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Rock lobster stock assessment

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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I. Introduction

a) Overview

This document describes the current state of the rock lobster fishery and resource in New Zealand.

Two species are taken by the fishery for rock lobsters: the red rock lobster Jasus edwardsii and the green or packhorse rock lobster Jasus verreauxi. The latter species is abundant only in the northern part of the country, and contributes only about a 1% share to the total catch. This document therefore deals only with J. edwardsii.

b) Description of the fishery

The present fishery for rock lobsters is a "controlled fishery" with restricted entry (Annala 1983a,b) introduced in 1979-1980. Each of 10 controlled fishery areas (CFAs) has a calculated optimum number of vessels based on yield modelling and landing patterns (Saila et al. 1979; Annala 1983b). In 1987, 773 vessels were licensed to fish for rock lobsters; this number has been nearly constant for several years. Much of the fishery is conducted from small, fast dayboats. A few larger vessels, especially in the southern part of the country, make longer trips.

The fishery is prosecuted all around New Zealand including the Chatham Islands.

The fishery is currently restricted by limited entry, a size limit, and a prohibition on taking egg-bearing females. The size limit, or minimum legal size (MLS), was based until June 1988 on tail length, and was 152 mm. On 1 June 1988 this was changed to the equivalent measure in tail width, measured between spines on the second abdominal segment (Breen, Booth & Tyson 1988a). The MLS is 54 mm for males and 58 mm for females. For part of the year in most of the Otago area the MLS is 127 mm tail length.

There are no seasonal restrictions except at the Chatham Islands. Fishing may take place in any location except that commercial fishermen must fish only in their assigned CFA. There are two small Marine Reserves closed to all fishing and several other small areas closed to commercial fishing. Fishing is restricted mainly to potting, except for a small number of commercial divers and trawlers with rock lobster permits. No limit on pots is imposed, but pots must provide gaps for sub-legal escapement. Tailing at sea is permitted only in part of the Southern CFA; in the rest of the country rock lobsters must be landed alive.

An amateur fishery is well developed, involving potting, SCUBA diving and free diving. No licence is required, but a daily bag limit of 6 is imposed and amateurs must respect the same size limit and berried female restrictions as the commercial fishery.

The Maori fishery has a very long standing. The legal regulation of Maori fishing is currently sub judice. A section of legislation allows rock lobsters to be taken under special permit for huis and tangis.

c) Review of the literature

The literature on *Jasus edwardsii* is considerable. The most relevant articles are cited in context below. Reviews of fishery-related literature are provided by Booth (in press) and Annala (1983a). The annotated bibliography of McKoy (1979) was updated by Breen & McKoy (1988); the new bibliography is indexed by subject and area.

II. Review of the Fishery

a) Catch and effort

Catch data are available from 1930 to the present. Data before 1945 have been obtained from the Annual Reports on Fisheries, published by the Marine Department; subsequent data were taken from later summaries (see Table 1). Although the early data were compiled on a financial year basis (1 April through 31 March), later data were published by calendar year.

Effort data form a less continuous series. From 1945 to 1962, only the number of vessels is available. From 1963 to the present, vessel-days are available; except for a 5-year hiatus beginning in 1974. From 1979 to the present, pot-lifts have been given for most of the catch taken by pots. Data from 1963 to 1973 are given by Annala & King (1983). Data from each year since 1978 have been published as a separate report (see, for instance, Sanders 1986).

Table 1 gives reported catch data from all of New Zealand, 1930-1987. The area of greatest interest is the combination of the North & South Islands (including Stewart Island), within which there is considered to be one stock (Annala 1986; see below). Table 2 gives catch and effort data, 1945-1987, for this area. Reported catches are shown in Fig. 1. Effort, as vessels, vessel-days and pot-lifts, is shown in Fig. 2.

In the past, catches have probably been under-reported to some extent. The period 1974-1978 is thought to be particularly suspect (Annala & Esterman 1986). McKoy (unpub. data) compared reported landings with export statistics for 1974-1985 (Table 3).

Reporting is thought to have improved with the introduction of the controlled fishery (Annala 1983a), and again with development of the ITQ proposal where initial ITQs would be awarded on the basis of past landings. In 1987 the industry made representations that the catch and effort data were suspect for a number of reasons. MAF agreed to conduct an `audit' in which catch histories for each vessel could be corrected. This procedure is still scheduled to be conducted in 1988.

Variation of catch between areas can be seen in Table 4, which gives catches for each CFA, 1979-1986. Variation in fishing season is shown in Table 5, which gives total reported landings by month, 1979-1986.

CPUE, using vessel-days as the measure of effort, is shown in Fig. 3. For the years prior to 1963, vessel-days were estimated from the numbers of vessels under the assumption that vessel-days per vessel were constant at the 1970 level. As vessel-days per vessel have increased since 1977 (Fig. 4), and probably did so from 1945-1963, this assumption has a conservative effect on the CPUE trend.

CPUE based on pot-lifts is shown in Fig. 5. For the period 1963-1978, pot-lifts were estimated from vessel-days by assuming a constant 45 pot-lifts per day. As argued above, this assumption is thought to have a conservative effect on the CPUE trend. In any case, CPUE since 1979, based on real effort data, shows a clear downward trend.

Catch collated by fishing year (1 April-31 March) is given in Table 6.

b) Other information

Rock lobsters cannot be aged, so no information on age structure is available.

Very little recent catch sampling has been carried out. Beginning in 1987, a pilot catch sampling program has been conducted in Otago, Napier and Tauranga. In each area, three boats are each sampled monthly. It is proposed to design a full-scale sampling program based on results of the pilot study. Catch sampling has also been carried out at Stewart Island, beginning in 1987, to estimate relative abundance of the recruiting and pre-recruit year-classes, for comparison with estimates of juvenile abundance and puerulus settlement.

In 1986 and 1987, catch sampling was conducted to determine the relation between tail length and two other morphometric lengths. These data (Fig. 6) show that much of the catch is very close to the present minimum legal size. Data from Stewart Island catch sampling (Fig. 7) support this, and show broad temporal variability.

c) Information on Maori and recreational fishing patterns

No analysis of Maori fishing patterns has been made. Some information is available in Fishery Officers' files, relating to permits issued to take rock lobsters for huis and tangis (see Ib above). No collation of these data is available.

A vigorous amateur fishery (see Ib above) is important in some areas, especially in summer. At Kaikoura the amateur catch may reach 20% of the reported commercial catch (Cairns 1985). A report on methodology and cost of estimating the overall amateur catch has been prepared by the Centre for Resource Management, University of Canterbury, under contract.

Previous analyses have ignored the amateur catch. The implicit assumption has been that amateur catches are small and a roughly constant proportion of the reported commercial catch. It is more likely that the amateur catch has been increasing.

III. Research

a) Stock structure

Genetically, there appears to be only one population of *J. edwardsii* (Smith et al. 1980). This view is supported by the long larval life and wide distribution of planktonic larvae in the sea (Lesser 1978; Booth 1979) and by movement patterns of juveniles, especially in the South Island (eg. Street 1973). There is even some doubt that the Australian *J. novaehollandiae* is a distinct species (Booth & Street in prep.). Some *J. novaehollandiae* larvae may settle on the southwest coast of New Zealand, but the significance of such settlement management of the fishery is unknown.

Rock lobsters in the North & South Islands and Stewart Island combined are considered to form one stock, with a separate management unit at the Chatham Islands (Annala 1986; Breen, Booth & Chant 1988). Differences in growth, size at first female maturity, larval settlement patterns, and landing trends within the North & South Islands combined hint that more than one stock may exist within this area.

Much of the larval supply for the Chatham Islands stock may come from the North & South Islands (Lesser 1978); in contrast, probably no Chatham Islands larvae settle to the west.

b) Resource surveys

Settlement Index

Puerulus settlement has been monitored at several localities around New Zealand since the mid-1970s and early 1980s using specially-designed collectors (Booth 1979, 1984; Booth and Tarring 1986).

Highest catches have been made along the east coast of the North Island south of Matakaoa Point. Low catches have been made along the east coast of the South Island; moderate catches in the southwest. This pattern has been consistent since sampling began. The reasons for it are not clear and could be several, including fewer phyllosoma larvae in the seas surrounding the South Island. Results from plankton sampling support this explanation. Fine-meshed midwater trawling conducted seasonally during 1987-88 along transects off the major rock lobstering coasts yielded large numbers of late stage larvae off the east coast of the North Island (up to 317 per tow; mean 56.0), a few off Fiordland (up to 3; mean 0.3), and only a single specimen off the east and south coasts of the South Island.

Yearly indices of settlement strength are available from some key sites (Table 7). There is considerable yearly variation at all sites. Strength of settlement has been compared with pre-recruit strength at Stewart Island, and a strong correlation found (Breen, Booth & Tyson 1988b).

Low settlement indices in recent years at Stewart Island and along the east coast of the South Island are of concern. Puerulus settlement along parts of this coast is now much lower than in the late 1960`s and early 1970`s (Booth and Bowring 1988). In contrast, levels of settlement remain generally high along the east coast of the North Island. The decreased settlement in the south might be caused by heavy exploitation in an area where few females bear eggs before recruiting.

c) Other studies: growth, mortality, migrations

Growth of juveniles has been measured at Gisborne & Stewart Island with tagging and model length frequency analyses (McKoy & Esterman 1981; Annala & Bycroft 1985). Mean carapace lengths (CL) of the first 3 yr-classes, by sex, at these two locations are given in Table 8.

Growth of older animals has been well studied at several locations using various techniques (Street 1969; 1970; Booth 1980; McKoy & Esterman 1981; McKoy 1985; Annala & Bycroft 1988). Growth rates vary between the sexes and between areas. A summary of growth parameters from ten locations is provided by Annala & Breen (1988). Values of parameters relating moult frequency and moult increment to size are given in Table 9 for Gisborne and Stewart Island for each sex.

Size at the onset of maturity (SOM) for females varies greatly between areas (Annala et al. 1980; Annala 1980a; Annala & Breen 1988a; MacDiarmid 1987; Booth 1983a). At Mahia, 50% of females are mature at about 62 mm CL; whereas at Stewart Island the size at 50% maturity is about 110 mm.

Mortality has been studied through tagging and analysis of size frequency distributions (SFDs). An instantaneous rate of natural mortality M = 0.10 is generally used for analytical purposes (Annala 1977; 1979; 1980b; Annala & Breen 1988; 1989). With a variety of techniques, fishing mortality rate has been estimated for males and females in several areas. For Gisborne, the best-studied area, Annala (1980b) estimated F = 0.38-2.49. Annala & Breen (1989) consider the present rate to be near F = 1.0.

Movements of rock lobsters have been studied in tagging experiments (Street 1971; 1973; 1980; Annala 1981; Booth 1980, 1983b; Annala & Bycroft 1983; McKoy 1983; MacDiarmid 1987). Movements are of two types. Seasonal inshore/offshore movements are associated with moulting and breeding (MacDiarmid 1987). Alongshore movements may also be seasonal, and may involve very long distances. Both kinds of movement may be called "runs" by fishermen describing changes in catchability.

In most areas, most tagged lobsters have been recovered within 5 km of their release point. However, in southern New Zealand migrating lobsters are reported to form an important part of the catch in some years. Fishermen profess to distinguish "run" lobsters by their colour. After tagging, many of these lobsters are recovered long distances from the release point. Movements involve males and immature females, are seasonal, and are highly directional: from Banks Peninsula towards Otago, Otago towards Foveaux Strait and Stewart Island, and from Stewart Island towards Fiordland (Fig. 8). These movements are against the prevailing inshore currents, and reproduction is an obvious potential motive.

d) Estimate of biomass and demographic parameters

No estimate of biomass is available from direct survey. Estimates of the unfished biomass B_0 and the biomass associated with MSY are available from surplus-production modelling. Please see the next section.

e) Analysis of sustainable yields

Several authors have used catch and effort data from this fishery to calculate surplus-production curves. Saila et al. (1979), Fogarty & Murawski (1986) and Annala & Esterman (1986) estimated the surplus-production curve using numbers of vessels as the best measure of effort, 1945-1982. Their results are shown in Fig. 9. Their estimates of deterministic equilibrium maximum sustainable yield (MSY) centred on 4600-4700 t.

