Fisheries and Population Biology of Lobsters *(Homarus Americanus)* at Arnold's Cove, Newfoundland

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by

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ABSTRACT

Ennis, G. P., P. W. Collins, G. Dawe, and W. R. Squires. 1986. Fisheries and population biology of lobsters (*Homarus americanus*) at Arnold's Cove, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1438: iv + 34 p.

Characteristics of the lobster fishery at Arnold's Cove, Placentia Bay, on the southeast coast of Newfoundland, are described. Results from ongoing monitoring of the fishery for catch and effort, catch rates, and composition of landings as well as temperature conditions during the fishing season for the 1970 to 1984 period are presented. Details of various aspects of lobster population biology and dynamics in the area such as length-weight relationships, growth, estimates of standing stock, recruitment and exploitation rates are included along with a discussion of some general management considerations for the fishery.

RÉSUMÉ

Ennis, G. P., P. W. Collins, G. Dawe, and W. R. Squires. 1986. Fisheries and population biology of lobsters (*Homarus americanus*) at Arnold's Cove, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1438: iv + 34 p.

L'article donne les caractéristiques de la pêche du homard dans l'anse Arnold et la baie Placentia et sur la côte sud-est de Terre-Neuve. Il présente également les résultats de la surveillance courante de la pêche, en ce qui a trait aux prises et aux efforts de pêche, aux taux de prises et à la composition des débarquements, ainsi qu'à la température durant la saison de pêche, pour la période allant de 1970 à 1984. Il fournit de pus des renseignements sur les différents aspects de la biologie et de la dynamique de la population de homard de la région, tels que le rapport longueur-poids, la croissance, les évaluations de stock actuel, le recrutement et les taux d'exploitation et traite de certaines considérations de gestion générale de la pêche.

INTRODUCTION

The lobster fishery and various aspects of lobster population biology in the area of Arnold's Cove, Placentia Bay on the southeast coast of Newfoundland have been studied since 1969. The study has included biological sampling, annual monitoring of the fishery for catch and effort, catch rates, composition of landings, and temperature conditions. Growth per molt and movement data have been obtained from sphyrion tagging and carapace strap tagging of commercial lobsters has been conducted annually in autumn following the molting period to obtain estimates of standing stock, recruitment and exploitation rate during the spring fishing season. Shell condition sampling following the molting period has been conducted annually as well to provide a basis for estimating proportions molting.

The time series of data from annual monitoring activities has been analyzed and is presented here. Also presented are data and analyses on aspects of lobster biology at Arnold's Cove that have not been considered in detail elsewhere.

MATERIALS AND METHODS

Samples of lobsters for detailed biological examination were obtained at Arnold's Cove during May and October in both 1969 and 1970. These were total catches from conventional wooden lobster traps with the 44.5 mm (1 3/4 in) lower lath spacing required for commercial fishing in Newfoundland. Observations included various length and weight measurements, sexing, ovary color, ova and egg diameter (see Squires 1970 for full details).

Sphyrion tagging was conducted during June-August 1970 and June-July 1975. Details are provided in Ennis (1978).

Starting in 1970 thermographs were maintained on the bottom near Arnold's Cove at a depth of approximately 9 m during the lobster fishing season (April 20-June 30). Since April 1980 thermographs have been maintained at this site year-round. Starting in 1970 as well, fishermen have maintained records of their daily catches (by number) of commercial legal lobsters and effort expended (traps hauled) throughout each fishing season in logbooks provided to them. In addition, lobster landings from several fishermen have been sampled for carapace length and sex periodically throughout each fishing season. Counts of traps in use in the Arnold's Cove area sometime between mid May and mid June were obtained from 1971 to 1980 by field staff who covered the fishing grounds in boats and counted lobster trap buoys. In this area traps are set close to shore on individual lines so that one buoy indicates the presence of one trap. During this period, fishing effort, as indicated by the number of traps in use, is at its peak.

In the fall of 1970, following the molting period, special fishing was carried out. Commercially legal lobsters were tagged with carapace strap tags (Wilder 1954) and released immediately after being removed from the traps. Field staff maintained frequent contact with fishermen during the following spring fishing season to ensure return of all recaptured tags. Carapace strap tagging was repeated in 1976 and has been each year since. Highly visible secondary marks (colored lobster claw bands positioned on the carpopodite of each claw) have been applied as well since 1976 to obtain estimates of tag loss over the 6-month period between tagging and the start of the following spring fishing season. Also starting in 1976, all lobsters caught during the autumn tagging period were examined for shell condition to determine whether each had molted during the preceding summer molting period (Ennis 1977).

RESULTS AND DISCUSSION

THE FISHERY

General Description

Arnold's Cove is located in the northern end of Placentia Bay on the southeast coast of Newfoundland (Fig. 1). The lobster grounds in the area are a relatively narrow band of rocky bottom extending 10-25 m offshore (except for a shoal-water area farther from shore near the mouth of Arnold's Cove) from mostly 5-10 m high cliffs and stretches of gravel-sand and cobble-boulder beaches along approximately 10 km of shoreline. At the present time 14 licenced individuals fish for lobsters in the Arnold's Cove area and the number of conventional wooden-lathed lobster traps each is licenced to fish (as per the existing licencing policy introduced in 1976) ranges from 50 to 400. A limit of 150 traps per fisherman has been proposed for the area (Ennis 1982). Traps are set individually and usually in depths less than 20 m. Fishing is carried out from 6-9 m open boats mostly outboard but also inboard powered and practically all hauling is done manually. The annual fishing season opens April 20 and closes June 30, egg-bearing females and all lobsters smaller than 81 mm (3 3/16 in) carapace length are protected from exploitation.

Catch and Effort

Lobster fishing statistics (landings and number of traps) are available for Placentia Bay (Statistical Area H) from 1953 and for Statistical Sections 29, 30 (which includes Arnold's Cove), 31 and 32 within Placentia Bay since 1969 (Fig. 1). Statistical Sections are the smallest units for which these data are available from the fisheries statistical reporting system.

Annual lobster landings in Placentia Bay have fluctuated markedly (Fig. 2). Although there were a number of sharp fluctuations from year to year, landings declined fairly steadily from 462,915 lb (210 t) in 1955 to 103,276 lb (46.9 t) in 1971, then increased dramatically to 905,694 lb (410.8 t) in 1979. These longer term trends coincide with similar trends in landings for Newfoundland as a whole (Ennis 1982). Following the 1979 peak, there was a sharp decline to 420,385 lb (190.7 t) in 1982, a slight recovery to 603,505 lb (273.8 t) in 1983 and preliminary data indicate that 1984 landings were around 677,053 lb (307.1 t).

A measure of nominal effort that is available (from 1956 to 1973) is the number of traps that fishermen indicated on their licence applications they intended to fish each year. For Placentia Bay, this number increased from 25,750 in 1956 to 36,075 in 1965 then declined to 13,030 in 1972. This decline in effort coincided with a decline in landings (Fig. 2). A licencing policy was implemented in 1976 which eliminated a number of licence holders from future participation in the fishery and restricted those remaining to the number of traps they had indicated on their 1975 licence applications that they intended to fish that year. As per this policy, in 1977 the licenced fishermen were registered to fish 60,721 traps. The consensus among DFO field personnel (and among fishermen) is that considerably more traps than the number allowed are being used. Obviously, there was a dramatic increase in effort between 1972 and 1977 and this undoubtedly contributed heavily to the dramatic increase in landings over this period (Fig. 2). The bulk of Placentia Bay lobster landings come from Statistical Section 30 and the pattern of landings for this section determines the pattern for the bay as a whole (Fig. 2).

Accumulative catch at Arnold's Cove during the 1983 fishing season, derived from logbooks provided by several fishermen, and accumulative tag returns by these same fishermen, demonstrate that the bulk of annual landings are taken during the first few weeks of fishing. For example, 89% of the landings and 92% of the tags were taken prior to the end of May (Fig. 3). The bulk of annual fishing effort is expended during the early weeks of the season as well. Total trap hauls for weekly intervals peaked during the second week of fishing and dropped to much lower levels during most of the remainder of the season (Fig. 4). The percentage of tagged lobsters present on the grounds at the beginning of each week that were taken during the week also peaked during the second week of fishing and dropped sharply thereafter. In general, this percentage fluctuated in relation to total trap hauls for the week but fluctuations in average weekly temperature (through its effect on lobster catchability) were also an important factor (Fig. 4).

Catch Rates

Catch rates are usually highest during the first or second week of the fishing season and decline rapidly as the season progresses. However, the pattern of variation over the course of the fishing season is variable from year to year (Fig. 5). The overall decline in catch rates over the fishing season is the result of the fishing-up process, however, the sharp week to week fluctuations within fishing seasons are mostly related to temperature changes although other factors, such as variability in the number of traps on the grounds, number of traps hauled, soak time and weather conditions, contribute. Although there are frequently sharp fluctuations, temperature increases over the fishing season (Fig. 7) and tends to keep catch rates much higher than would be the case if the low early season temperatures prevailed throughout. When mean weekly catch rates for a season are adjusted to a standard temperature (see Ennis et al. 1982), the week to week fluctuations are smoothed and the decline over the season is usually more pronounced (Fig. 13, Table 5).

The highest and lowest mean CPUE's for 1-week intervals are 1.06 lb (.48 kg)/trap haul during the first week of fishing in 1981 and .11 lb (.05 kg)/trap haul during the last week of fishing in 1977. Season averages range from .34 lb (.15 kg)/trap haul in both 1970 and 1972 to .66 lb

(.30 kg)/trap haul in 1976. Season averages increased over the 1970 to 1976 period but have been generally declining since then. From 1976 to 1984 total annual trap hauls and exploitation rates have fluctuated but at much higher levels than measured in 1971 (Table 1) and over this period there has been a downward trend in standing stock which accounts for the declining catch rates.

Size and Sex Composition of Landings

In Arnold's Cove, lobsters just below the minimum legal size of 81 mm (3 3/16 in) carapace length grow an average of 13 mm on molting in the case of males and 10 mm in the case of females (Ennis 1978). This means that the majority of lobsters growing to commercial sizes in any year will be contained within the 81-93 mm and 81-90 mm size ranges for males and females, respectively. The percentage of lobsters landed that are within these size ranges has ranged from 55.6 to 90.8 for males and 44.4 to 82.8 for females (Fig. 6). The exceptionally low percentage (29.8) of female recruits in the Arnold's Cove fishery in 1971 was caused by the release in 1969 of large numbers (approximately 4000 lb) of female lobsters that had become spawny in a commercial holding facility at Arnold's Cove. These lobsters had been held much longer than usual beyond the fishing season because of a pollution problem in Placentia Bay at the time and became legally available to the Arnold's Cove fishery in 1971 after hatching the eggs and molting in 1970. These additional females on the grounds resulted in an abnormal sex ratio in 1971 as well (Table 2). The lowest percentage in the recruit size ranges occurred in 1970 (the earliest that these data are available) for both males and females. It increased sharply to 81.7 and 71.0% for males and females respectively in 1972 and since then it has fluctuated somewhat but tended towards higher values in recent years. Year to year variability in exploitation rate and recruitment to the standing stock accounted for fluctuations in percentages within the recruit size ranges. The sexes are usually very close to equally represented in the landings, however, excepting the unusual situation in 1971, the M:F ratio has varied from 1:1.43 (in favor of females; $P < .001$) in 1970 to 1:0.76 (in favor of males; $P < .001$) in 1973 (Table 2).

