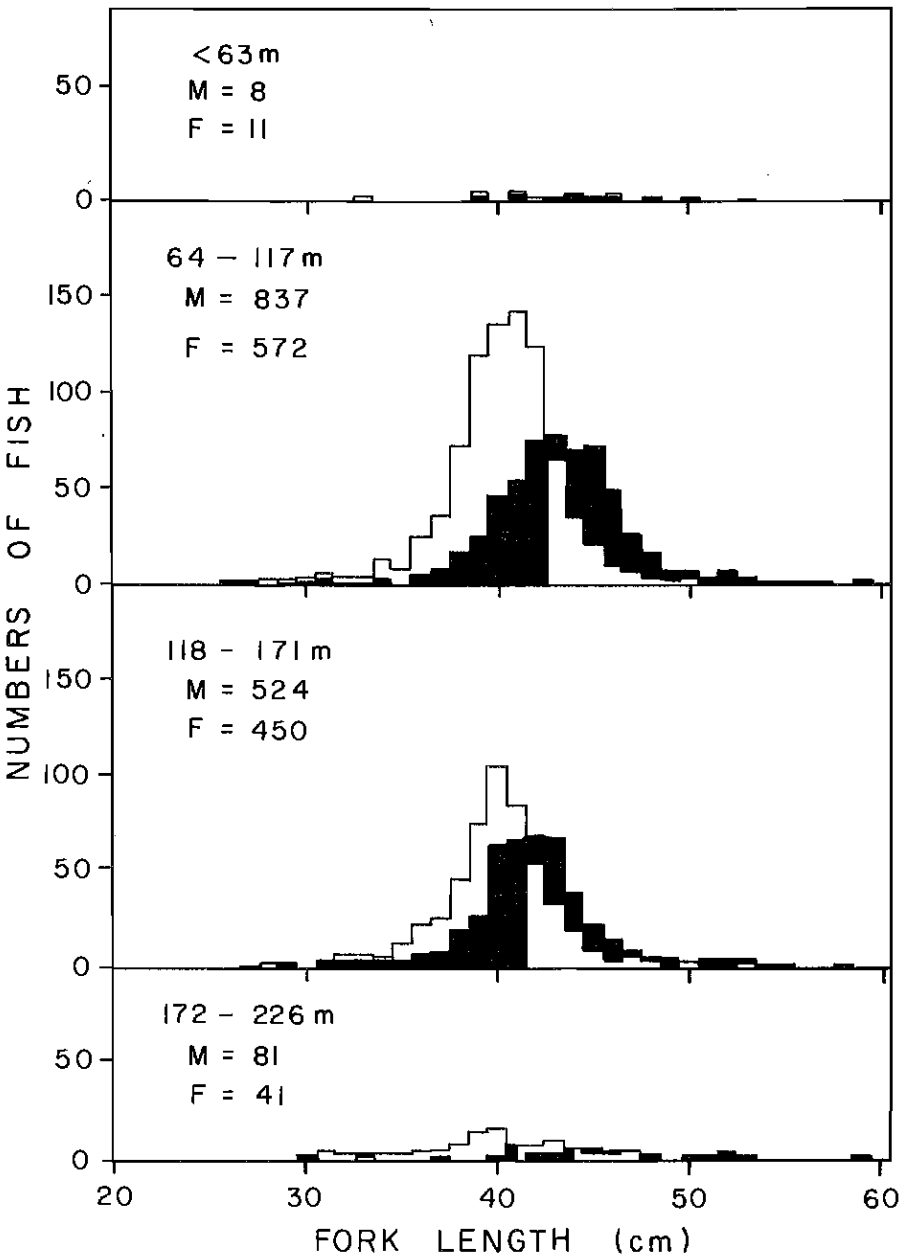

Fig. 30. Length frequency of walleye pollock, by depth interval, Strait of Georgia, April 22-May 2, 1981.