Vessels are a crude measure of effort, but unfortunately the better measure of vessel-days is available only for 1963 to present and the best measure, potlifts, only from 1979 to the present. Fig. 4 shows that vessel-days per vessel have generally increased since 1977; pot-lifts per vessel-day have increased steadily since 1979. Together these have resulted in a threefold increase in nominal fishing power for the average `vessel' in the fishery.

Annala & Esterman (1986) also used vessel-days as the measure of effort (Fig. 10), and estimated MSY as 4600 t. Whereas the analysis based on vessels suggested that present effort might be near optimum (Fig. 9), this analysis shows present effort to be greater than optimum, and corresponding equilibrium catches are lower than MSY. When catch is plotted against pot-lifts (estimated as described above), the same conclusion can be drawn (Fig. 11). Recent effort levels are far to the right of the dome in this curve.

Breen (unpub.) used the dynamic method of Schnute (1977) in combination with the non-linear parameter estimation technique of Mittertreiner & Schnute (1985). Because the method is based on a symmetrical production curve, and the curve is probably asymmetrical for this species (Fig. 9), this method did not give credible fits.

Breen (unpub.) also used the PRODFIT procedure of Fox (1975) with data from the North & South Islands combined through 1986 (Table 2). Analyses based on vessel-days are described in the first part of Table 13. The basic analysis suggests that deterministic MSY = 5115 t and that present level of effort would give an equilibrium yield of about 4250 t (see Fig. 12).

Analysis based on estimated pot-lifts, 1945-1986 is shown in Fig. 11 (see Table 13, runs 6-9). Estimated MSY = 4500-4700 t, and is sensitive to the number of cohorts over which effort is averaged. The estimated deterministic equilibrium present sustainable yield (PSY) is about 4100 t. This is the catch which, on average, could be sustained at the present level of fishing effort if the population were at equilibrium. These estimates are not sensitive to the initial value of m, the shape parameter.

Surplus-production results can be summarized as follows. The fishery expends more effort than is required to take the equilibrium deterministic MSY. As a consequence, stock size is smaller than optimum and equilibrium deterministic PSY (about 4200 t) is lower than equilibrium deterministic MSY (about

4700 t).

The surplus-production analyses just discussed do not take into account unreported commercial catch, nor amateur and Maori catch. Some idea of the scale of recent unreported commercial catch can be gleaned from Table 3, but trends in unreported commercial effort are simply unavailable. Even less is known about amateur and Maori catches (section IIc). A proposed audit of commercial fishing return data might improve our understanding of commercial catch and effort trends since 1979. Impacts of various alternative trends in the remaining catch and effort data on MSY and PSY estimates can be studied by analysing simulated data. This will be done systematically after the audit of existing data is complete.

Yield-per-recruit (YPR) modelling results were reported by Saila et al. (1979) based on the Beverton-Holt model, using growth data and mortality estimates from the Gisborne fishery. At the present minimum legal size, optimum fishing mortality rate was estimated to be F = 0.25-0.50 for males; 0.45-0.60 for females. (The two values come from using two alternative growth models.) Estimates of F from the fishery range from 0.38-2.49 (Annala 1980b). Except for male YPR estimated using the von Bertalanffy growth parameters, the YPR curves were flat. Thus, while fishing mortality rate (hence effort) was higher than required to take the optimum YPR, only small increases in equilibrium YPR could be expected from a reduction to optimum fishing mortality rate.

Annala & Breen (1988; 1989) reported YPR from several areas around New Zealand, using growth data specific to each area and a modified version of Caddy's (1977, 1979) crustacean model. Regional variation in growth results in wide regional variation in YPR (Tables 10 & 11). At the present minimum legal size (MLS), optimum fishing mortality ranges from F = 0.15-0.60 for females and F = 0.10-0.40 for males. Fig. 13 shows one example. If present fishing mortality rate is assumed to be F = 1.0 then the optimum MLS ranges from 79-97 mm carapace length (CL) for females and 108 mm to >122 mm CL for males. (The present MLS is equivalent to about 93 mm CL for females and 101 mm CL for males.) $F_{0.1}$ is near 0.15 for both males and females, based on the YPR estimates made with empirical growth curves.

For both sexes, these results confirm that the present yield (or a slightly greater yield) could be taken at equilibrium with much less fishing mortality. Males appear to be growth overfished.

Egg-per-recruit (EPR) analyses use growth, maturity, mortality and fecundity data in simple simulations to estimate how many eggs would be produced by a cohort at equilibrium with a specified combination of F and MLS. These were also carried out by Annala & Breen (1988; 1989) using data from several locations around New Zealand. Expressed as a percentage of eggs produced by a virgin cohort, EPR varies from 2.6% at Stewart Island to 50.2% at Kaikoura (Table 12). Annala & Breen weighted the regional estimates using regional catch data to obtain an EPR estimate for New Zealand as a whole. This estimate was 27%.

EPR estimates from the model used are over-estimates. The tail length size limit in place prior to June 1988 was widely abused (Breen et al. 1987; 1988a), so effective MLS was less than the nominal MLS. Additional mortality not addressed in the model is caused by poor handling practices. These two sources of error also affect the YPR estimates presented above.

f) Models of alternative management strategies

Alternative management strategies have not been modelled. In 1986 and 1987, the focus of management was on bringing ITQ management into the fishery (Anon. 1986a; b). Alternatives to this plan have not been formally identified, discussed, proposed or evaluated. A model incorporating current biological data is being used to evaluate the biological impacts of various TAC strategies.

IV. Management implications

The present estimated sustainable catch is less than deterministic maximum sustainable catch; but effort is higher than the estimated optimum. This has been the situation for at least a decade. The fishery has thus not been able to realize its full biological potential.

The fishery expends a great deal of surplus effort. Recent catch levels (sustainable or not) could be taken with less than half the present effort if the stock were permitted to rebound and stabilize at a higher level. The surplus effort represents a major cost to the fishery system, which could be eliminated if stocks were permitted to rebuild.

The catch levels of recent years for the North & South Islands combined are probably not sustainable, based on surplus-production modelling results. Declining CPUE suggests that catches have been greater than local PSY levels for some time. The biological safety of the fishery depends on stopping and reversing the present trend toward increased effort and decreased stock levels.

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LITERATURE CITED

ANNALA, J.H. 1977: Effects of increases in the minimum legal size on the Otago rock lobster fishery. N.Z. Fish. Res. Div. Occ. Pub. 13: 1-16.

ANNALA, J.H. 1979: Mortality estimates for the New Zealand rock lobster, Jasus edwardsii. Fishery Bull. 77(2): 471-480.

ANNALA, J.H. 1980a: Size at the onset of maturity. Catch 7(7): 19.

ANNALA, J.H. 1980b: Mortality estimates for the rock lobster, Jasus edwardsii, near Gisborne, New Zealand. N.Z. J. Mar. Freshw. Res. 14(4): 357-371.

ANNALA, J.H. 1981: Movements of rock lobsters (Jasus edwardsii) tagged near Gisborne, New Zealand. N.Z. J. Mar. Freshw. Res. 15: 437-443.

ANNALA, J.H. 1983a: New Zealand rock lobsters. Biology and fishery. N.Z. Fish. Res. Div. Occ. Pub. 42: 36 pp.

ANNALA, J.H. 1983b: The introduction of limited entry. The New Zealand rock lobster fishery. Mar. Policy 7: 101-108.

ANNALA, J.H. 1986: Red rock lobsters. pp. 116-120. In G.G. Baird and J.L. McKoy (eds.) Background papers for the total allowable catch recommendations for the 1986-1987 fishing year. N.Z. Min. Ag. Fish., Wellington. 117 pp.

ANNALA, J.H., and BREEN, P.A. 1988: Yield- and egg-per-recruit data inputs and model results for the rock lobster Jasus edwardsii from 10 areas around New Zealand. Fisheries Research Centre Int. Rep. 87: 1-29.

ANNALA, J.H., and BREEN, P.A. 1989: Yield- and egg-per-recruit analyses for the New Zealand rock lobster, Jasus edwardsii. N.Z. J. Mar. Freshw. Res.

ANNALA, J.H., and BYCROFT, B.L. 1983: Fiordland rock lobster study. Catch 10(11): 28.

ANNALA, J.H., and BYCROFT, B.L.. 1985: Growth rate of juvenile rock lobsters (Jasus edwardsii) at Stewart Island, New Zealand. N.Z. J. Mar. Freshw. Res. 19: 445-455.

ANNALA, J.H., AND BYCROFT, B.L. 1988: Growth of rock lobsters (Jasus edwardsii) in Fiordland, New Zealand. N.Z. J. Mar. Freshw. Res. NZ J. Mar. Freshw. Res. 19: 445-455.

ANNALA, J.H., and ESTERMAN, D.B. 1986: Yield estimates for the New Zealand rock lobster fishery. pp. 347-358. In G.S. Jamieson and N.F. Bourne (eds.) North Pacific Workshop on Stock Assessment and Management of Invertebrates. Can. Spec. Pub. Fish. Aq. Science 92.

ANNALA, J.H., and KING, M.R. 1983: The 1963-1973 New Zealand rock lobster landings by statistical area. N.Z. Fish. Res. Div. Occ. Pub. Data Ser. 11: 1-20.

ANNALA, J.H., McKOY, J.L. J.D. BOOTH, and PIKE, R.B. 1980: Size at the onset of sexual maturity in female *Jasus edwardsii* (Decapoda: Palinuridae) in New Zealand. N.Z. J. Mar. Freshw. Res. 14(3): 217-227.

ANON. 1986a: Rock lobster fisheries: Proposed policy for future management. Fish. Manag. Div., N.Z. Min. Agric. Fish. Wellington. 36 pp.

ANON. 1986b: Rock lobster fisheries: Proposed management policy. Fish. Manag. Div., N.Z. Min. Agric. Fish. Wellington. 28 pp.

BOOTH, J.D. 1979: Settlement of the rock lobster, *Jasus edwardsii* (Decapoda: Palinuridae), at Castlepoint, New Zealand. N.Z. J. Mar. Freshw. Res. 13(3): 395-406.

BOOTH, J.D. 1980: Biological area studies. Tauroa (Reef) Point. Catch 7(7): 27.

BOOTH, J.D. 1983a: Chatham Islands rock lobster study. Catch 10(1): 13-16.

BOOTH, J.D. 1983b: Rock lobster investigated. Comm. Fishing (NZ) 22(5): 10-11.

BOOTH, J.D. 1984: Rock lobster fishery causes concern. Catch 11(2): 12-23.

BOOTH, J.D. in press: History of biological research into the rock lobsters of New Zealand. In B.F. Phillips (ed.) Workshop on rock lobster ecology and physiology. CSIRO Circular.

BOOTH, J.D., & BOWRING, L.D. 1988: Decreased abundance of the puerulus stage of the rock lobster *Jasus edwardsii* at Kaikoura, New Zealand. N.Z. J. Mar. Freshw. Res. 22: 613-616.

BOOTH, J.D., & R.J. STREET. (submitted): Trans-Tasman population continuity in Australasian stocks of *Jasus* subgroup "*lalandii*" rock lobsters. NZ Journal of Marine & Freshwater Research.

BOOTH, J.D., and TARRING, S.C. 1986: Settlement of the red rock lobster, Jasus edwardsii, near Gisborne, New Zealand. N.Z. J. Mar. Freshw. Res. 20: 291-297.

BREEN, P.A., BOOTH, J.D., and K CHANT. 1988: Current state of the rock lobster fishery. Catch 15(1): 26-31.

BREEN, P.A., BOOTH, J.D., and TYSON, P.J. 1987: Measurements for new rock lobster size limit. Catch 14(7): 13-15.

BREEN, P.A., BOOTH, J.D., and TYSON, P.J. 1988a: Feasibility of a minimum size limit based on tail width for the New Zealand rock lobster Jasus edwardsii. N.Z. Fisheries Research Technical Report 6: 16 pp.

BREEN, P.A., BOOTH, J.D., AND TYSON, P.J. 1988b: Juvenile rock lobsters at Stewart Island. Catch 15(9): 21-22.

BREEN, P.A., and McKOY, J.L. 1988: An annotated bibliography of the New Zealand red rock lobster, Jasus edwardsii. NZ Fish. Occ. Pub. 3: 43 pp.

CADDY, J.F. 1977: Approaches to a simplified yield-per-recruit model for crustacea, with particular reference to the American lobster, Homarus americanus. Fish. Mar. Serv. MS Rept. 1445: 1-14.

