New Zealand Fisheries Assessment Research Document 88/24

Rig

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RIG

Mustelus lenticulatus

I. Introduction

(a) Overview

Between 1982 and 1985, considerable research effort was directed towards rig. Most of the results of this research have been analysed and published. This paper summarises the results which are relevant to fishery management, viz analyses of commercial fishing statistics and catch composition, stock distributions and exploitation rate estimates based on tagging programmes, and sustainable yield estimates based on exploitation rates and trends in catch per unit effort (CPUE). Finally, the management implications of the estimated yields, and other regulatory measures, are considered.

(b) Description of the fishery

The current fishery for rig is mainly commercial, and more than 75% of the commercial catch is taken by set net; the remainder is mainly trawl by-catch. Set net fisherman target fish for rig during spring-summer (particularly October-December) when rig aggregate in shallow coastal waters. At other times, rig catches are low. Rig are fished commercially around the whole mainland coast, but most are taken around the south-west North Island, eastern and southern South Island, and in the major North Island harbours.

Before the introduction of ITQs, the only management measures significantly affecting the operations of the rig fishery were minimum legal mesh sizes for set nets (150 mm) and trawl nets (100 mm), and prohibitions on trawling in all harbours and some coastal waters. Amateurs were further restricted in the amount of net they could set (60 m) and their daily catch limit (30 rig). In 1986, the minimum trawl mesh size was raised to 125 mm in the Hauraki Gulf (year-round) and the remainder of the Auckland Fishery Management Area (October to March), and the minimum set net mesh size for rig was dropped to 125 mm.

On 1 October 1986, when ITQs were introduced, an annual rig quota of 1420 tonnes for all of New Zealand was established. This quota continued to apply during the 1987/88 fishing year. Management measures in force before the introduction of ITQs were also retained.

(c) Literature review

Historical trends in rig catch and CPUE, and seasonal and regional patterns in catch composition (sex ratios and length-frequencies) were analysed for the major New Zealand rig fisheries by Francis & Smith (1988). Massey & Francis (in press) reported in detail on the Pegasus Bay fishery.

A rig tagging programme was conducted around the South Island between 1982 and 1984, and results were used to examine movement patterns and stock distributions, and to estimate exploitation rates (Francis 1988a, in press).

The reproductive biology of rig sampled at Kaikoura and Nelson during the late 1970s was described by Francis & Mace (1980). Since then further work has been done on reproductive biology around the South Island to refine estimates of size at maturity, fecundity and duration of the reproductive cycle (Francis unpublished data).

Three management papers summarising some of the research results and providing yield estimates for rig stocks have been produced recently (Francis 1985, 1986, 1988b).

The results arising from the above studies that are relevant to stock assessment are described where appropriate in sections II - IV.

II. Review of the Fishery

(a) Catch, effort, and CPUE

Reported annual landings for the period 1946-1987 are given in Table 1 and Fig. 1. Nearly all the commercial rig catch is landed by domestic vessels. Reported landings by chartered and foreign licensed vessels were zero up to 1983/84, 4 t in 1984/85 and 8 t in 1985/86.

Landings data should be interpreted cautiously, because of probable under-reporting of catches, and dumping of rig, especially during the period up to the mid-1970s when the demand for rig flesh was low. Nevertheless, Fig. 1 shows three major phases in the development of the fishery. Landings were low, but increased slowly between 1945 and 1970. During the 1970s, there was a period of rapid increase in landings, due to increasing consumer acceptance of rig flesh, the introduction of monofilament nylon set nets, and the rapid expansion of the set net fleet. From the late 1970s to the mid 1980s, annual landings fluctuated between 3000 and 4000 tonnes. The introduction of ITQs in 1986 led to a sharp drop in rig landings in 1986/87.

Landings by statistical area for 1984/85 and 1985/86 fishing years are shown in Fig. 2. The data for 1985/86 are further divided into three-month periods in Fig. 3. The highest landings in most areas were made in the spring or summer quarters (usually spring in the major fishing areas). Graphs showing monthly landings for the period 1975-84 for 11 major rig fishing regions are given by Francis & Smith (1988).

Five rig "stocks" are recognised for the purpose of yield estimation (see below), and their boundaries are marked with bold lines in Fig. 2. To determine the average annual landings from each stock in recent years, landings were calculated for a seasonal year (1 July - 30 June). This is because the rig season straddles the 1 October boundary used for the fishing year. Seasonal year landings between 1976/77 and 1985/86 are given in Table 2, and are plotted by Francis & Smith (1988). The ECSI and WCNI stocks have produced the most rig during the last decade.

A CPUE index was calculated for selected set net vessels in 10 regions around New Zealand for the period 1975/76 to 1985/86. Vessels were selected for the analysis if they met the following criteria:

1. Net length was recorded.
2. Net length exceeded 350 m per day, averaged over one month.
3. The vessel was likely to have been target fishing for rig (on the basis of its catch species mix).

The weight (Kg green weight) of rig caught per 100 m of net per day was calculated for individual vessels for each month of the rig seasonal peak (which varied from 3 to 6 months). For each region the geometric mean of the vessel CPUEs was calculated for each month, and then the mean of the monthly means was calculated. (This index weights all months of the rig season equally. Francis & Smith (1988) also calculated an index that weighted the months by their fishing effort; differences between the two indices were negligible.) The CPUE index was calculated separately for the whole fleet and for the top five vessels. Further details of the calculation procedure, assumptions, and biases of the indices were given by Francis & Smith (1988). Data for 1986/87 were not used because the introduction of ITQs drastically reduced rig landings and the number of vessels fishing for rig, and altered the data base.

The results of the CPUE analyses are shown in Fig. 4; corresponding graphs of effort and mean net length used by the fleets were given by Francis (1988b). For each region showing a significant decline in the CPUE index, the equivalent annual rate of decline of the stock size (percent per year) was calculated and

is shown above each line in Fig. 4. Detailed discussions of these results are given by Francis (1986, 1988b) and Francis & Smith (1988). There were significant downward trends in CPUE (up to 1984/85) for the whole fleet and top five vessels at New Plymouth, Golden Bay - Tasman Bay, Kaikoura, Lyttelton and Canterbury Bight, and for the whole fleet at Manukau Harbour and South Taranaki. The decline rates ranged from 7-24 % per year (Fig. 4). The data points for 1985/86 deviated from the long-term trends in several of the regions, in some cases by large amounts. Possible explanations for the deviations are discussed by Francis (1988b). The most likely is that reported landings were inflated by fishermen in the lead-up to the introduction of ITQs in order to increase their apparent catch histories. 1985/86 data are therefore considered to be unreliable.

The CPUE index underestimates stock abundance in the early years, and overestimates abundance in the later years, because of their biases (see Francis & Smith (1988) for details). For stocks that are declining in size, the slopes of the CPUE graphs underestimate the real rates of decline.