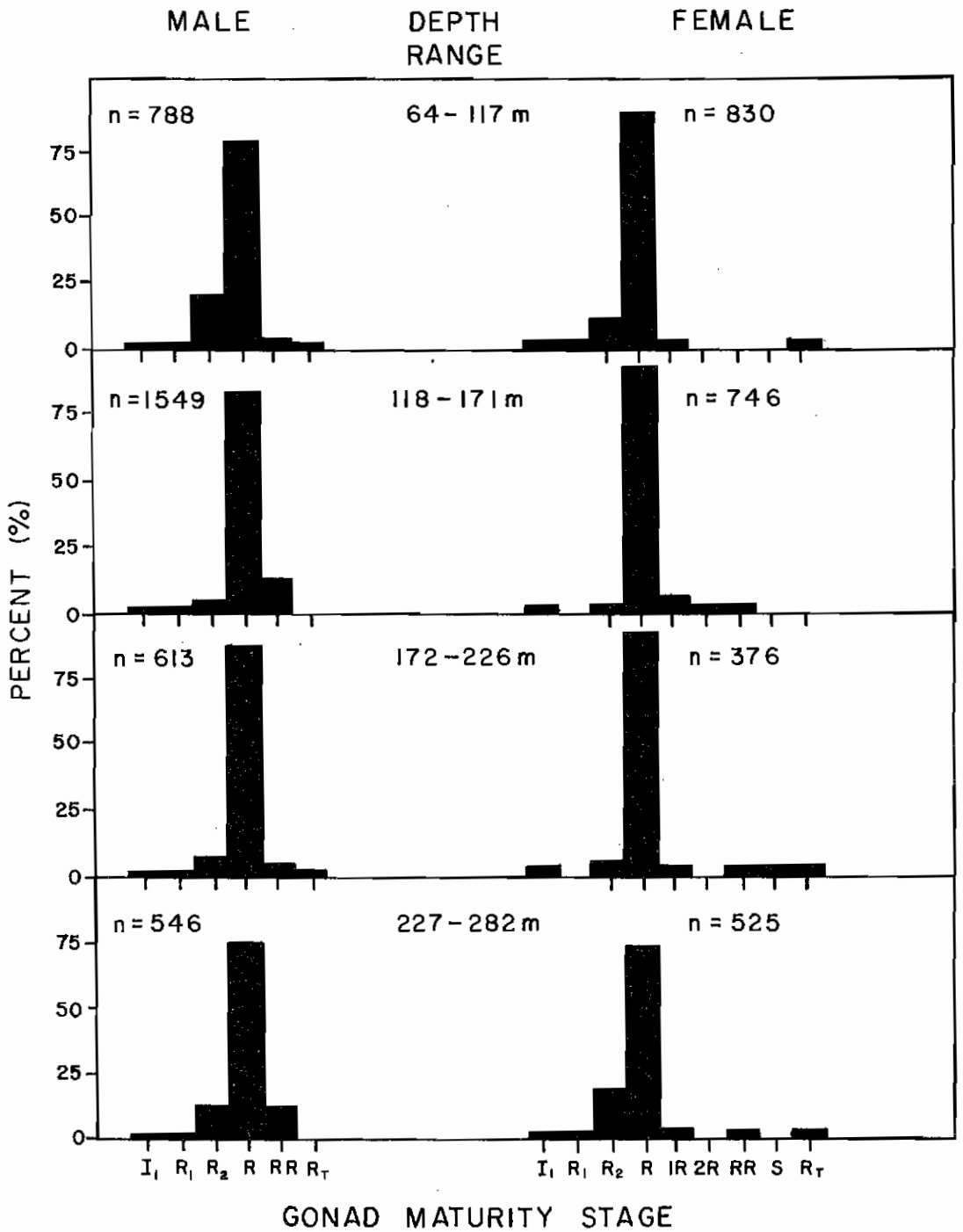

Fig. 31. Walleye pollock gonad maturity stages, by depth interval, collected throughout the Strait of Georgia, February 20-March 3, 1981.