CADDY, J.F. 1979: Notes on a more generalized yield per recruit analysis for crustaceans using size-specific inputs. Fish. Mar. Serv. MS Rept. 1525: 1-7.

CAIRNS, N.D. 1985: Assessment of the Kaikoura amateur fishery for rock lobsters. MSc. Thesis, University of Canterbury. Christchurch. 86 pp.

FOGARTY, M.J., and MURAWSKI, S.A. 1986: Population dynamics and assessment of exploited invertebrate stocks. pp. 228-244 In G.S. Jamieson and N.F. Bourne (Eds.) North Pacific Workshop on stock assessment and management of invertebrates. Can. Spec. Pub. Fish. Aq. Science 92.

FOX, W.W. 1975: Fitting the generalized stock production model by least-squares and equilibrium approximation. Fish. Bull 73: 23-36.

LESSER, J.H.R. 1978: Phyllosoma larvae of Jasus edwardsii (Hutton) (Crustacea: Decapoda: Palinuridae) and their distribution off the east coast of the North Island, New Zealand. N.Z. J. Mar. Freshw. Res. 12: 357-370.

MacDIARMID, A.B. 1987: The ecology of Jasus edwardsii (Hutton) (Crustacea: Palinuridae). PhD Thesis, University of Auckland, Auckland NZ. 169 pp.

McKOY, J.L. 1979: An annotated bibliography of the New Zealand rock lobster Jasus edwardsii (Hutton). N.Z. Fish. Res. Div. Occ. Pub. 18: 1-16.

McKOY, J.L. 1983: Movements of rock lobsters, Jasus edwardsii (Decapoda: Palinuridae), tagged near Stewart Island, New Zealand. N.Z. J. Mar. Freshw. Res. 17: 357-366.

McKOY, J.L. 1985: Growth of tagged rock lobsters (Jasus edwardsii) near Stewart Island, New Zealand. N.Z. J. Mar. Freshw. Res. 19: 457-466.

McKOY, J.L., and ESTERMAN, D.B. 1981: Growth of rock lobsters (Jasus edwardsii) in the Gisborne region, New Zealand. N.Z. J. Mar. Freshw. Res. 15: 121-136.

MITTERTREINER, A., and SCHNUTE, J. 1985: Simplex: A manual and software package for easy nonlinear parameter estimation and interpretation in fishery research. Can. Tech. Rept. Fish. Aq. Sci. 1384: 1-90.

SAILA, S.B., ANNALA, J.H., McKOY, J.L. and BOOTH, J.D. 1979: Application of yield models to the New Zealand rock lobster fishery. N.Z. J. Mar. Freshw. Res. 13(1): 1-11.

SANDERS, B.M. 1986: The 1985 New Zealand rock lobster landings. N.Z. Fish. Res. Div. Occ. Pub. Data Ser. 29: 1-31.

SCHNUTE, J. 1977. Improved estimates from the Schaefer production model: theoretical considerations. J. Fish. Res. Bd. Canada 34: 583-603.

SMITH, P.J., McKOY, J.L., and MACHIN, P.J. 1980: Genetic variation in the rock lobsters Jasus edwardsii and Jasus novaehollandiae. N.Z. J. Mar. Freshw. Res. 14(1): 55-63.

STREET, R.J. 1969: The New Zealand crayfish Jasus edwardsii (Hutton). N.Z. Mar. Dept. Fish. Tech. Rep. 30: 1-31.

STREET, R.J. 1970: New Zealand rock lobster Jasus edwardsii (Hutton) South Island fisheries. N.Z. Mar. Dept. Fish. Tech. Rep. 54: 1-28.

STREET, R.J. 1971: Rock lobster migration off Otago. Commercial Fishing (N.Z.) 10(6): 16-17.

STREET, R.J. 1973: Trend in the rock lobster fishery in southern New Zealand, 1970-1971. N. Z. Min. Agric. Fish. Tech. Rep. 116: 1-13.

STREET, R.J. 1980: Southern rock lobster research. Catch 7(9): 25-26.

Table 1. Total landings, 1930-1987. Landings from 1930-1944 are taken from Annual Reports on Fisheries, New Zealand Marine Department. These are given by financial years ending 31 March. They include packhorse lobsters. Landings from 1945-1962 are from Annala (1983a), reported by calendar year, including packhorse. Landings from 1963-1973 are from Annala & King (1983) for J. edwardsii only, reported by calendar year. Landings from 1974-1978 are from Annala (1983a), for both species reported by calendar year. Landings from 1979-1987 are for J. edwardsii only, reported by calendar year in Fisheries Research Occasional Publications (eg. Sanders 1986). Landings for 1986 and 1987 are for J. edwardsii only, for the calendar year (Sanders, pers. comm.)

Year	Landings (t)	Year	Landings (t)
1930	104	1960	3762
1931	139	1961	4042
1932	106	1962	4583
1933	253	1963	4508
1934	453	1964	4483
1935	350	1965	4916
1936	334	1966	6991
1937	450	1967	7542
1938	620	1968	10883
1939	470	1969	8855
1940	410	1970	6336
1941	539	1971	5523
1942	621	1972	4387
1943	656	1973	4664
1944	553	1974	4161
1945	809	1975	3318
1946	854	1976	3702
1947	919	1977	3540
1948	1370	1978	3711
1949	1872	1979	4444
1950	2672	1980	4534
1951	2834	1981	4510
1952	3324	1982	4747
1953	4160	1983	4938
1954	5541	1984	5402
1955	8450	1985	5430
1956	6547	1986	5219
1957	5049	1987	4200 (not final)
1958	4447		
1959	4018		

Table 2. Red rock lobster landings, 1945-1987, for the North & South Islands and Stewart Island combined. Data before 1979 are from Annala & Esterman (1986); subsequent data are from annual Occasional Publications (eg. Sanders 1986). Catch includes a pro-rated portion of catch reported without area information. Vessel-days and pot-lifts were estimated by first calculating CPUE based on returns with sufficient effort information, then dividing the total catch by CPUE as described by Annala & Esterman (1986).

year	catch	boats	days	lifts	kg/day	kg/lift
45	809	90				
46	854	98				
47	919	112				
48	1360	148				
49	1872	406				
50	2672	238				
51	2834	471				
52	3324	500				
53	4160	560				
54	5541	557				
55	5909	551				
56	6547	584				
57	5049	528				
58	4447	728				
59	4018	632				
60	3762	706				
61	4042	710				
62	4583	812				
63	4554	950	41478		109.79	
64	4597	659	47817		96.14	
65	4984	783	50779		98.15	
66	5295	829	55159		96.00	
67	4782	946	57192		83.61	
68	4975	1097	72135		68.97	
69	4786	1280	80844		59.20	
70	4699	1246	72071		65.20	
71	4478	1298	70935		63.13	
72	3495	1399	71177		49.10	
73	3784	1460	68490		55.25	
74	3643	1309	72242		50.43	
75	2987	1393	72242		41.35	
76	3311	1639	72242		45.83	
77	3237	1903	72242		44.81	
78	3418	1786	72242		47.31	
79	4050	1517	75717	3699	53.49	1.09
80	4190	1074	71794	4066	58.36	1.03
81	4058	909	67572	4022	60.05	1.01
82	4331	815	68612	4401	63.12	0.98
83	4385	788	71839	4973	61.04	0.88
84	4911	773	77052	5751	63.74	0.85
85	4856	773	73251	5791	66.29	0.84
86	4640	773	69838	5766	66.44	0.80
87	3744	773	60651	5230	61.70	0.72

Table 3. Comparison of total reported rock lobster landings with reported rock lobster exports. Landings are reported for year of landing; exports for year of exports,; so lobsters landed in one year may be exported the next year. Data from J.L. McKoy (pers. comm.). Exports are estimated as the sum of whole lobsters and tails, where tails are converted to whole weight with a conversion factor of 3.0. Processed rock lobsters are not included.

Year	Total landings (tonnes)	Total exports (tonnes)	difference (%)
1974	4161	4690	+ 529 t (13%)
1975	3318	4224	+ 906 t (27%)
1976	3702	4508	+ 806 t (22%)
1977	3539	4539	+1000 t (28%)
1978	3711	4955	+1244 t (34%)
1979	4547	4864	+ 317 t (7%)
1980	4549	5097	+ 548 t (12%)
1981	4552	4623	+ 71 t (2%)
1982	4801	5599	+ 798 t (17%)
1983	5014	5264	+ 250 t (5%)
1984	5447	5235	- 212 t (-4%)
1985	5444	5120	- 324 t (-6%)

Table 4. Total red rock lobster landings (kg) by Controlled Fishery Area, 1979-1986.

NTH - Northland,
TAR - Taranaki,
WHB - Wellington/Hawkes Bay,
GSB - Gisborne,
BOP - Bay of Plenty,
CBM - Canterbury/Marlborough,
OTG - Otago,
STH - Southern,
WLD - Westland.

	1979	1980	1981	1982	1983	1984	1985	1986
NTH	97396	146896	191054	211875	238591	215553	207027	226846
TAR	40722	48773	55047	33041	20670	39232	42904	47429
WHB	481120	561521	584315	824574	953274	918923	784750	924633
GSB	470381	542833	568635	725337	753438	755206	604557	589716
BOP	261993	432794	393605	345028	278853	281392	308284	299321
CBM	405569	480756	469492	581241	515720	782243	647109	698961
OTG	404716	298959	270100	131063	109793	192588	314369	314870
STH	1731085	1628517	1447842	1451162	1471455	1681694	1902651	1519696
WLD	59622	29380	41853	28171	42917	44509	44513	35981
CHT	384043	342508	452682	415297	553351	491390	574049	561946
Not Given	106766	21078	6251					
Total	4443413	4534015	4480876	4746789	4938062	5402730	5430213	5219399

Table 5. Total red rock lobster landings by month, 1979-1986.

	1979	1980	1981	1982	1983	1984	1985	1986
Jan	384430	476798	580204	510163	607785	721018	551581	630691
Feb	249084	274326	275493	277343	393918	397331	306456	413433
Mar	98267	81998	92963	126847	133027	138929	97364	117880
Apr	22507	37629	45105	35775	45821	37947	47267	46028
May	69917	85929	80774	107306	81200	145658	86479	102272
Jun	207831	188672	172544	223444	306658	326535	283805	207373
Jul	307945	341208	296984	301881	324167	294294	361122	225629
Aug	377014	393737	357049	362999	360677	319658	597449	333265
Sep	528951	449316	558818	530495	403119	617470	636681	553349
Oct	843928	806706	754001	809057	684690	873536	872661	831556
Nov	847562	758739	667187	734996	890556	818149	803468	962467
Dec	506435	638918	629758	717482	706442	712505	785683	795458
Total	4443871	4533976	4510880	4737788	4938060	5403030	5430016	5219401

Table 6. Total rock lobster landings (both species combined from all of New Zealand) by fishing year from 1985.

Year	Landings (t)
1983-84	5400
1984-85	5430
1985-86	5190

Table 7. Indices of puerulus settlement (J.D. Booth, unpublished data). Settlement is given as mean catch per collector per month over the main settlement period, based on catches of 3-12 collectors.

Site	1979	1980	1981	1982	1983	1984	1985	1986	1987
Gisborne (Apr-Sep)	-	-	3.41	8.56	6.75	4.59	12.17	8.33	25.94
Napier (May-Sep)	2.36	4.79	7.63	3.57	4.27	1.20	0.71	-	-
Castlepoint (Dec-Jul)	-	-	-	-	8.85	7.16	3.70	1.97	6.75
Kaikoura (Jan-Jul)	-	-	-	0.02	0.60	0.20	0.28	0.05	0.69
Moeraki (Apr-Sep)	-	-	0.40	0.00	0.06	0.00	0.00	0.00	0.67
Stewart Is.	-	-	5.89	0.27	2.44	0.11	0.00	0.11	1.00

Table 8. Length-at-age (mm carapace length) estimates for juvenile red rock lobsters from Stewart Island and Gisborne, from Annala & Bycroft (1985).

	Stewart Island males			Stewart Island females		
Age	1982	1983	1984	1982	1983	1984
1	33.1	32.4	33.7	31.3	34.1	32.2
2	54.2	49.6	50.8	52.1	47.3	47.6
3	73.4	69.5	64.8	70.1	66.0	62.1

	Gisborne males		Gisborne females	
Age	1978	1979	1978	1979
1	37.2	40.4	34.0	41.9
2	57.6	59.2	52.0	58.8

Table 9. Adult growth rates for Stewart Island and Mahia East. Parameters are from Annala & Breen (1988a). Growth is described by two relationships. First, moult increment is a function of pre-moult length:

$$MI = a + b\ CL$$

where MI is moult increment (mm CL) and CL is pre-moult carapace length (mm). Second, intermoult period tm (years) is related to pre-moult length and is presented here as a table.

