Canadian Manuscript Report of
Fisheries and Aquatic Sciences 2086

1990

LENGTH-AT-AGE BY SEX FOR PACIFIC COD IN BRITISH COLUMBIA

by

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Cat. No. Fs 97-4/2086E ISSN 0706-6473

Correct citation for this publication:

Foucher, R. P. and A. V. Tyler. 1990. Length-at-age by sex for Pacific cod in British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2086: 39 p.

ABSTRACT

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For Pacific cod (Gadus macrocephalus), relatively minor differences in size-at-age between males and females were found through the use of five analytical methods. We also discovered that the proportion of females increased with size to the extent that males were virtually absent in larger size categories. Thus, minor size-at-age differences among large fish would be unlikely to influence modal analysis of length-frequency data for age determinations for Pacific cod without separating the data by sex.

RÉSUMÉ

Foucher, R. P. and A. V. Tyler. 1990. Length-at-age by sex for Pacific cod in British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 2086: 39 p.

Dans le cas de la morue du Pacifique (Gadus macrocephalus), l'utilisation de cinq méthodes d'analyse a permis de relever des différences relativement mineures au niveau de la taille en fonction de l'âge, entre les mâles et les femelles. Nous avons également remarqué que la proportion de femmelles augmentait avec la taille au point oü il n'y avait pratiquement plus de mâles dans les catégories de poissons de grande taille. Les petites différences de taille en fonction de l'âge chez les poissons de grande taille auraient donc peu de chance d'influer sur l'analyse modale des données sur la fréquence des longueurs pour déterminer l'âge chez la morue du Pacifique sans séparer les données selon le sexe.

INTRODUCTION

There seems to be little published information as to the degree of difference in growth rate or mean-length-at-age by sex for Pacific cod in British Columbia waters.

Reports for Pacific cod in Alaskan waters (Brown et al. 1984; Brown and Wilderbuer 1984) have presented evidence, based on scale readings, for a difference in rate of growth by sex. In contrast, in a paper examining results of tagging projects in Hecate Strait, Ketchen (1984) stated that "It remains uncertain whether there is a significant difference in growth rate between the sexes."

Any conclusive evidence would have to be based on a reliable ageing method. Various structures - scales, vertebrae, otoliths and opercular bones - have been investigated with questionable success. Fin rays are still under investigation, with present results showing that zones on sectioned fin rays are very clear and correct interpretation can provide details on the growth pattern (Beamish et al. In press). Some of the problems associated with scales, which were used for a number of years in both British Columbia and Alaskan waters, have been demonstrated in Foucher and Fournier (1982), Foucher et al. (1984) and Bakkala (1984).

Because the stocks of Pacific cod in Canadian waters appear to have only seven or eight age classes that can be detected as distinct modes, routine estimations of age composition have been carried out using length-frequency data only. A modal analysis method, described by Foucher and Fournier 1982, has been used to estimate age composition for samples collected as far back as the mid 1950s. This method of age determination has been used without regard to a possible difference in growth rate by sex mainly because the fish sampled were not identified to sex for most of the time series.

The work reported here is one of the first to examine factors affecting the validity of the method of age-determination by length-frequency analysis. Beamish et al. (In press) compared results from the length-frequency and fin-ray methods and found that both methods appeared to produce similar estimates of age composition. The present paper examines the evidence for any significant difference in mean length at age by sex and evaluates the impact this might have on the age-determination method.

METHODS

To calculate and evaluate mean lengths at age by sex, five different methods are used here:

1) Age determination using skeletal structures. The results of some previous work (unvalidated) are examined to assess the usefulness of this information. Also, Pacific cod from eight commercial fishery samples and one research sample collected between May 1986 and June 1989, were aged by fin-ray analysis (Beamish et al. in press). These results are examined for significant differences in mean length at age by sex.

2) Tagging experiments. Past tagging experiments have been analyzed by Ketchen (1984) and Westrheim (1985). Results are examined here in light of the present question.

3) Prominent modes. Isolated, prominent modes which can reasonably be assumed to represent a single age group are examined for significant differences in mean lengths by sex. This is most useful for younger age groups which tend to be less mixed with adjacent age groups. A range of lengths is identified by eye which contains as much as possible of the mode being examined while excluding those lengths which might be part of the next age group. The mean and standard deviation of the fish thus selected is calculated by sex and the t-test is used to test for significant differences.

4) Age determination by length-frequency analysis. This method is used to determine age composition separately for males and females from the same samples. These tests were done blind (without knowledge of the sex of the length-frequency at the time of age determination) to guard against bias. The t-test was used to test for significant differences in the resulting mean lengths. The samples analyzed are grouped by month from individual samples taken at port from commercial landings in Hecate Strait. Months were selected which had large sample sizes and, for a few cases, prominent modes.

5) Sex ratio. Calculate the percentage of females by length over the range of lengths sampled. Deviations from an equal mixture could indicate differences by sex in any one or more of the following: growth rate, mortality rate, or behaviour such as spawning migrations. While it is not possible to separate these factors, this procedure could help identify to what degree age determination of samples with sexes combined might be a problem. If the proportion of males in the larger length intervals is very low, then the effect of any difference in mean length at age by sex on the age-determination method's ability to separate age groups will be minimized. Results are plotted with the ratios smoothed over 3 cm with equal weighting.

RESULTS

1) Age determination using skeletal structures. While

evidence has been reported for a difference in mean length at age by sex for Alaskan waters, other age determinations produced by the same agency (Alaskan Fisheries Science Centre) for cod from the eastern Bering Sea have been shown to be in error (Bakkala 1984). Interestingly, it was length-frequency analysis that revealed the problem. Bakkala described how the high abundance of small fish in 1978 and the understanding that cod peaked in the fishery at age 3 lead to a prediction of increased landings in 1980. When this did not occur and a modal analysis was carried out, it was discovered that the dominant mode had been assigned to two age groups. Other evidence helped to show that the dominant mode in the distributions of 1978-80 were composed of only one age group, in each case corresponding to the strong 1977 year class. The explanation, by careful examination of modes, for the late recruitment of the strong 1977 year class adds credibility to the use of length-frequency analysis. The results cast doubt on the other Alaskan results and, also, on other scale readings using the method of Kennedy (1970). Westrheim and Shaw (1982) further describe the difficulties with this method. Differences in mean length-at-age by sex from scale readings are not considered dependable.

An investigation (Beamish et al. In press) comparing the length frequency and fin-ray methods of estimating age of Pacific cod found similar age compositions from the two methods. In 35 cases (each with at least 10 fish), in which mean lengths at age of males and females could be compared using results of fin-ray analysis, neither sex dominated overall as the larger:

Incidence, by sex, of greater mean length at age

	Age								
	1	2	3	4	5	6	7	8	Total
Males larger	1	6	4	1	2	1	-	1	16
Females larger	1	2	4	6	1	2	2	1	19

Of these, there were four instances of a significant difference (T-test) in mean lengths at age, two for each sex. Males were larger at age two in both cases; whereas females were larger once each at ages three and four (Table 1).

The mean lengths as determined by fin-ray analysis (Table 1 and Figure 1) show some doubtful growth patterns. For instance, of fish sampled January 14, 1987, the mean length of 25 males assigned to age 3 was 46.4 cm, only 1.7 cm greater than the mean length of age 2 males of 44.7 cm, the latter being a length consistent with other observations for age-2 fish at this time. For the April 8, 1987 sample, the same difference is only 0.2 cm. For females sampled December 10, 1986, the mean length found for age-2 females was only 0.3 cm larger than for age 1. This unrealistic growth pattern casts doubt on any suggestion that fin-ray analysis shows a difference in growth rate by sex.

2) Tagging experiments. Growth rate as revealed by tag-return data has not shown a difference by sex. The report of results from tagging experiments in 1978 and 1979 (Westrheim 1985) did not include any description of growth rates by sex because of the small number of returns that were identified to sex. Ketchen (1984) did calculate growth rates by sex but did not find any conclusive evidence for different growth rates. In an earlier paper, Ketchen (1964) had concluded that variations in growth rate noted among fish recovered from a tagging at White Rocks Ground were more likely due to there being fast and slow growing components in the population.

3) Prominent modes. Twenty samples were located from the Strait of Georgia, of fish that had been sexed and in which the distribution included a prominent mode. For the age group corresponding to the prominent mode, mean lengths-at-age by sex were calculated. The results, arranged by mean length of males (Table 2) that females were larger than males in 12 and males were larger than females in 8 of the 20 cases. There was a statistically significant difference in mean length by sex for only two samples. For the March 1977 sample of 88 fish, the mean length of females (47.4 cm) was 1.4 cm longer than that for males (46.0 cm). For the March 1978 sample of 316 fish, the mean length of females (56.2 cm) was 0.9 cm larger than that for males (55.3 cm). Thus, there is evidence for a small difference in mean length by sex. However, the difference observed here, of up to 1.4 cm, while significant, is small compared to the difference in mean length between ages. For example, age-2 males in March 1977 were 46.0 cm and age-3 males in March 1978 were 55.3 cm, an increase of 9.3 cm.