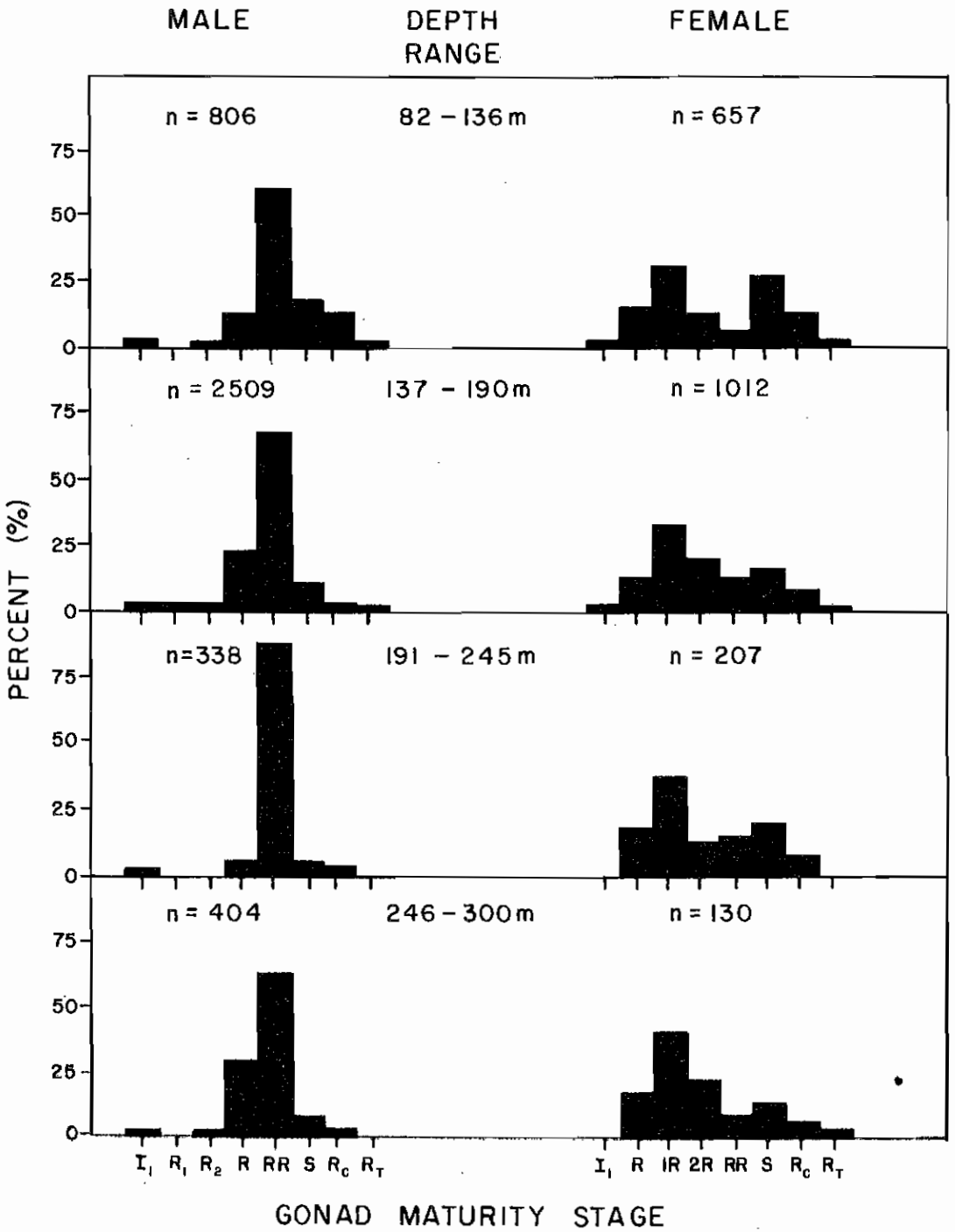

Fig. 32. Walleye pollock gonad maturity stages, by depth interval, collected in the south central Strait of Georgia, March 24-April 3, 1981.

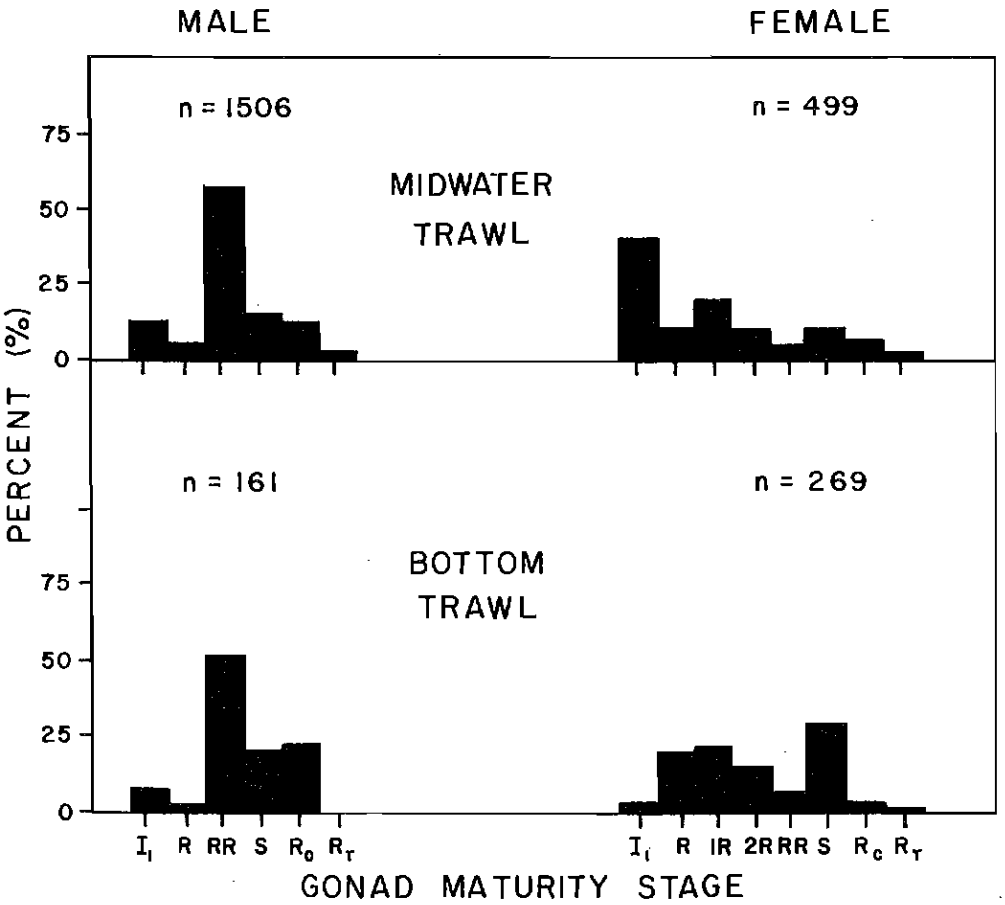

Fig. 33. Walleye pollock gonad maturity stages, for midwater and bottom trawl samples, collected in the Active Pass-Point Roberts area, April 9-12, 1981.