	Males				Females			
	Stewart Is.		Mahia East		Stewart Is.		Mahia East	
a	7.04		7.75		7.52		6.61	
b	0.973		1.00		0.953		0.962	
	CL	tm	CL	tm	CL	tm	CL	tm
	77.5	0.43	85.0	0.63	77.5	0.62	65	1.0
	82.5	0.65	95.0	0.67	82.5	0.59	115	1.0
	87.5	0.67	102.5	0.65	87.5	0.43	152	1.0
	92.5	0.56	112.5	0.69	92.5	0.67		
	97.5	1.00	122.5	0.74	105.0	1.0		
	102.5	0.65	132.5	0.81	155.0	1.0		
	112.5	0.69	142.5	0.90				
	132.5	0.81	152.5	1.00				
	152.5	1.00						

Table 13. Results of surplus-production analysis using the Fox (1975) procedure.

Input

Run #	Effort	Initial M	Cohorts	Notes
1	Days, 63-86	1	4 to 1	
2	same	1	2 to 1	Same as Fig. 10 plus new data
3	same	1	2 to 1	days scaled up by pot-lifts/day
4	same	1	4 to 1	same as 3 but cohorts different
5	same	2	4 to 1	same as 4 but m different
6	Lifts, 45-86	1	6 to 1	data shown in Fig. 11.
7	same	1	4 to 1	same as 6 but cohorts different
8	same	2	4 to 1	same as 7 but m different
9	same	0	4 to 1	same as 7 but m different

Output

Run #	Parameters A	B	m	MSY	f_{opt}	approx. PSY
1	0.9676	7.45440E-05	0.351	5031	23999 a	4200
2	0.9683	7.15428E-05	0.361	5115	23958 a	4250
3	2.2480	4.31060E-05	0.401	4382	77892 a	4235
4	2.8741	9.42850E-05	0.201	4339	121172 a	4339
5	2.4626	1.44844E-04	0.010	4353	153019 a	4337
6	0.1584	1.93866E-01	0.241	4473	2573 b	4150
7	0.3823	1.39310E-04	0.491	4651	2845 b	4100
8	0.3815	1.39467E-04	0.490	4651	2847 b	4100
9	0.3814	1.39516E-04	0.490	4650	2845 b	4100

a vessel-days
b pot-lifts (thousands)

Figure 1. Total catches from the North & South Islands combined, 1945-1987. For data sources see Table 2.

Figure 2. Effort (vessels, vessel-days, pot-lifts) for the North & South Islands combined, 1945-1987. See text for details of estimation of vessel-days before 1963 and pot-lifts before 1979.

Figure 3. Catch per unit effort (Kg/vessel-day), 1945-1987. See text for details of estimation of vessel-days before 1963.

Figure 4. Changes in effort per unit nominal effort, 1963-1987.
a) changes in vessel-days per vessel;
b) changes in pot-lifts per vessel-day.

Figure 5. Catch per unit effort (Kg/pot-lift), 1945-1987. See text for details of estimation of potlifts before 1979.

Figure 6. Length frequencies observed in all morphometric sampling (Breen, Booth & Tyson, 1988a) during 1986-1987.

Figure 7. Length frequencies observed in catch sampling at Stewart Island, 1987.

Figure 8. Movements by tagged rock lobsters (from Annala 1983a). Circles denote areas of release; thin and thick arrows represent movements by "few" and "many" tagged lobsters respectively.

Figure 9. Surplus-production curves from Saila et al. (1979) (top); Annala & Esterman (1986) (middle) and Fogarty & Murawski (1986) (bottom). All use "vessels" as the unit of fishing effort.

Figure 10. Surplus-production curve from Annala & Esterman (1986) using "vessel-days" as the unit of fishing effort.

Figure 11. Catch plotted against estimated pot-lifts for the North & South Islands combined, 1945-1987. See text for estimation of pot-lifts before 1979. The line is from surplus-production analysis (Breen unpublished).

Figure 12. Results of surplus-production modelling (Breen unpublished) using estimated vessel-days, 1945-1986, as the measure of effort.

Figure 13. A yield-per-recruit curve for male rock lobsters at Kaikoura, from data in Annala & Breen (1988).