A test for significant difference in mean length-at-age by sex from fish within prominent modes sampled from the west coast of Vancouver Island (Foucher et al. 1980) showed no significant difference between age-2 male and female fish from Big Bank (Table 3, Figure 2) but a significant difference for age-3 male and female fish from Firing Range (Table 3, Figure 3) with females being 1 cm longer.

No significant difference in mean length-at-age by sex was found for two samples from Queen Charlotte Sound (Table 4).

For Hecate Strait, comparisons were made between mean lengths of males and females for obvious modes in length frequencies from various grounds. Of the 13 comparisons made (Table 5), the mean length of males was greater in six cases and females were greater in seven cases. However, all but one of these were for fish aged two or less. Only three cases yielded a significant difference by sex and, in one of these, the males were significantly larger than the females.

In summary, by area:

Area	Number of tests	Number of significant differences	Number of sign. results with females > males
Strait of Georgia	20	2	2
W. coast Vancouver Is.	2	1	1
Queen Charlotte Sound	2	0	0
Hecate Strait	13	3	2

4) Age determination by length-frequency analysis. For the six samples selected (Table 6), the length-frequency method estimated mean lengths at age of females to be significantly longer than for males in 16 age groups (significance level = 0.05, t-test). Males were significantly longer in 5 cases. Considering only the dominant age class in each sample, females had a greater mean length in four cases and males in two. In four of these six samples, the dominant mode was composed of age-4 fish, most of which would be mature.

For the three samples where age-4 was the dominant age class and females were significantly larger than males, it is of interest to examine the difference in mean length between males and females. This difference between sexes can be compared to the difference in mean length between adjacent ages:

	Age 4 females	Age 4 males		Age 3 females		Age 5 females	
	Mean (A)	Mean (B)	Diff. (A-B)	Mean (C)	Diff. (A-C)	Mean (D)	Diff. (D-A)
March 1986	68.6	67.3	1.3	61.7	6.9	73.9	5.3
April 1986	65.7	63.6	2.1	59.2	6.5	73.4	7.7
July 1983	65.0	63.8	1.2	57.8	7.2	70.9	5.9

The differences between sexes are small compared to the differences between adjacent ages. Specifically, the differences in mean length (column A-B above) between age-4 males and females for the three samples are 1.3, 2.1 and 1.2 cm. These differences (A-B) between sexes are 18.8, 32.3 and 16.7%, respectively, of the differences between age 3 and 4 females (A-C). Similarly, the same differences (A-B) are 24.5, 27.3 and 20.3%, respectively of the difference in mean length between age 4 and age 5 females (D-A). This gives an indication that differences by sex would hardly be confused with differences by age group. For example, the March 1986 length-frequency distributions for each of males and females are very similar, though the females are slightly larger (Figure 4).

For comparison, we estimated age composition, by sex, for the March 1986, April 1986 and July 1983 samples (Table 7). The total age frequency, obtained by summing the number at age for each sex (aged separately), is very similar to that obtained when the whole sample is aged with both sexes included (Figure 5).

That males do not generally reach the same size as females, is apparent from Table 6 where mean length at age is given for six samples. This could be due to decreased growth rate, increased mortality, altered behaviour that interferes with sampling results (such as spawning migrations) or some combination of these. On the other hand, if it were solely from decreased growth rate it should be revealed in an examination of the sex ratio by length categories as detailed below.

5) Sex ratio. The percentages at length calculated for commercial samples from Amphitrite Bank for February 1977 (Figure 6) and 1978 (Figure 7) show that males were more common than females until 65 cm (1977) or 72 cm (1978). Beyond these lengths females were more common, making up more than 75% at 73 cm (1977) and at 76 cm (1978).

The overall pattern of percentages by length of females for commercial samples from southern Queen Charlotte Sound collected during April-June 1977-82 was similar to that for Amphitrite Bank. One difference was that for smaller sizes the sex ratio was much closer to 50:50 (Figure 8). Beyond 72 cm females made up more than 75%. The high percentage of females at 37-40 cm was affected by sample size with only 1 or 2 fish in each interval.

Calculation of the percent females at length for 2,562 fish sampled from Two Peaks Ground during a research cruise in September 1979 (Westrheim et al. 1980) again showed the percentage of females at smaller sizes varying around 50%. Females dominated above 68 cm and made up more than 75% at 82 cm (Figure 9).

DISCUSSION AND CONCLUSIONS

Until a method of ageing using a skeletal structure can be shown to be valid, direct ageing will not be able to reliably demonstrate whether there is any difference in growth rate by sex.

Tagging of fish at all ages and their recapture over extended periods would be the most certain method of determining growth rates by sex. However, because of the high natural mortality rate of Pacific cod and the large proportion that are typically returned within a few months of tagging, a very large number of fish would have to be tagged to get a significant number of returns one or two years later. Experiments so far have not had enough returns to demonstrate a difference in mean length at age by sex.

The analysis of modal lengths showed some evidence of higher growth rates for females but not consistently. Significant differences in growth rates by sex would be expected to show up mainly after maturation. Because modes for older ages become less distinct from each other, modal analysis is less useful for older fish.

Significant differences in mean length at age by sex as determined by length-frequency analysis were not common nor did they always indicate that females were larger. Where significant differences were found, the effect on age composition appeared to be minimal as the difference in mean length at age between sexes was small relative to that between ages.

The observed, lower percentage of females of smaller sizes from the west coast of Vancouver Island is consistent with a possible behavioral pattern in which males remain longer in the area sampled which is a known spawning ground, while groups of females arrive, spawn and leave, and are therefore less vulnerable to capture. Such patterns are found in other species such as Dover sole (Harling et al. 1977) and Petrale sole (Ketchen and Forrester 1966). The sex ratio was much closer to 50:50 in samples from other areas in seasons other than the spawning season.

For areas where fish were captured during a season other than the time of spawning, the observed lower proportion of males among large fish could be due to a mixture of lower growth and increased mortality. It is likely due more to increased mortality because, if it was from lower growth, an increased percentage of males at intermediate lengths would be expected (assuming a 50:50 mixture to start with).

The difference in mean length for successive age groups decreases with age, so it is possible that different growth rates for males and females could complicate the age-determination process for older age groups. However, as Ketchen (1961) mentions and as results reported here show, the sex ratio beyond age 4 considerably favours females. This greatly reduced availability of males would tend to reduce the effects of ageing error resulting from any difference in growth rates. In view of this effect and the inconclusive evidence that females consistently are significantly larger than males of the same age, the dangers of significant ageing errors are probably minimal. Age determination results for the historical collection of length-frequency samples (much of which was not sexed) probably do not contain significant error from this source. Future age determinations by length-frequency analysis could be done disregarding sex, however, where sample size is sufficient, separating by sex before age determination may slightly improve the ability to discriminate between age classes.

ACKNOWLEDGEMENTS

Readings of fin ray ages were done by R. Beamish and D. Gillespie. The manuscript was reviewed by D. Gillespie, S. MacLellan and R. Stanley.

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Table 1. Numbers, mean lengths and standard deviations, by sex, by age, and t-test results for comparisons of mean length at age by sex for Pacific cod. Age determinations were by fin-ray analysis.

Date/area[a]/ total no.[b]	Age	Males No.	Males Mean	Males S.D.	Females No.	Females Mean	Females S.D.	D.f.[c]	t	Significant (at 0.05)
Jan 14/87	2	7	44.7	2.50	4	45.8	1.50	9	0.79	No
	3	24	46.3	3.12	24	48.6	3.73	46	2.32	Yes
WR	4	11	53.3	5.85	13	54.7	5.76	22	0.59	No
	5	31	61.6	4.88	29	62.2	5.29	58	0.46	No
N=305	6	22	68.1	6.17	23	67.6	4.78	43	0.30	No
	7	14	70.6	5.65	21	73.9	5.61	33	1.70	No
	8	4	74.8	2.50	12	75.8	3.83	14	0.48	No
	9	0	-	-	5	79.8	8.14	-	-	-
	Total	113			131					
Jan 19/87	2	0	-	-	1	46.0	-	-	-	-
	3	2	50.5	0.71	8	49.8	0.89	8	1.02	No
WR	4	2	56.0	2.83	6	54.7	2.34	6	0.66	No
	5	13	61.2	3.51	15	59.5	3.98	26	1.19	No
N=200	6	14	65.4	4.86	15	65.5	4.55	27	0.06	No
	7	18	68.1	5.40	18	71.2	6.06	34	1.62	No
	8	4	73.3	6.34	10	71.7	4.14	12	0.57	No
	9	4	73.8	3.86	3	77.7	5.86	5	1.07	No
	10	2	78.5	0.71	1	76.0	-	-	-	-
	11	0	-	-	3	74.3	3.06	-	-	-
	Total	59			80					
Apr 8/87	1	3	37.7	2.52	0	-	-	-	-	-
	2	38	43.1	5.35	32	40.8	3.82	68	2.03	Yes
FR	3	53	43.7	5.83	51	43.1	5.14	102	0.56	No
	4	8	54.1	7.12	8	55.3	5.39	14	0.38	No
N=200	5	4	59.8	6.29	1	48.0	-	-	-	-
	6	2	62.0	12.73	0	-	-	-	-	-
	Total	108			92					
Apr 27/87	2	10	50.3	3.97	7	46.9	2.79	15	1.95	No
	3	69	51.0	3.99	61	50.8	4.42	128	0.27	No
HS	4	13	54.4	2.93	7	55.6	3.21	18	0.85	No
	5	1	57.0	-	0	-	-	-	-	-
N=200	6	0	-	-	2	65.5	10.61	-	-	-
	7	1	66.0	-	0	-	-	-	-	-
	Total	94			77					

[a] Area: BU = Butterworth; FR = Firing Range; HS = Horesehoe; NWC = Northwest Corner; RI = Reef Island; SW = Swiftsure; WR = White Rocks.