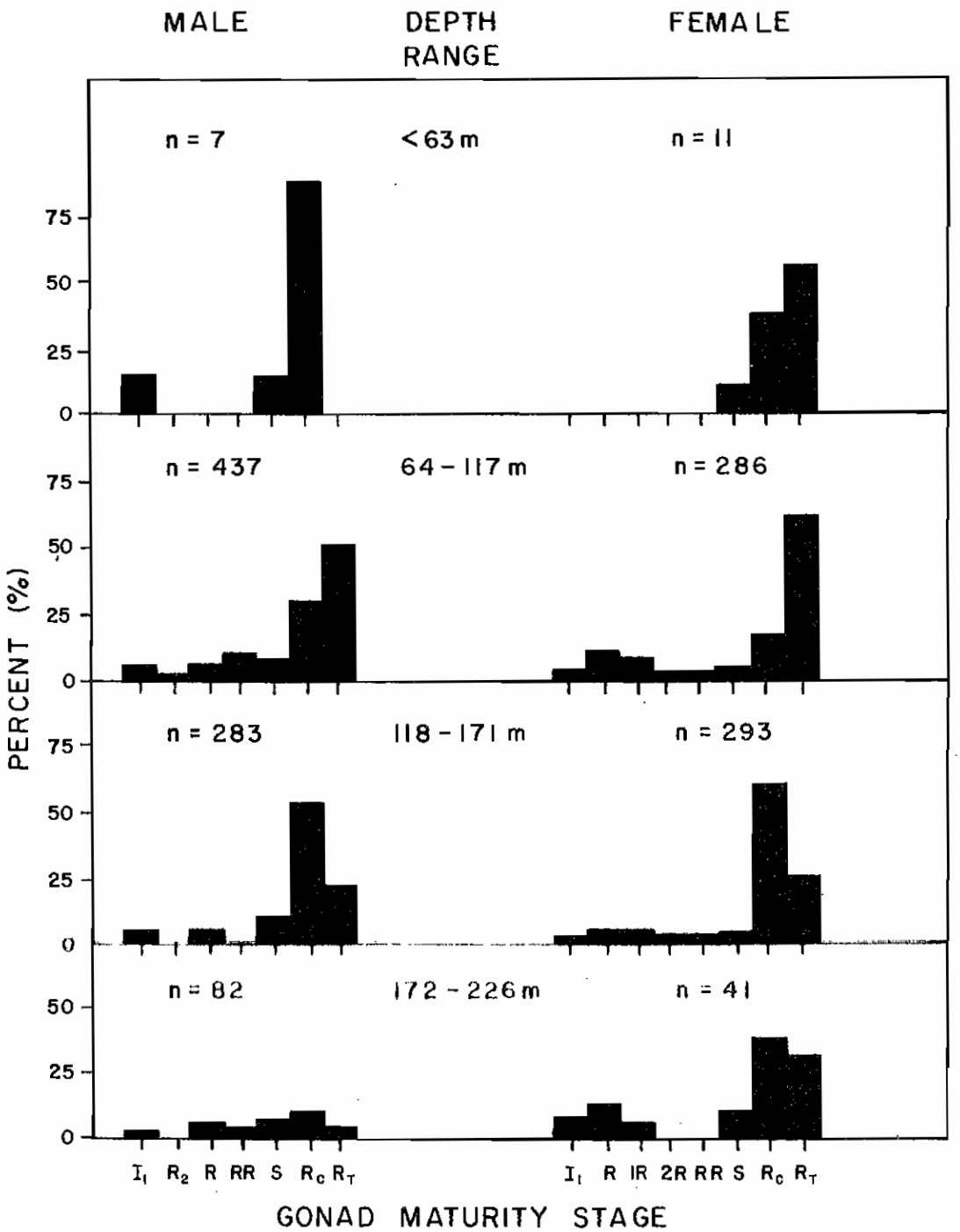

Fig. 34. Walleye pollock gonad maturity stages, by depth interval, collected throughout the Strait of Georgia, April 22-May 2, 1981.