Figure 1

Fig. 1. Reported landings 1945–1987

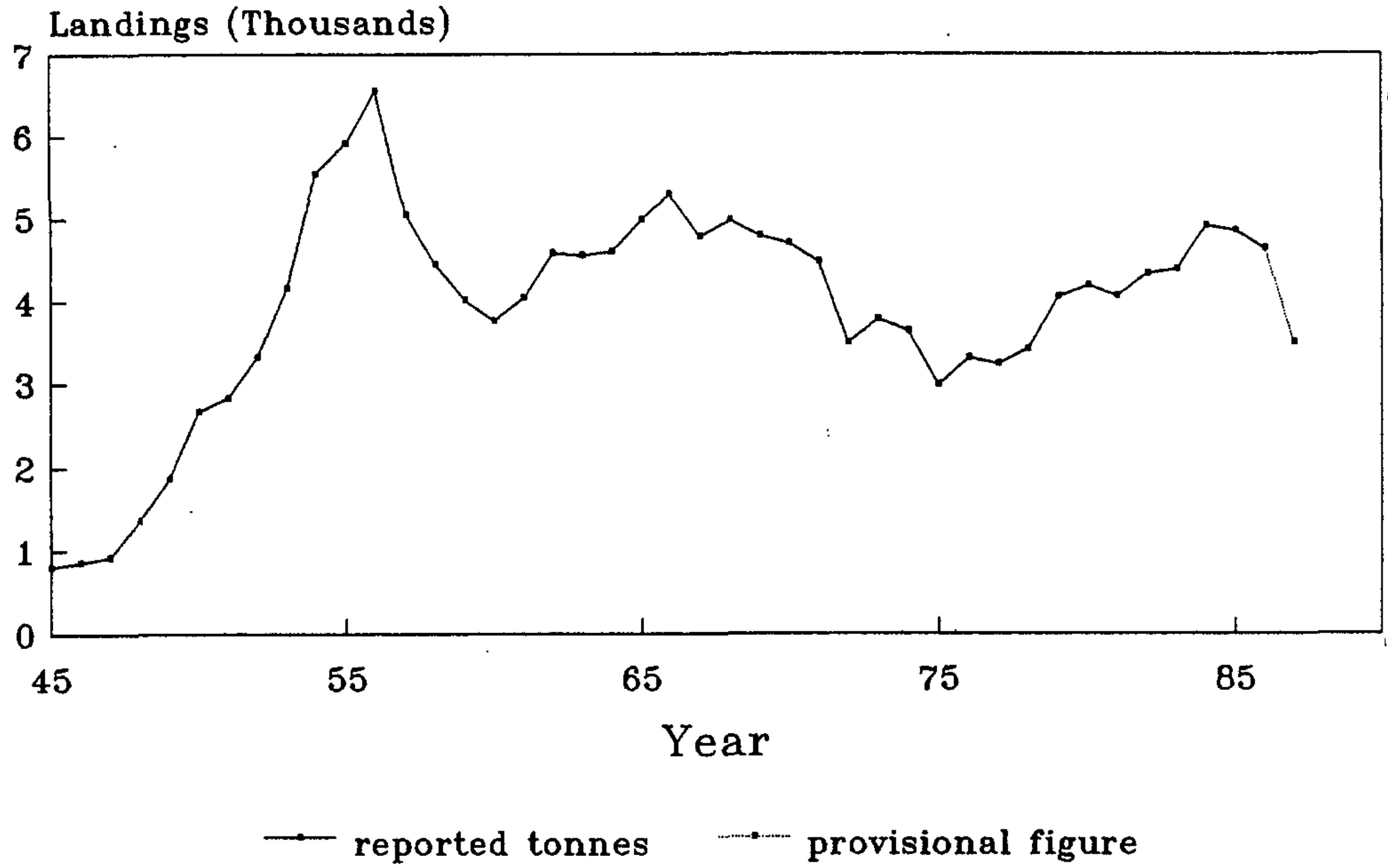


Fig 2. Effort (days, lifts and vessels) 1945–1987

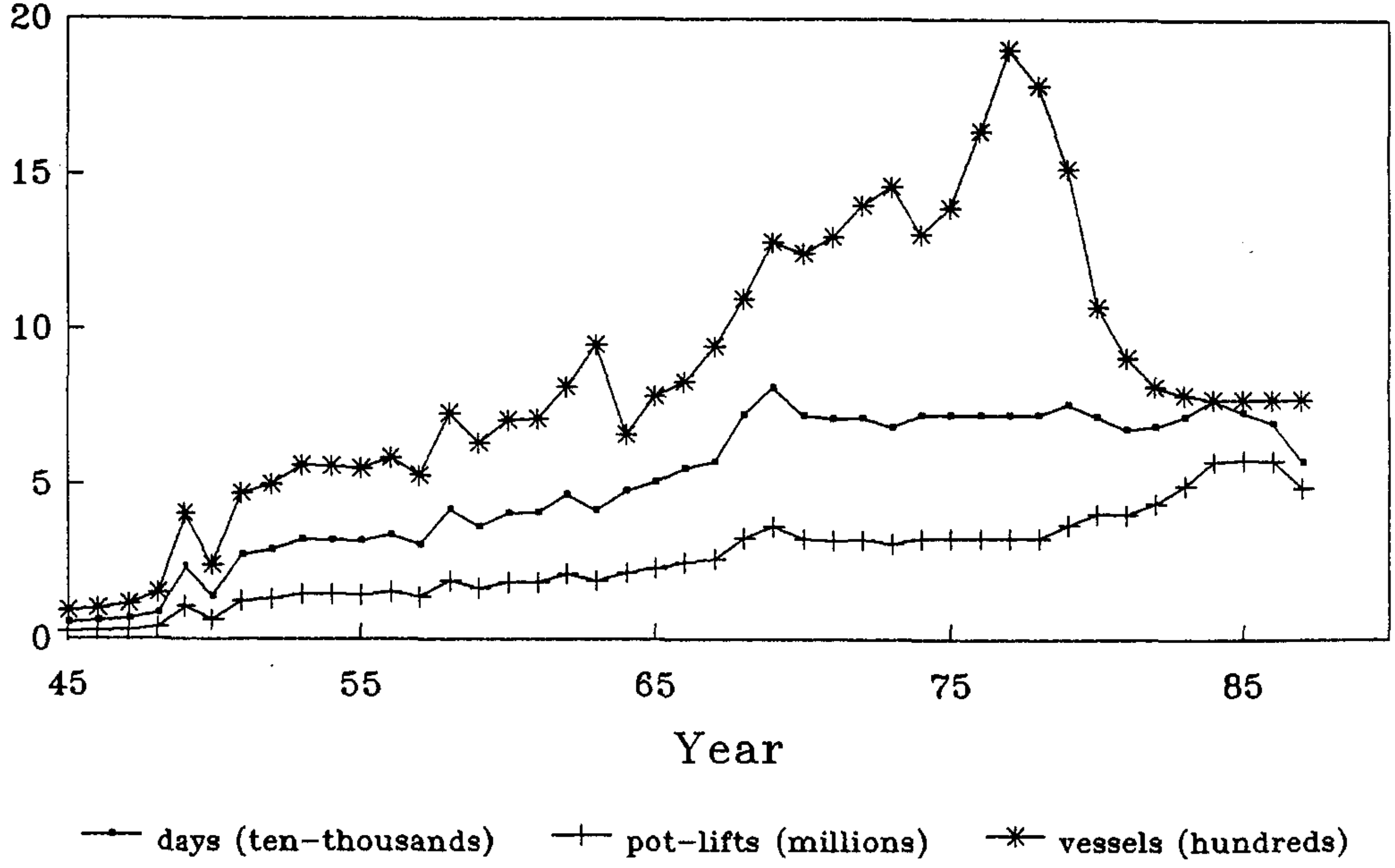


Figure 2

Fig. 3. Catch per vessel-day
1945-1987

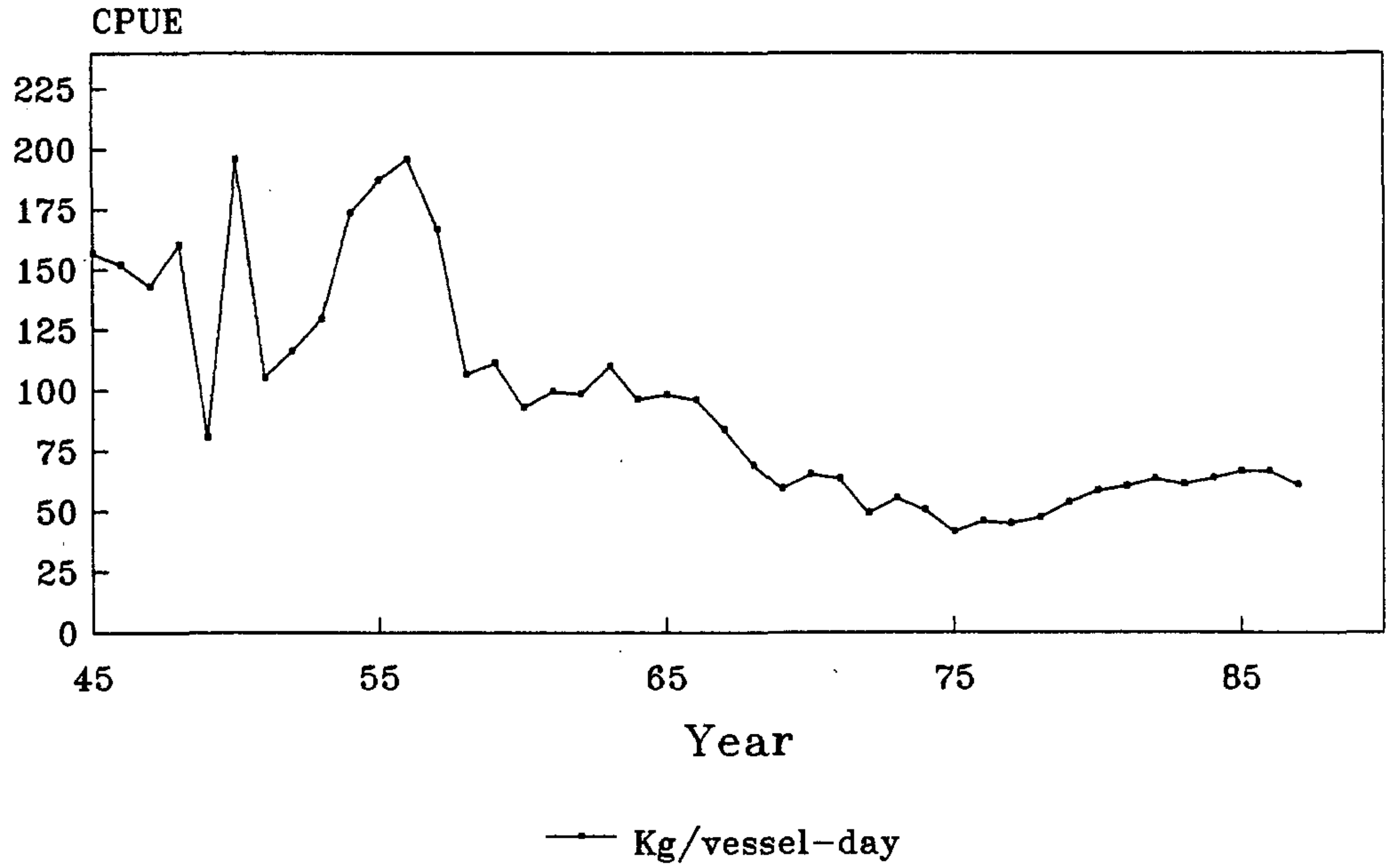


Figure 3

Fig. 4a. Changes in vessel-days/vessel 1963-1987

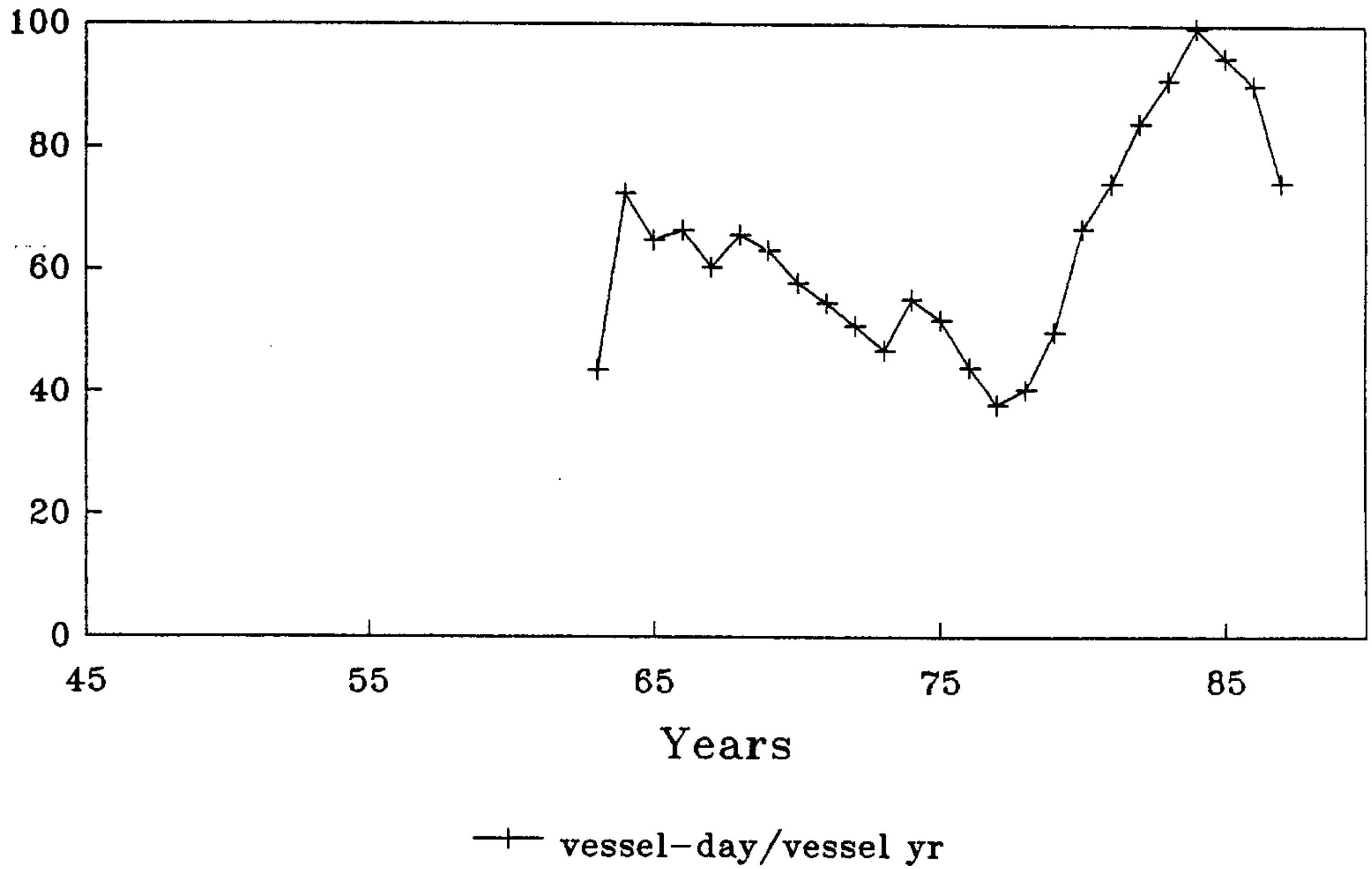


Figure 4a

Fig. 4b. Changes in pot-lifts/day 1979-1987

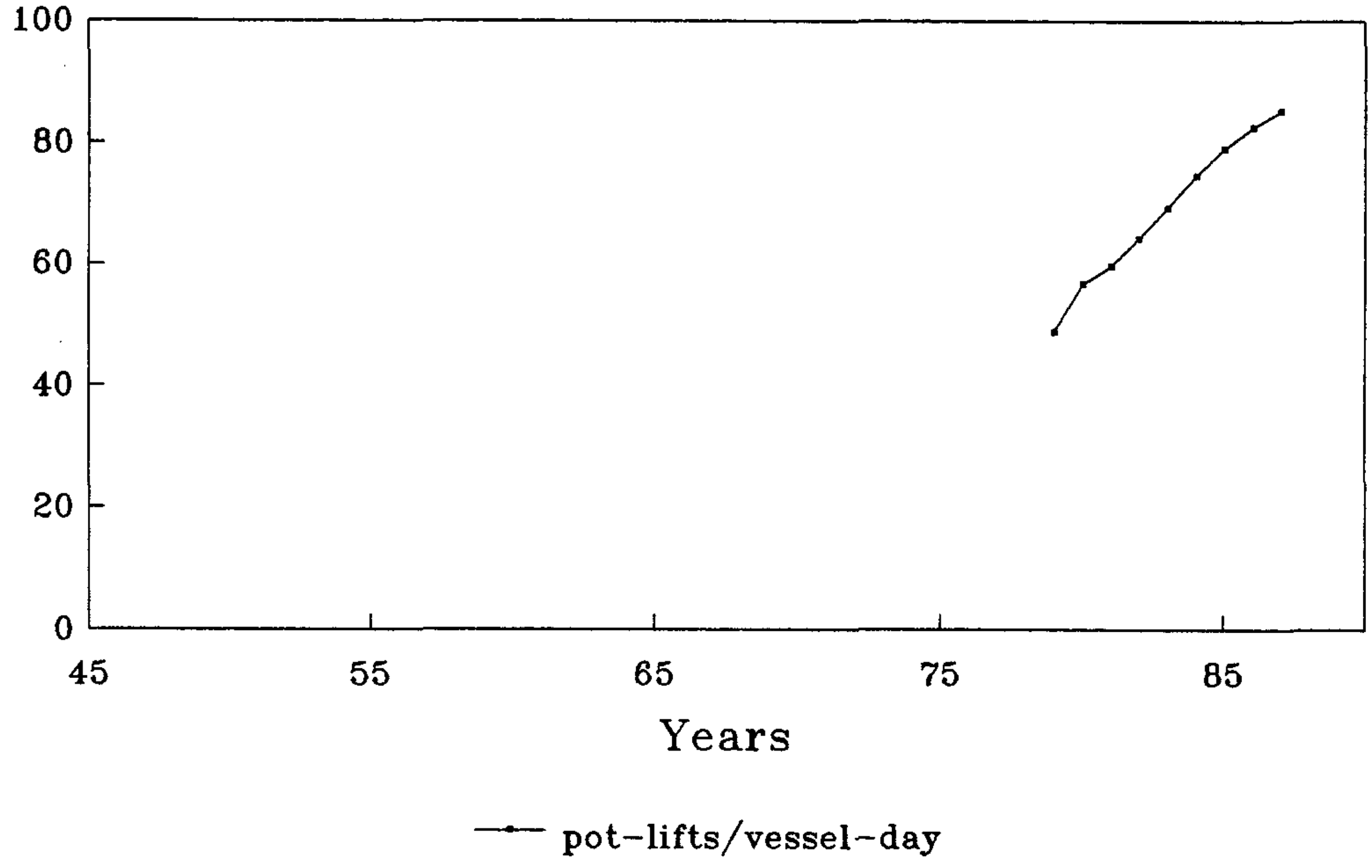


Figure 4b