[b] Not all fish were assigned ages.

[c] Degrees of freedom.

Table 1 (continued).

Date/area/ total no.	Age	Males No.	Males Mean	Males S.D.	Females No.	Females Mean	Females S.D.	D.f.	t	Significant (at 0.05)
May 14/87	2	23	45.2	6.01	20	44.0	3.49	41	0.78	No
	3	50	48.1	5.04	59	48.8	4.97	107	0.73	No
SW	4	15	60.9	7.69	13	57.7	9.51	26	0.98	No
	5	2	59.5	14.85	8	66.1	10.72	8	0.74	No
N=200	6	5	70.6	3.91	2	69.0	2.83	5	0.51	No
	7	1	74.0	-	0	-	-	-	-	-
	Total	96			102					
May 30/86	1	2	40.0	8.49	1	32.0	-	-	-	-
	2	33	54.5	6.98	28	53.3	7.50	59	0.65	No
HS	3	48	62.8	5.01	37	63.9	7.27	83	0.83	No
	4	37	64.8	5.26	38	68.8	4.75	73	3.46	Yes
N=294	5	17	68.6	4.65	12	67.9	8.52	27	0.29	No
	6	9	66.9	4.59	13	69.5	5.90	20	1.11	No
	7	1	77.0	-	3	72.3	5.13	-	-	-
	8	0	-	-	0	-	-	-	-	-
	9	0	-	-	1	80.0	-	-	-	-
	10	1	65.0	-	1	74.0	-	-	-	-
	Total	148			134					
June 1989	1	18	32.9	2.67	13	32.7	3.25	29	0.19	No
	2	17	44.6	5.65	16	46.2	4.76	31	0.88	No
Eastward	3	17	48.4	5.66	26	52.5	7.81	41	1.86	No
Ho charter	4	9	61.3	8.79	16	66.6	6.34	23	1.75	No
- mixture	5	5	65.8	9.31	5	72.6	5.27	8	1.42	No
of grounds	6	0	-	-	5	72.0	5.83	-	-	-
N=150	7	1	59.0	-	-	-	-	-	-	-
	Total	67			81					
Dec 10/86	0	5	44.6	1.82	1	44.0	-	-	-	-
	1	120	46.0	2.39	93	46.5	3.12	211	1.32	No
BU/NWC	2	40	48.7	4.66	41	46.8	3.20	79	2.14	Yes
	3	6	55.7	8.02	5	55.6	10.60	9	0.02	No
N=370	4	4	70.5	4.04	4	66.0	3.74	6	1.63	No
	5	3	71.7	3.51	3	67.3	2.31	4	1.81	No
	6	0	-	-	4	68.8	8.30	-	-	-
	7	1	73.0	-	0	-	-	-	-	-
	8	0	-	-	0	-	-	-	-	-
	9	0	-	-	1	82.0	-	-	-	-
	Total	179			152					

Table 2. Summary of results of t-tests for significant differences in mean lengths of males and females for samples from the Strait of Georgia.

	Males			Females				
Date	Length (cm)	S.D.	N	Length (cm)	S.D.	N	t	$\bar{x}_1=\bar{x}_2$
Age 1								
Dec 1982	40.55	2.12	78	40.51	2.42	81	0.11	Yes
Nov 1982	41.33	1.93	57	41.48	1.54	56	0.46	Yes
Nov 1979	44.95	2.81	80	44.76	2.42	82	0.46	Yes
Dec 1979	45.33	2.01	30	45.90	2.72	20	0.98	Yes
Dec 1978	45.63	1.47	30	45.23	2.00	21	0.82	Yes
Age 2								
Apr 1980	45.65	3.05	102	46.27	2.98	115	1.51	Yes
Mar 1977	46.04	2.64	51	47.43	3.19	37	2.23	No
Feb 1979	46.12	1.87	59	46.67	2.05	76	1.61	Yes
Feb 1977	46.21	2.06	29	45.79	2.42	33	0.73	Yes
Jan 1980	46.70	1.75	41	46.38	2.10	47	0.77	Yes
Aug 1977	52.04	1.82	40	51.79	2.33	53	0.56	Yes
Sep 1980	52.26	2.78	87	52.39	2.93	74	0.29	Yes
Nov 1977	52.36	2.64	194	52.29	2.52	211	0.27	Yes
Age 3								
Jan 1982	53.53	2.13	83	53.76	2.32	72	0.64	Yes
Mar 1982	55.13	2.73	87	55.21	2.86	146	0.21	Yes
Mar 1978	55.27	2.78	188	56.15	3.02	128	2.67	No
Dec 1978	56.54	2.12	26	56.88	2.22	16	0.50	Yes
Dec 1979	56.85	2.44	27	57.27	2.41	11	0.48	Yes
Feb 1977	58.26	2.47	23	59.91	2.84	11	1.74	Yes
Mar 1977	59.36	1.50	11	59.17	2.56	6	0.20	Yes

Table 3. Summary of results of t-tests for significant differences in mean lengths of males and females for samples from the west coast of Vancouver Island, February-March 1979. Data from Foucher et al. 1980.

Area	Length range used(cm)	Age	Males Length (cm)	Males S.D.	Males N	Females Length (cm)	Females S.D.	Females N	t	$\bar{x}_1=\bar{x}_2$
Big Bank	36-47	2	41.32	3.30	154	41.61	2.97	153	0.81	Yes
Firing Range	56-67	3	60.60	3.21	479	61.64	3.20	498	5.14	No

Table 4. Summary of results of t-tests for significant differences in mean lengths of males and females for commercial-fishery samples from Queen Charlotte Sound.

Date	Length range used(cm)	Age	Males Length (cm)	Males S.D.	Males N	Females Length (cm)	Females S.D.	Females N	t	$\bar{x}_1=\bar{x}_2$
May 1979	45-53	2	49.06	2.32	146	48.85	2.09	157	0.82	Yes
July 1978	58-64	3	60.90	1.80	153	61.07	1.90	181	0.83	Yes

Table 5. Summary of results of t-tests for significant differences in mean lengths of males and females for Hecate Strait samples.

		Males			Females				
Date	Area[a]	Length (cm)	S.D.	N	Length (cm)	S.D.	N	t	$\bar{x}_1=\bar{x}_2$
Age 0									
Nov 4-5/87	HS	22.07	0.96	41	22.09	1.42	33	0.07	Yes
Age 1									
Mar 14/66	BU	23.01	2.40	475	20.76	2.31	468	14.66	No
Apr 17-23/83	5D	27.70	2.90	83	28.80	2.70	100	2.65	No
Feb 6-24/68	HS	27.76	2.48	194	27.75	2.57	187	0.04	Yes
Jul 7-10/79	HS	29.15	3.28	189	29.14	3.33	191	0.03	Yes
Aug 11-24/80	5D	30.24	3.07	300	30.14	3.16	267	0.38	Yes
Apr 15-25/83	5C	30.90	2.30	51	32.80	2.60	34	3.54	No
Jul 22/66	BO	35.27	3.07	211	35.40	2.97	226	0.45	Yes
Jul 16-21/78	TP/BU	36.08	2.56	51	35.86	2.56	58	0.45	Yes
Sep 9-17/79	TP	37.57	3.02	788	37.43	3.01	870	0.94	Yes
Nov 27/86	WR	41.59	3.13	96	41.63	3.36	128	0.09	Yes
Age 2									
Aug 18-19/79	TP/OH	47.67	3.82	33	49.13	3.30	46	1.82	Yes
Age 3									
Feb 13-26/68	BO	56.89	2.81	322	57.25	2.85	382	1.68	Yes

[a]Area: BO = Bonilla; BU = Butterworth; HS = Horseshoe; OH = Oval Hill; TP = Two Peaks; WR = White Rocks; 5C = Major area 5C (southern Hecate Strait; and 5D = Major area 5D (northern Hecate Strait).

Table 6. Numbers, mean lengths and standard deviations by age and t-test results for comparisons of mean length at age by sex for Pacific cod. (Age determinations were by length-frequency analysis).