Changes in the CPUE indices suggest that ECSI, WCSI, and WCNI stocks have been declining steadily during the last decade. A different CPUE analysis for statistical areas 13 and 14 (Poverty Bay, Hawke Bay and Wairarapa) indicated that the SECNI stock was declining at 19-24% per year (Francis 1985). There is no evidence from the CPUE index of a decline in the NECNI stock.

(b) Other information

Massey & Francis (in press) analysed the sex and maturity composition of the Pegasus Bay rig catch during 1979/80 and 1982/83. Most fisherman used 178 mm mesh set nets during both periods. Males dominated the early-season catches (November - December) whereas females dominated late-season catches (January - April). It was estimated that 30,000 rig were caught during the 1982/83 season, and that the catch comprised mainly mature males (48%) and immature females (31%). Only 30% of the females caught were mature.

Details of sex and maturity composition at a number of South Island localities are given by Francis & Smith (1988). Regional, seasonal and depth differences in sex ratios are apparent. For example, the Kaikoura fishery is based mainly on females, whereas the Canterbury Bight fishery is based on males. In Golden Bay, males are caught in deep water during the spring, whereas females are taken in shallow water during summer.

The mean size of rig caught, and the proportion of mature rig, both increase with set net mesh size (Francis & Smith 1988). This is due to the size selectivity of set nets (Kirkwood & Walker 1986).

(c) Recreational and Maori fisheries

Rig are caught in set nets by recreational fishermen throughout New Zealand, but there is no information on the quantity taken. Recreational landings have probably declined during the last decade as stock sizes have declined and as commercial fishermen progressively worked further from the coast and intercepted the schools of aggregating rig.

Maori fishermen traditionally caught large numbers of "dogfish" during the last century and early this century. Rig was probably an important species, though spiny dogfish and school shark were also taken. The early practice of having regular annual fishing expeditions, during which thousands of dogfish were sun-dried on wooden frames, appears to have died out. However, rig are still caught by Maori in parts of the North Island, especially the tidal harbours of the Auckland region. More than 97% of the recaptures of rig tagged around the South Island and Manawatu coasts were returned by commercial fishermen, indicating that in those areas Maori and recreational catches are minor.

III. Research

(a) Stock structure

Information on rig stock distributions has been obtained from tagging programmes around the South Island (Francis 1988a). Many tagged rig were recaptured close to their tagging sites, but more than half had travelled more than 50 km. Recaptured females travelled further than males: 52% of females travelled more than 200 km, whereas only 15% of males did. Recorded rig movements greater than 150 km are shown in Fig. 5. Males and females moved in both directions along the east coast of the South Island between Cook Strait and Foveaux Strait. No ECSI rig moved to SECNI, but a number of females moved through Cook Strait to the south-west North Island. There was some interaction between WCSI and WCNI females, but because few rig were tagged off WCNI, the degree of interaction could not be determined.

Kaikoura and Nelson rig mature at different lengths (Francis & Mace 1980), and maturity data from south Westland indicates that stock mixing occurs there (Francis, unpublished data).

Taken together, the tagging data and length-at-maturity data indicate that a single rig stock ranges between Cook Strait and Foveaux Strait along the east coast of the South Island. This ECSI stock mixes with the WCSI stock in the Cook Strait region, and in south Westland.

The northern limit of the WCSI stock is unclear. However, for the purpose of stock assessment, a stock boundary near Cook Strait has been adopted.

Using the geographical ranges of the South Island stocks as a guide, a further stock boundary was assumed to separate a WCNI stock from east coast North Island stocks at North Cape. Two east coast North Island stocks (with a common boundary at East Cape) were recognised on the basis of the very different trends in CPUE at Auckland - Thames (no apparent decline) and Poverty Bay - Wairarapa (rapid decline).

(b) Resource size estimates

No surveys to estimate rig resource sizes have been carried out.

(c) Other studies

Rig give birth to live young about 30 cm long in spring, after a 10-12 month gestation period. The number of young produced increases markedly with the size of the mother, the average number being about 10 (Francis & Mace 1980). At least some of the females mate immediately after the birth of their litter and thus produce young annually. An unknown proportion of females appear to have a one year resting period between pregnancies.

Rig are recruited into the set net fishery at about 80-90 cm though the length depends on the mesh size being used. Males mature at a smaller size than females. In the ECSI stock, males and females mature at about 90 and 100 cm respectively, and in the WCSI stock males and females mature at about 80 and 85 cm respectively. Techniques for aging rig have not yet been developed. However, analysis of length-frequency modes in juvenile rig suggests that they reach maturity at about 4-6 years (Francis unpublished data). Females reach a maximum length of 140 cm and males reach 117 cm. Longevity is not known, but growth rates after maturity are probably low to moderate.

Actual predators are virtually unknown, though the larger sharks and carnivorous teleosts are potential predators of young rig. Natural mortality is assumed to be low to moderate.

Recruitment of juveniles to the adult population is likely to be directly dependent on the number of young produced. Environmental factors are probably

much less important to newly born rig than to the eggs and larvae of fishes that have a planktonic stage in their life cycle. A decrease in the number of adult females reproducing probably leads to a reduction in the number of recruits. This effect would be exacerbated by a decline in the number of young produced per female if fishing pressure was sufficient to reduce the average size of females in the stock.

The results of the rig tagging programme around the South Island were used to estimate exploitation rates (Francis in press). Double-tagging experiments to estimate tag loss rates showed that the probability of tags being retained after one year at liberty was 0.79. Recapture rates increased with rig length, because larger rig are more vulnerable to commercially-used mesh sizes. Crude recapture rates, and rates corrected for tag loss, are given for four data sets in Table 3. First year corrected recapture rates for areas 18, 20 and 22 were 8-11% for 75-89 cm males, and 7% for the only female sample in this size class. For males ≥ 90 cm, corrected recapture rates were 8% (trawl sample) and 19% (set net sample). For females ≥ 90 cm, recapture rates were 16% (trawl) and 27% (set net). Maximum total (uncorrected) recapture rates for areas 18, 20 and 22 were 35% for males and 33% for females.

First year corrected recapture rates and total recapture rates for areas 34-36 in 1982/83 were similar to those of trawl samples tagged in areas 18, 20 and 22 in 1983/84. The first year corrected recapture rate of 75-89 cm males tagged from trawl samples in areas 37-38 was only 1%; however the total recapture rate (14%) was greater than that for areas 34-36 during the same year.

The highest recapture rates were obtained for set net-tagged rig off ECSI. Also, recapture rates for trawl-tagged rig were higher for those classed as being in "excellent" or "good" condition at the time of tagging than for those classed as "poor". These results suggest that trawl-tagged rig might have suffered high initial mortality.

In addition to initial mortality of tagged rig, there are two other sources of negative bias in the recapture rate estimates: non-recognition (or non-recovery) of tags, and non-reporting of recovered tags. Some instances of the latter are known to have occurred, but the magnitude of this bias was not estimated. These two biases, plus losses due to initial mortality, mean that first year recapture rates underestimate the annual exploitation rates.

