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A report on the CRA3 fishery for red rock lobsters (*Jasus edwardsii*)

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EXECUTIVE SUMMARY

A unique suite of management measures was imposed on the CRA3 fishery for the fishing years 1993-94 through 1995-96. Data are available from just over two years of fishing under the 'CRA3 package'. We present some indicators from the recent fishery: catch and effort data, catch sampling abundance and size data, commercial fishery data, and assessment results.

The first two fishing years and early part of the third year of the CRA3 package were good. A high percentage of the quota was taken in the winter fishery in each year; an expected result of the package. The apparent abundance of legal males, reflected in all data sources, has increased substantially since 1992. The abundance of legal males in the adjoining CRA4 does not show a similar increase. The abundance of sublegal males also increased. Several alternative explanations for this are available, some related to and some independent of the CRA3 package. The data do not allow these explanations, not necessarily exclusive, to be distinguished.

A simple model is described and fitted to commercial CPUE data from 1989. Forward projections from the model indicate that rebuilding of the recruited biomass is likely to occur at the present level of catch, and with 25% or 33% increases in commercial catch, even if recruitment should decrease by 25% for three years. The model suggests that retaining the concession winter size of 52 mm is beneficial at this stage.

INTRODUCTION

This report examines the recent fishery in quota area CRA3, the Gisborne area.

Management measures in Gisborne

In 1993 a suite of management measures was introduced to the Gisborne fishery (*see*. Anon 1993). These resulted from concerns expressed by the industry and were based on proposals developed by a group comprising the fishers, processors, local Maori, and recreational representatives. The group's proposals were presented to and discussed by the National Rock Lobster Management Group (NRLMG) in late 1992 and early 1993, evaluated by MAF Fisheries Marine Research and discussed with the Minister of Fisheries.

The suite of measures (hereinafter called the "CRA3 package") eventually accepted by the Minister in May 1993 comprised the following.

1) A substantial reduction in the CRA3 TACC, from about 330 t to 164 t (Annala 1994). (This was actually implemented prior to the remaining measures.)

2) A reduction in the minimum legal size for males, from the 54 mm tail width (TW) in effect throughout the rest of the country except for Otago, to 52 mm TW for commercial fishers only. This reduced MLS applies to June, July and August only.

3) A reduction of the commercial season length. The season was previously unrestricted; under this measure it was opened for commercial fishers in only the months April, June, July, August, February and March (the fishing year runs from April to March).

Measures 2 and 3 were designed to move the fishery into one based on a winter season, when the price was higher than during the rest of the year. Measure 3 was also an attempt to reduce poaching by restricting the length of time that gear was in the water. This could be effective where thieves remove lobsters from commercial gear. It was also possible that these measures could reduce *Octopus* predation and sublegal handling mortality.

4) A closure for non-commercial fishers from the beginning of September through the end of November.

5) A prohibition on landing females in the commercial winter season (June, July and August), applicable to the commercial fishery only.

It was agreed that this suite of measures would remain in place for three years; for the fishing years 1993-94, 1994-95 and 1995-96, and then be evaluated.

It was also agreed that the industry would fund "a full-time technician" to collect data on the fishery. The industry chose to contract MAF Fisheries Marine Research to conduct catch sampling at sea to fulfil this obligation.

The industry agreed to phase in 54 mm welded steel mesh in all commercial pots by 1997.

Scope of this report

In this report, we look at several indicators of abundance and average size of the lobsters available in the CRA3 fishery. We use these to determine whether the available stock in CRA3 increased after the package was introduced. We also examine some comparable data from the adjoining area to the south, CRA4.

The indicators examined are catch and effort patterns, the abundance of lobsters in MAF's catch sampling, catch rates reported in commercial fishery statistics, and the sizes of males observed in catch sampling.

As always when dealing with recent extractions from the fishery databases, some of these **data are preliminary** and may be subject to revision as new data are included and data grooming is carried out.

We then fit a simple model to the fishery data for October 1989 through May 1995, and use this model to make forward simulations to assess the impact of management alternatives. The most likely management alternatives to consider are: a 25% or 33% increase in TACC, and a change from the present 52 mm winter MLS back to an MLS of 54 mm for males. The CRA3 users have expressed a preference for a 33% increase in TACC with no change to winter MLS; all other elements of the package to remain.