Date/area[a] /total no.	Age	Males No.	Males Mean	Males S.D.	Females No.	Females Mean	Females S.D.	D.f.[b]	t	Significant (at 0.05)
Mar 1986	2	41	49.8	2.99	41	48.8	2.09	80	1.76	No
	3	219	59.5	2.88	144	61.7	2.43	361	7.56	Yes
WR	4	209	67.3	2.21	281	68.6	2.07	488	6.68	Yes
	5	3	72.1	1.54	27	73.9	1.70	28	1.75	No
	6	3	75.8	0.88	0	77.3	1.34	-	-	-
	7	-	-	-	3	79.9	0.97	-	-	-
	Total	475			496					
Apr 1983	2	166	49.9	3.21	160	49.5	3.17	324	1.13	No
	3	228	58.8	2.91	301	60.5	2.89	527	6.68	Yes
TP	4	142	64.4	2.60	163	66.6	2.60	303	7.37	Yes
	5	36	70.4	2.30	24	73.0	2.32	58	4.27	Yes
	6	5	76.9	2.00	19	77.6	2.03	22	0.69	No
	7	-	-	-	1	82.3	1.74	-	-	-
	8	-	-	-	1	85.6	1.46	-	-	-
	9	-	-	-	1	88.8	1.17	-	-	-
	Total	577			670					
Apr 1986	2	22	48.1	3.41	28	49.8	3.29	48	1.78	No
	3	169	56.7	2.80	117	59.2	2.98	284	7.23	Yes
TP	4	218	63.6	2.30	266	65.7	2.66	482	9.18	Yes
	5	72	69.7	1.80	83	73.4	2.35	153	10.87	Yes
	6	14	75.2	1.30	17	77.8	2.03	29	4.14	Yes
	7	6	78.1	0.80	8	82.0	1.72	12	5.12	Yes
	Total	501			519					
Jun 1987	1	63	44.2	1.92	66	43.7	1.82	127	1.52	No
	2	677	52.6	4.53	439	51.2	3.58	1114	5.46	Yes
TP	3	98	60.2	3.79	205	57.3	3.08	301	7.10	Yes
	4	28	68.0	3.04	43	65.6	2.58	69	3.57	Yes
	5	7	73.1	2.29	12	73.2	2.08	17	0.10	No
	6	-	-	-	8	77.6	1.59	-	-	-
	7	-	-	-	-	-	-	-	-	-
	8	-	-	-	-	-	-	-	-	-
	9	-	-	-	1	86.0	-	-	-	-
	Total	873			774					

[a] Area: BU = Butterworth; TP = Two Peaks; WR = White Rocks.
[b] Degrees of freedom.

Table 6. (continued).

Date/area/ total no.[b]	Age	Males No.	Males Mean	Males S.D.	Females No.	Females Mean	Females S.D.	D.f.	t	Significant (at 0.05)
Jul 1983	2	10	46.8	1.15	42	50.2	2.22	50	4.67	Yes
	3	78	54.4	3.49	79	57.8	2.75	155	6.78	Yes
TP/BU	4	207	63.8	3.04	203	65.0	2.45	408	4.40	Yes
	5	112	69.8	2.60	104	70.9	2.16	214	3.37	Yes
	6	32	74.4	2.15	41	75.7	1.86	71	2.77	Yes
	7	1	78.5	1.71	10	79.7	1.56	9	0.73	No
	8	3	81.3	1.26	0	82.8	1.26	-	-	-
	9	-	-	-	1	85.5	0.97	-	-	-
	Total	443			480					
Sep 1985	1	13	45.1	1.66	4	44.0	1.33	15	1.20	No
	2	60	57.5	1.63	33	55.5	2.79	91	4.37	Yes
TP/BU	3	23	62.9	1.59	90	62.3	2.32	111	1.17	No
	4	101	68.8	1.56	102	68.0	1.86	201	3.32	Yes
	5	26	72.6	1.53	24	73.9	1.39	48	3.14	Yes
	6	-	-	-	3	77.9	0.93	-	-	-
	7	-	-	-	-	-	-	-	-	-
	8	-	-	-	1	83.0	-	-	-	-
	Total	223			257					

Table 7. Percentage age composition for selected samples of Pacific cod aged separately (males, females and total - summed after ageing) and aged as a whole sample (with both sexes included) and the difference between them. Age determination by length-frequency analysis.

Sample	Age	Aged separately						Aged with both sexes	Difference
		Male		Female		Total			
		No.	%	No.	%	No.	%	%	%
Mar 1986	2	41	8.6	41	8.3	82	8.4	9.4	1.0
	3	219	46.1	144	29.0	363	37.4	35.5	1.9
	4	209	44.0	281	56.7	490	50.5	51.7	1.2
	5	3	0.6	27	5.4	30	3.1	3.1	0
	6	3	0.6	0	-	3	0.3	0.1	0.2
	7	-	-	3	0.6	3	0.3	0.2	0.1
	Total	475		496		971			
Apr 1986	2	22	4.4	28	5.4	50	4.9	4.5	0.4
	3	169	33.7	117	22.5	286	28.0	29.3	1.3
	4	218	43.5	266	51.3	484	47.5	50.3	2.8
	5	72	14.4	83	16.0	155	15.2	9.5	5.7
	6	14	2.8	17	3.3	31	3.0	5.2	2.2
	7	6	1.2	8	1.5	14	1.4	1.2	0.2
	Total	501		519		1020			
Jul 1983	2	10	2.3	42	8.8	52	5.6	0	5.6
	3	78	17.6	79	16.5	157	17.0	19.6	2.6
	4	207	46.7	203	42.3	410	44.5	56.0	11.5
	5	112	25.3	104	21.7	216	23.4	20.6	2.8
	6	32	7.2	41	8.5	73	7.9	2.9	5.0
	7	1	0.2	10	2.1	11	1.2	0.8	0.4
	8	3	0.7	0	-	3	0.3	0	0.3
	9	-	-	1	0.2	1	0.1	0.1	0
	Total	443		480		923			

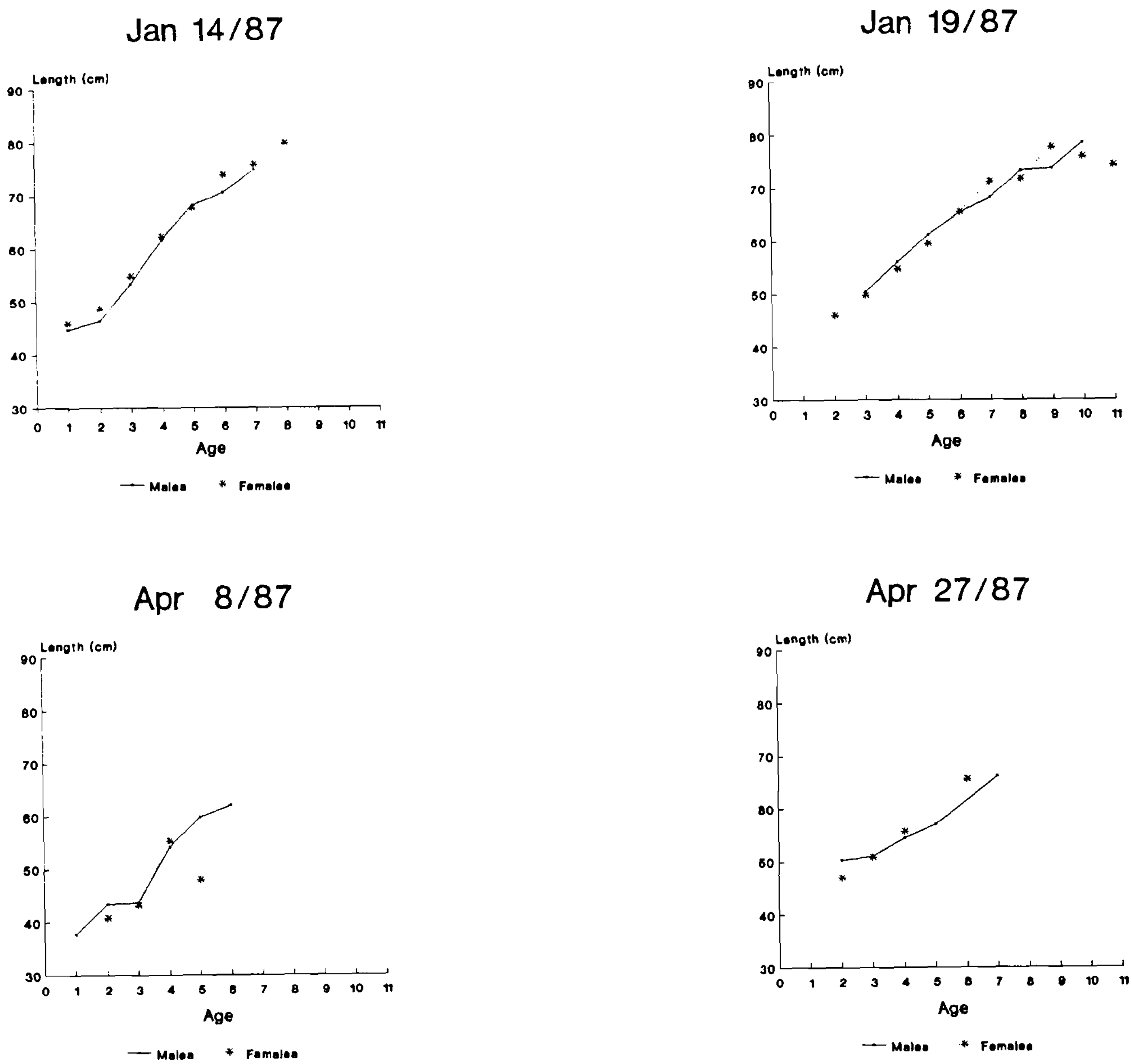

Figure 1. Mean length at age, by sex, by sample, found by fin-ray analysis of Pacific cod. (See Table 1).