Exploitation rates of ECSI rig ≥ 90 cm probably exceeded 20% per year at the time of tagging for both sexes; the exploitation rate for females may have exceeded 30%, but the sample size was small and the precision probably low. Exploitation rates of 75-89 cm ECSI rig probably exceeded 10% per year. Males probably experienced high fishing mortality, and females very high fishing mortality, after reaching maturity. Females probably also experienced high fishing mortality before maturity.

First year recapture rates for area 34-36 trawl-tagged rig were similar to those for ECSI trawl-tagged rig, suggesting that exploitation rates were similar on east and west coasts of the South Island. The very low first year recapture rate of area 37-38 75-89 cm males was remarkable considering that the total recapture rate (14%) exceeded that of area 34-36 males. Small sample size again precludes strong conclusions. Both sexes probably experienced 10% per year exploitation rates before maturity, and similar rates to ECSI rig after maturity.

(d) Biomass estimates

The absolute biomass of exploitable rig in the WCSI and ECSI stocks at the time of the tagging programme was estimated by dividing the mean annual reported landings during the period 1981-83 by the estimates of the annual exploitation rates. The estimation of biomass by this method is based on the assumption that tagged rig mix thoroughly with the untagged stock. Tagged rig are capable of

travelling considerable distances in 20 days (Francis 1988a), so only rig at liberty more than 20 days were used in the estimation of exploitation rates.

Most of the commercial set net catch is composed of rig more than 90 cm long (Francis & Mace 1980, Francis & Smith 1988, Massey & Francis in press), so exploitation rate estimates for the ≥ 90 cm length class were used. Exploitation rates used were 25-30% for ECSI and 20% for WCSI. A lower value was used for WCSI than for ECSI for two reasons:

1. Only trawl-tagged rig were released off WCSI, so it is not certain whether exploitation rates were as high as off ECSI;
2. The WCSI catch may include a higher proportion of rig less than 90 cm (because set net mesh sizes tend to be smaller than off ECSI), and their exploitation rate is less than that of longer rig.

Exploitation rate estimates are still likely to be conservative because of the biases caused by non-recognition and non-recovery of tags.

The following biomass estimates were obtained:

ECSI: B_{max} = 1400 t/0.25 = 5600 t
B_{min} = 1400 t/0.30 = 4667 t

WCSI: B = 650 t/0.20 = 3250 t

No biomass estimates are available for other rig stocks.

(e) Yield estimates

The large declines in CPUE indicate that the exploitation rates being experienced by South Island rig stocks up to 1986 were unsustainable. It is thought that rig stocks can only sustain a low exploitation rate because of their low to moderate growth rates after maturity, low natural mortality rate, and low fecundity.

It is possible that over-exploitation has reduced the already low fecundity by reducing the average size of rig in some stocks. Thus rig stocks subjected to heavy fishing may be vulnerable to recruitment failure.

Yield estimates were made for rig stocks by Francis (1985, 1986, 1988b). For ECSI and WCSI stocks, the yield estimates were originally based on the biomass estimates derived from the tagging programme (see above) and an assumed annual production of 7.5% of the stock biomass (Francis 1985). Stock reduction analysis was then used (Francis 1986) to estimate the decline in yield caused by catches that continued to exceed the original yield estimates.

Exploitation rate estimates were not available for other rig stocks, so yields were estimated by interpreting historical catch data in the light of CPUE trends (Francis 1985, 1986).

ECSI and WCSI stocks

Maximum Constant Yield (MCY) can be estimated for ECSI and WCSI stocks by using the formula:

$$MCY = 0.5(M\bar{B})$$

where $\bar{B}$ is the minimum historic estimate of exploitable biomass. Only one biomass estimate is available for ECSI and WCSI, so MCY cannot be determined precisely. However, a crude estimate was obtained using the single biomass estimate in place of the minimum historic biomass estimate. MCY estimates were based on natural mortality coefficients of M = 0.1 and M = 0.2.

ECSI: MCY_{min} = 0.5(0.1 x 4667 t) = 233 t
MCY_{max} = 0.5(0.2 x 5600 t) = 560 t

WCSI: MCY_{min} = 0.5(0.1 x 3250 t) = 163 t
MCY_{max} = 0.5(0.2 x 3250 t) = 325 t

Since the minimum historic biomass is probably less than the single biomass estimate, MCY values are probably at the bottom end of these ranges.

Other stocks

No biomass estimates are available for the other rig stocks. Inter-annual variability in biomass is unknown, but is probably low in view of very low fecundity, and presumed low natural mortality. A value of c = 0.9 was used in the following calulations.

WCNI: The period 1977/78 - 1981/82 appeared to have relatively constant effort (± 30%) and no trend in landings.

$$MCY = c\bar{Y}$$

where c is a constant and $\bar{Y}$ is the average yield.

$$MCY = 0.9(680\ t) = 612\ t$$

However, CPUE declined significantly in 3 of the 4 regions examined over the period used for MCY estimation, so this calculation is inappropriate, and MCY is likely to be considerably less than 612 t.

NECNI: The period 1977/78 - 1980/81 had relatively constant effort (± 15%) and no trend in landings in the Hauraki Gulf (the part of the stock range that accounts for most of the catch).

$$MCY = c\bar{Y} = 0.9(318\ t) = 286\ t.$$

SECNI: No effort data are available, but effort probably increased during the last decade. Landings declined steadily from 200-300 t before 1980 to 80 t in 1985/86. CPUE declined rapidly during the period used for MCY estimation.

$$MCY = Y_{proj} = 0\ t$$

where Y_{proj} is the yield projected ahead from the CPUE trend.

MCY estimates

MCY estimates by stock are shown in Table 4.

Rig stock boundaries do not correspond with FMA boundaries for NECNI and WCNI stocks. For these stocks, MCY was allocated to the appropriate FMA in proportion to the landings (based on statistical areas). For other stocks, stock boundaries approximately coincide with FMA boundaries. Estimated MCYs by FMA are given in Table 5.

Estimation of Current Annual Yield is not possible with currently available data.

(f) Models

No models have been used to estimate rig yields.

IV. Management implications

The TACs in force during 1986/87 and 1987/88 are considerably lower than historical rig landings. Quota Monitoring Reports (QMRs) indicate that 1986/87 landings fell well short of the TACs in Auckland and Central West FMAs (Table 5). It is not known which stock(s) (WCNI or NECNI) benefitted from the shortfall in the Auckland FMA; thus landings from the WCNI stock, and possibly the NECNI stock, may have been well below the MCYs. In the other FMAs (and therefore stocks), landings were similar to the MCYs.

At these levels of exploitation, the current TACs are probably sustainable for most stocks. However, the high proportion of immature females being caught in some areas, and the low mesh sizes used in the Auckland FMA, are of considerable concern. Because of the low fecundity of rig, exploitation of immature rig increases the risk of recruitment failure. As long as immature rig are being exploited, the MCYs are probably lower than could be achieved if larger mesh sizes were being used.

Since the introduction of ITQs, a higher proportion of the rig catch has been taken by trawlers, many of which do not have adequate quota. By-catch problems may increase as stocks recover.