Fig. 5. Catch per pot-lift 1945–1987

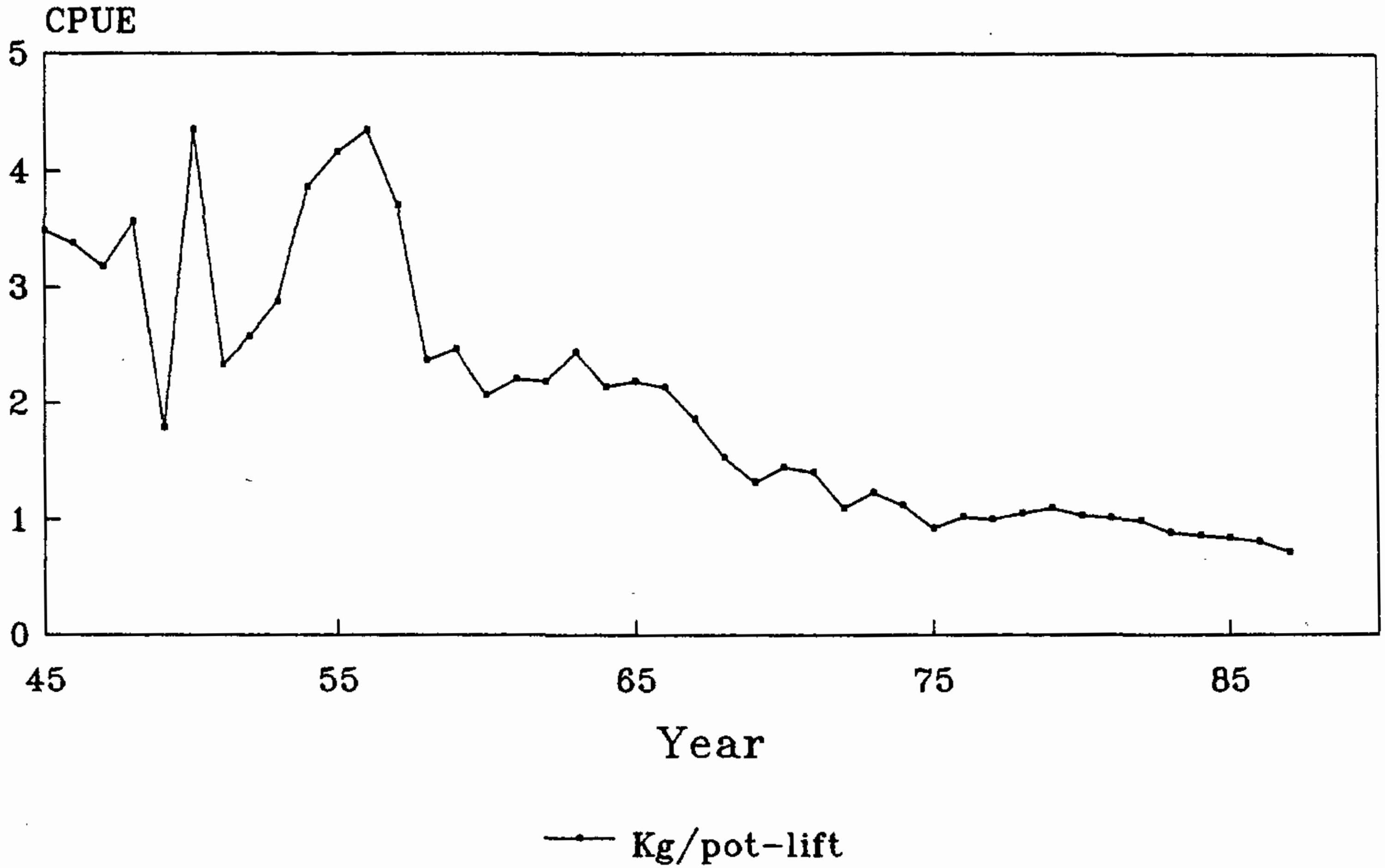


Figure 5

Figure 6

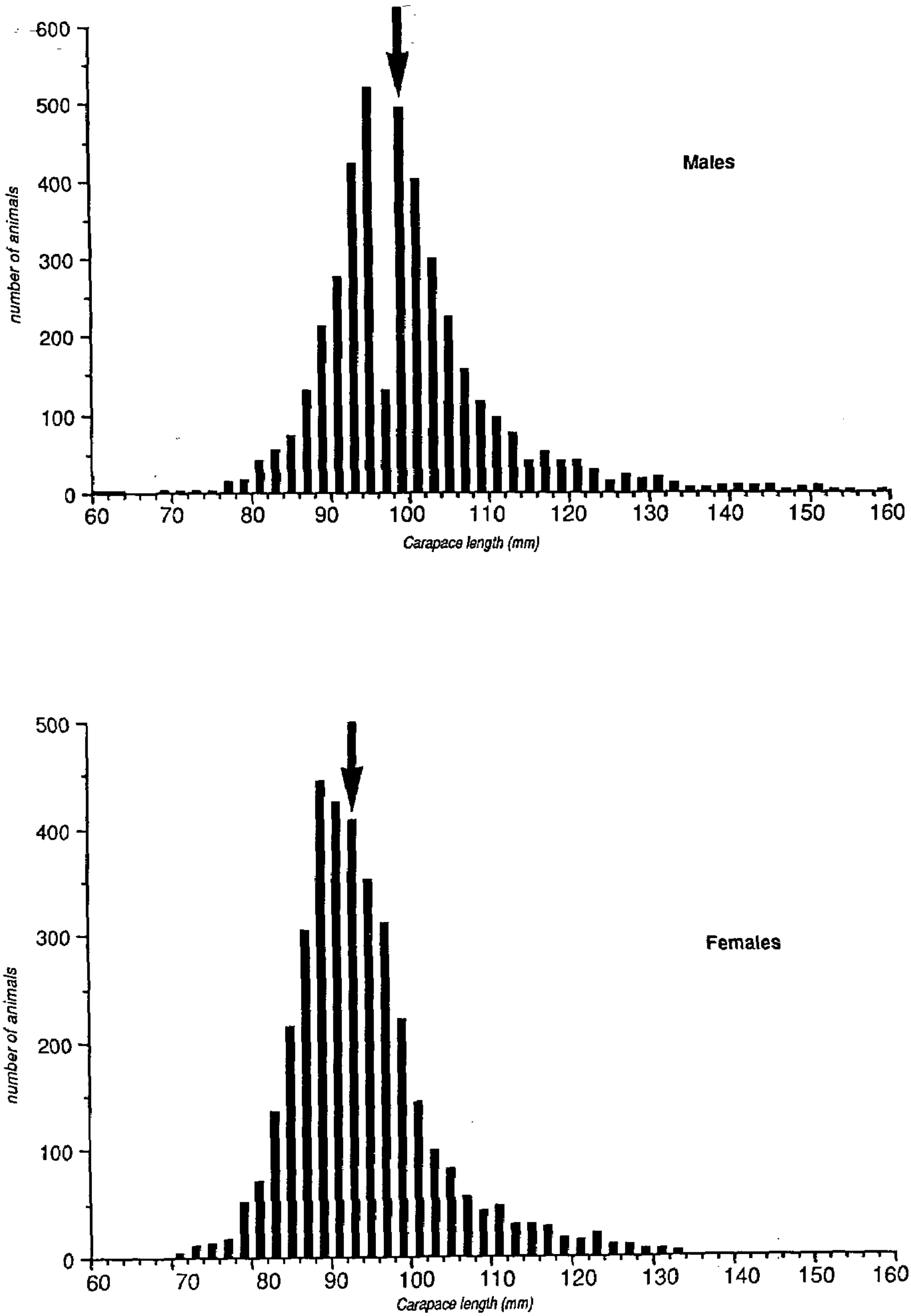

Males
number of animals
Carapace length (mm)
0
100
200
300
400
500
600
60
70
80
90
100
110
120
130
140
150
160
Females
number of animals
Carapace length (mm)
0
100
200
300
400
500
60
70
80
90
100
110
120
130
140
150
160

Figure 7

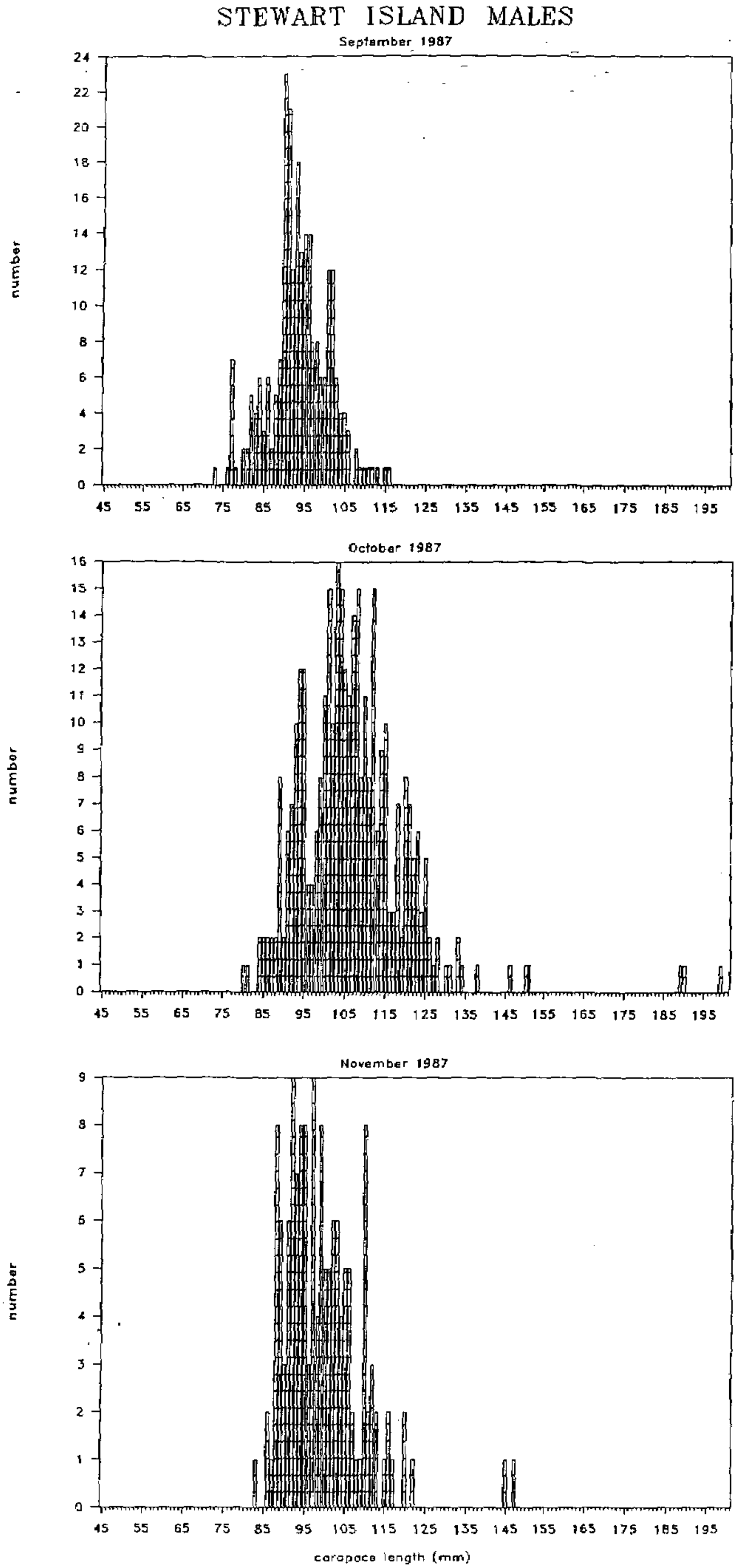
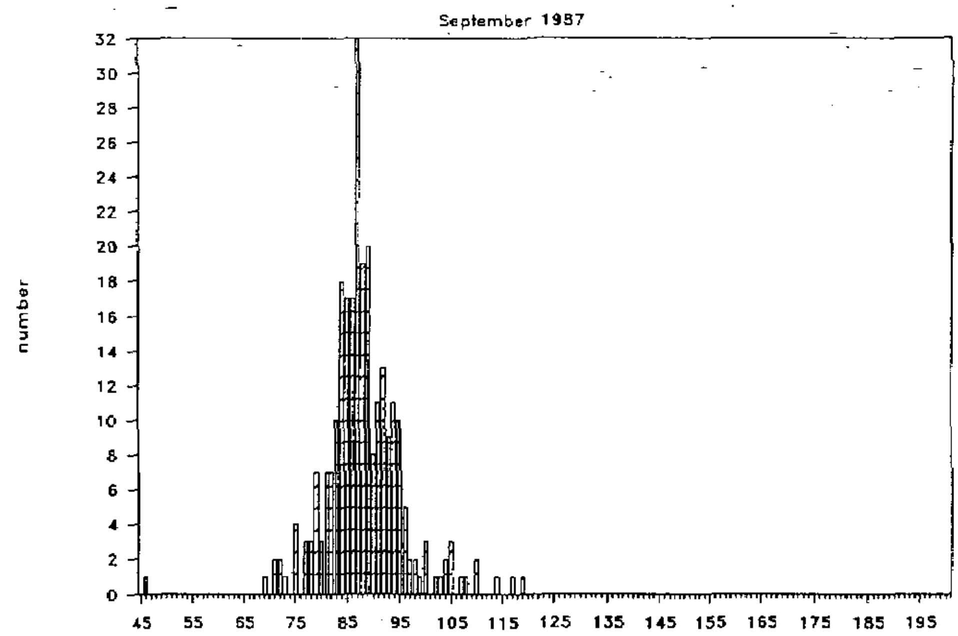
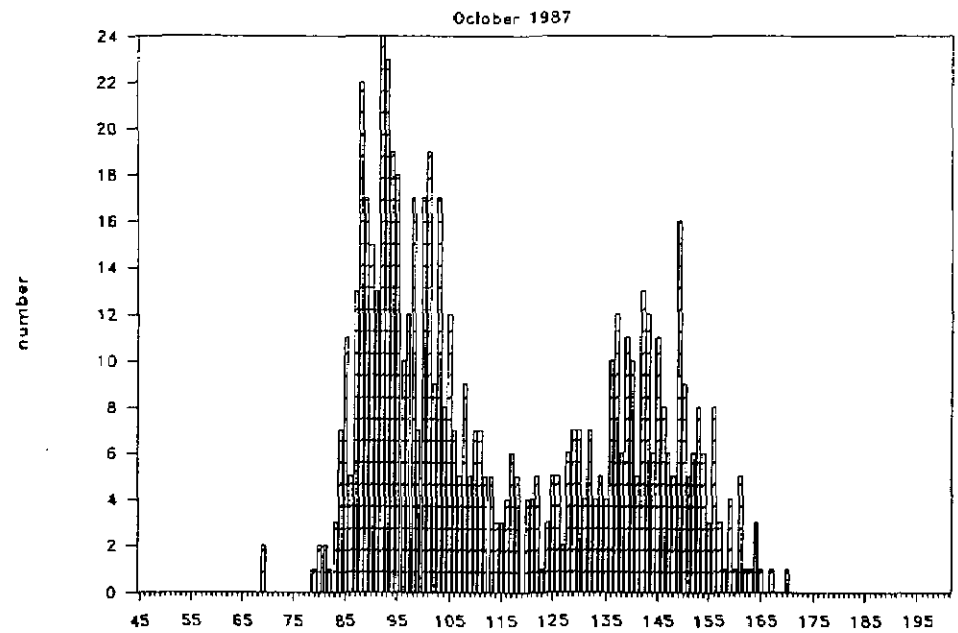