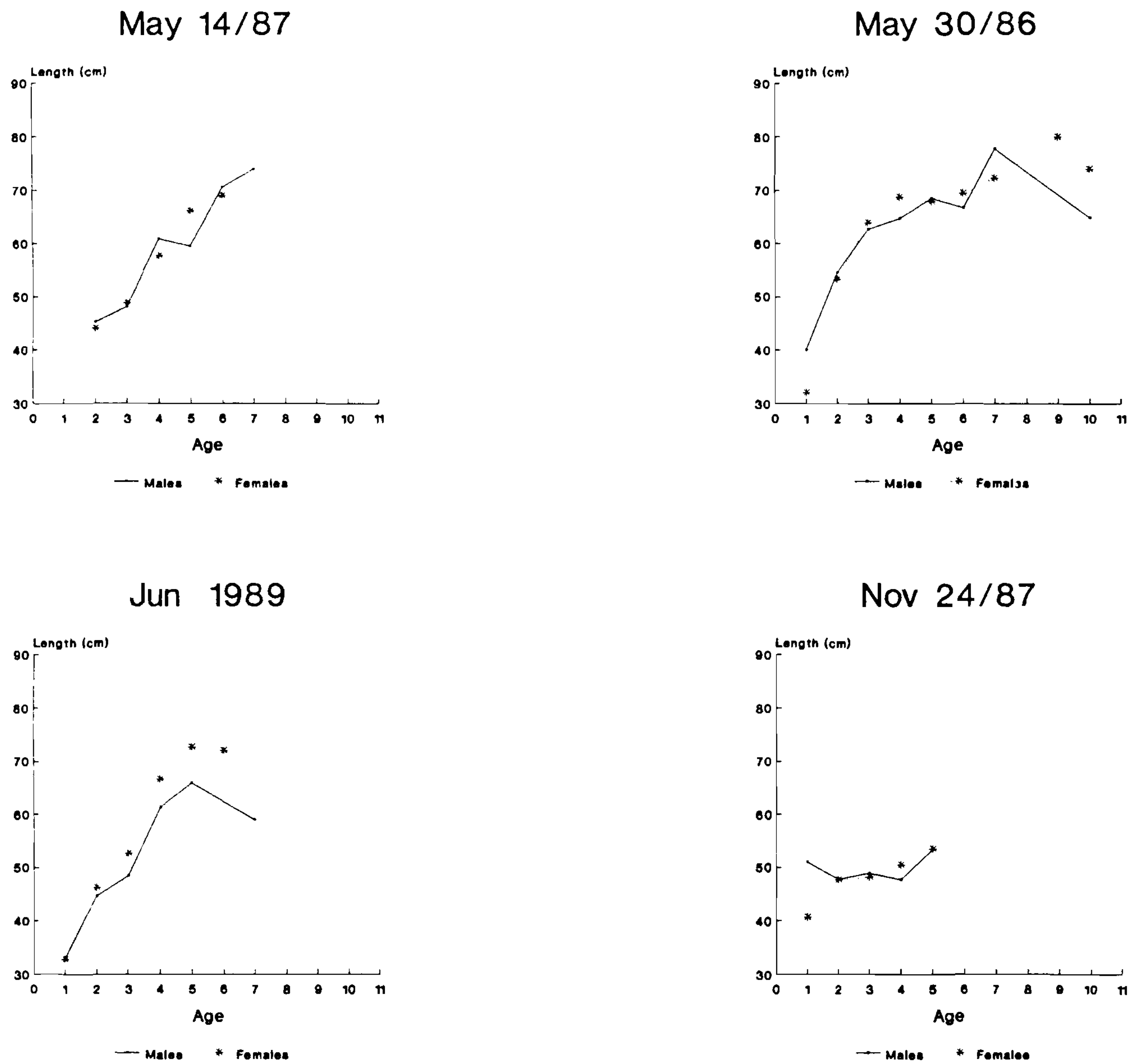

Figure 1. Cont'd.

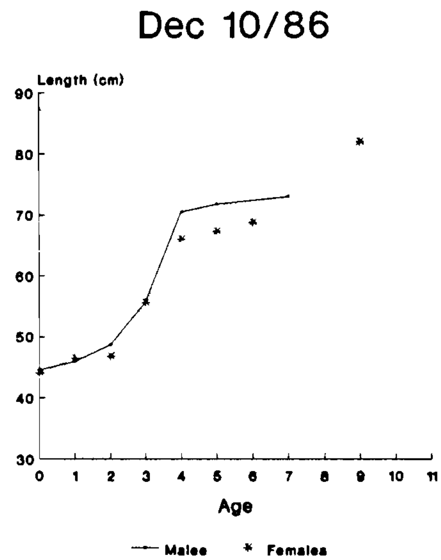

Figure 1. Cont'd.

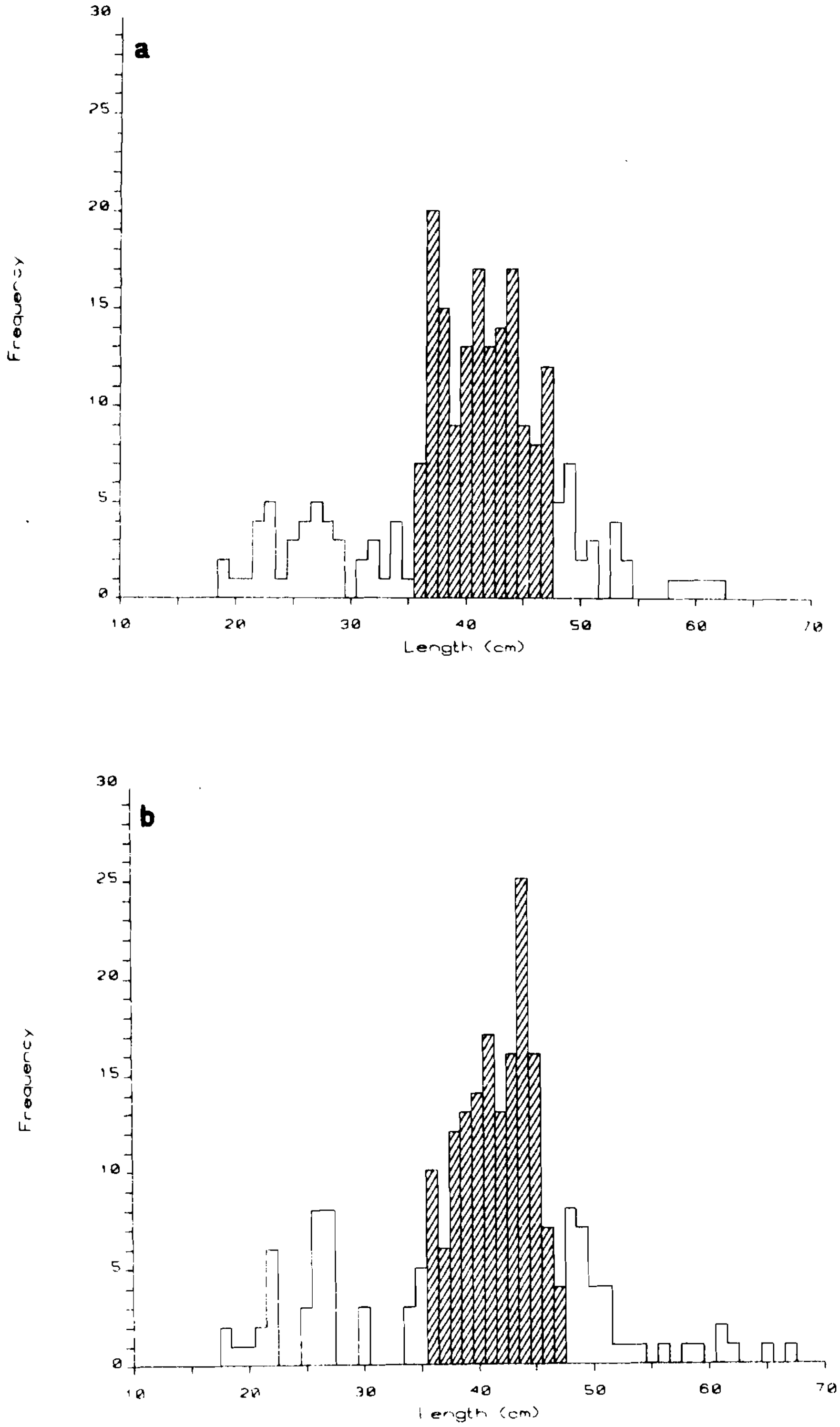

Figure 2. Length frequency of Pacific cod sampled at Firing Range, February-March 1979. Hatched region indicates length range selected for comparison of modal length by sex. a) male, N=226 (total), 154 (selected); b) female, N=229 (total), 153 (selected).