DATA

Catch sampling

The Stock Monitoring Group catch sampling data include sampling conducted since 1989, both as a MAF project and under contract from the CRA3 fishers. These data contain information on the number in every pot and size and sex composition of lobsters in a subsample of the total catch.

Table 1 shows the dates and statistical areas of all catch sampling conducted in CRA3 to date, both the Stock Monitoring sampling and the sampling conducted under contract from CRA3. The table shows the numbers of pots lifted, fish counted and fish measured. CRA3 comprises 3 statistical areas: 909, 910 and 911 from north to south (Figure 1). Before 1993, catch sampling was confined to November, restricted to areas 909 and 910, and comprised 3-5 days' sampling per year.

In 1993, 1994 and 1995, sampling was more evenly distributed over the three statistical areas, although 910 remains the most intensively sampled area. Sampling was concentrated in June, July and August (the new winter fishery) and November (to compare with previous years). Numbers of days sampled were increased substantially in 1993.

Catch and Effort Landing Returns system

The CELR database provides an estimated average biomass of legal sized fish per potlift for every day for every fisher. We collapse the data from this form into records for each fisher for each month (Breen et al. 1994), and remove suspect records at that time as described by Booth et al (1994).

Table 2 gives a summary of the CELR data for 1989-95: for each statistical area, it shows the month, number of pot-lifts recorded, estimated[1] weight of legal-sized fish caught, and the raw catch per unit effort (CPUE; catch weight divided by the number of pot-lifts to give kg/pot-lift)[2].

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[1] This is not straightforward: see Booth et al. (1994) for details of the procedure.

[2] For the major assessments recently, and for the 'decision rule' procedure, 'standardised' CPUE has been used: this involves a multiple linear regression model and includes the effects of statistical area, month and year on CPUE (see Breen et al. 1994). Standardised and 'raw' CPUEs do not differ very much.

Predicted vs observed catch and effort

The pattern of effort and catches predicted by MAF Fisheries Marine Research (Breen, unpub. report to the Minister of Fisheries, 1993) and reported to the Minister are shown in Figure 2. The actual patterns are shown in Figure 3.

The 1993 report predicted that most of the effort would be channelled into the winter fishery, and that remaining quota would be cleaned up in February & March. It predicted that winter catches would increase and summer catches decrease after 1993 (Figure 2). These predictions were realised (Figure 3), but the effort required to take the winter catch dropped from 1993 to 1994, and more of the quota was taken in winter 1994 than was predicted.

In other words, catch and effort patterns shifted further than predicted but changed in the directions predicted.

ABUNDANCE ESTIMATES

Catch sampling

Estimates of abundance made from catch sampling are shown in Table 3 for each of three statistical areas separately.

November is the only month with a time series of catch sampling data covering the periods before and after the CRA3 package was introduced. Figure 4 shows the abundance of legal males seen in catch sampling in November, in all three statistical areas combined. The abundance index is the number of legal males per pot-lift, where legal males is defined as those equal to or greater than 52.0 mm TW. This definition was applied to the period before the CRA3 package for comparison with the CRA3 package period.

Abundance estimates were calculated as follows. The proportion of legal males in the total catch was estimated from the subsample of fish measured in each day's fishing. This proportion was multiplied by the mean number of fish per pot, based on counts of the fish in every pot during the day's fishing. Sublegal males and females were estimated in the same way. The monthly average was weighted by the number of pots observed each day.

A bootstrap analysis of the variability in the component parts of this procedure (Breen & Kendrick, unpublished data) indicated that bootstrapping from the daily estimates of legal males per pot-lift, calculated as just described, estimated the variance satisfactorily. In the time available, and given the clear trends in the data, bootstrap estimates of confidence limits have not been made.

The data should really be viewed separately by statistical area. Figures 5 to 7 show male abundance (number per pot-lift) for areas 909 to 911 respectively. In each Figure, parts a and b show the abundance of legal and sublegal males respectively. Thus Figure 5a is legal males in area 909, Figure 6b is sublegal males in area 910, etc.

In each figure the individual points are the estimate from one day's sampling, and the lines connect averages for a month by area block of data (averages are weighted by the number of pots sampled). Sampling has not been uniform over time (Table 1).