STEWART ISLAND MALES
September 1987
October 1987
November 1987
number
carapace length (mm)

Figure 7 cont.

STEWART ISLAND FEMALES





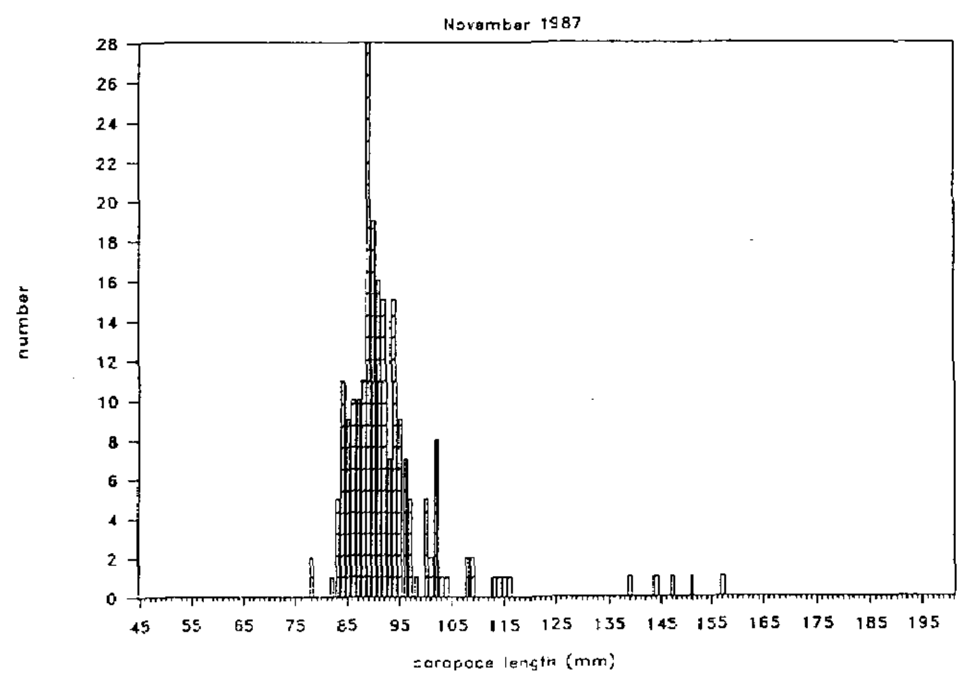


Figure 8

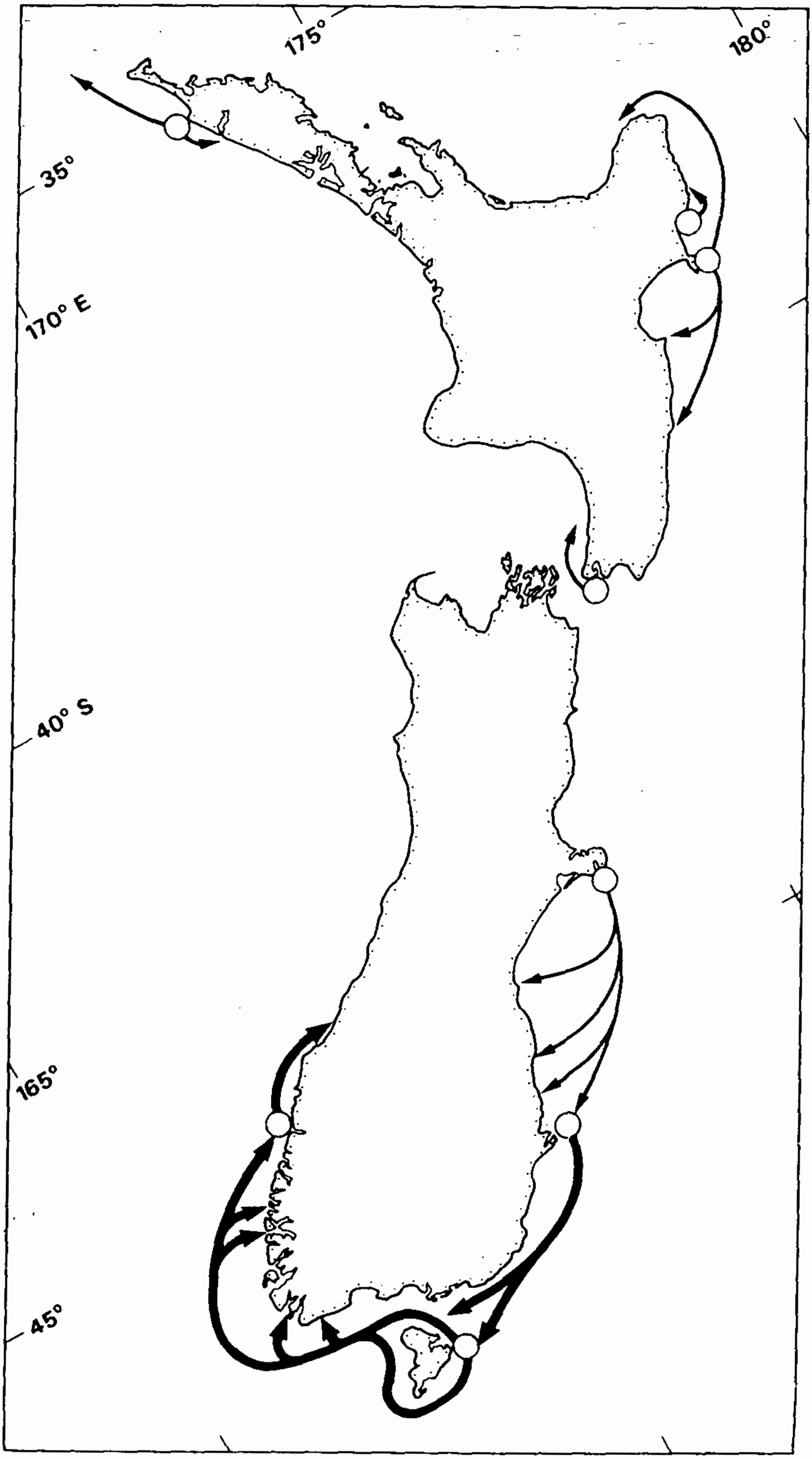
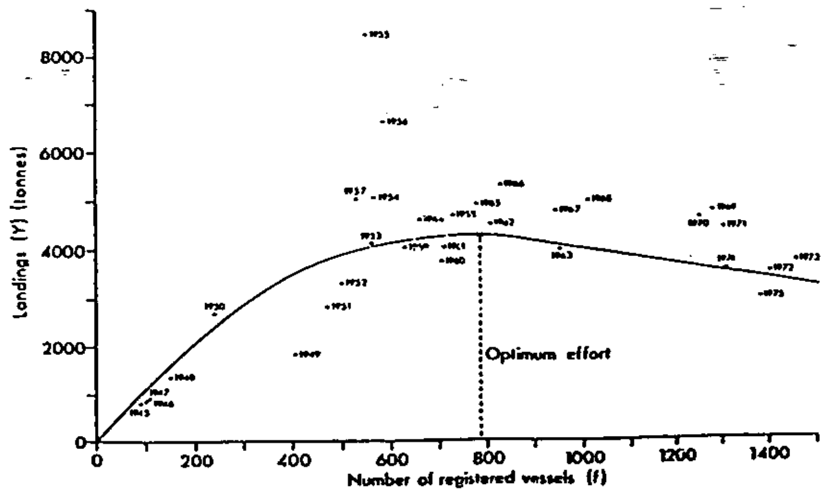
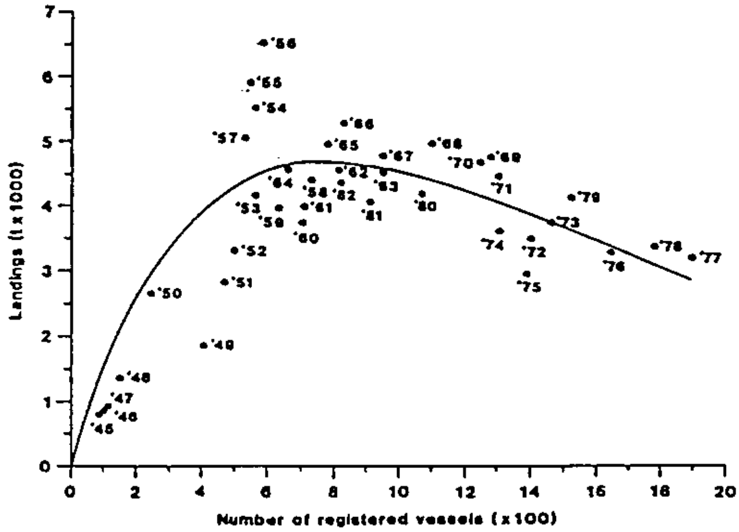


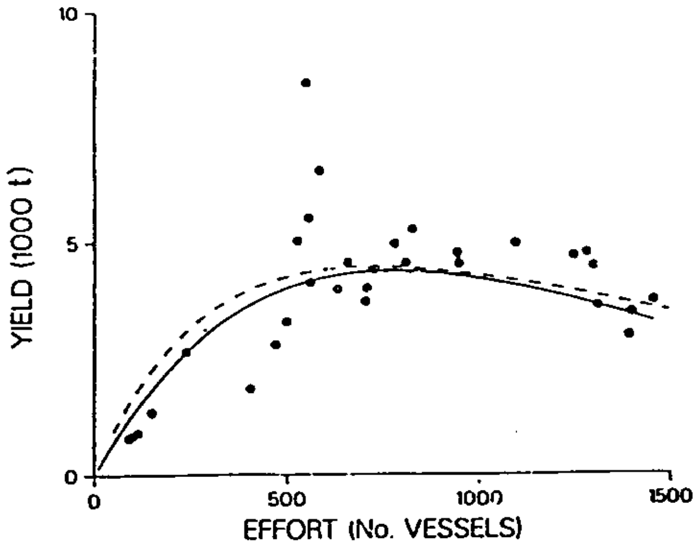
Figure 9



Landings (Y) (tonnes)
Number of registered vessels (f)
Optimum effort
0
200
400
600
800
1000
1200
1400
2000
4000
6000
8000