V. References

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Table 1: Rig landings, 1946-87. Data for 1946-1983 are landings for calendar years; after that, data are for fishing years (1 October - 30 September).

Year	Landings (t)	Year	Landings (t)
1946	114	1967	737
1947	179	1968	677
1948	178	1969	690
1949	208	1970	930
1950	288	1971	1120
1951	331	1972	1011
1952	372	1973	-
1953	332	1974	2040
1954	307	1975	1841
1955	315	1976	2610
1956	307	1977	3281
1957	379	1978	3300
1958	418	1979	2701
1959	444	1980	3000
1960	516	1981	3006
1961	560	1982	3335
1962	658	1983	3753
1963	570	1983-84	3671
1964	650	1984-85	3200
1965	723	1985-86	2914
1966	850	1986-87*	1089

- No data available
*Provisional, from Quota Monitoring Reports

Table 2: Seasonal year (1 July - 30 June) rig landings (tonnes) by stock. Chatham Is. landings were omitted. Data up to 1982/83 are based on regions of landing (King 1985), and for subsequent years are based on statistical areas of capture.

	Stock					
Year	NECNI	SECNI	ECSI	WCSI	WCNI	Area unknown
1976/77	392	238	1321	760	686	
77/78	358	266	1133	666	742	
78/79	356	274	1050	535	699	
79/80	289	239	1114	496	628	
80/81	267	203	1389	425	607	
81/82	370	193	1336	607	721	
82/83	502	168	1377	748	860	
83/84	397	137	1285	585	1085	198
84/85	368	90	1199	429	940	178
85/86	443	80	875	399	893	208

Table 3: Tagging and recapture data for four tag batches. Percentage recaptures were rounded to the nearest integer, and first-year recaptures corrected for tag loss are given with their 95% confidence limits in parentheses.

Tagging data								Recapture data		
								First year		Total
Statistical areas	Method	Tag type	Single/ Double	Time period	Sex	Length class (cm)	Number tagged	Crude % recaptured	Corrected % recaptured	Crude % recaptured
East coast										
18,20,22	Set net	B	S	Oct-Dec 1982	M	75-89	31	10	11 (10.7-12.1)	10
					M	≥90	240	17	19 (18.1-20.8)	35
					F	≥90	69	25	27 (25.3-29.4)	33
18,20,22	Trawl	B	D	Nov 83- Jan 84	M	75-89	90	8	8*	11
					M	≥90	159	8	8	17
					F	75-89	68	7	7	13
					F	≥90	49	16	16	22
West coast										
34-36	Trawl	A,B	S	Jul 82- Jun 83	M	75-89	198	8	9 (8.2-9.3)	10
					M	≥90	148	11	13 (11.9-13.4)	15
					F	75-89	65	3	4 (3.3-3.8)	5
					F	≥90	37	11	13 (11.9-13.4)	22
37-38	Trawl	A,B	S	Jul 82- Mar 83	M	75-89	86	1	1 (1.2-1.3)	14

* Double-tagged rig not corrected for tag loss.

Table 4: Maximum Constant Yield (MCY) estimates for each rig stock.

Stock	MCY(t)
ECSI	233
WCSI	163
WCNI	<612
NECNI	286
SECNI	0

Table 5: Fishing year (1 October - 30 September) landings, estimated Maximum Constant Yields, and current TACs (tonnes) by Fishery Management Area.

FMA	1985/86 landings	1986/87 landings*	MCY	1986/87 TAC	1986/87 landings as % TAC*
Auckland	845	373	<630	540	69
Central East	96	56	0	60	93
Central West	465	125	<268	240	52
Challenger	367	224	163	240	93
South-east + Southland + Subantartic	921	311	233	330	94
Kermadec	0	0	0	10	0
Area not reported	212	?			
Total	2906	1089		1420	

*Provisional, from Quota Monitoring Reports.

Figure captions

Fig. 1 Total New Zealand reported landings 1945-1987 (based on data in Table 1).

Fig. 2 Domestic rig landings (tonnes) by statistical area for the fishing years (1 October - 30 September) 1984/85 (upper number) and 1985/86 (lower number). Bold lines indicate stock boundaries used for stock assessment, and capitalised abbreviations are the stock names.

Fig. 3 Domestic rig landings (tonnes) by statistical area and season for 1985/86.

Fig. 4 Trends in CPUE for set net vessels during the rig season (x = top five vessels. o = whole fleet). Solid lines indicate significant declines, numbers are percentage declines per year.

Fig. 5 Diagrams of movements > 150 km made by rig tagged during the 1982/83 season (solid lines) and 1983/84 season (broken lines). Dots indicate statistical area of tagging and arrowheads indicate area of recapture. Lines linking dots and arrowheads represent hypothetical routes. Numbers at arrowheads indicate number of recaptures if more than one. A, Females, northward movements (N=40); B, Females, southward movements (N=25); C, Males, northward movements (N=25); D, Males, southward movements (N=17).