These was an apparent increase in legal male abundance in 1994 and 1995 in all three areas. During the short winter season, there was also a clearly defined decrease in legal male abundance from June to August in 1993 and 1994. This is best seen in area 910, the area with the highest sampling density, but can also be seen in area 911 in 1994. This decline is part of the fishing process, and is not by itself a cause of concern. The decline between June and July 1995 in area 910 may have been caused by poor fishing conditions in July.

There was an apparent increase in sublegal males in area 909 in 1994. The time series is too short for area 911, and for area 910 a small increase in sublegal abundance is accompanied by a large increase in the variance.

Figures 8 and 9 shows results from catch sampling in CRA4, areas 912 and 913 respectively. We examined CRA4 to see whether the increase in legal males observed in CRA3 also occurred in CRA4. A similar increase in CRA4 might indicate a general increase in recruitment over a wide area; or perhaps alternatively that migration from CRA3 to CRA4 might be important. Figures 8 and 9 show no similar increase in legal or sublegal male abundance in CRA4.

Figure 10 shows another comparison between the predictions from the 1993 model (Breen, unpub. report to the Minister of Fisheries, 1993) and what was observed in 1993 and 1994. The figure shows relative abundances (numbers of model fish in the predictions, kg\potlift in the observations. The observed data are not continuous because catch sampling was concentrated in the winter fishery plus November.

There are several points to note. The steep declines in abundance predicted during the winter fishery were observed and were more dramatic than predicted. The November abundance, which was predicted to increase slowly after the package was introduced, increased much more quickly than predicted. The abundance of sublegals increased; this was not predicted by the model.

CELR data

The raw CPUE (total catch divided by total effort, Table 2), can be used an abundance index. Because fishers report only the weight of fish landed, there is no separation of males and females (but the winter fishery is male-only), and sublegal abundance cannot be estimated.

Figure 11 a-c shows the CPUE for each of the three statistical areas in CRA3, and Figure 11d shows the three areas combined (all of CRA3). The 1994 increase in male abundance, clearly seen in catch sampling (Figures 5-7) is also seen in the commercial CPUE data as reported to the CELR system. CPUE shows a generally rising trend from mid-1993, especially in areas 910 and 911.

Note that some catches and effort have been assigned to months in which the fishery was closed. Such problems are typical of the CELR database.

Size frequency distribution

Figure 12 shows a comparison between 1993 and 1994 of size distributions of all male fish from the combined CRA3 samples measured in the months June through August (the winter fishery). It compares the number of fish, in 0.5 mm increments of tail width, per 100 pot-lifts in which fish were measured. Note the decrease in number of fish per pot from June through August in both years, as seen above. In both years the length frequency develops a steep shoulder at 52 mm, at the MLS. Note also the increasing numbers of larger fish between the years 1993 and 1995, indicating more escapement recently than the pre-package fishery.

Figure 13 compares June and July samples in the three years 1993 through 1995 (august 1995 is not available at this stage). Note the increase in larger fish in 1995 compared with 1993.

Figure 14 shows the size distribution (and relative abundance) of males in November of each year, 1989 through 1994. Abundance was much higher in 1993 and 1994 than in previous years.

SAMPLING DESIGN

We examined the relation between sample size and precision of the abundance estimates, particularly the legal male abundance estimates. Figure 15 shows the relation between number of days sampled per unit (a unit is a month x area group of samples) and the precision of the abundance estimate. This is based on area 910, using two sets of real data as the basis for bootstrapping. A good level of precision (CV less than 10%) can be achieved with 4 days' sampling, at least for this area. This should be viewed as a minimum requirement.

November sampling should be continued in areas 909 & 910 to continue the existing time series. In at least one area, preferably 910, sampling should be conducted in each of the three months of the winter season. This gives a minimum of 20 days' sampling to cover area 910. The minimum additional work required is 4 days' sampling in June in each of the other two areas, or 28 days' sampling at a minimum. Additional sampling is desirable in the two areas in late July or early August.

YIELD- & EGG-PER-RECRUIT ANALYSIS

Recent assessments have examined the yield- and egg-per-recruit situation in the Gisborne fishery (Breen & Anderson 1993; Breen & Kendrick 1994; 1995). These analyses use information on growth, natural mortality, maturity and fecundity to explore the potential yield to the fishery and egg production of a recruit entering the fishery. The analysis can be used to explore the impacts of altering the MLS or of changing the intensity of fishing. From the analysis, 'reference points' can be calculated. The reference points used by

Breen & Kendrick (1995) were F_{max}, the fishing mortality rate that maximises yield-per-recruit, and $F_{25\%}$, the rate that would result in 25% of the virgin egg production.