Water Temperature

At the start of the fishing season (April 20), temperature on the Arnold's Cove lobster grounds at a depth of 9 m ranges between 0 and 2°C (Fig. 7). Warming generally proceeds quite slowly. The highest temperature reached by the end of May ranges from around 4 to 8°C and from around 7 to 10°C by the end of the fishing season (June 30). Sharp fluctuations of 4-6°C over the 1-3 days occur commonly throughout the fishing season. These occur as a result of strong onshore or offshore winds either piling up warm surface water or causing deep, cold water to upwell in the near-shore area. During the annual temperature regime, mean temperature increases to a maximum of 12-13°C during August and decreases to a minimum of around 1°C during March (Fig. 8).

BIOLOGY

Various aspects of the biology of lobsters in the Arnold's Cove area have been treated in detail in other papers. These are mentioned and references provided, however, only those aspects not previously published or those for which additional data or analyses are avaialble will be covered in detail in this report.

Length-weight Relationships

Curvilinear carapace length-whole weight relationships derived from log-log (base 10) regression analysis are presented for Arnold's Cove lobsters (Fig. 9). The log-log equations are as follows:

males:	log ww = 3.1485 log cl - 3.3660 (n = 161; r^2 = .99)
non-ovigerous females:	log ww = 2.9109 log cl - 2.9408 (n = 250; r^2 = .99)
ovigerous females:	log ww = 2.7673 log cl - 2.6289 (n = 177; r^2 = .97)

These log-log relationships were compared by analysis of covariance. Only males and ovigerous females had similar residual variances ($P > .2$); however, the slopes of these relationships were different ($P < .001$). For the male relationship the slope was significantly greater than 3 ($P < .001$), indicating positive allometric growth whereas for non-ovigerous ($P < .001$) as well as ovigerous ($P < .001$) females, slopes were significantly less than 3, indicating negative allometric growth.

Reproductive Biology

Aspects of reproductive biology of Arnold's Cove lobsters considered elsewhere include size-maturity and size-fecundity relationships (Ennis 1980, 1981, 1984a), the incidence of molting and spawning in the same season in female lobsters (Ennis 1984b), non-extrusion by mature females (Ennis 1984a) and egg loss following extrusion (Ennis 1984c). Based on these details of reproductive biology, a new lobster egg per recruit computer program was written (Ennis and Collins 1983) and an assessment of the impact of size limit and exploitation rate changes in the fishery on egg production in the Arnold's Cove population has been done (Ennis 1985). This assessment demonstrates that a considerable increase in egg production can be achieved by increasing the size limit and/or reducing exploitation rates.

Growth

Growth per molt. Premolt and postmolt carapace lengths for sphyrion tagged lobsters that were known to have molted only once between tagging and recapture were analyzed using a program (HIATT) which was developed by Somerton (1980) for fitting a pair of straight lines to crustacean growth increment data. Plots of premolt-postmolt data often demonstrate an abrupt change in slope which is associated with attainment of sexual maturity. For males two straight lines intersecting at 78 mm fitted the data better than a single straight line (the so called HIATT growth diagram). Onset of maturity in male lobsters in the Arnold's Cove area occurs at around 70 mm (Ennis 1980) and intersection of the two lines at 78 mm is considered an artifact associated with the paucity of data at and below the size where intersection of two lines fitted to such data would be expected to occur. In the case of females a single straight line fitted the data better than a pair and, as with males, the paucity of data at sizes below 75 mm is the likely reason for the absence of an inflection associated with onset of maturity.

The single straight line equations derived from least squares regression of postmolt carapace length on premolt carapace length are:

$Y = 1.1967\ X - 3.3650$ ($n = 55$, $r = .99$) for males and
$Y = 0.9980\ X + 9.6242$ ($n = 114$, $r = .99$) for females (Fig. 10).

Analysis of covariance demonstrated that these relationships had similar residual variances but different slopes ($P < .001$). The slope for males is significantly greater than 1 ($P < .001$) and meets Kurata's (1962, p. 31) requirement ($b > 1.05$) for progressive growth, i.e. molt increment increases with premolt size. The slope for females, however, is not significantly different from 1 ($P > .5$) and meets Kurata's requirement ($1.05 > b > .95$) for arithmetic growth, i.e. molt increment is constant in relation to premolt size. Molt increments calculated from the equations above for premolt carapace lengths of 70 and 100 mm are 10.4 mm and 14.9 mm, respectively for males, which represent relative molt increments of 14.9% and 16.3%, and for females are 9.5 mm and 9.4 mm which represent relative increments of 13.6% and 9.4%.

Proportions molting. Estimates of proportions molting were derived from the fall shell condition sampling as described by Ennis (1978). Curves of proportion molting in relation to size thus derived (Fig. 11) show substantial annual variation for both males and females. Much of this variation is related to year to year variation in temperature conditions (Ennis 1983a). The much greater variability for females is associated with the greater scarcity and in some years absence of animals at larger sizes and the inherent sensitivity of probit analysis to weighting affecting the slope of the curve. The data for all years were combined and "average" proportion molting - size relationships were derived (Fig. 10). The probit equations for these relationships are $Y = 15.3802 - 0.1103\ X$ ($n = 5465$) for males and $Y = 11.0759 - 0.0624\ X$ ($n = 2560$) for females. The data (Fig. 11) indicate that for both sexes all animals in the 60-70 mm carapace length range molt in a given year. There is no evidence that in this area lobsters of this size range molt more than once in a year. Estimates from the probit equations indicate that proportion molting annually drops to 50% at 94 mm and 97 mm for males and females, respectively, and to 0% at 130 mm and 160 mm. The prevalence of molters among females at sizes > 100 mm (9 out of 13 from a total sample of 2560) is inconsistent with the data at smaller sizes. In addition to the very small numbers sampled as a result of high exploitation rates applied at smaller sizes, it probably relates to the fact that the majority of females that reach large sizes do so as a direct result of their egg-bearing status providing protection from exploitation. In the fall shell condition sampling which provides the basis for estimates of proportion molting, molters for a certain premolt size would have been egg-bearing during the preceding spring fishing season whereas the non-molters would have been non-egg-bearing and fully exposed to exploitation. A detailed consideration of other possible biases associated with the method of estimating proportions molting is provided in Ennis et al. (1982).

Growth curves. Growth curves were generated by combining molt increment and proportions molting data (all years combined - Fig. 11) as described by Ennis (1978, 1980b). Ages 6 and 7 were assigned to the starting size of 61 mm CL. The basis for assigning these ages is given in Ennis (1980b). Estimates of mean size at successive ages were obtained and these were run on a version of the Allen (1966) program to generate estimates of the von Bertalanffy parameters. The resulting equations are as follows:

$$\ell_t = 113.9 \left[1-e^{0.3089\ (t-3.6941)}\right] \quad \text{for males and}$$

$$\ell_t = 123.6 \left[1-e^{0.1990\ (t-3.6913)}\right] \quad \text{for females.}$$

Growth curves derived from these equations (Fig. 12) indicate that males attain larger sizes at age up to 14 years beyond which females grow faster. The larger L_∞ for females is likely to be an artifact associated with the sampling situations imposed by the fishery as considered in the preceding section.

Estimates of Standing Stock

Standing stock was estimated using both the Peterson and Leslie methods, initially for 1971 and subsequently for each year from 1976 to 1984. Details of the analyses and a consideration of the assumptions of the models are provided in Ennis et al. (1982) in relation to similar estimates in a study of lobsters at Comfort Cove, Notre Dame Bay. The general conclusion regarding these assumptions reached in the Comfort Cove study apply as well to this study of lobsters at Arnold's Cove. The main difference related to the Peterson model and involved a higher estimate of tag loss at Arnold's Cove - 7.3% (Table 3) compared to 1.7% at Comfort Cove. Where violation of the assumptions could be identified, corrections were made to eliminate bias in the estimate. Some assumptions could not be tested but as far as can be judged there are no violations which would introduce serious bias. It appears that the estimates are reliable, however, absolute accuracy is not a major consideration since the main purpose of this study is to measure and explain major fluctuations in abundance. Any biases that may be presented should be consistent from year to year and any substantial differences in the estimates should reflect real changes in population size.

The data on which the Petersen estimates are based are provided in Table 4 and those for the Leslie estimates in Table 5 and Figure 13. Confidence limits for the Petersen estimates (Fig. 14) ranged from ± 6.1 to ± 20.4% and those for the Leslie estimates (Fig. 14) ranged from -5.9 to -18.5% and from +7.2 to +40.0%. Trends in the two estimates are the same and for most years there was reasonably close agreement between them. They indicate that between 1971 and 1976 there was a very dramatic increase in standing stock in the Arnold's Cove lobster population and that since 1976 there has been a declining trend (Fig. 14).

Exploitation rate in the Arnold's Cove fishery has ranged as high as 96% in recent years (Table 4). It is obvious that recruitment is the major factor in determining the size of the standing stock in any given year. The upper limits of the recruit size ranges (81-93 mm for males; 81-90 mm for females) were determined from the premolt-postmolt relationships. The number of recruits (i.e. the number of lobsters that molted to commercial size (> 81 mm CL) since the preceding fishing season) was estimated as described by Ennis (1979) using data from the preceding fall shell condition sampling and from commercial catch sampling during the fishing season. The proportion of recruits in the standing stock varied from 67.3 to 81.6% (Table 6).

The increased recruitment during the 1970's, as indicated by the standing stock estimates for the Arnold's Cove lobster population, appears to have been fairly widespread in Placentia Bay. The landings data for Placentia Bay (since 1953) and for Statistical Section 30 (since 1969) within Placentia Bay which includes Arnold's Cove (Fig. 2), indicate a dramatic increase in abundance of lobsters from a very low level in the late 1960's - early 1970's to a very high level in 1976, in comparison to historical levels. Landings in Statistical Sections 29, 31, and 32 (Fig. 2), which make up the remainder of Placentia Bay, increased during the 1970's as well but not nearly as dramatically as in Section 30. Similarly, the landings data also indicate that the declining recruitment trend at Arnold's Cove in recent years is widespread in Placentia Bay.

GENERAL DISCUSSION AND CONCLUSIONS

Standing stock estimates for Comfort Cove, Notre Dame Bay, on the northeast coast of Newfoundland for the period 1972-81 (Ennis 1983b) indicate a dramatic increase in abundance of lobsters over the period followed by a declining trend since 1981 (Ennis, unpublished estimates). Landings for Notre Dame Bay over the period followed the same trends (Ennis 1982, Ennis et al. 1982, unpublished data). There is a remarkable similarity with trends in estimates of standing stock at Arnold's Cove and landings in Placentia Bay as presented in this paper. This indicates that the dramatically increased recruitment during the 1970's and subsequent decline observed at Comfort Cove and at Arnold's Cove was a widespread phenomenon.

The cause of the increased recruitment during the 1970's is uncertain. Environmental conditions for survival of lobster larvae to settlement stage or for survival and growth of postlarval and early juvenile stages may have been much better than average during the late 1960's - early 1970's. Another possibility is improved conditions (eg. reduced competition) for growth and survival of early juveniles and prerecruits because of low levels of recruit abundance as indicated by commercial landings during the early 1970's.