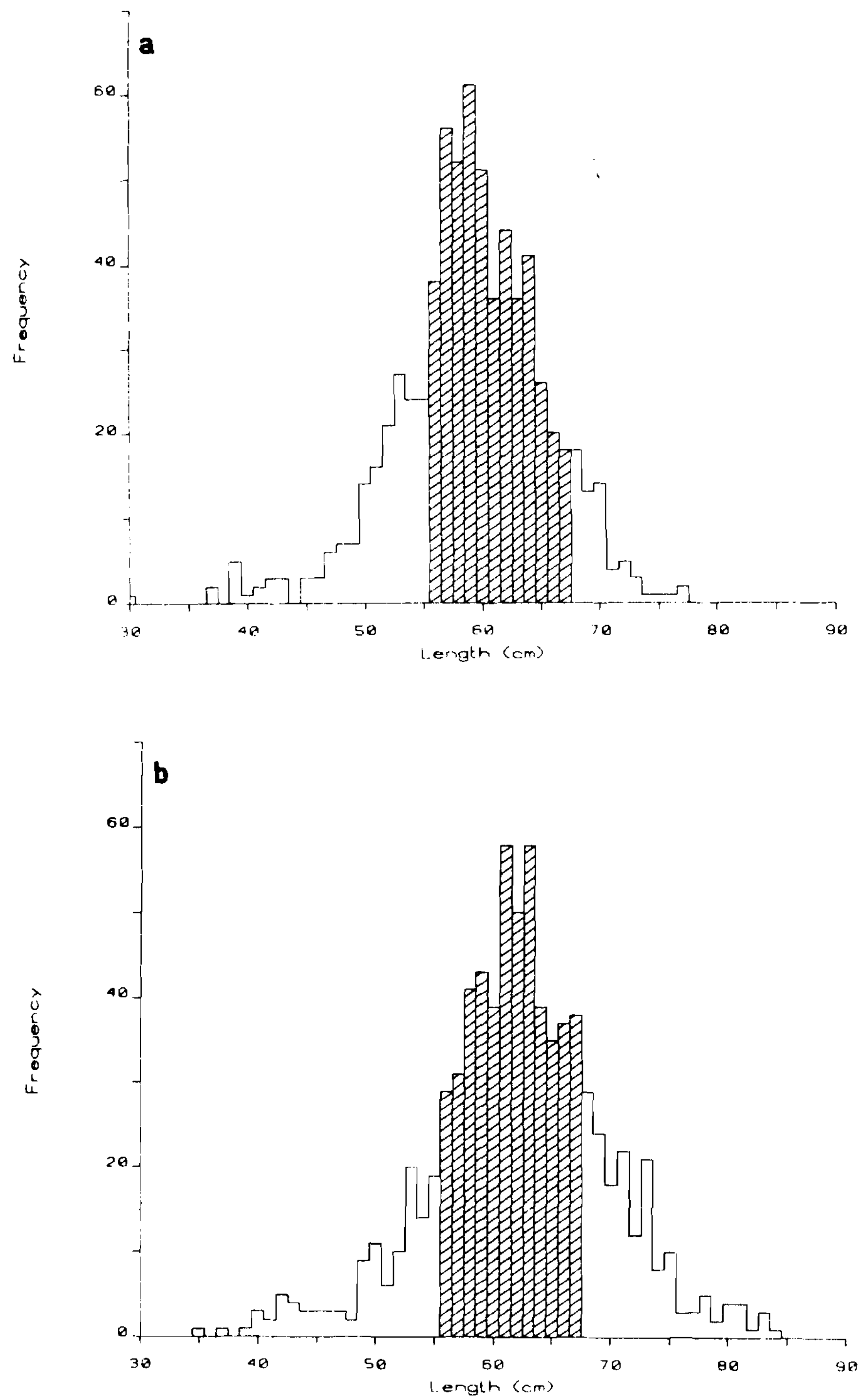

Figure 3. Length frequency of Pacific cod sampled at Big Bank, February-March 1979. Hatched region indicates length range selected for comparison of modal length by sex. a) male, N=710 (total), 479 (selected); b) female, N=788 (total), 498 (selected).

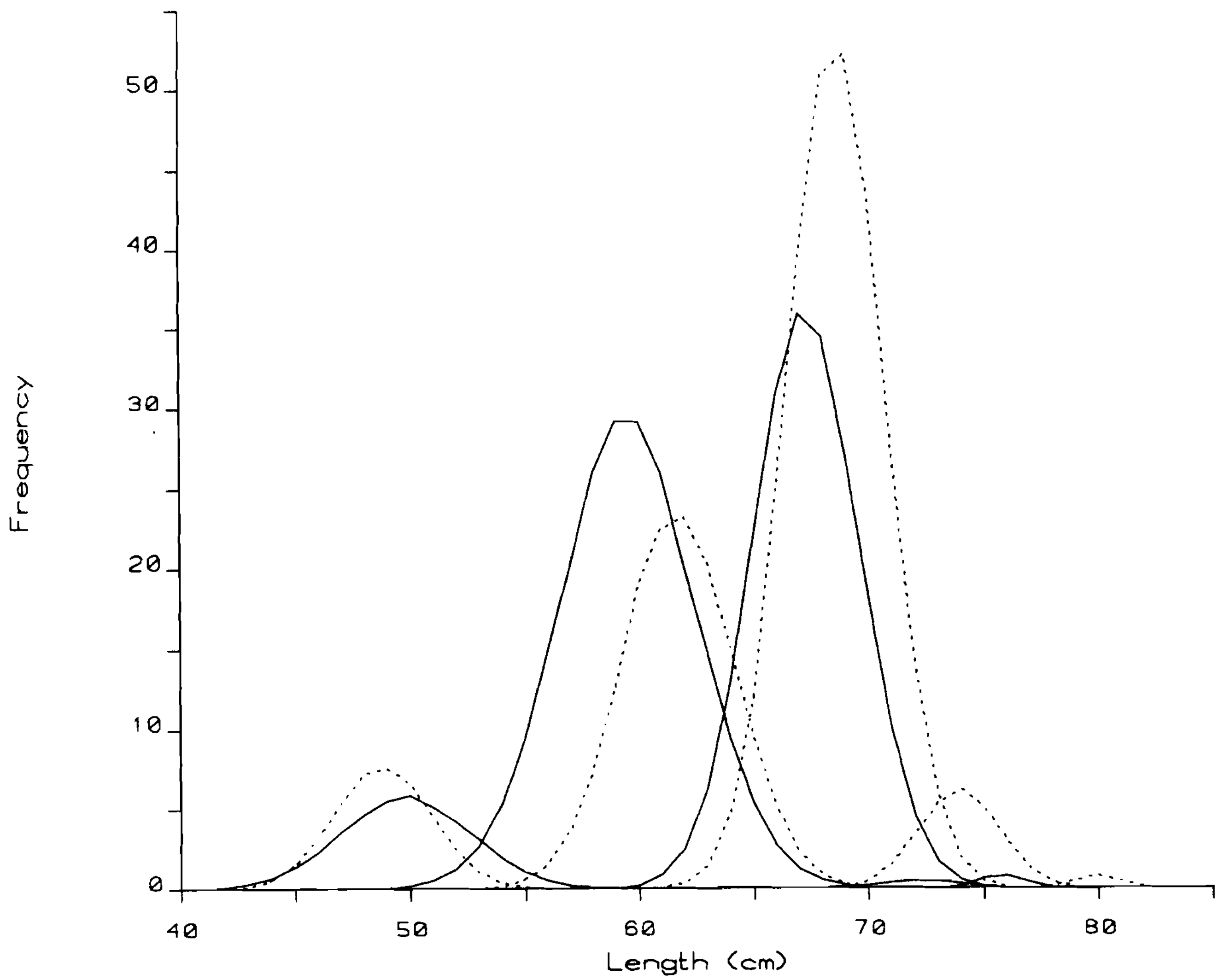

Figure 4. Expected frequency by age for males and females from distributions as determined by length frequency analysis. March 1986 sample White Rocks, N = 475 (males - solid line), 496 (females - dashed line).