Fig. 1

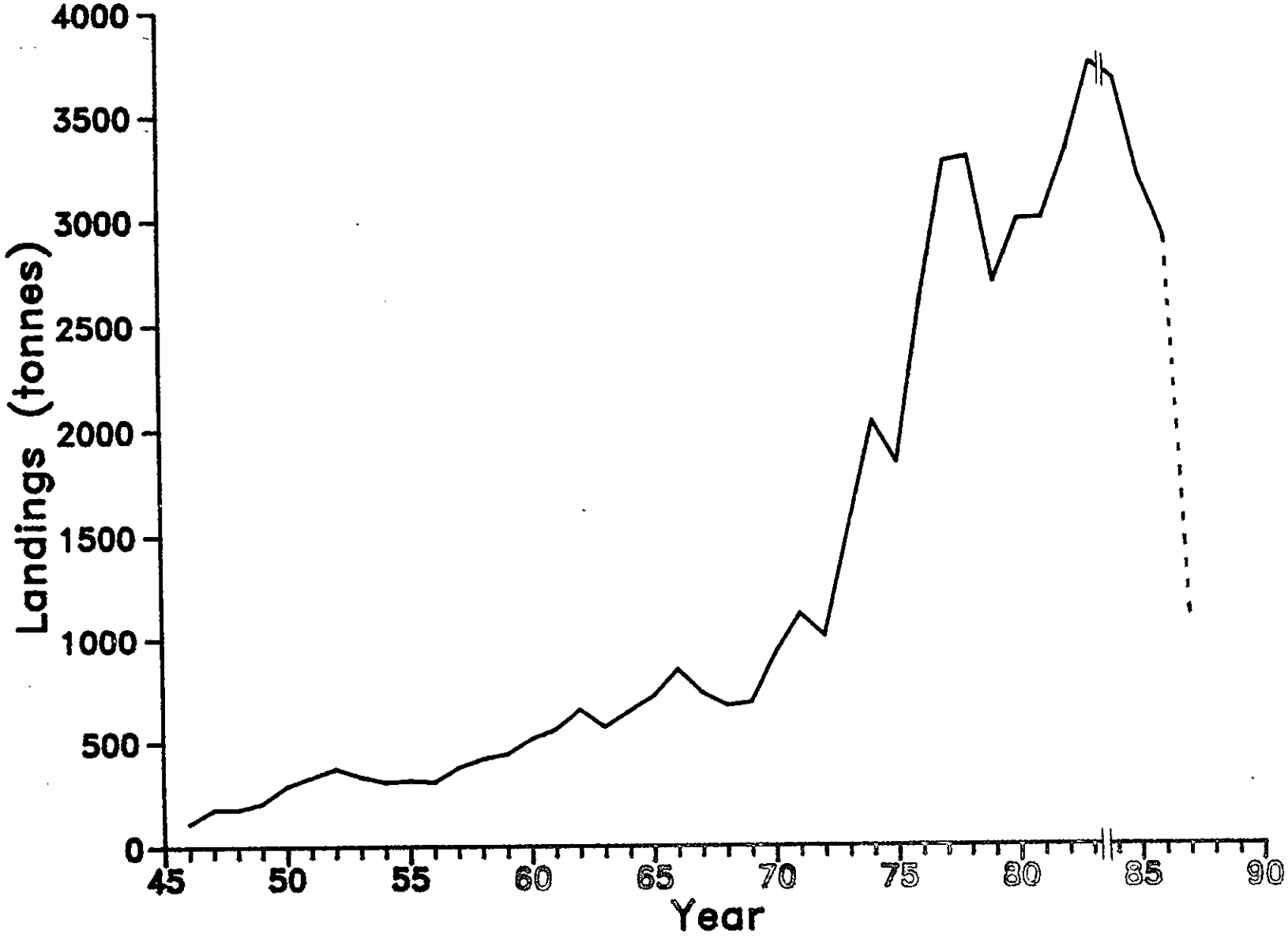
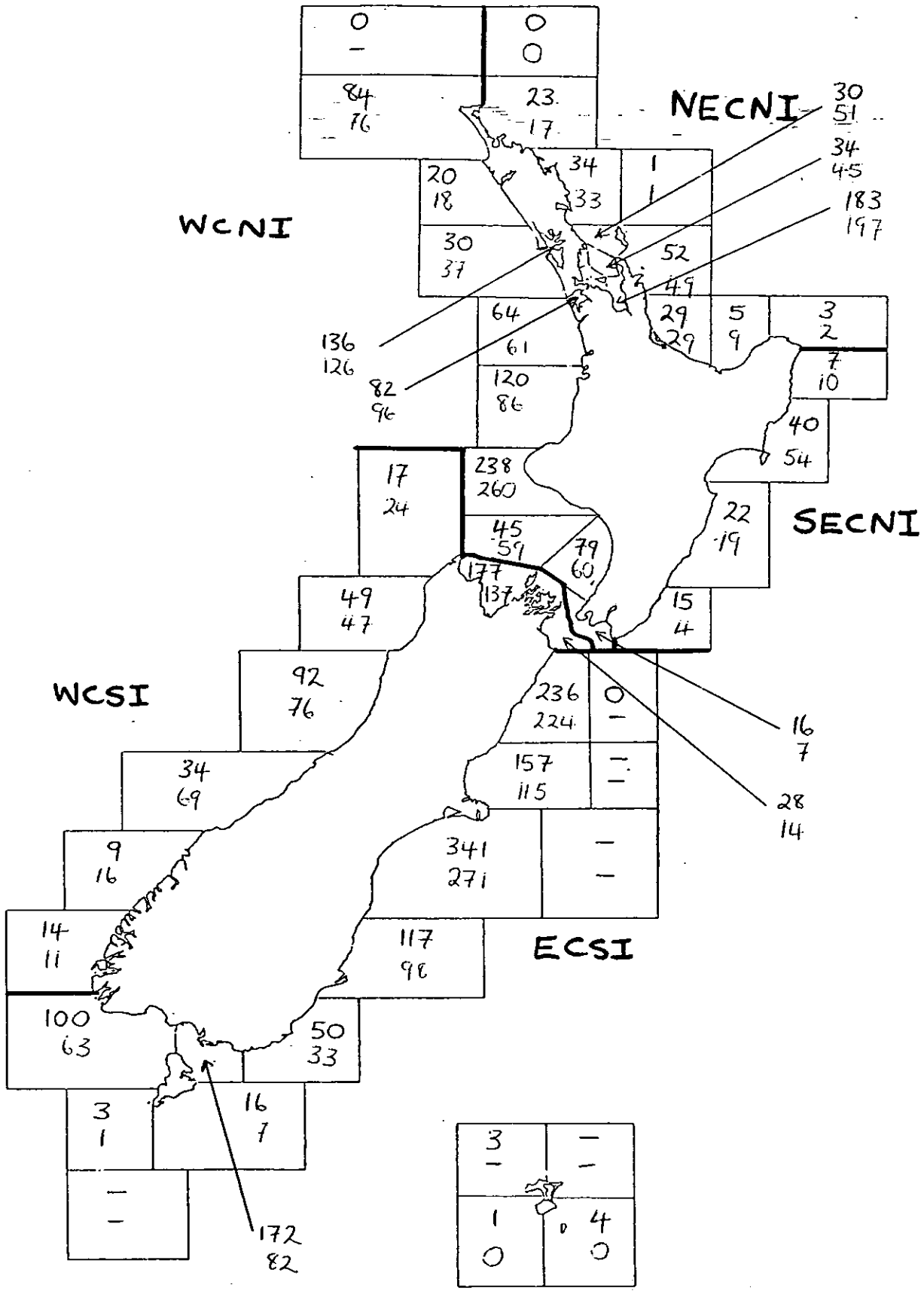

Landings (tonnes)
4000
3500
3000
2500
2000
1500
1000
500
0
45
50
55
60
65
70
75
80
85
90
Year