Breen & Kendrick (1995) used different stock-recruit relationships in estimating YPR and EPR to see the effect of relaxing the usual assumption of constant recruitment. We compared the equilibrium yields, biomass and egg production under the reference fishing rates with those under the estimated current fishing rate $F_{current}$. The current fishing mortality rate was estimated from lobster tail width distributions from the time series of catch sampling data. Results are as follows for three values of 'steepness' in the stock-recruit relation. A steepness of 1.0 is equivalent to assuming constant recruitment.

steepness	$F_{current}$				F_{max}				$F_{25\%}$			
	F	YPR	EPR	B_{curr}/B_0	F	YPR	EPR	B_{curr}/B_0	F	YPR	EPR	B_{curr}/B_0
1.0	1.50	346	28.7	4.3	0.248	449	50.2	21.1	>2	319	26.9	3.4
0.8	1.50	289	27.9	3.6	0.207	422	50.6	23.2	1.295	302	25.0	4.0
0.6	1.50	182	15.0	2.2	0.158	380	51.4	26.6	0.581	282	25.0	6.5

The current fishing rate estimates were very high, and for this analysis they were actually truncated at 1.5, corresponding to an annual removal rate of 78%. By contrast, estimated F_{max} is only 0.25, corresponding with an annual removal rate of 22%. This suggests that recent removal rates are much higher than optimal, and that biomass is much lower than the optimum biomass (only 4% of B_0 vs 21% of B_0 at optimum). Yields are also reduced as a consequence: the analysis suggests that 30% more yield would available by reducing $F_{current}$ to F_{max}.

However, the analysis does not suggest that there is 'recruitment' overfishing: estimated egg production is a high percentage of virgin egg production (except at low steepness, but low steepness is considered highly unlikely).

The estimate of $F_{current}$ may be higher than the actual recent mortality rates. The assumptions of the method are that mortality rates are constant (whereas the recent rate has decreased because of the reduced TACC) and that recruitment has been constant (whereas recruitment probably increased in the past year at least).

MODELLING

Modelling was required to assess the likely impacts of changes to the suite of management measures. The approach taken was to build a simple size-class structured model, fit the parameters to existing CPUE data, then to make forward simulations from the model in different scenarios.

Data

Catch, effort, and raw CPUE from the CELR were collated from CRA3 for each month from October 1989 (8910) through May 1995 (9505) (Table 2). For months that were actually closed to commercial fishing under the CRA3 package, some landings and effort were reported to the CELR. These were corrected by setting both catch and effort to zero, and defining CPUE as zero.

Description of the model

As in the modelling conducted in 1993 to assess the CRA3 package (Breen 1993, unpublished report to the Minister of Fisheries), the model assumed an all-male fishery. The fishery before the CRA3 package was a mixed male and female fishery but was predominated by males. Very few females are taken in the present fishery.

The model considered lobsters in three size classes: those less than 52.00 mm tail width (indexed as SSL), those 54.00 mm or above (indexed as L), and those in between (indexed as SL). The model assumed that all moulting in these sizes occurs once per year in October, so recruitment was modelled in October.

Initial numbers (at t = 8910) in the model for each size class were given by:

(5) $$N_{SSL,t} = 0.333\ R_0$$

(6) $$N_{SL,t} = 0.667\ R_0$$

where R_0 is a constant annual recruitment to the single cohort beneath 54 mm tail width. In October of each model month, this cohort was updated from equations (1) and (2). The initial number of legal-sized males was a parameter:

(7) $$N_{L,8910} = N_0$$

For months other than October, the numbers of small lobsters changed according to

(8) $$N_{SSL,t+1} = N_{SSL,t}\ \exp\text{-}(M/12 + hF_t)$$

where M is the instantaneous annual rate of natural mortality (assumed to be 0.1), F_t is instantaneous fishing mortality for month t (see below), and h is a constant that determines what proportion of F_t the associated mortality on sublegal fish will be. Associated mortality includes deaths caused by poor handling, predation by *Octopus*, and illegal removals from pots.