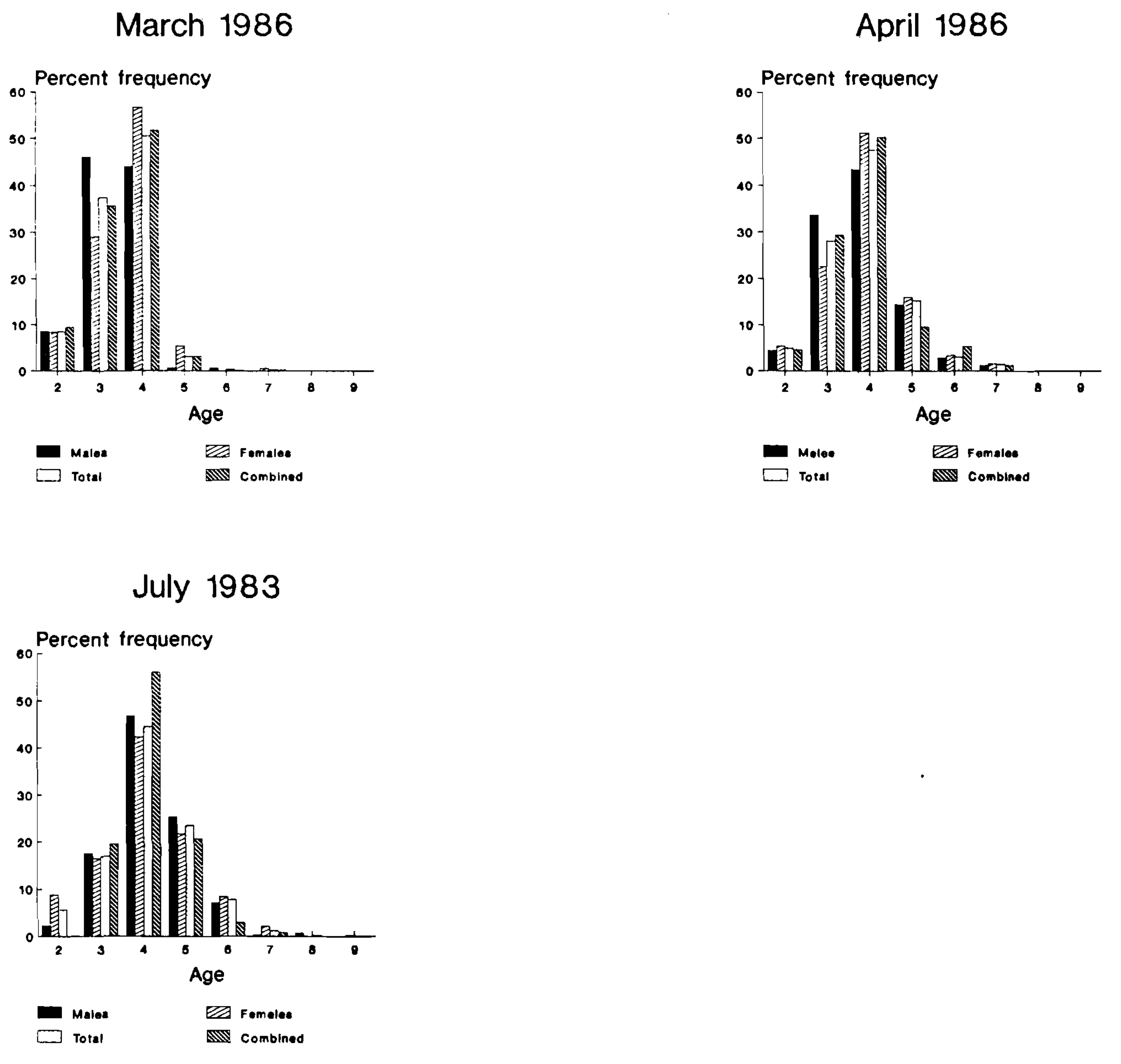

Figure 5. Percent frequency by age as determined by length-frequency analysis for males, females, total (males and females summed after age determination) and combined (total sample including both sexes aged together) for selected samples. (See Table 6).

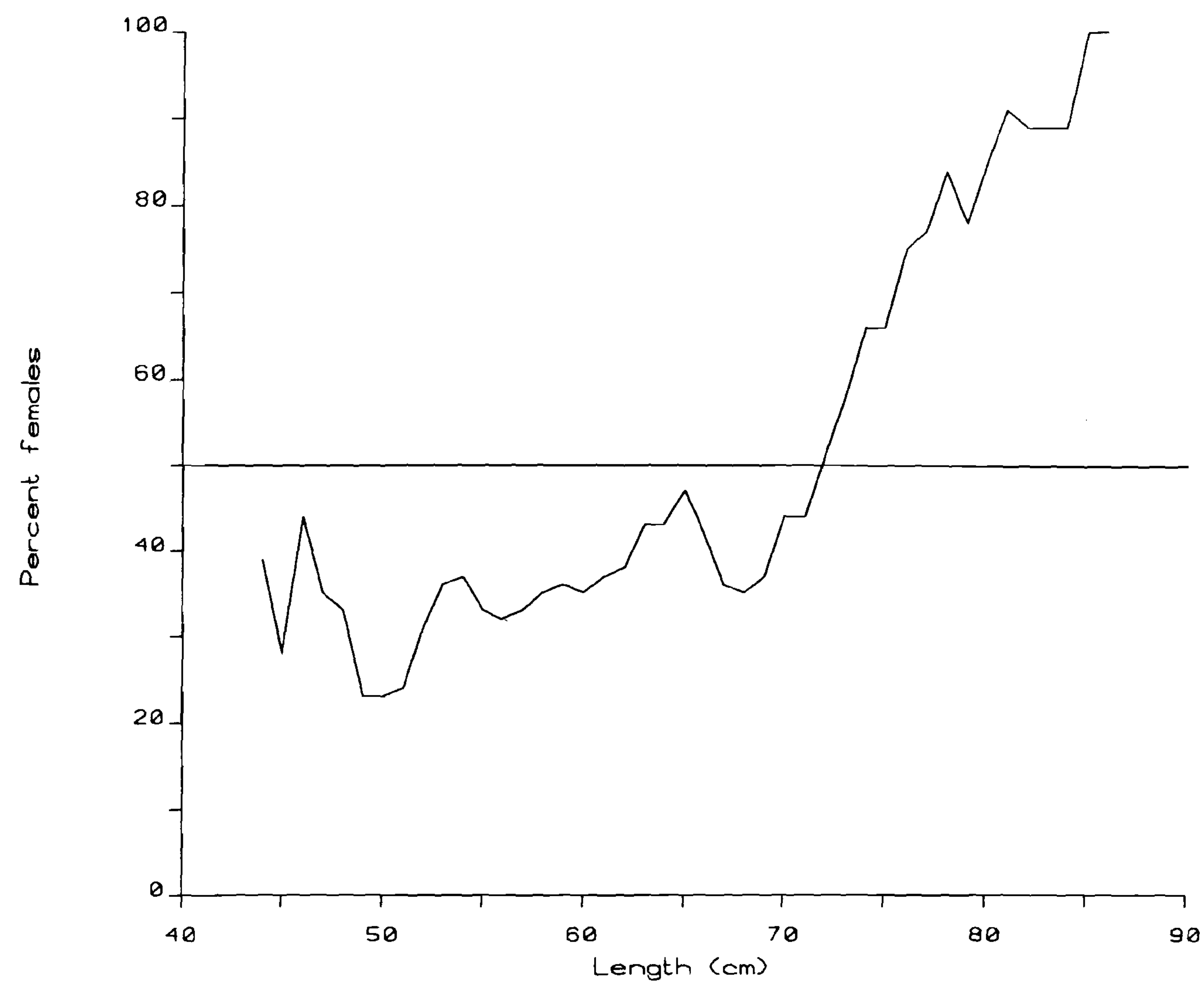

Figure 6. Percent female Pacific cod by length, Amphitrite Bank, February, 1977. Number sampled = 1,323.

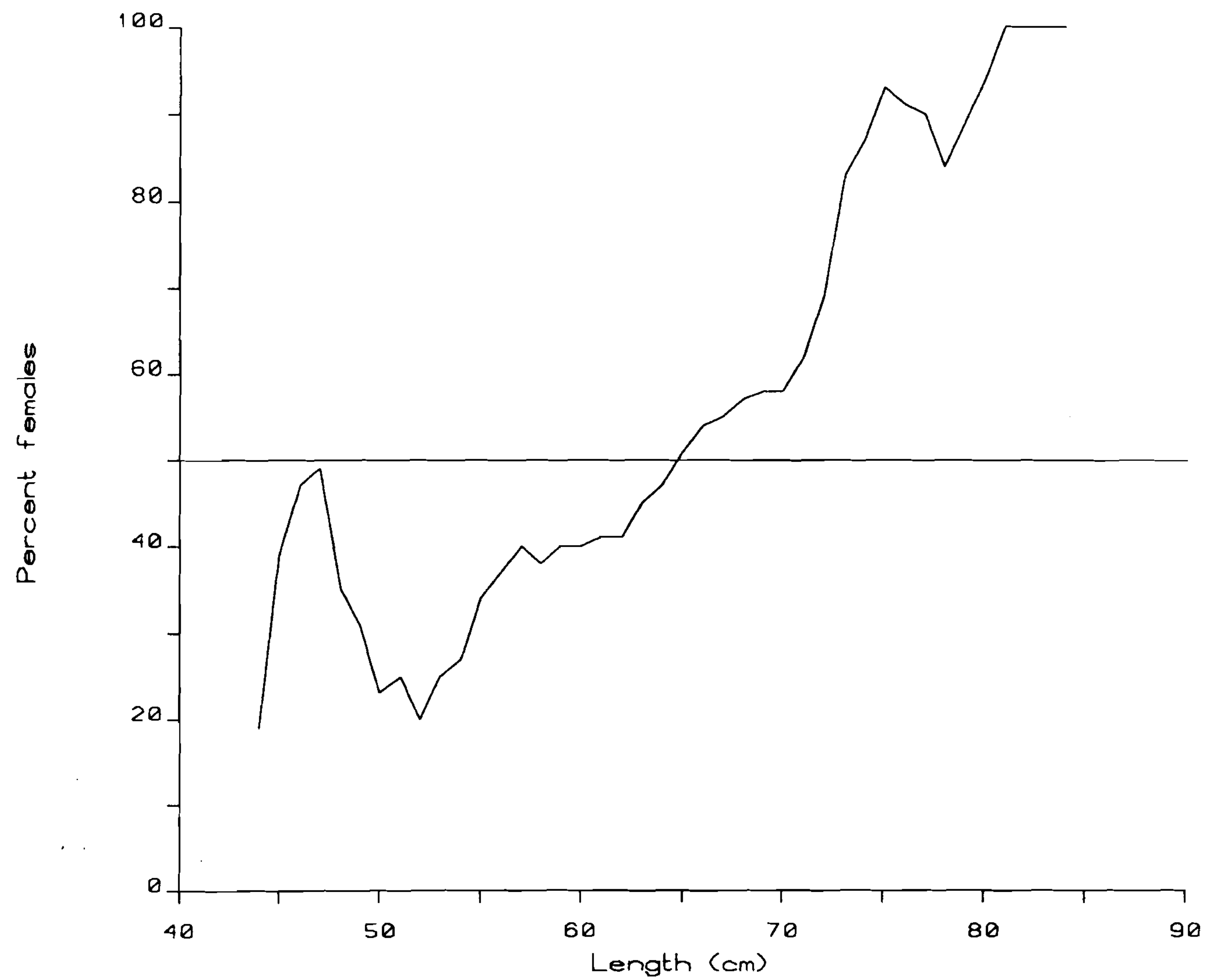

Figure 7. Percent female Pacific cod by length, Amphitrite Bank, February, 1978. Number sampled = 1,429.