In both Notre Dame and Placentia Bays, the period of increased recruitment was preceded by a period of declining landings and fishing effort (Ennis 1982) which was much more substantial for Notre Dame Bay than for Placentia Bay. It is difficult to judge whether these events in the fishery might have affected the level of egg production to the point where subsequent recruitment was affected. Exploitation rates might have declined somewhat as a result of the declining effort thereby allowing greater relative levels of egg production but the declining landings over the period would indicate reduced levels of abundance of egg-bearing females that would negate the preceding effect. It seems likely that the dramatically increased recruitment observed in these areas was mostly independent of events in the fishery.

Along with the increased recruitment during the 1970's there was a dramatic increase in fishing effort (Ennis 1982) that also contributed to the increased landings over the period. The increased exploitation rates observed at Comfort Cove and Arnold's Cove over this period are no doubt indicative of a general trend in these areas and in Newfoundland generally. The catch and effort data that are available for the Newfoundland lobster fishery are not amenable to analysis using surplus yield models which might give a reliable indication of MSY and associated fishing effort. The main reasons are an inconsistent and largely inadequate measure of effort and highly variable application and enforcement of the size limit and berried female regulations over the history of the fishery. However, assessments (Ennis 1978b, 1980c) clearly indicate that current exploitation rates are considerably in excess of those that would maximize yield per recruit at the current minimum legal size. In addition, an egg per recruit assessment (Ennis 1985) indicates that egg production, and probably subsequent recruitment to the stocks, could be substantially increased with an increase in size limit and/or a reduction in exploitation rate. There is little doubt that were a surplus yield analysis possible, it would show that current effort is substantially greater than that associated with MSY and current yields are substantially less than MSY.

Although it appears that recruitment in lobster stocks is highly dependent on environmental conditions, it is likely that the level of recruitment is greatly limited by the relatively low level of egg production under existing conditions in the fishery. Historically, there have been substantial declines in landings at substantially lower levels of exploitation than currently prevail. The declining recruitment trend observed at Comfort Cove and at Arnold's Cove since the period of increased recruitment and the corresponding decline in landings in Notre Dame and Placentia Bays generally, indicate that the relatively high landings of recent years for Newfoundland as a whole won't be sustained over the long term and that declines to levels of the early 1970's and possibly lower should be anticipated.

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Table 1. Counts of lobster traps on the fishing grounds at Arnold's Cove, estimated number of trap hauls and exploitation rates for each season, 1971-84.

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Trap counts	386	349	520	733	935	1066	1063	-	1012	1080	-	-	-	-
Trap hauls	13777	-	-	-	-	36746	47000	48028	35955	48475	33893	33520	36056	40389
Exploitation rate (%)	69.9	-	-	-	-	79.3	81.4	85.4	79.8	82.1	96.1	77.9	90.0	82.3

Table 2. Sex ratios in commercial landings at Arnold's Cove, 1970-84.

Year	No. males	No. females	M:F	P
1970	306	437	1:1.43	< .001
1971	337	661	1:1.96	< .001
1972	534	410	1:0.77	< .001
1973	928	704	1:0.76	< .001
1974	1227	1078	1:0.88	< .005
1975	1162	967	1:0.83	< .001
1976	1774	1572	1:0.89	< .001
1977	1960	1910	1:0.97	> .25
1978	862	882	1:1.02	> .50
1979	1140	1215	1:1.07	> .10
1980	1399	1366	1:0.98	> .50
1981	1202	1263	1:1.05	> .10
1982	1219	1506	1:1.24	< .001
1983	1436	1647	1:1.15	< .001
1984	1439	1186	1:0.82	< .001

Table 3. Estimates of tag loss between tagging in the fall and the fishing season the following spring at Arnold's Cove, 1977-83.

Year	No. of fishermen canvassed	No. of tags returned	No. of lobsters observed with secondary marks only	% tags lost
1977	8	293	24	8.2
1978	6	231	12	5.2
1980	7	326	19	5.8
1982	7	200	9	4.5
1983	8	336	37	11.0
All years	-	1386	101	7.3

Table 4. Data from which Petersen estimates of population size at Arnold's Cove were obtained.

Year	No. of lobsters tagged preceding fall			No. of tagged lobsters in population at beginning of fishing season			No. of tagged lobsters returned during fishing season			Exploitation rate (%) M and F combined	No. of tagged lobsters returned by fishermen providing catch data		No. of lobsters caught by fishermen providing catch data	
	M	F	Total	M	F	Total	M	F	Total		M	F	M	F
1971	166	263	429	154	244	398	99	179	278	69.9	57	128	241	473
1976	193	57	250	179	53	232	145	39	184	79.3	85	18	5758	5102
1977	374	124	498	347	115	462	291	85	376	81.4	145	42	4698	4569
1978	389	121	510	361	112	473	309	95	404	85.4	166	52	4833	4951
1979	343	153	496	318	142	460	250	117	367	79.8	164	70	4524	4823
1980	372	127	499	345	118	463	278	102	380	82.1	180	67	5643	5509
1981	344	156	500	319	145	464	306	140	446	96.1	209	96	5341	5603
1982	301	191	492	279	177	456	221	134	355	77.9	152	92	3573	4420
1983	341	156	497	316	145	461	278	137	415	90.0	213	107	5150	5808
1984	347	151	498	322	140	462	270	110	380	82.3	185	80	5121	4221

Table 5. Data from which Leslie estimates of population size at Arnold's Cove were obtained.

	Week of fishing season	Observed CPUE	Avg. Temp. (°C)	CPUE adjusted to 4°C	Cumulative catch
1971					
	1	0.377	1.95	0.612	235
	2	0.333	1.78	0.570	671
	3	0.318	3.15	0.378	1125
	4	0.284	3.85	0.293	1672
	5	0.247	4.70	0.219	2242
	6	0.241	7.76	0.142	2691
	7	0.181	7.85	0.105	2990
	8	0.149	5.80	0.112	3193
	9	0.162	7.98	0.093	3336
	10	0.104	7.68	0.062	3436
	11	0.154	8.96	0.080	3474
1976					
	1	0.716	0.32	2.297	1596
	2	0.658	0.93	1.546	5130
	3	0.759	3.51	0.836	9039
	4	0.592	3.91	0.603	12691
	5	0.362	2.26	0.537	15189
	6	0.381	4.08	0.376	16892
	7	0.279	4.98	0.236	18194
	8	0.258	5.21	0.211	18774
	9	0.193	6.51	0.131	19065
	10	0.227	6.95	0.146	19255
	11	0.341	7.80	0.199	19362
1977					
	1	0.501	1.35	0.994	1202
	2	0.551	2.28	0.811	4523
	3	0.497	2.85	0.633	8493
	4	0.333	2.80	0.430	11387
	5	0.331	3.61	0.358	13767
	6	0.323	4.71	0.285	15644
	7	0.321	5.25	0.260	17151
	8	0.278	5.56	0.216	18022
	9	0.144	7.23	0.090	18451
	10	0.091	5.35	0.073	18604

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Table 5. (Cont'd.)

	Week of fishing season	Observed CPUE	Avg. Temp. (°C)	CPUE adjusted to 4°C	Cumulative catch
1978					
	1	0.359	1.53	0.667	595
	2	0.459	2.11	0.709	3071
	3	0.450	2.55	0.617	6565
	4	0.374	2.70	0.495	9389
	5	0.404	3.73	0.425	12005
	6	0.418	5.35	0.334	14199
	7	0.246	5.08	0.205	15592
	8	0.252	5.08	0.210	16574
	9	0.321	6.73	0.213	17184
	10	0.269	8.15	0.152	17656
	11	0.242	9.95	0.115	18015
1979					
	1	0.484	1.20	1.014	456
	2	0.364	1.21	0.762	1608
	3	0.346	1.58	0.633	3263
	4	0.353	1.90	0.581	4978
	5	0.421	2.43	0.597	6835
	6	0.539	4.15	0.525	9249
	7	0.434	5.03	0.364	11346
	8	0.422	7.85	0.246	12794
	9	0.320	8.11	0.181	13778
	10	0.346	8.55	0.187	14341
	11	0.490	10.05	0.230	14622
1980					
	1	0.645	0.38	1.993	2226
	2	0.296	-0.16	1.328	5281
	3	0.244	-0.06	1.011	6812
	4	0.318	1.26	0.652	8603
	5	0.468	3.41	0.527	11049
	6	0.270	2.90	0.341	13155
	7	0.292	3.71	0.309	14580
	8	0.269	5.33	0.216	15649
	9	0.255	6.13	0.182	16380
	10	0.243	8.36	0.1339	16937

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Table 5. (Cont'd.)

	Week of fishing season	Observed CPUE	Avg. Temp. (°C)	CPUE adjusted to 4°C	Cumulative catch
1981					
	1	0.856	2.15	1.312	2678
	2	0.670	3.35	0.763	7372
	3	0.430	3.60	0.466	10593
	4	0.350	5.35	0.280	12638
	5	0.295	7.60	0.176	14088
	6	0.194	4.98	0.164	14951
	7	0.192	8.08	0.111	15353
	8	0.177	5.00	0.149	15648
	9	0.144	7.68	0.085	15840
	10	0.161	8.93	0.084	15924
	11	0.243	10.36	0.111	15983
1982					
	1	0.548	1.00	1.252	1432
	2	0.398	1.40	0.773	4115
	3	0.325	0.45	0.965	6193
	4	0.180	-0.03	0.730	7276
	5	0.240	0.70	0.628	7760
	6	0.349	3.18	0.413	8665
	7	0.307	4.25	0.294	9841
	8	0.281	4.53	0.256	10756
	9	0.217	5.50	0.170	11348
	10	0.208	4.93	0.177	11576
1983					
	1	0.720	1.28	1.467	1820
	2	0.553	3.33	0.633	5533
	3	0.417	3.70	0.442	8642
	4	0.248	2.02	0.394	10311
	5	0.280	4.97	0.237	11309
	6	0.259	1.43	0.499	12145
	7	0.214	4.02	0.213	12718
	8	0.185	6.35	0.129	13255
	9	0.199	7.18	0.125	13691
	10	0.158	9.12	0.081	13916
	11	0.247	11.58	0.102	14001

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Table 5. (Cont'd.)

	Week of fishing season	Observed CPUE	Avg. Temp. (°C)	CPUE adjusted to 4°C	Cumulative catch
1984					
	1	0.690	0.20	2.385	779
	2	0.373	0.00	1.480	2350
	3	0.328	0.62	0.892	4001
	4	0.344	1.07	0.761	5832
	5	0.382	3.15	0.455	7976
	6	0.285	2.62	0.384	9812
	7	0.281	5.63	0.216	11155
	8	0.215	4.72	0.190	12279
	9	0.208	4.40	0.194	12927
	10	0.215	5.77	0.162	13244
	11	0.179	6.73	0.119	13378

Table 6. Estimates of the percent recruits in standing stock at Arnold's Cove, 1971-84.