Fig. 2

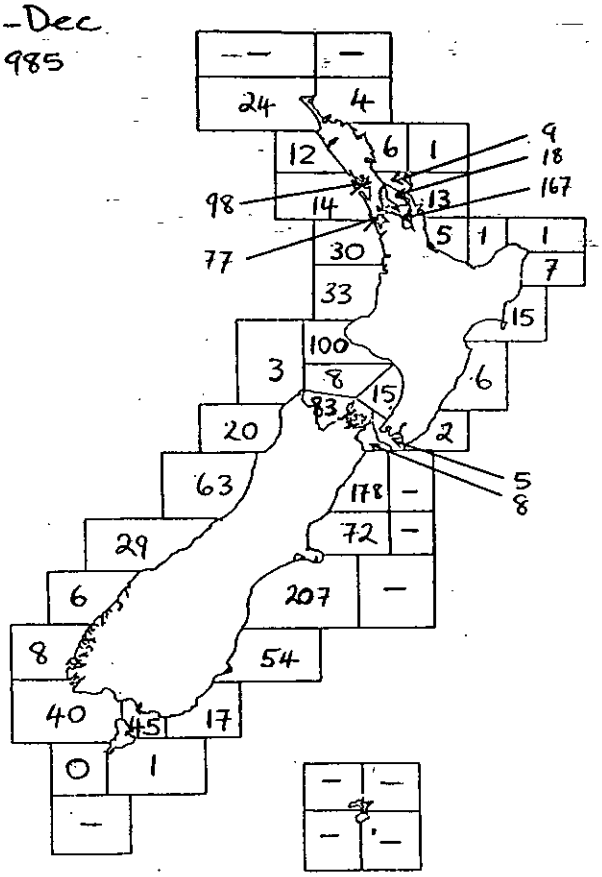


Area unknown 187
212

Total 3196
2906

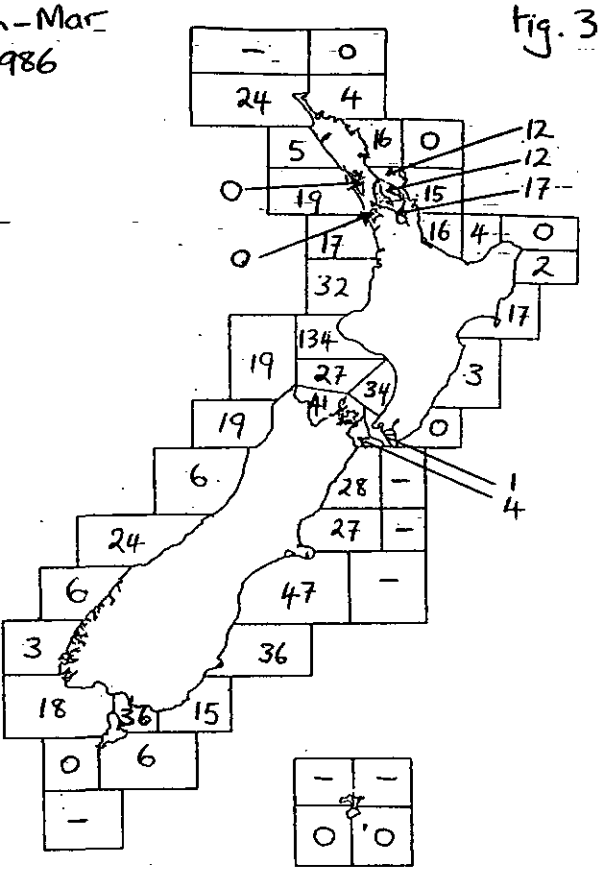
fig. 3

Oct-Dec
1985



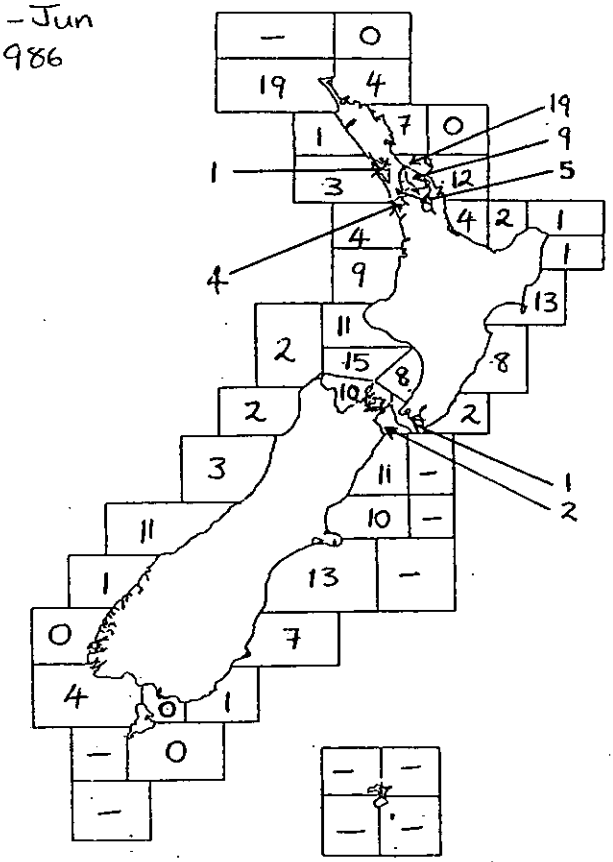
Area unknown = 106 t Total = 1611 t

Jan-Mar
1986



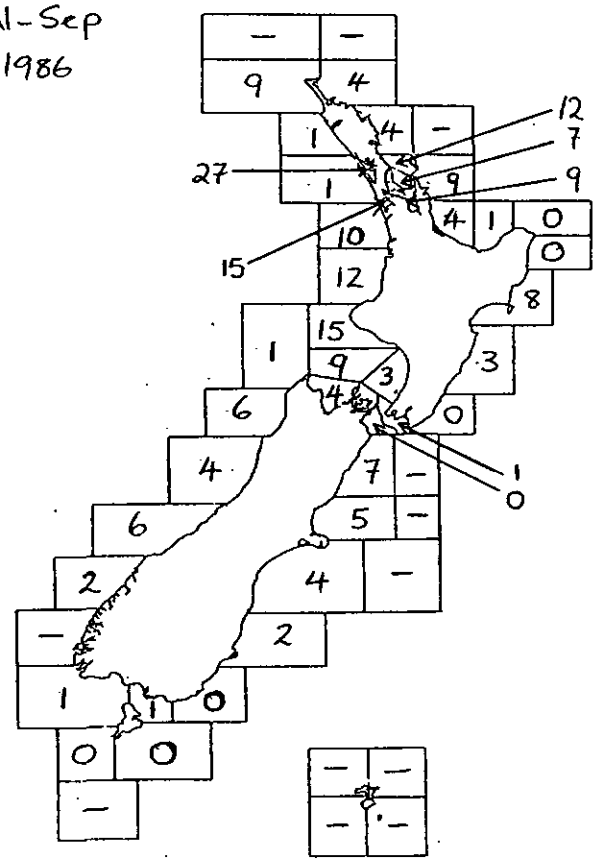