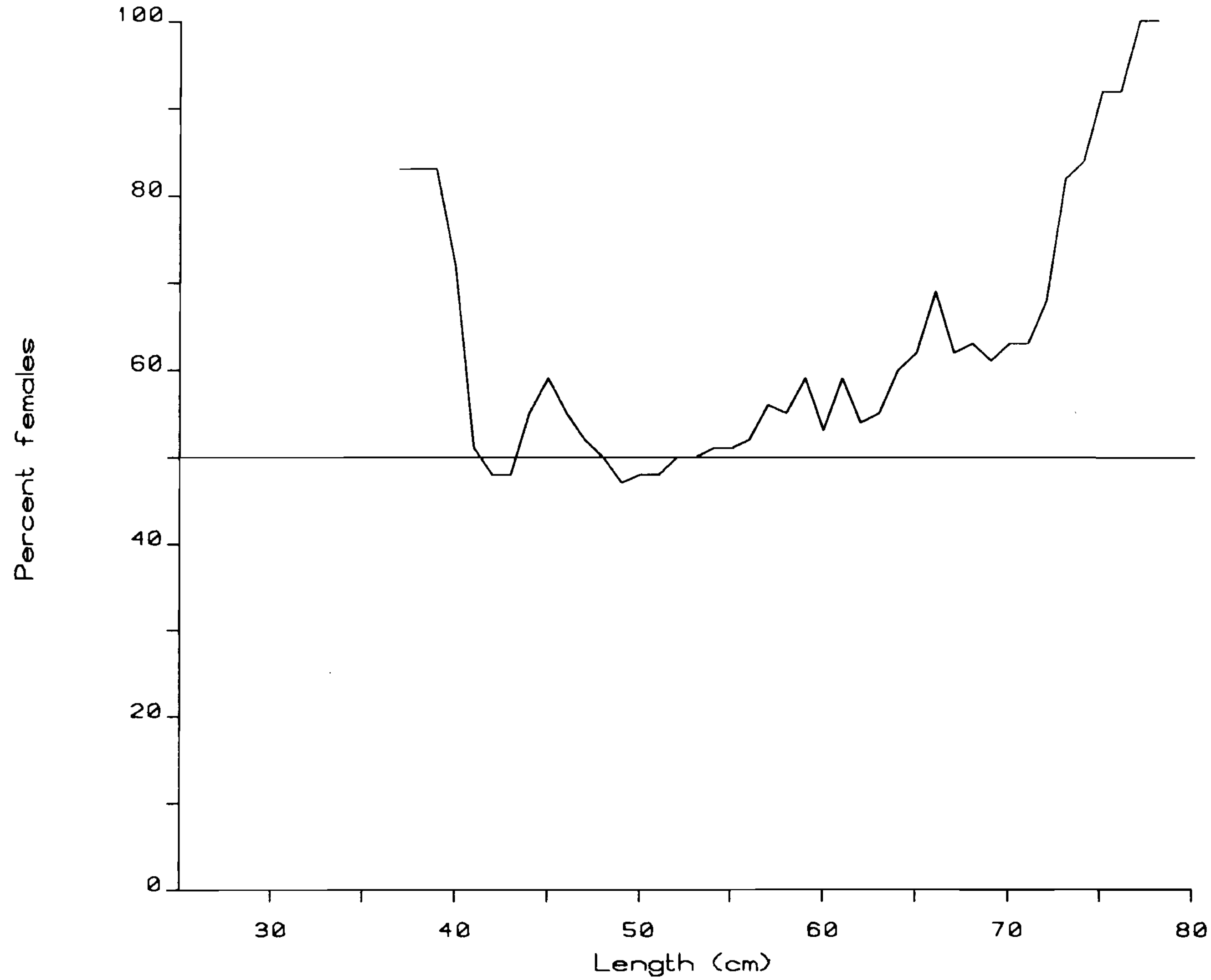

Figure 8. Percent female Pacific cod by length, southern Queen Charlotte Sound, April - June, 1977-82. Number sampled = 4,266.

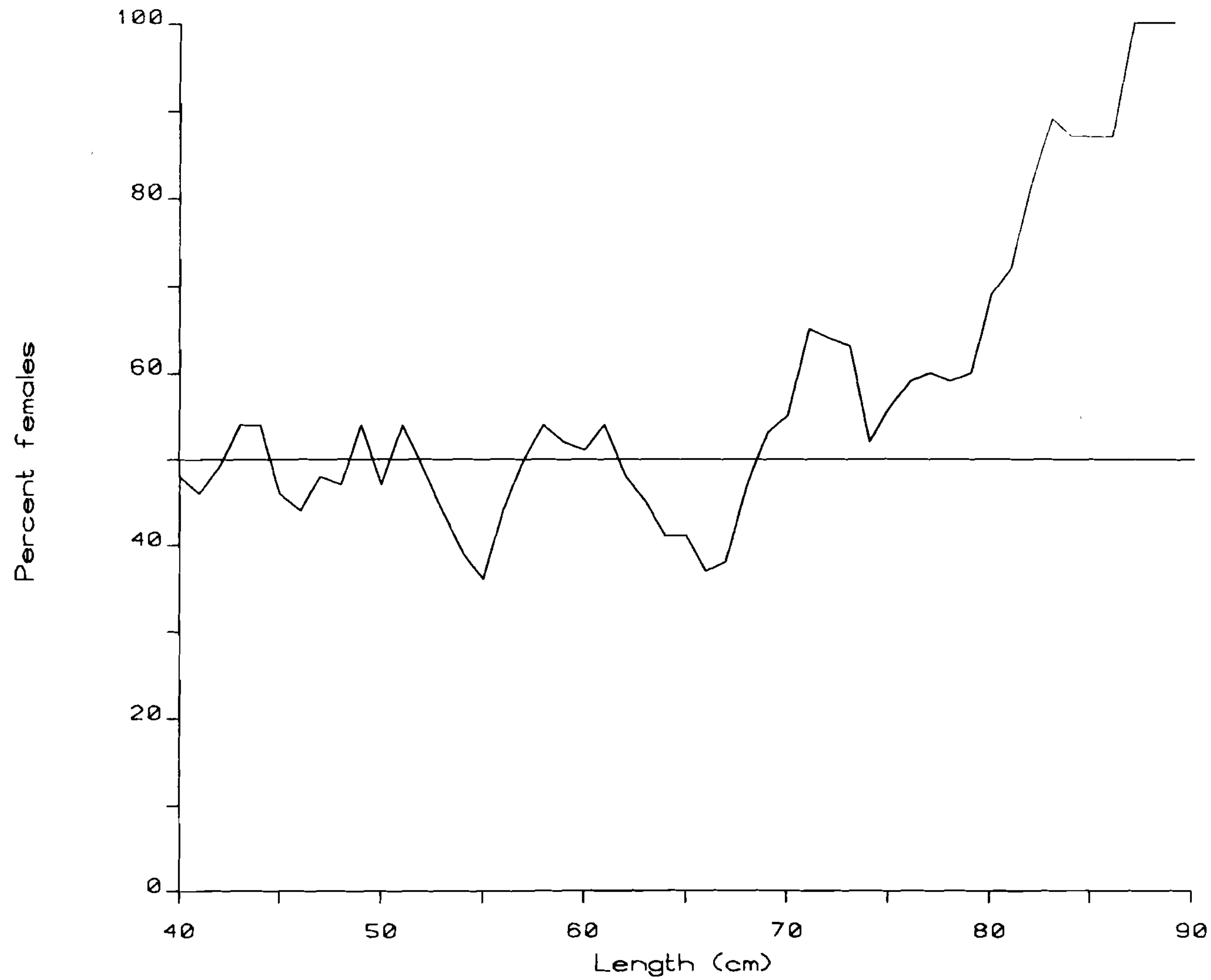

Figure 9. Percent female Pacific cod by length from commercial samples from Two Peaks Ground, northern Hecate Strait, September 9-17, 1979. Number sampled = 2,562.