Year	Standing stock estimate		Percent in recruit size range[1]		Percent molters in recruit size range[2]		No. recruits in standing stock		Percent recruits in standing stock M and F combined
	M	F	M	F	M	F	M	F	
1971	647	900	60.8	29.8					
1976	12054	14503	76.4	82.8	84.6	96.5	7785	11582	72.9
1977	11200	12328	82.5	76.0	93.3	90.4	8618	8475	72.7
1978	10478	10550	81.6	78.2	93.5	74.7	7992	6169	67.3
1979	8748	9716	85.2	81.3	86.8	95.1	6471	7511	75.7
1980	10789	9643	81.6	77.1	96.0	91.8	8457	6824	74.8
1981	8140	8435	81.8	77.3	96.0	95.4	6392	6220	76.1
1982	6541	8462	90.8	80.0	96.8	96.1	5749	6498	81.6
1983	7630	7853	83.6	82.8	97.0	92.1	6188	5986	78.6
1984	8913	7387	87.8	74.5	97.5	87.5	7625	4818	76.3

[1] based on commercial catch sampling
[2] based on shell condition sampling preceding fall

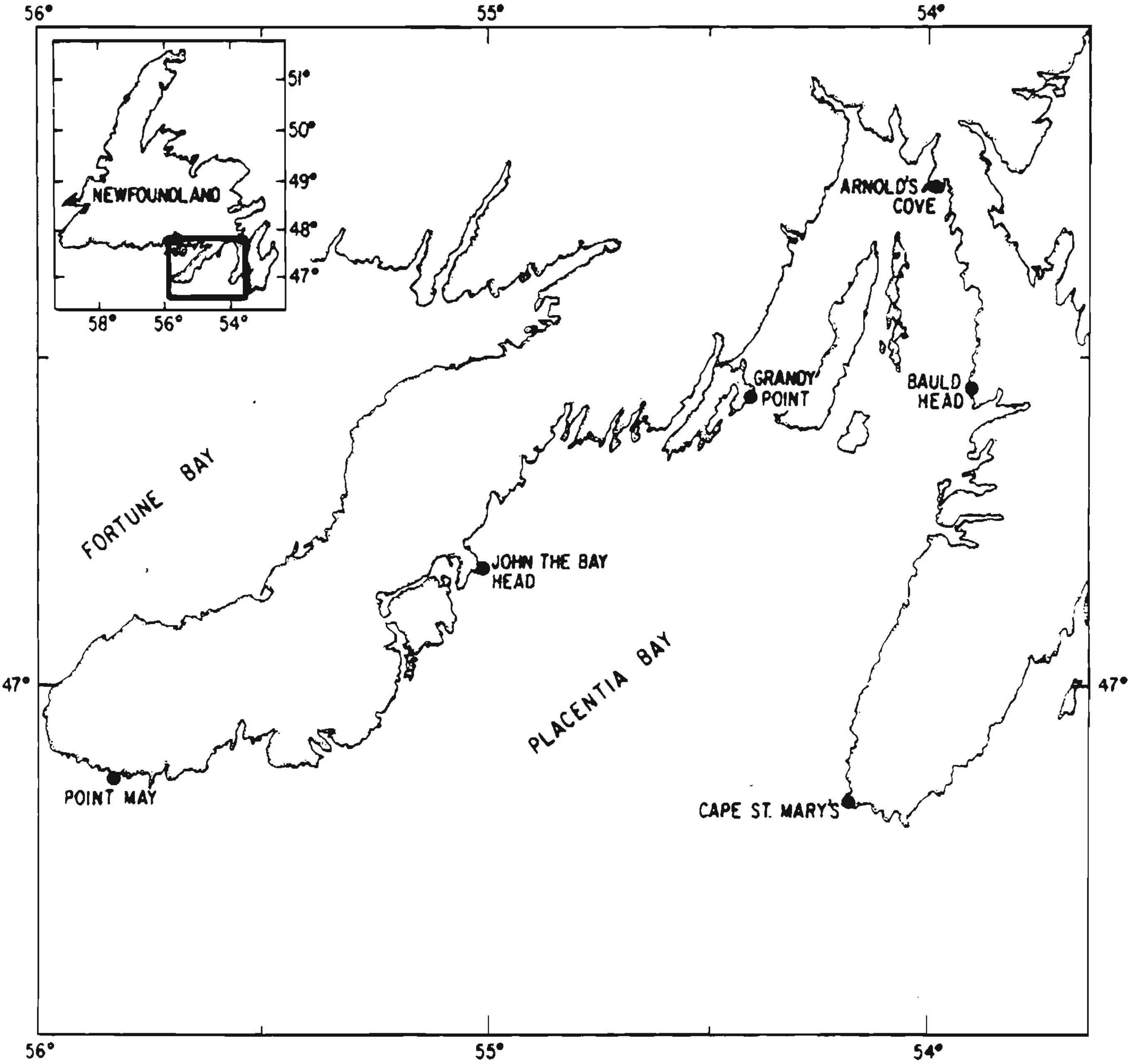

Fig. 1. Map of Placentia Bay (Statistical Area H), Newfoundland, with boundaries of Statistical Sections 29 to 32 indicated.

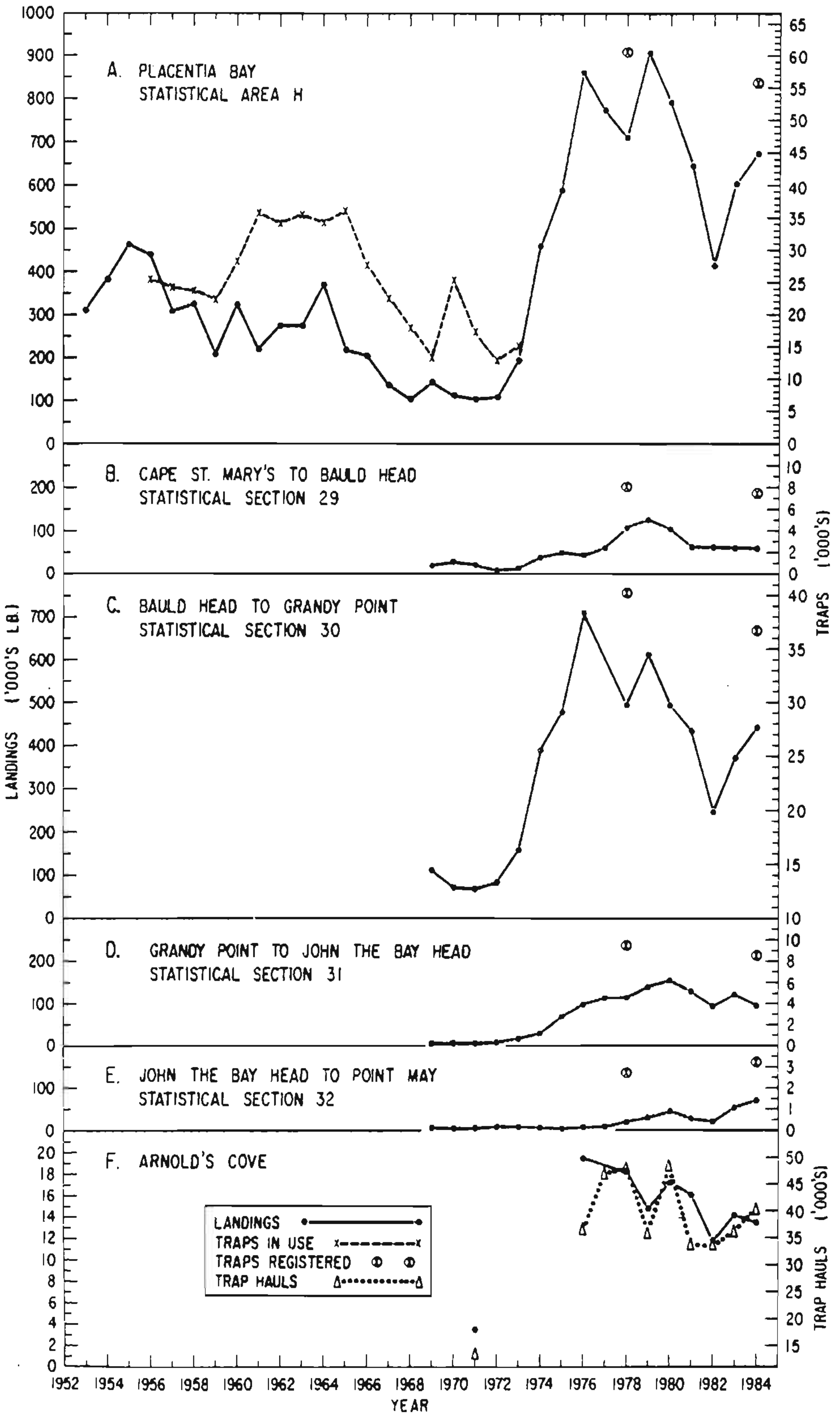

Fig. 2. History of lobster landings and effort for Placentia Bay (Statistical Area H) for Statistical Sections 29 to 32 and for Arnold's Cove.

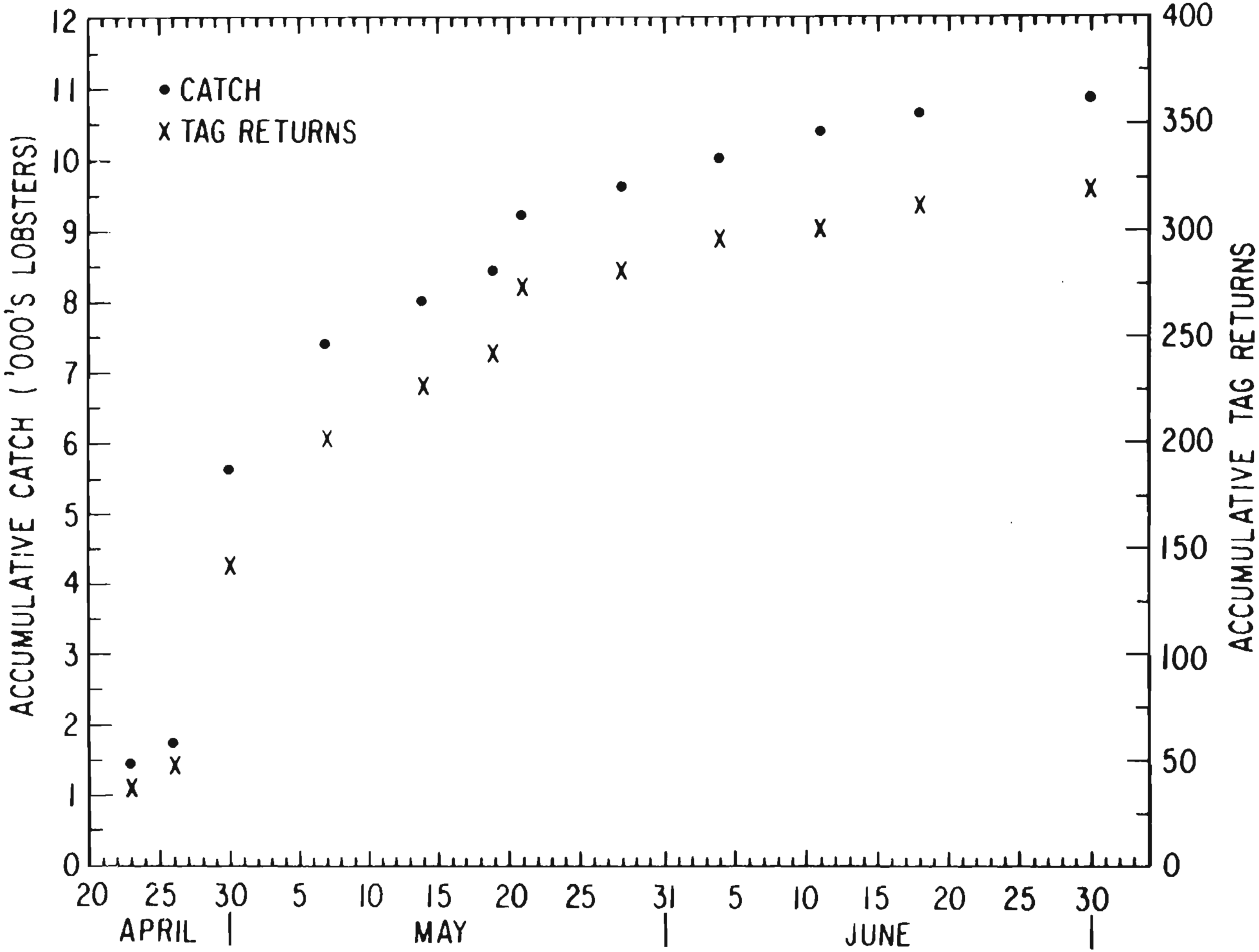

Fig. 3. Accumulative catch and strap tag returns at Arnold's Cove during the 1983 fishing season.