For months other than October, the numbers of fully recruited lobsters changed according to

(9) $$N_{L,t+1} = N_{L,t}\ \exp\text{-}(M/12 + F_t)$$

In October each year, numbers of these large lobsters changed according to

(10) $$N_{L,t+1} = (N_{L,t}\ \exp\text{-}(M/12 + F_t)) + ((N_{SSL,t} + N_{SL,t})\ \exp\text{-}(M/12 + hF_t))$$

For months other than October and before month 9306, the numbers of lobsters in the middle size group changed according to the same equation as (8):

(11) $N_{SL,t+1} = (N_{SL,t} \exp\text{-}(M/12 + hF_t))$

In the winter fishery in June, July and August of 1993 through 1995, the numbers changed according to the same equation as (9):

(12) $N_{SL,t+1} = N_{SL,t} \exp\text{-}(M/12 + F_t)$

Available biomass (kg) was calculated each month as

(13a) $B_{avail,t} = 0.502\ N_{L,t}$

where 502 g is the approximate mean weight of legal lobsters in the fishery. In the winter fishery in 1993 and 1994, where lobsters of the middle size class were also taken,

(13b) $B_{avail,t} = (0.502\ N_{L,t}) + (0.440\ N_{SL,t})$

The fishing mortality rate was then estimated from catch and available biomass. The monthly exploitation rate, $ERate_t$, was calculated as

(14) $ERate_t = catch_t \ / \ B_{avail,t}$

then

(15) $F_t = -\ln(1 - ERate_t) - M/12$

A catchability, q_t, was estimated for each month:

(16) $q_t = catch_t \ / \ (\ effort_t\ B_{avail,t})$

and then a single catchability for the whole period was estimated as the simple mean of all q_t, excluding months in which there was no catch.

Model CPUE, $CPUE_{pred}$, was calculated from

(17) $CPUE_{pred} = q_t\ B_{avail,t}$

Parameter estimation

The model was fit by minimising the sum of squared CPUE and *ERate* residuals, excluding months in which there was no fishing. The predicted exploitation rates in the winter fishery (the sum of catches in June, July and August divided by the beginning of June biomass) for 1993 and 1994 were estimated from the model. It was assumed that the true $ERate_{yr}$ was 0.55, and the squared residual was calculated for $ERate_{yr}$ in these two years and used in the fitting procedure.

The procedure minimised the sum T of squared residuals:

$$(18) \quad T = \Sigma\ (CPUE_{pred,t} - CPUE_{obs,t})^2 + wt1\ \Sigma\ (ERate_{yr} - 0.55)^2$$

where $wt1$ determines the relative weight of the $ERate_{yr}$ residuals - this was set to 10. Minimising was done on an EXCEL™ spreadsheet with the non-linear solver, changing the three parameters N_0, R_0, and h after finding appropriate starting values. IF statements were required to prevent values from taking on error values when the model biomass crashed in estimation and to prevent positive contributions to the function value in months with no fishing effort.

The model found the best fit at high values of h (0.75, when the upper bound on h was set there). Figures 16 and 17 show the parameter estimates and model fit when h was fixed at 0.0 and 0.4.

The fit to the real data was good for all years when $h = 0.4$, but the fit to recent data was not good when $h = 0.0$. As h is known to be greater than zero, subsequent forward simulations were made by assuming $h = 0.4$.

Forward simulations

Forward simulations were made by assuming values for catch in future months. The catch for 1995-96 was assumed to be the same as, and distributed over months in the same way as, the 1994-95 catch. Catches for 1996-97 and 1997-98 were assumed to be distributed over months in the same way as the 1994-95 catch, and were assumed to be 1.00, 1.25, 1.33 or 1.50 times as large as the 1994-95 catch.

Effort was calculated for each month from

$$(19) \quad effort_t = catch_t\ /\ (q\ B_{avail,t})$$

and all other calculations proceeded as described above. The MLS could be set at 52 mm or 54 mm in the winter fishery. IF statements were used to calculate the appropriate available biomass from equation (13a) or (13b), and numbers of lobsters in the middle size group from equation (11) or (12), depending on the MLS chosen. Annual recruitment in the three months of recruitment - October 1995, 1996 and 1997 - could be set at 1.00, 0.75 or 0.50 times R_0. This allowed the effects of reduced recruitment to be considered.

Indicators recorded from forward simulations were the effort required to take the catch in the three fishing years 1995-96, 1996-97 and 1997-98, and the biomass at the end of each fishing year.