Landings (t x 1000)
Number of registered vessels (x 100)



YIELD (1000 t)
EFFORT (No. VESSELS)
0
500
1000
1500
5
10

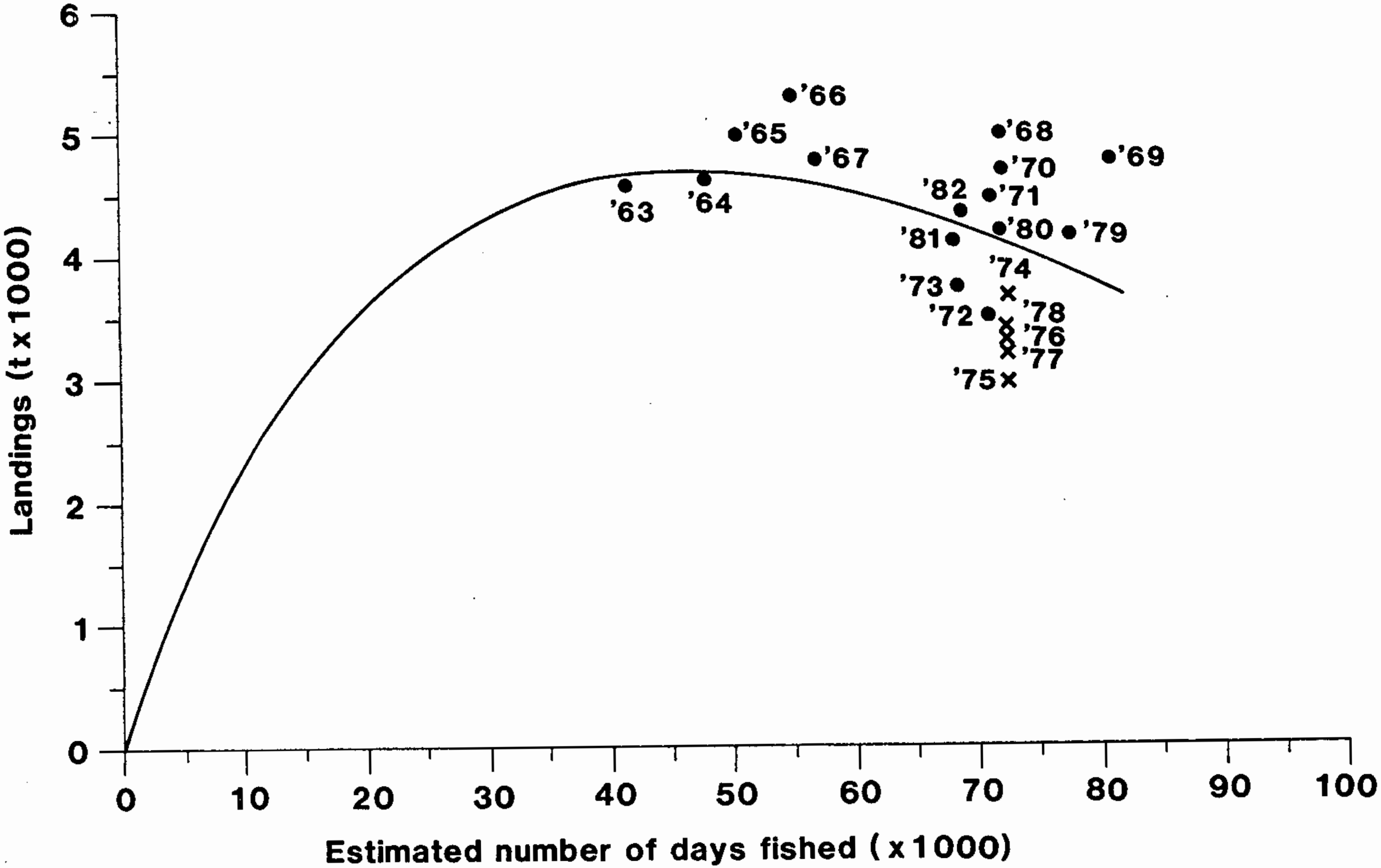

Landings (t x 1000)
Estimated number of days fished (x 1000)
0
1
2
3
4
5
6
0
10
20
30
40
50
60
70
80
90
100
'63
'64
'65
'66
'67
'68
'69
'70
'71
'72
'73
'74
'75
'76
'77
'78
'79
'80
'81
'82

Figure 10

Figure 11

Fig. 11. Catch vs pot-lifts 1945 - 1986

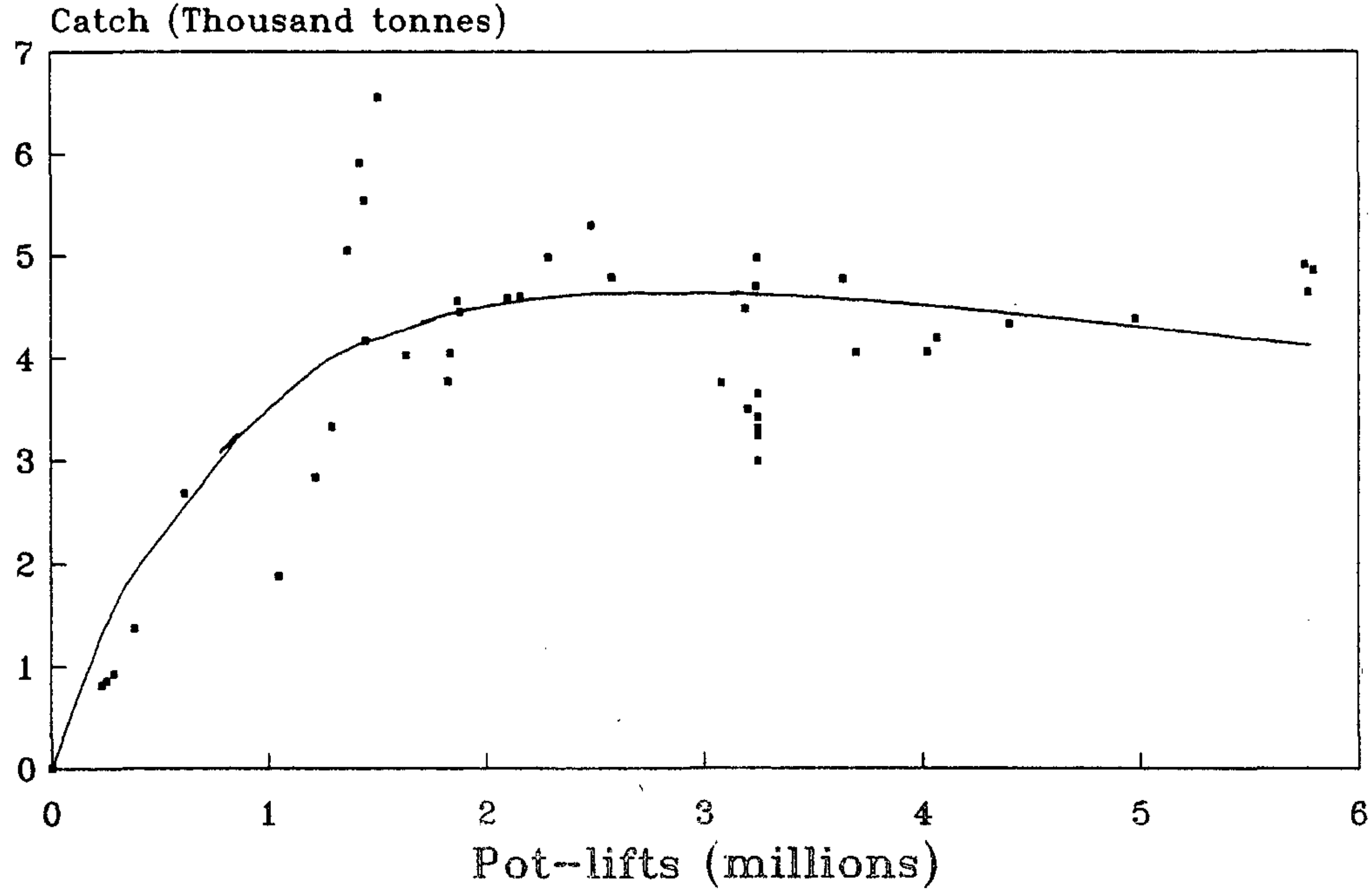


Figure 12

Fig. 12. Catch vs vessel-days 1963 - 1986

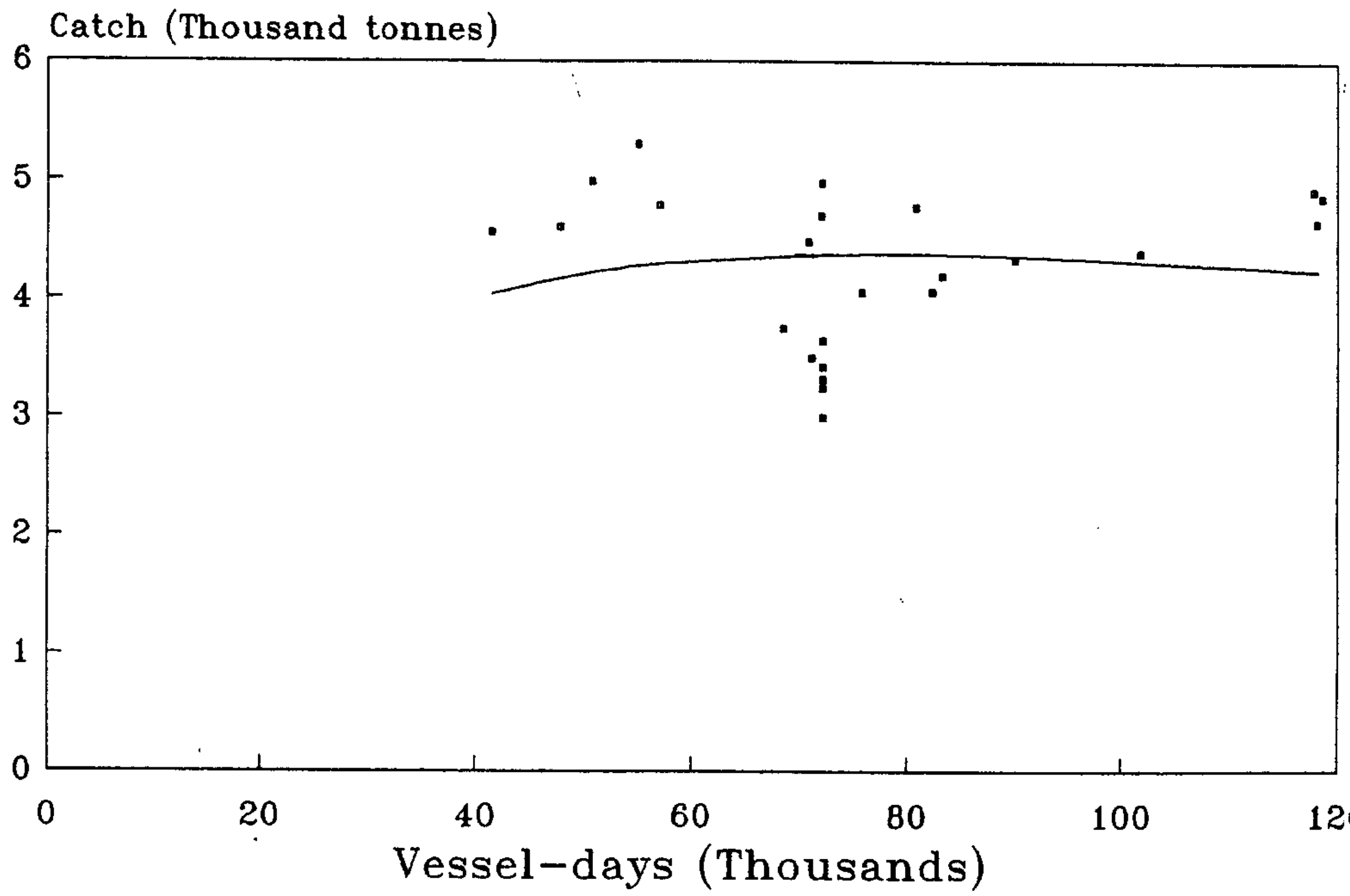


Figure 13

Fig. 13. Kaikoura males