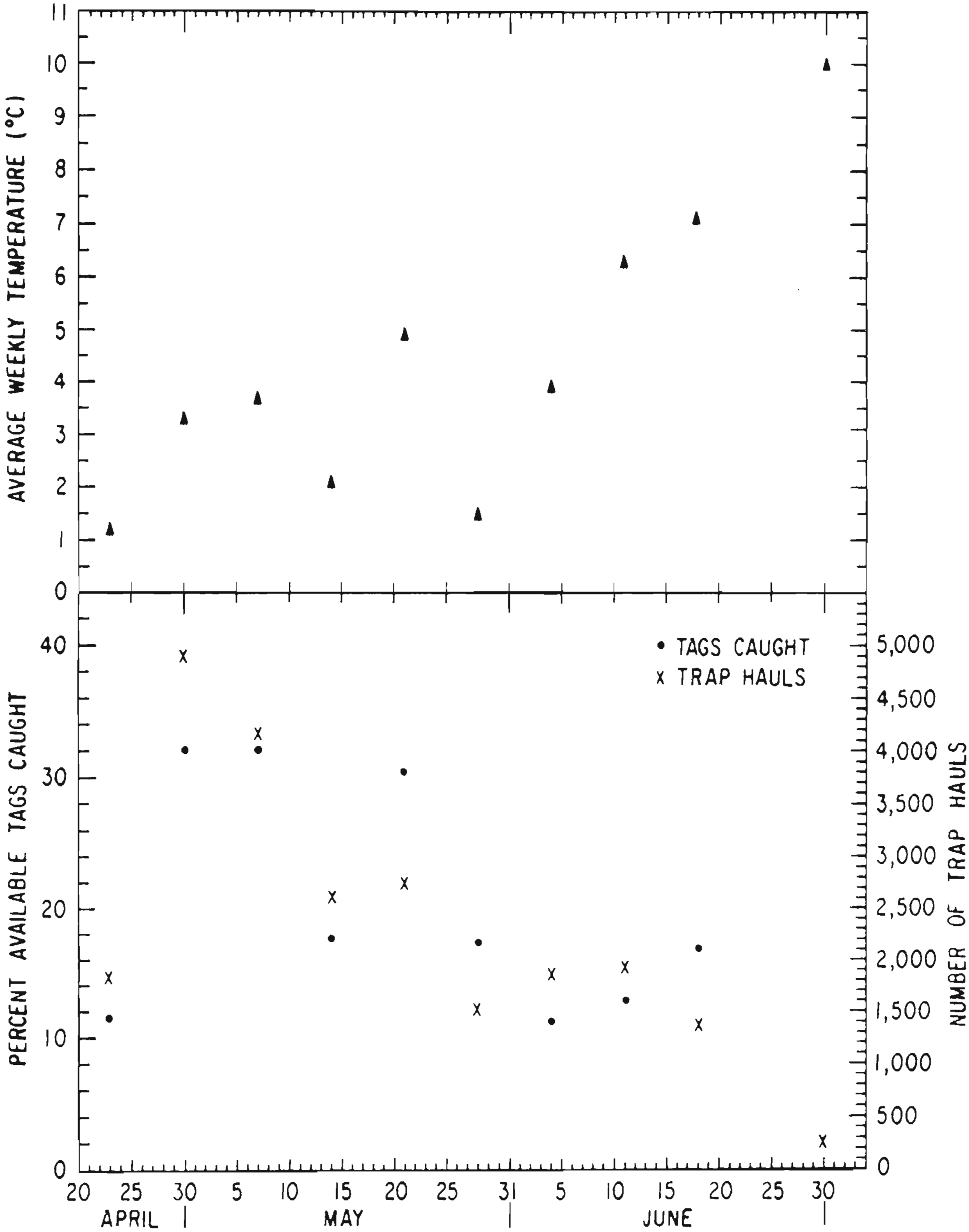

Fig. 4. Percent of available strap tagged lobsters caught, estimated number of trap hauls and average temperature at weekly intervals during the 1983 fishing season at Arnold's Cove.

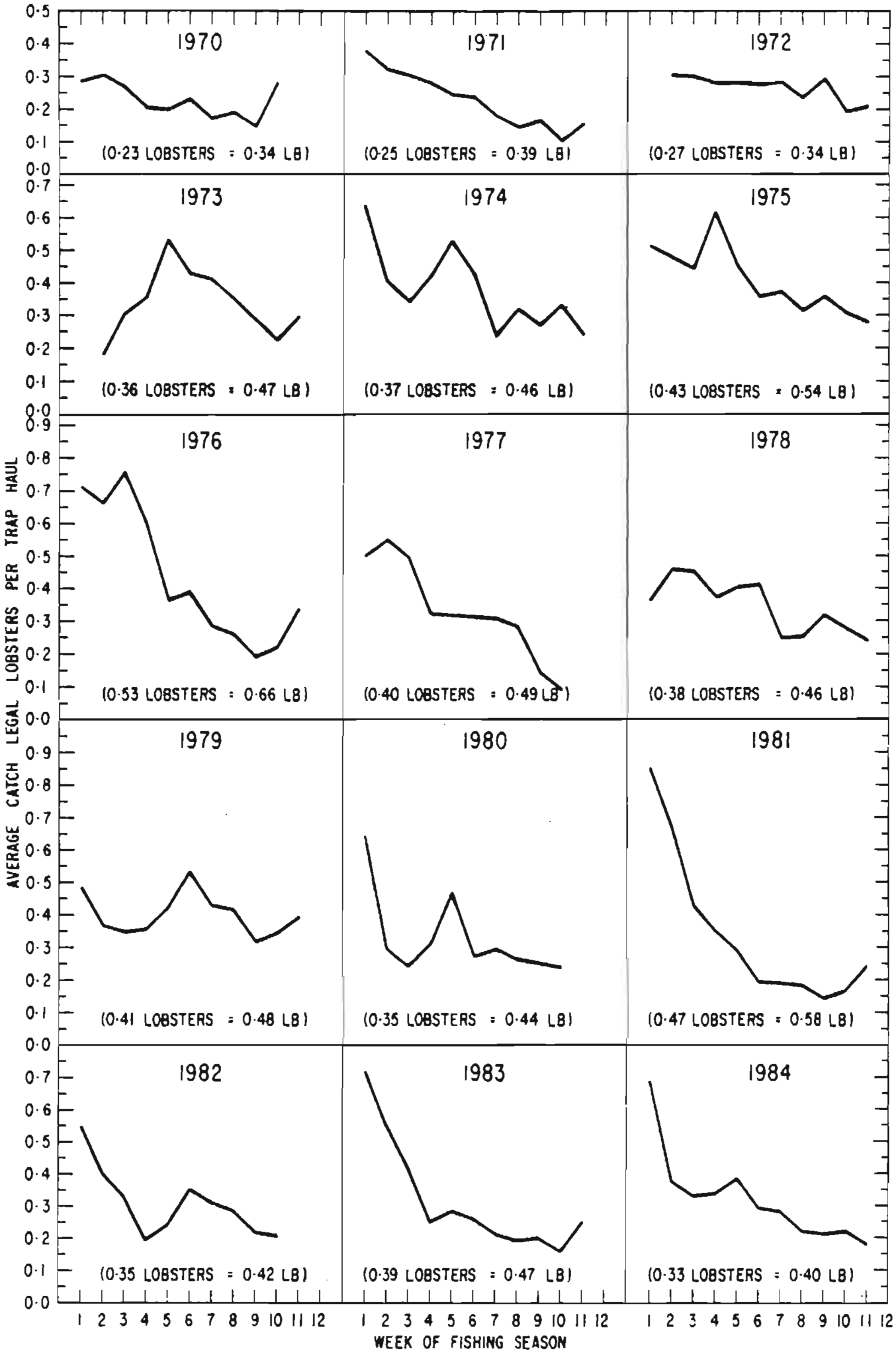

Fig. 5. Average weekly CPUE (number of commercial lobsters per trap haul) throughout the 1970 through 1984 fishing seasons at Arnold's Cove. Season averages and weight equivalents are provided for each year.