Results of forward simulations

Table 4 shows the impacts of each catch level for the two values of winter fishery MLS at each of three levels of recruitment. In most simulations, biomass continued to increase.

The exceptions were all those in which recruitment was only 0.50 R_0 and the catch was greater than the present catch.

In simulations where the catch remained at the present level, effort decreased. In simulations where the catch was increased, and where the biomass increased, required effort often increased to facilitate the new catch and then decreased again as biomass rebuilt.

In all simulated situations over the period simulated, effort was less and biomass was higher when the MLS remained at 52 mm in the winter fishery. This came about because increased MLS causes a reduction in $B_{avail,t}$ in the winter fishery, requiring more effort to take the same catch, because the catch must come entirely from the lobsters at or above 54 mm in the winter fishery, and because increased effort caused increased waste from associated mortality.

The option about to be suggested by the CRA3 users' group is highlighted in Table 4 and forward projections of biomass are shown in Figure 18. The option is likely to allow biomass to increase unless recruitment falls to half R_0.

DISCUSSION

Abundance

In the various data presented above there is a pattern of increased abundance of legal-sized males in the CRA3 fishery. This is seen in the number per pot estimated from catch sampling (eg. Figure 5, Figure 14), and in the CELR data (eg. Figure 11).

The increased abundance is not seen in CRA4 catch sampling (Figures 8 & 9). However, standardised CPUE increased significantly in the combined CRA4 & CRA5 fisheries between 1993 and 1994 (Breen & Kendrick, unpub. data)[3] as well as in the NSC substock. It is possible that CRA4 sampling, at relatively low frequency, is unrepresentative, or that abundance increased only in CRA5.

As well as increased legal male abundance, there appears to be increased sublegal male abundance in 1993 and 1994 (Figure 5b, Figure 14). This could have been caused by random or environmentally-caused fluctuation or by a reduction of sublegal mortality (in turn related to reduced poaching, reduced handling, or reduced *Octopus* predation). In other words, the increased recruitment may or may not have been brought about entirely by the CRA3 package. The absence of similar increase in CRA4 would point to the CRA3 package, but standardised CPUE clearly increased in 1994 in the NSN and NSC substocks (*see* Breen et al. 1994).

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[3] This was examined because the standardised CPUE for the NSC substock increased, and we explored the possibility that the increase was localised to CRA3.

YPR and EPR

Recent stock assessment (Breen & Kendrick 1994; 1995) has relied heavily on YPR and EPR estimates. For CRA3, recent assessments have suggested high fishing intensity, growth overfishing but not egg overfishing. Z estimates are now difficult to obtain from length frequencies, given that the assumption of equilibrium is violated by the increasing biomass. Z estimates from CPUE changes are likely biased because of changes in catchability.

Forward simulations

The model used is a very simple one. Potential problems include: the assumption of a male-only fishery (a good assumption now, but flawed for the early years); no non-commercial catch except as part of the associated mortality and related to F_t; no growth in the fully-recruited size class (reasonable in the early years, but flawed for recent years in which the abundance of larger fish is increasing); moulting restricted to October; the limited number of fish below 52 mm incorporated in the model (probably more cohorts are subject to associated mortality than are modelled here).

Despite these potential problems, the model appears to fit the real data quite well. Improvement to address the problems just listed would be best approached through fitting a full age-structured model; this is outside the scope of the present project, especially considering that CRA3 is not a stock, but only part of a substock.

The forward simulations suggest that increasing biomass will likely continue unless recruitment falls to half the present level for the next three years. This seems an unlikely possibility, but there is no time series of recruitment estimates. Puerulus settlement results (Booth & Forman 1995) from under the Gisborne wharf demonstrate considerable variability. However, the relation between this index and actual recruitment is still unknown.

These simulations present a generally optimistic outlook. The option favoured by the combined CRA3 users' group seems to be a safe course of action. At recruitment levels above 50% R_0 biomass should continue to increase, at 50% R_0 levels biomass would fall slightly. Continued monitoring is essential for annual evaluation of the fishery.

The need for better understanding of movements and catchability, and the need for exploration of ways to estimate pre-season biomass, is illustrated by these results.

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Table 1. Summary of catch sampling conducted in CRA3, both by MAF and under contract for CRA3, since 1989.