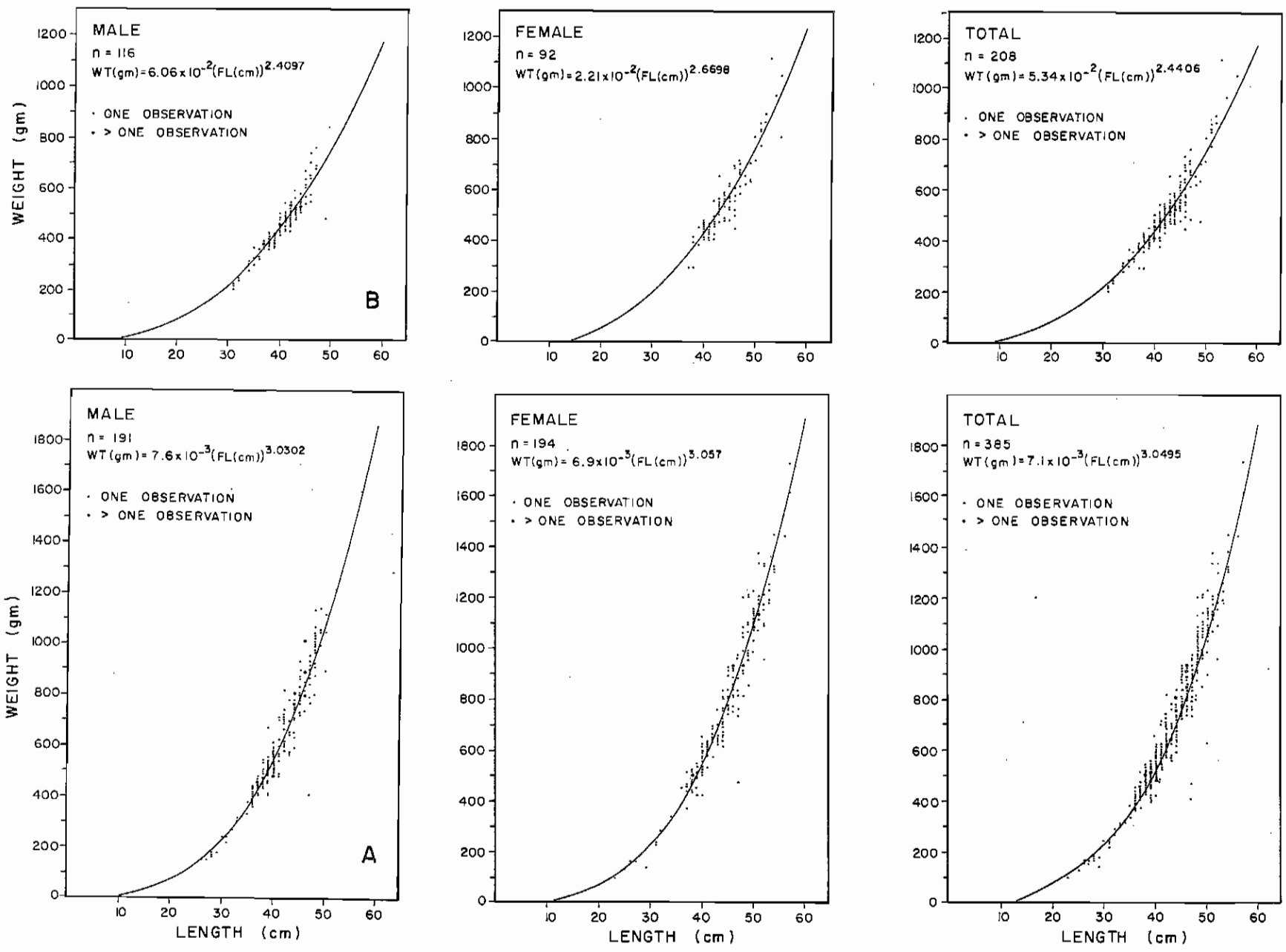

Fig. 35. Length-weight relationship for walleye pollock collected in the south central Strait of Georgia. A. February 20-March 3, 1981. B. March 24-April 3, 1981.