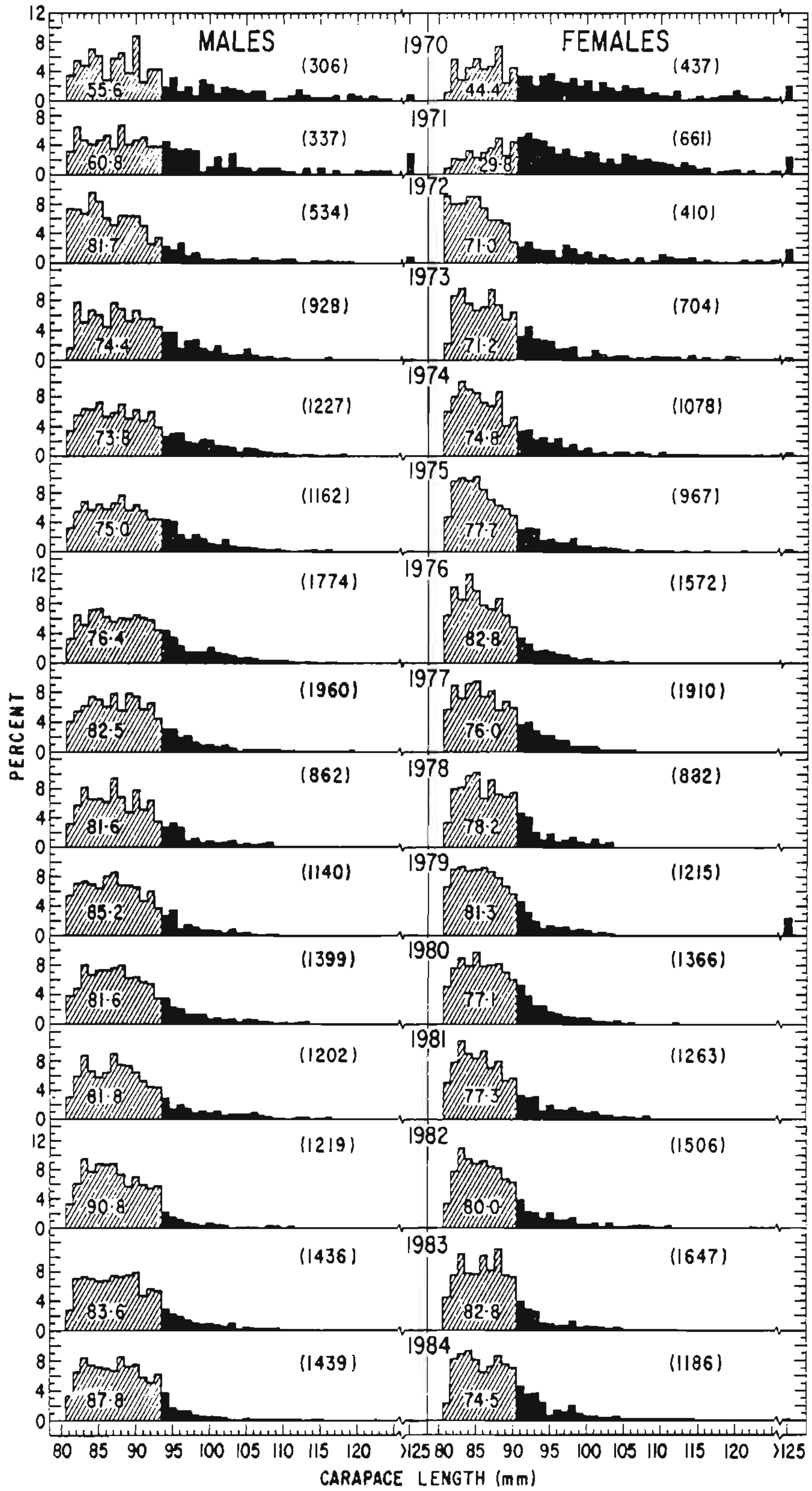

Fig. 6. Size frequency distributions of lobsters landed at Arnold's Cove during the 1970 through 1984 fishing seasons. Hatched areas and the numbers included represent proportions within the recruit size ranges. Sample sizes are indicated.

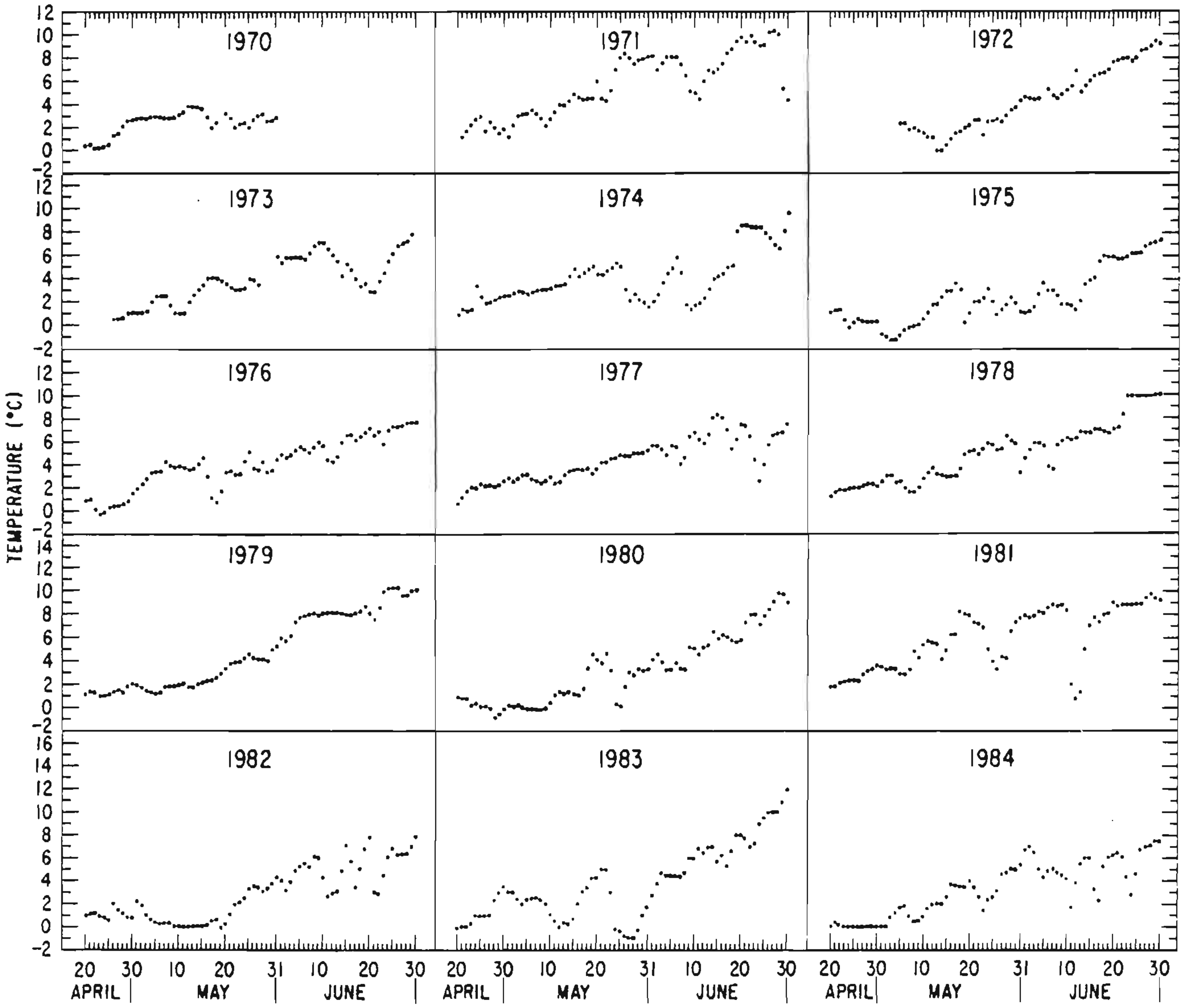

Fig. 7. Daily temperatures (°C) at a depth of 9 m on the lobster grounds at Arnold's Cove during April-July from 1970 through 1984.

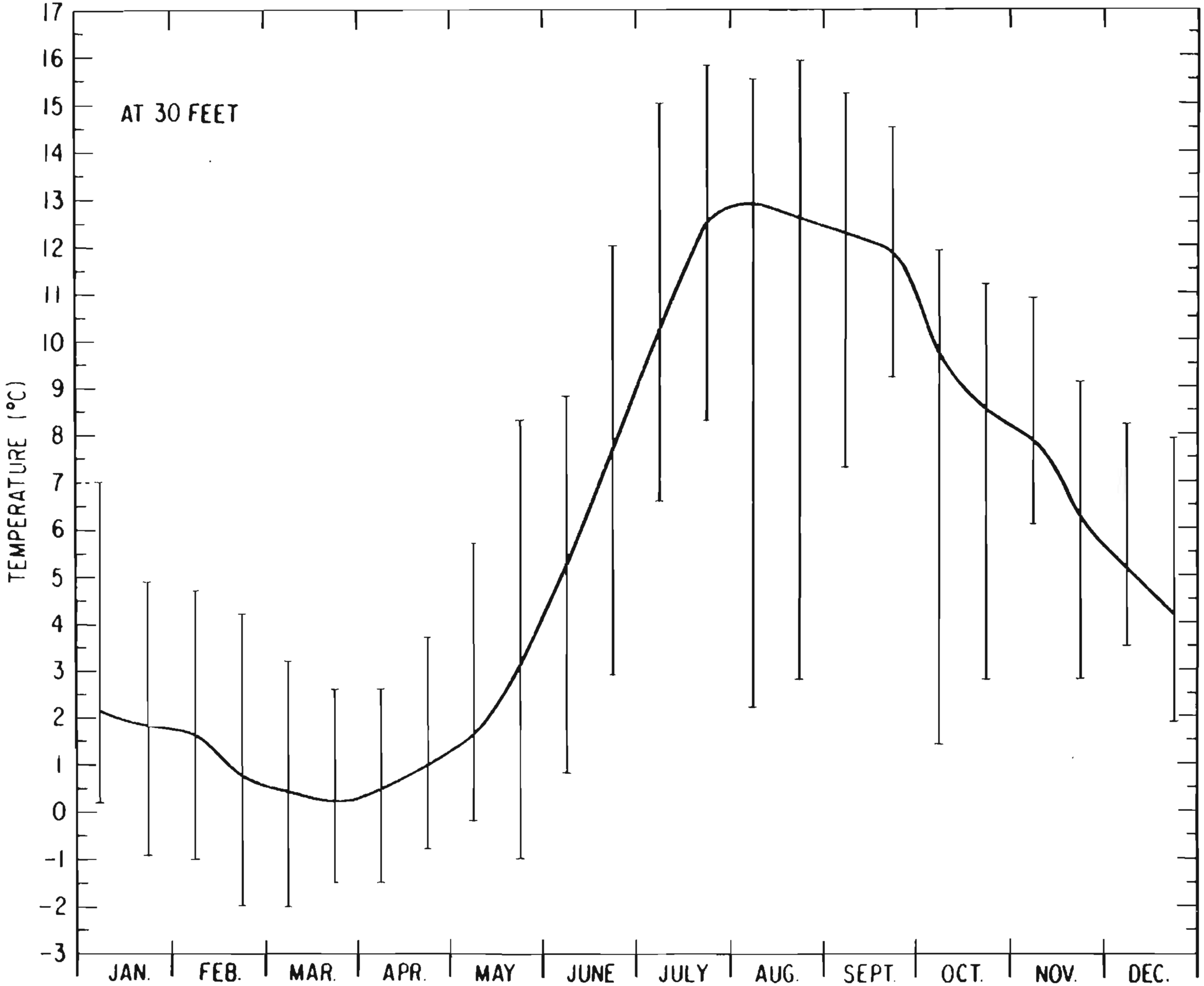

Fig. 8. Annual temperature regimes at Arnold's Cove. Points represent the average of the mean daily temperature for the first and second half of each month for the years 1980-83. Vertical lines indicate the range in daily mean temperatures.