Area unknown = 62 t Total = 808 t

Apr-Jun
1986



Area unknown = 26 t Total = 266 t

Jul-Sep
1986



Area unknown = 19 t Total = 226 t

Fig 4

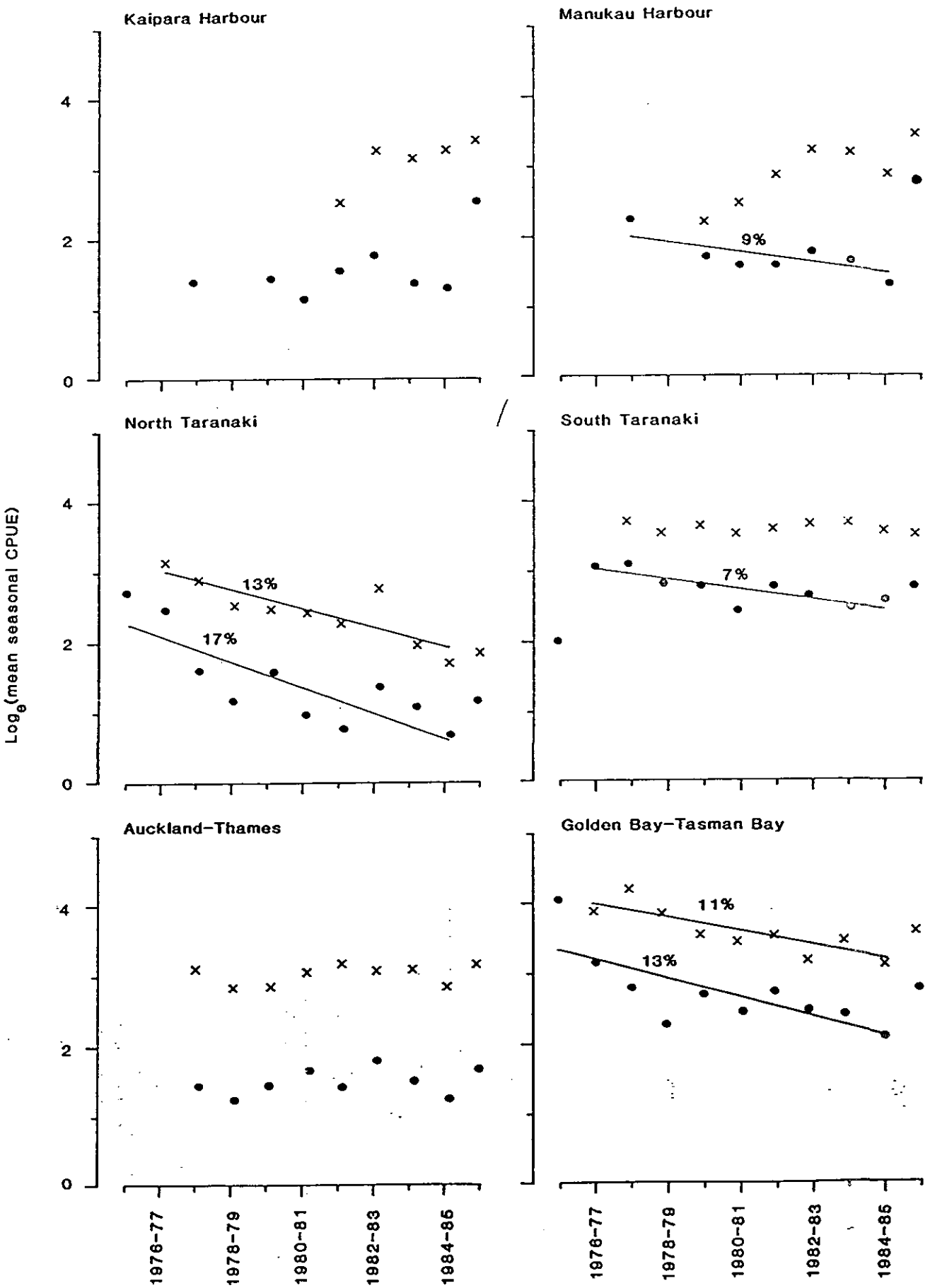
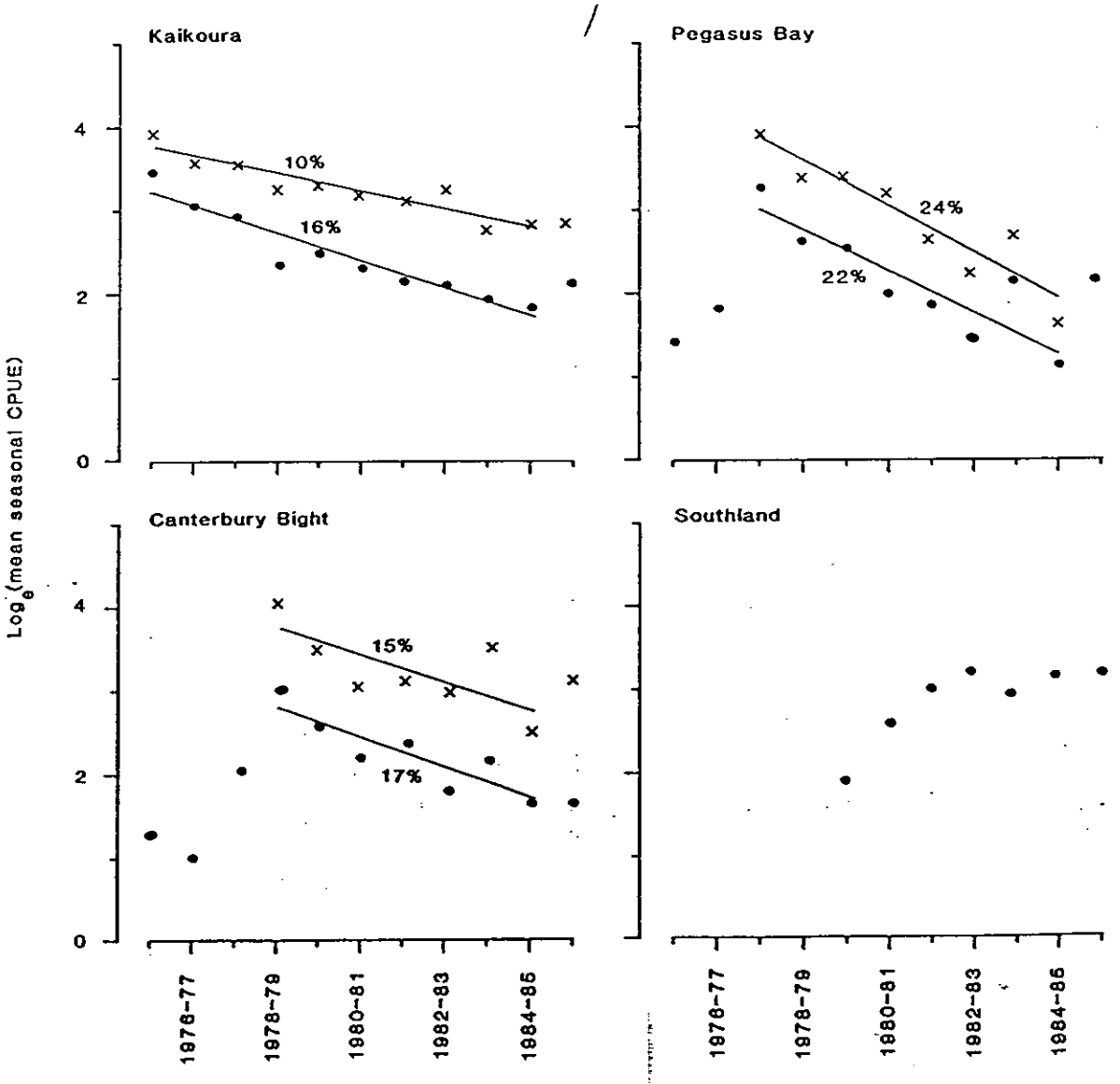
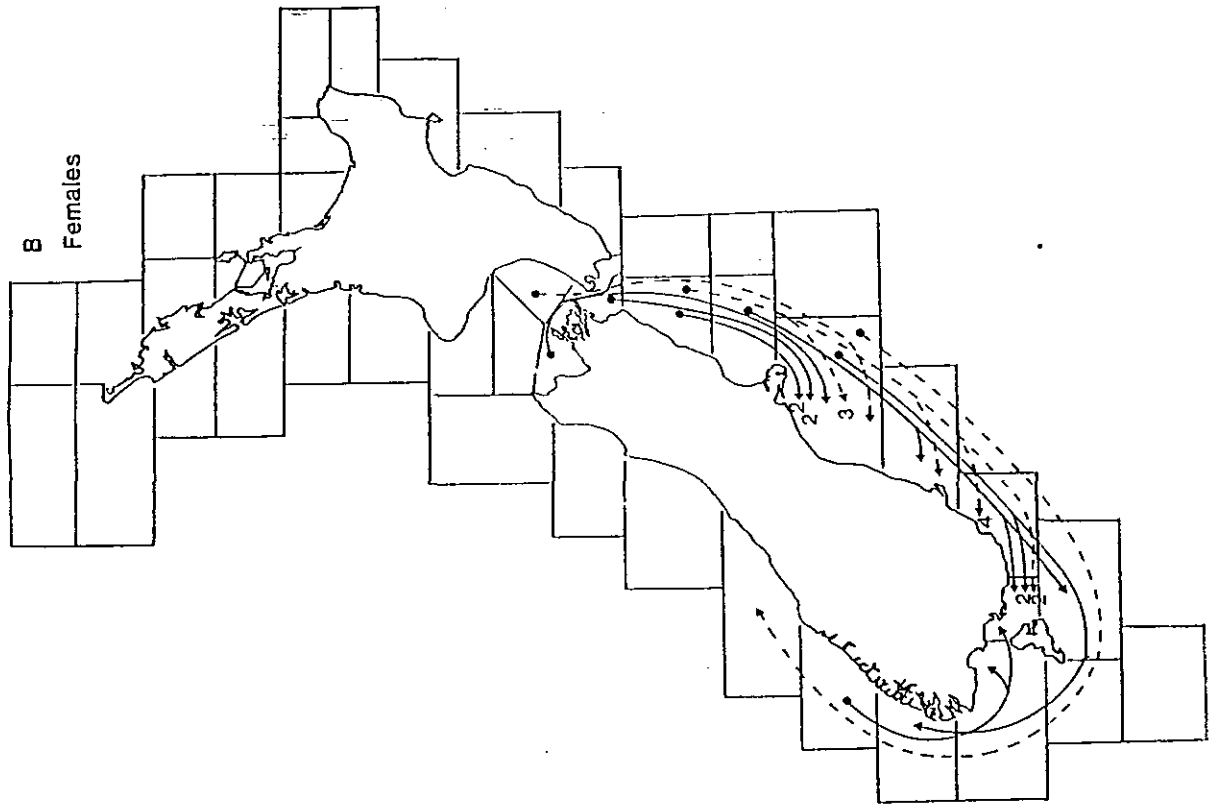