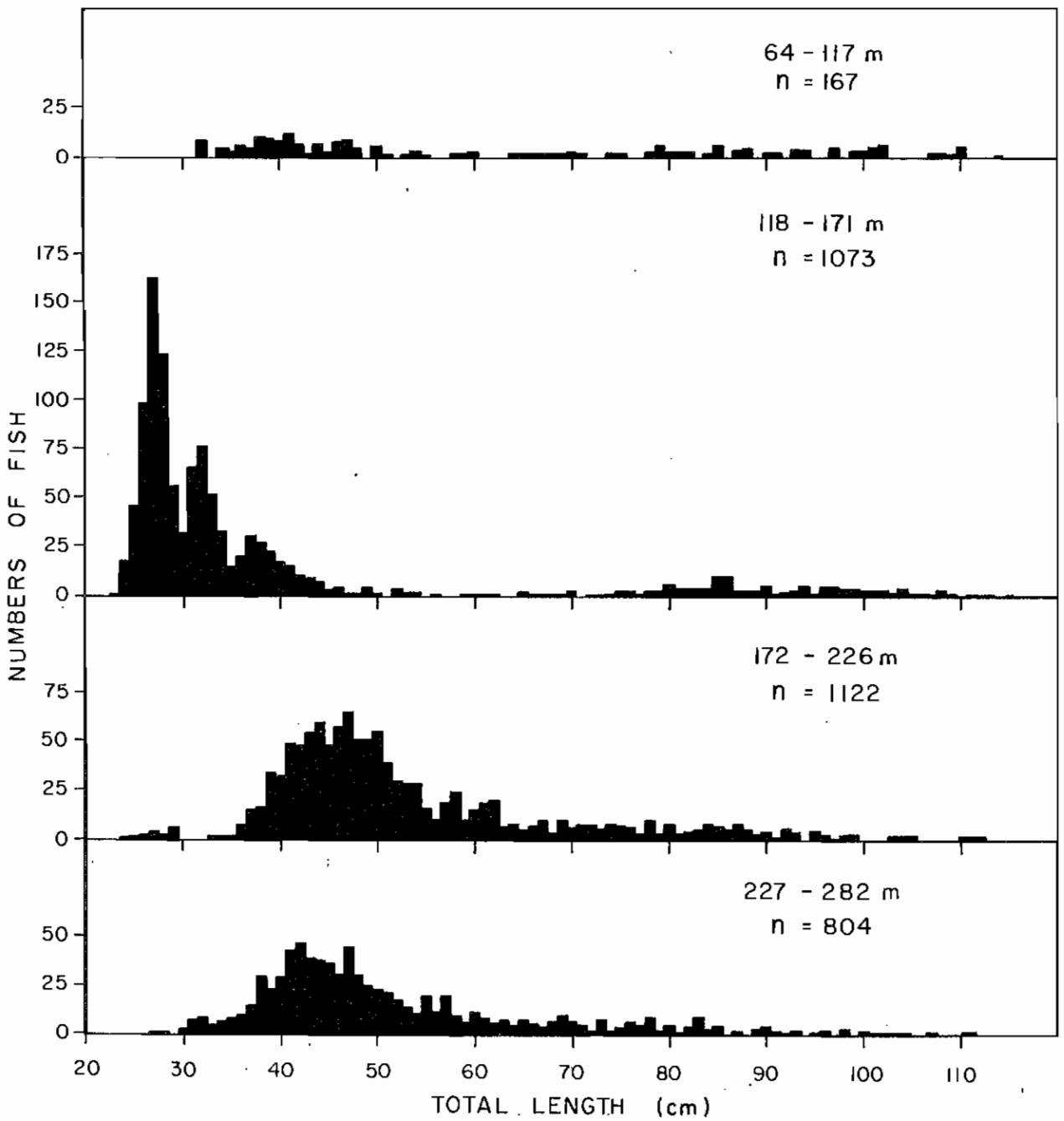

Fig. 36. Length frequency of dogfish, by depth interval, collected throughout the Strait of Georgia, February 20-March 3, 1981.