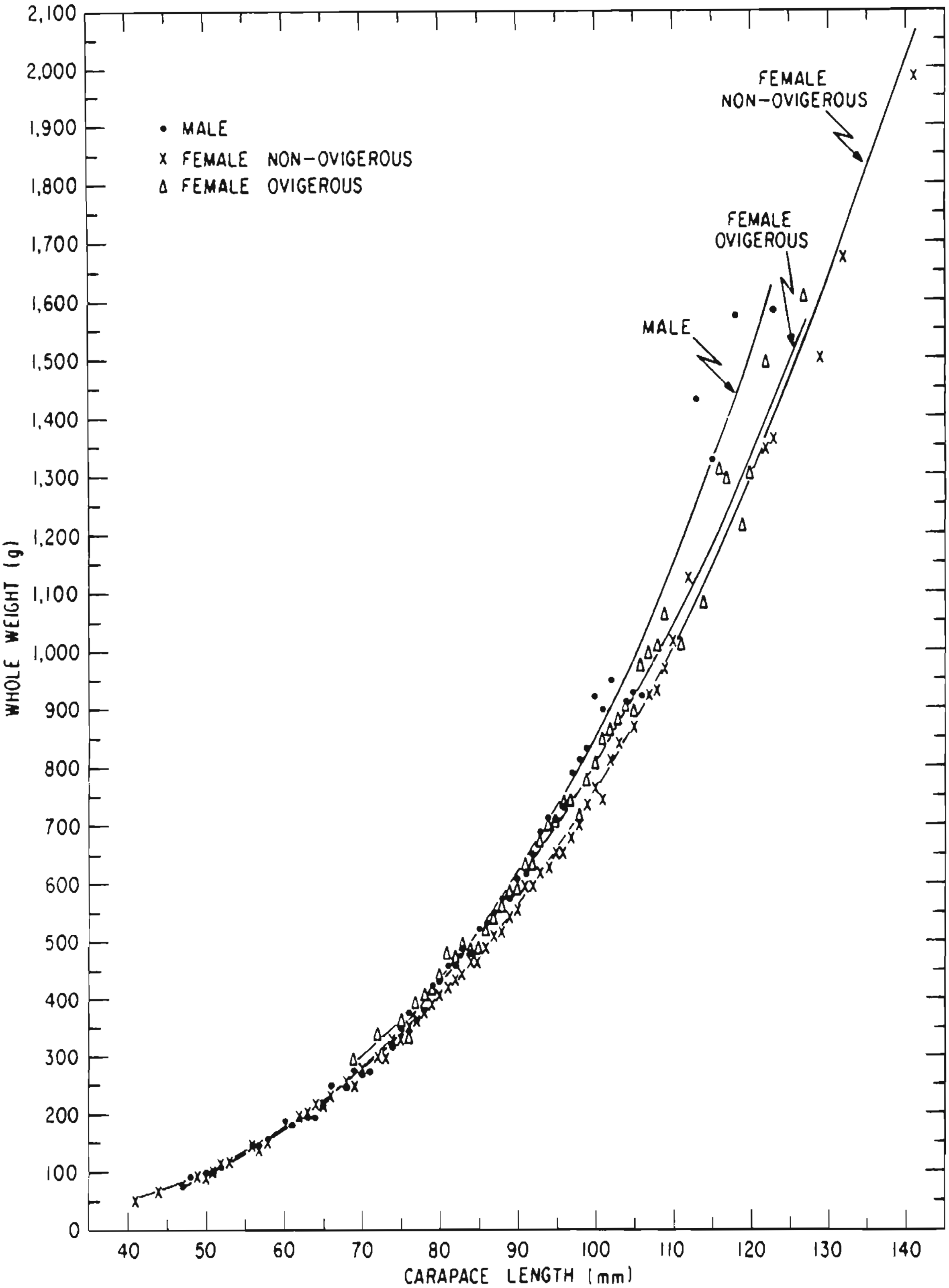

Fig. 9. Carapace length-whole weight relationships for Arnold's Cove lobsters.

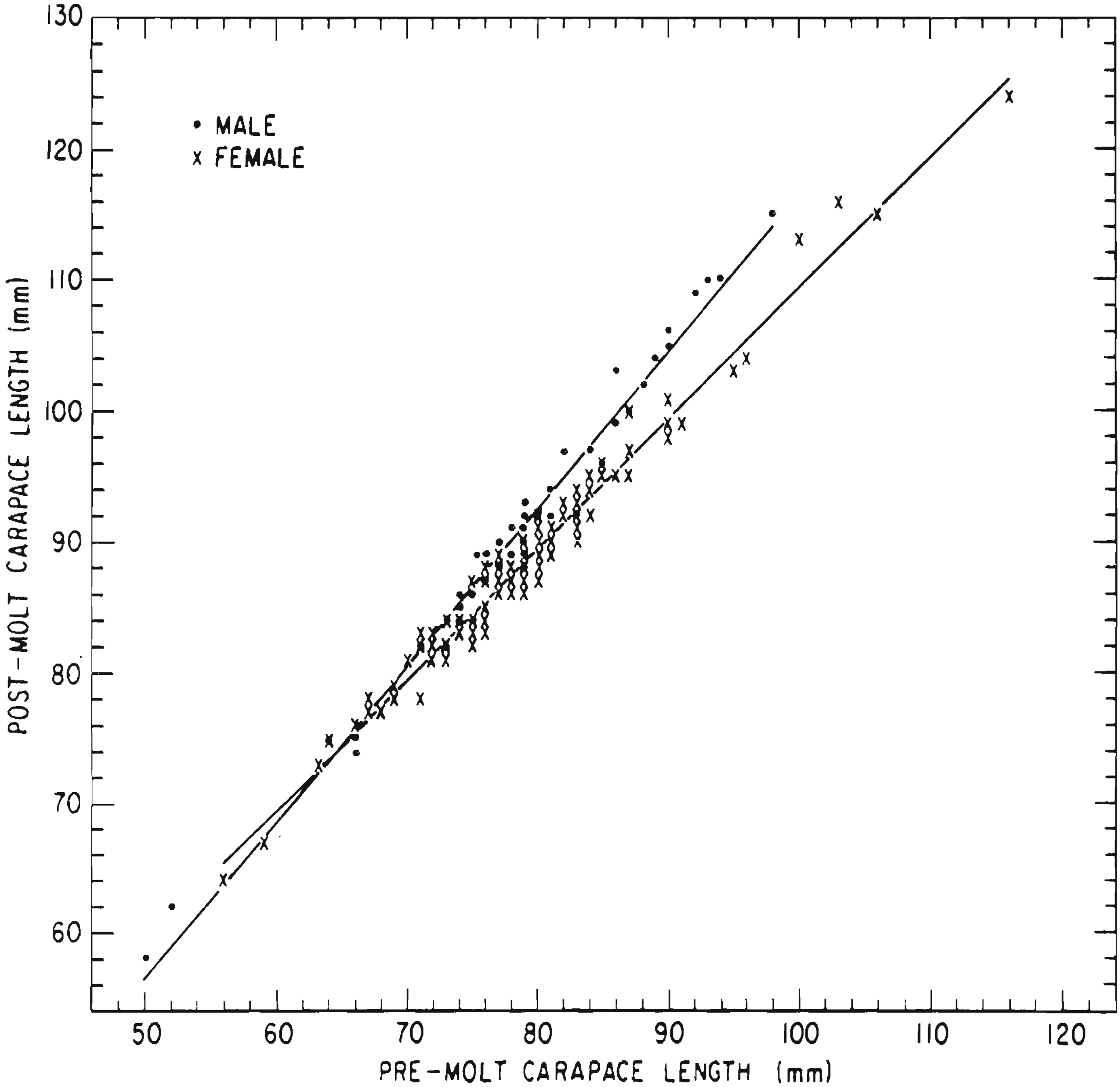

Fig. 10. Premolt-postmolt carapace length relationships for Arnold's Cove lobsters.

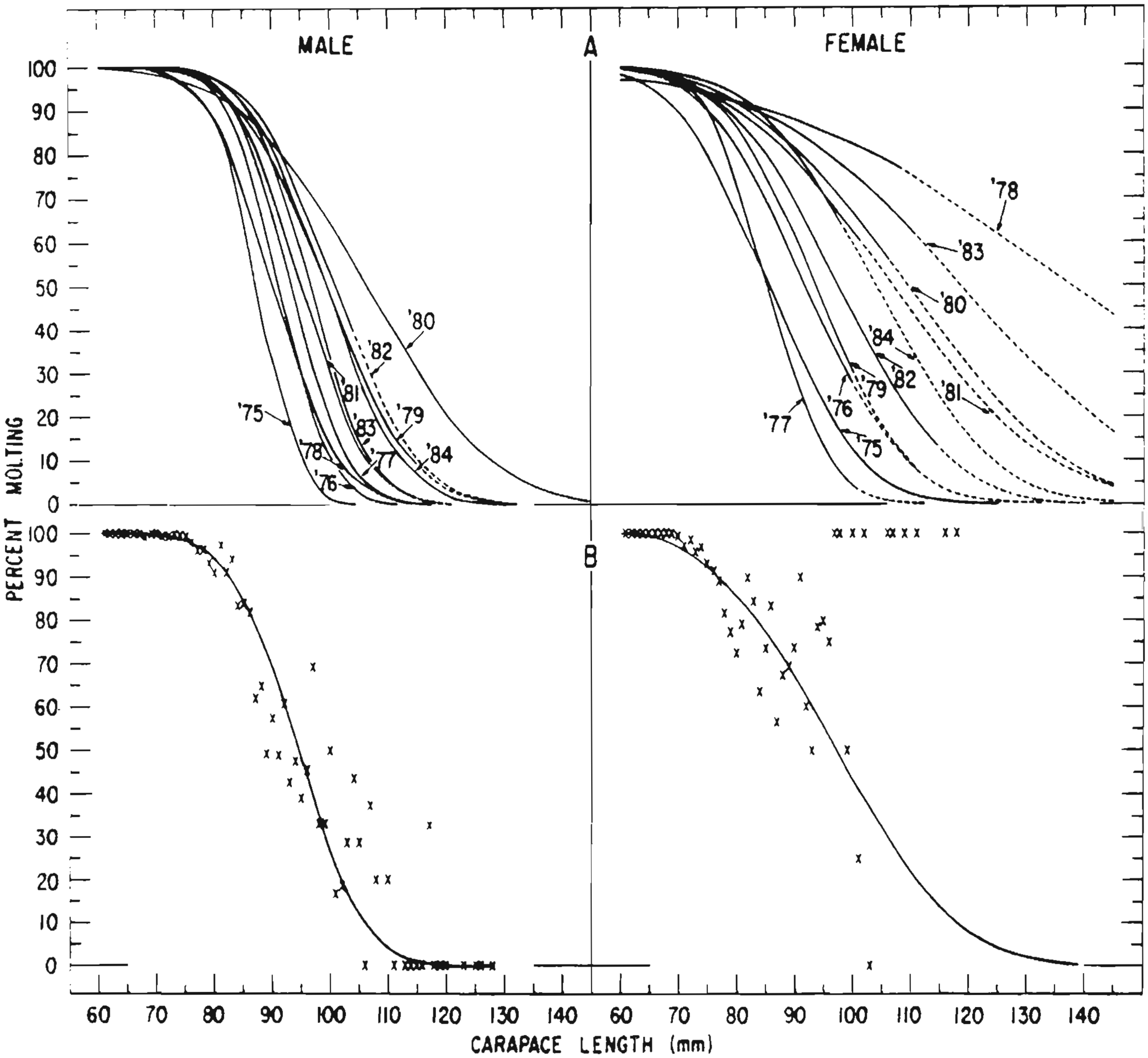

Fig. 11. Carapace length-proportion molting relationships for Arnold's Cove lobsters. A - relationship for each year 1976-84; B - relationship for all years combined.