Kaipara Harbour
Manukau Harbour
North Taranaki
South Taranaki
Auckland–Thames
Golden Bay–Tasman Bay
9%
13%
17%
7%
11%
13%
Log$_e$(mean seasonal CPUE)
0
2
4
1976-77
1978-79
1980-81
1982-83
1984-85

Fig 4 (cont.).


Kaikoura
Pegasus Bay
Canterbury Bight
Southland
10%
16%
24%
22%
15%
17%
Log$_e$(mean seasonal CPUE)
0
2
4
1976-77
1978-79
1980-81
1982-83
1984-85


B
Females
2
3
2
2

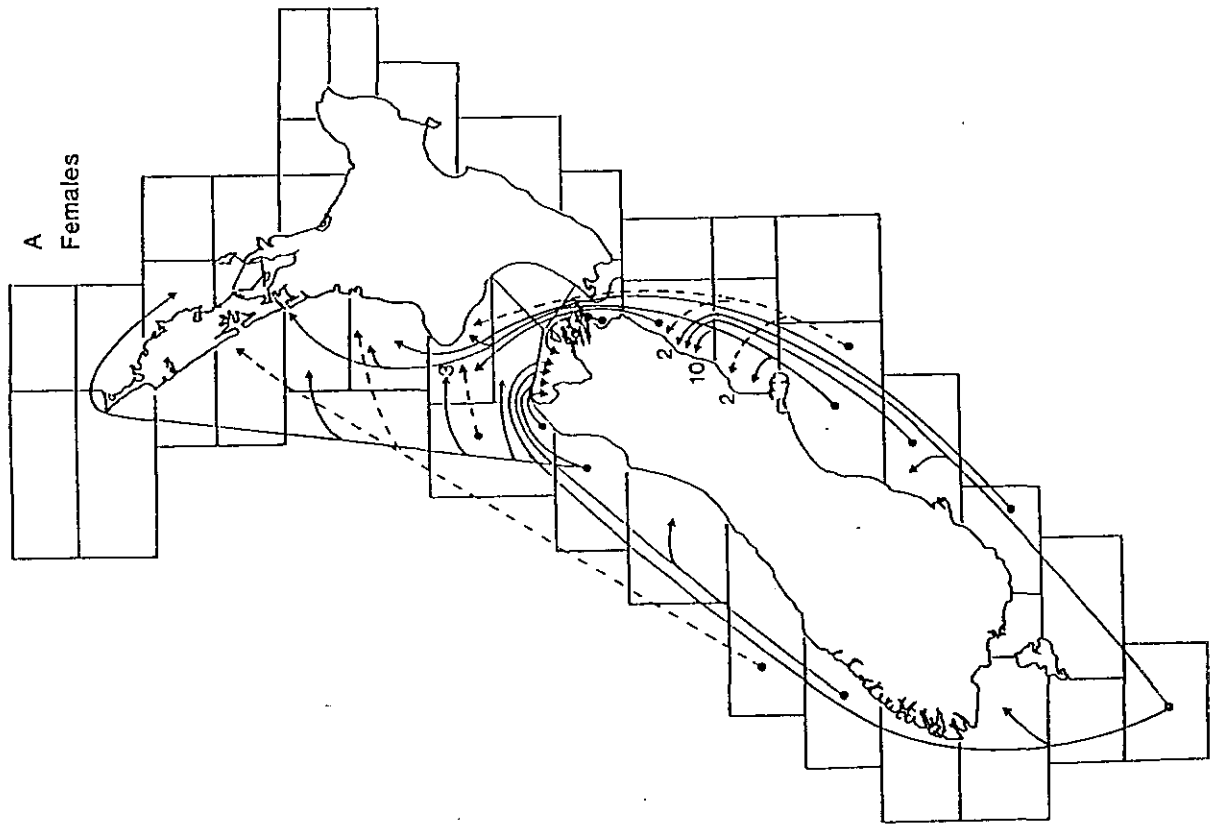

A
Females
3
2
10
2

Fig 5
cont.