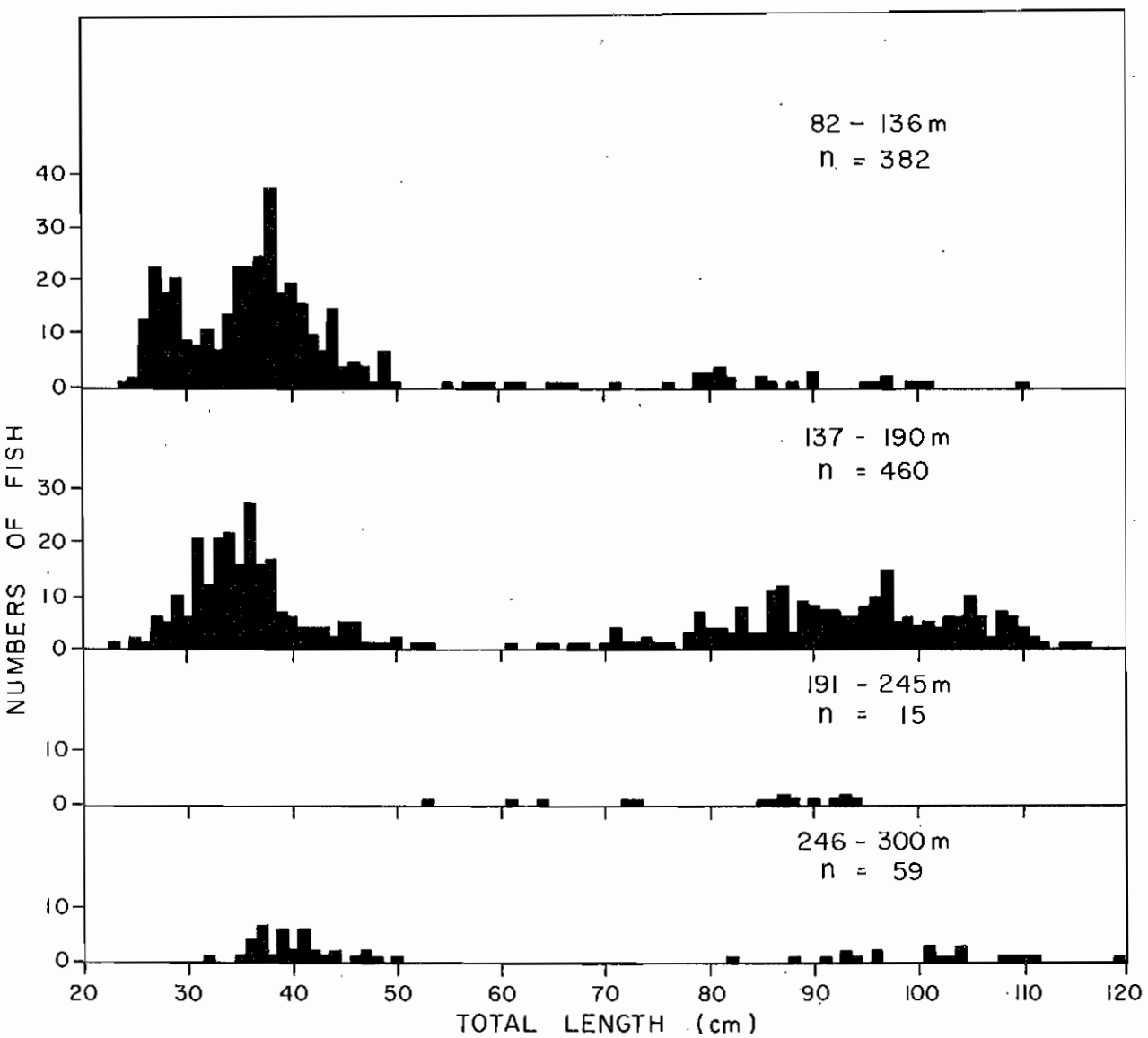

Fig. 37. Length frequency of dogfish, by depth interval, collected in the south central Strait of Georgia, March 24-April 3, 1981.