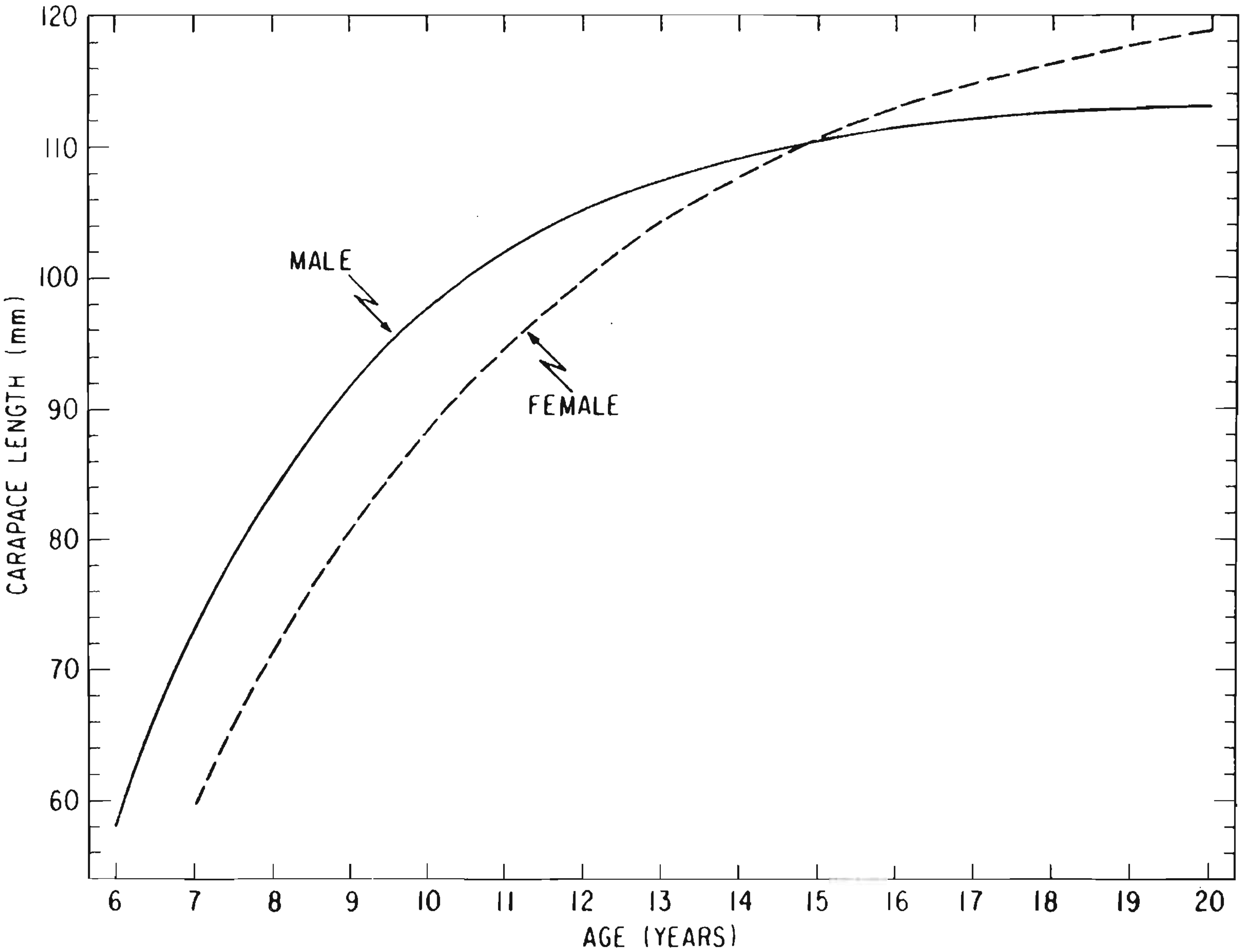

Fig. 12. Growth curves for Arnold's Cove lobsters.

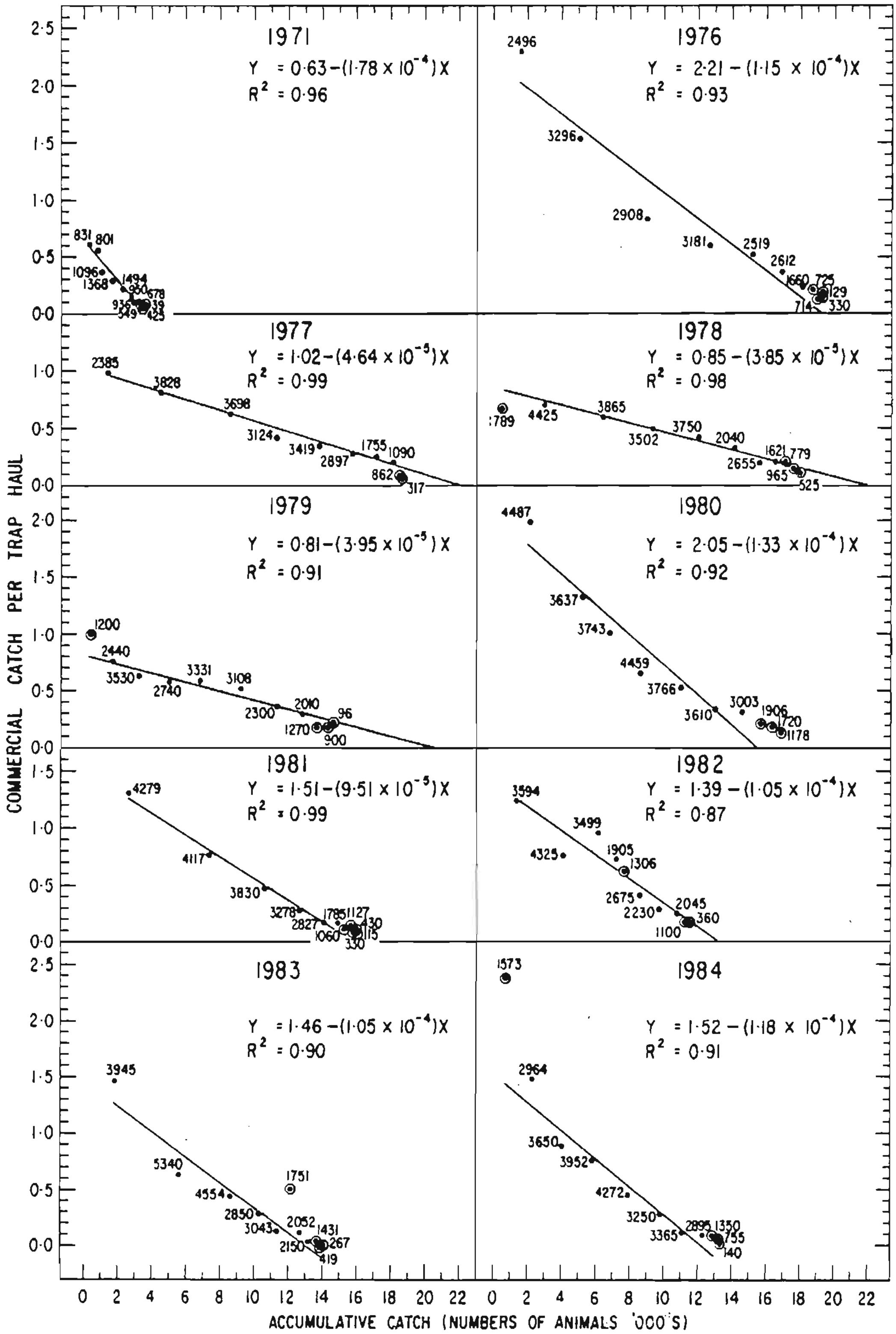

Fig. 13. Leslie analyses of Arnold's Cove CPUE data (adjusted to 4°C) for 1971 and 1976-84. Circled points were not used in the regressions. Numbers adjacent to points are total trap hauls on which the CPUE's are based.

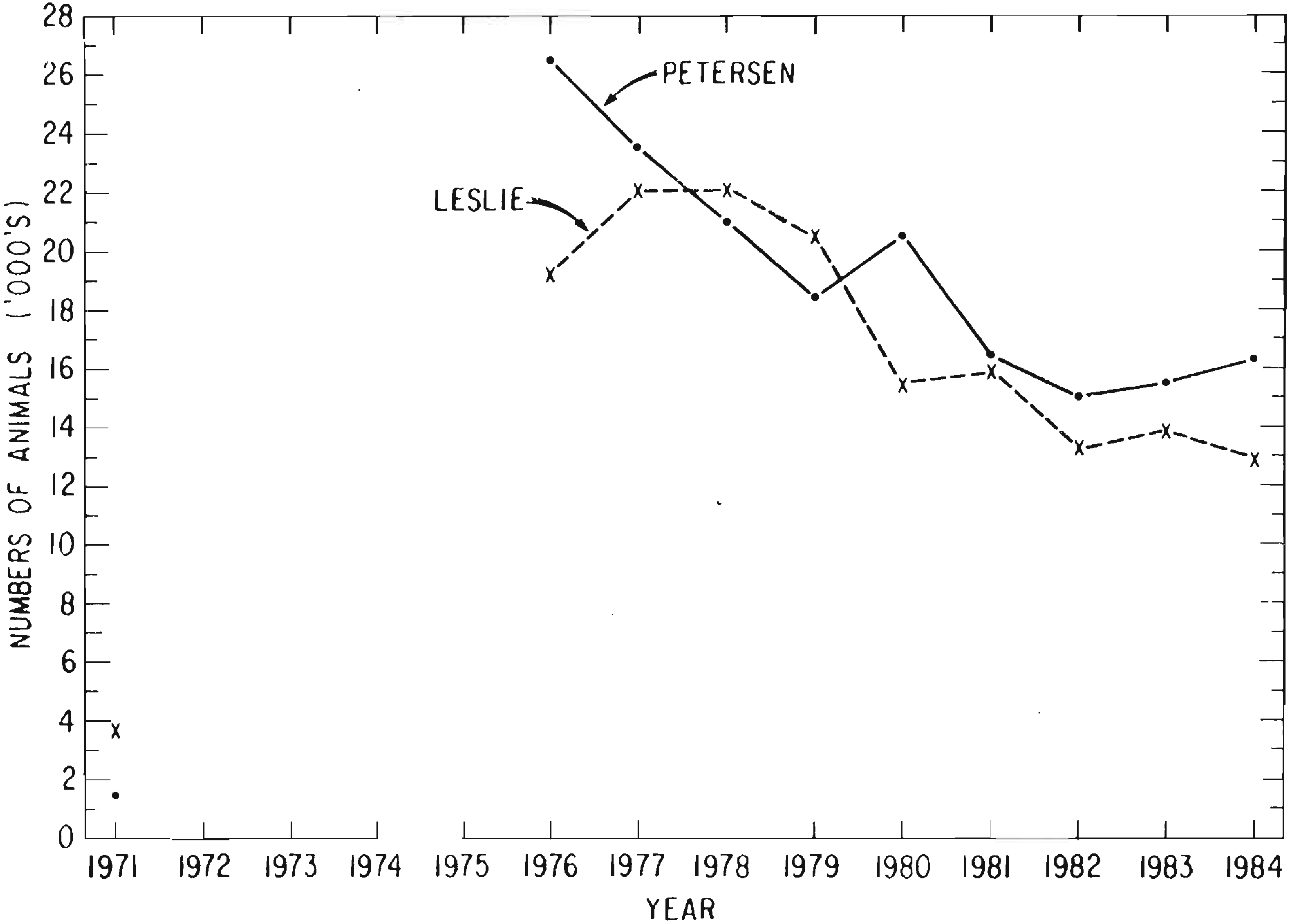

Fig. 14. Petersen and Leslie estimates of the standing stock of lobsters at Arnold's Cove for 1971 and 1976-84.