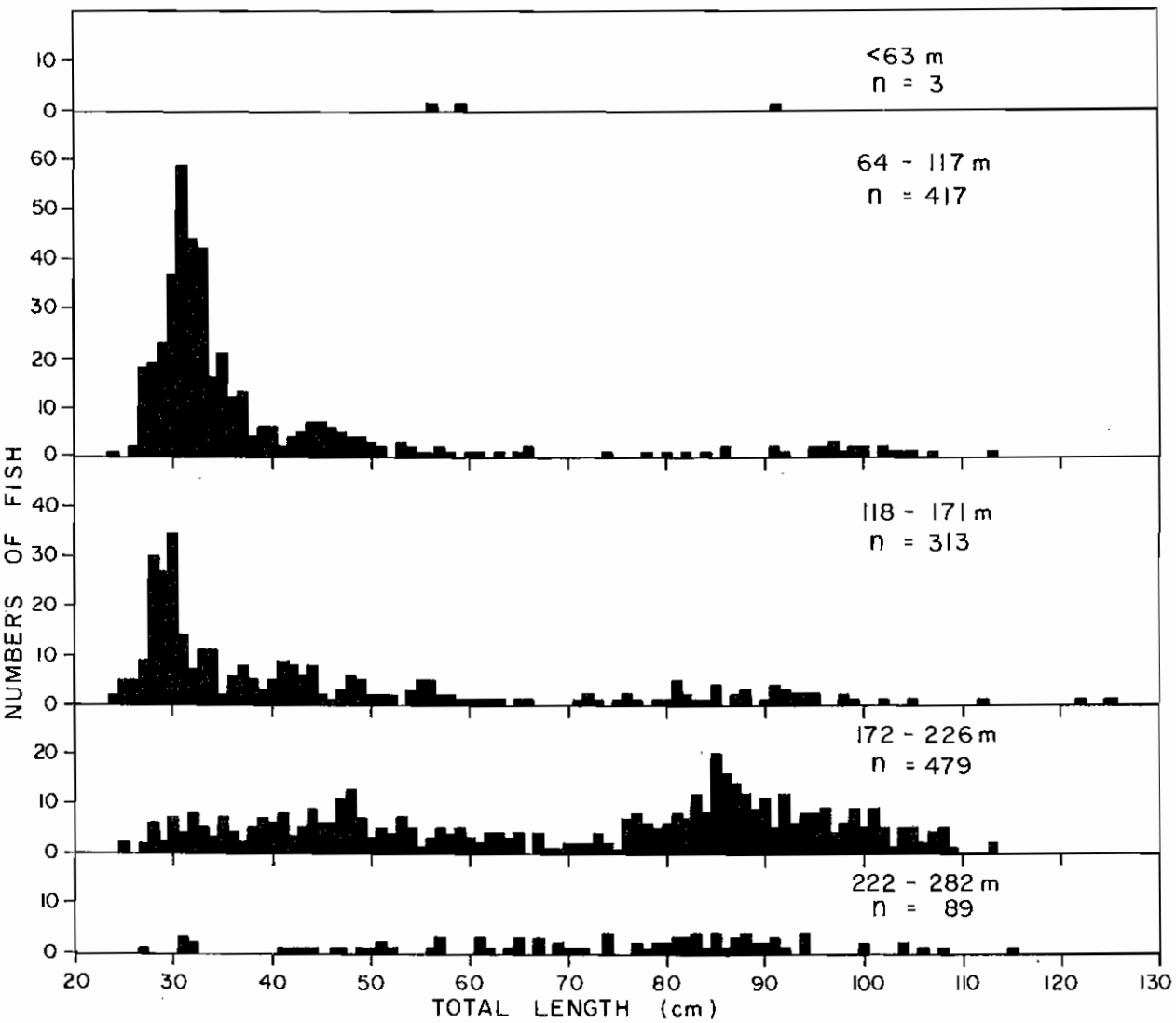

Fig. 38. Length frequency of dogfish, by depth interval, collected throughout the Strait of Georgia, April 22-May 2, 1981.

Appendix table 1. Pacific hake - maturity states.

	Female	Male
Immature 1 I-1	Virgin, ovary small, light pink and semi-transparent	Virgin, testes small, no convolutions.
Immature 2 I-2	Virgin, ovary still small, light pink and semi-transparent, some ova but without yolk.	Virgin, testes small and pink but convoluted.
Riping 1 R-1	Ovary small but starting to enlarge, fills about 1/4 body cavity, light yellow ova with yolk and opaque, blood vessels on ovary pronounced.	Testes about 1/4 body cavity and convoluted, contains small amount of milt, convolutions firm and pink.
Riping 2 R-2	Ovary larger, filling more than 1/3 the body cavity, yellow. Ova with yolk and opaque, blood vessels on ovary pronounced.	Testes about 1/2 body cavity, convoluted, loose and about 2/3 full of milt, edge of convolutions pink and firm.
Ripe R.	Ovary translucent yellow, fills 1/2-2/3 the body cavity, yellow ova opaque or translucent.	Testes large, convoluted and full of milt, fills about 2/3 of body cavity, some milt may flow from vent with pressure.
1 Ripe	Ovary large, fills 1/2-2/3 the body cavity, less than 1/2 the ova are translucent.	No stage in males.
2 Ripe 2R	Ovary large, fills 2/3 the body cavity, more than 1/2 the ova are translucent.	No stage in males.
Running ripe R.R.	Translucent ova flow from vent with slight pressure, ovaries almost fill body cavity, ova opaque or translucent, ova loose in ovary. Ovary translucent.	Testes large, milt flows from vent with slight pressure, edge of testes may be bloodshot in fresh specimens.
Spent S.	Ovary bloodshot, purple in color, some ova may remain translucent. Ovary flaccid about 1/3 body cavity.	Testes bloodshot and flaccid, may contain some milt, now reduced to less than 1/2 body body cavity.

Appendix table 1 (cont'd).

	Female	Male
Resorbing Resb.	Fish has not spawned, ovaries large, about 1/2 body cavity and is soft and flaccid, ova are large and watery.	No stage in males.
Recovery Rec.	Ovaries returning to pre-ripening size, less than 1/2 body cavity, not flaccid, moderately firm. Ova small, no bloodshot appearance.	Testes moderately firm, little milt and loose convolutions.
Resting Rest.	Ovaries small less than 1/4 body cavity, moderately firm, bloodshot appearance gone, white sheen to external ovary surface.	Testes small, firm and pink, may be some milt, with convolutions, less than 1/4 body cavity.

Appendix table 2. Walleye pollock - maturity stages.

	Female	Male
Immature 1 I-1	Virgin, no ova, ovary small and semi-transparent	Virgin, testes small, transparent, no convolutions of few and small convolutions.
Immature 2 I-2	Virgin, some ova but scattered in ovary, ovary semi-transparent and small, ova opaque.	Virgin, testes small and convoluted.
Ripening 1 R-1	Ovary starting to enlarge fills about 1/4 body cavity, ova opaque, blood vessels pronounced.	Testes beginning to enlarge fills about 1/4 body cavity, convoluted firm and beginning to contain milt.
Ripening 2	Ovary large, fills 1/3-1/2 body cavity, blood vessels pronounced, ova opaque.	Testes large, fills about 1/3 body cavity, extremely convoluted, contains milt.
Ripe R	Ovary large, fills 1/2-2/3 body cavity.	Testes extremely convoluted, filled with free flowing milt, testes large, fill 1/2-2/3 body cavity.
Running Ripe R.R.	Ovaries very large, ova flow from vent with slight pressure.	Testes very large, milt flows from vent with slight pressure.
Spent S.	Ovary bloodshot, purple in color, some ova may remain, ovary flaccid.	Testes bloodshot, may contain milt.
Resorbing Resb.	Ovaries large, watery; ova large, soft and flaccid.	No stages in males.
Recovering Rec.	Ovaries returning to pre-ripening size moderately firm, white sheen to external ovary.	Testes small moderately firm, some milt and losing convolutions.
Resting Rest.	Ovaries small and semi-transparent, ova opaque.	Testes small, firm, little milt and convoluted.