Month	Stat area	Sample numbers	Pots seen	Fish seen	Fish measured
Nov 89	909	12889	23	65	65
	909	12989	133	517	366
	910	13089	159	1085	486
Nov 90	909	14890	94	313	300
	910	15090	148	3080	914
	910	16290	149	2664	922
	910	16390	127	2272	1449
Nov 91	909	14091	95	528	514
	909	14191	99	584	557
	910	13191	121	2235	1082
	910	13291	155	2962	878
	910	13391	113	2689	1400
Nov 92	910	14392	119	2045	1778
	910	14492	148	1774	1070
	909	14592	57	73	73
	909	14692	91	213	206
	909	14792	90	193	193
Jun 93	910	11393	140	1591	626
	910	11493	111	1292	622
	910	11593	70	929	496
	910	11693	91	1089	587
July 93	910	11793	130	752	752
	910	11893	116	950	724
	910	11993	144	1897	793
	910	12093	91	1805	752
	910	12193	91	1417	788
	910	12293	127	906	876
	910	12393	91	1163	494
	910	12493	141	1751	633
Aug 93	910	80193	86	482	392
	910	80293	144	900	468
	910	80393	125	116	116
	910	80493	125	102	102
	910	80593	35	301	228
	910	12593	56	380	316
	910	12693	121	1008	568
	911	80693	110	164	160
	911	80793	143	228	228
	911	80893	89	110	110
	911	12793	68	74	73
	911	80993	97	152	152
	911	81093	99	402	402
	911	81193	128	188	188
	911	81293	92	511	511
	911	81393	92	282	282
	909	81493	117	854	275
	909	81593	142	870	473

Table 1 continued

Month	Stat area	Sample numbers	Pots seen	Fish seen	Fish measured
Nov 93	910	81693	100	1681	1681
	910	81793	99	2093	873
	910	81893	100	1854	995
	910	81993	100	2043	1009
	910	82093	100	2219	1207
	910	82193	100	2683	995
	911	82293	62	105	104
	911	82393	69	114	226
	911	82493	76	132	132
Feb 94	910	80194	93	1264	439
	910	80294	133	2145	875
	910	80394	102	1546	932
	910	80494	127	872	695
	910	80594	143	1360	695
	911	80694	85	309	309
	911	80794	141	674	674
	911	80894	140	582	579
	911	80994	70	532	443
	911	81094	100	407	407
	911	81194	96	426	426
	911	81294	84	286	286
	909	81394	139	1059	1030
	909	81494	110	1413	548
	909	81594	108	1238	423
June 94	910	81694	98	747	545
	910	81794	132	795	727
	910	81894	124	1228	1155
	910	81994	144	3815	1500
	910	82094	124	1270	1029
	910	82194	116	1596	871
	910	82294	147	1360	940
	910	82394	148	2992	1215
	911	82494	129	568	568
	911	82594	132	500	500
	911	82694	90	262	262
	911	82794	87	197	197
July 94	910	82894	108	1177	1005
	910	82994	130	630	623
	910	83094	126	1281	1235
	910	83194	121	995	966
	910	83294	116	1395	1185
	910	83394	84	792	776
	910	84994	163	1132	1132
	910	84194	19	76	76
	911	83494	100	276	276
	911	83594	89	547	547
	911	83694	163	1047	1047
	911	83794	136	334	334
	911	83894	72	129	129
	911	84094	114	332	332
	911	83994	96	244	244

Table 1 concluded.

Month	Stat area	Sample numbers	Pots seen	Fish seen	Fish measured
Aug 94	910	84294	140	1298	1165
	910	84394	124	1360	1195
	910	84494	136	508	508
	910	84594	115	863	863
	910	84694	136	404	404
	910	84794	138	630	630
	909	84894	145	1022	1022
	909	85194	159	1694	1575
	909	85094	161	1198	1175
Nov 94	910	85294	60	1468	1153
	910	85394	100	1732	1563
	910	85494	100	2245	1816
	910	85594	100	2692	2238
	910	85794	100	2505	1718
	910	85694	100	2874	2073
Feb 95	911	80195	125	1077	1055
	911	80295	53	469	469
	911	80495	56	195	195
	911	80595	57	522	522
	911	80695	61	230	230
	911	80795	76	271	271
	911	80395	127	1522	1522
	910	80895	142	1484	1147
	910	80995	132	1381	1290
Jun 95	909	81895	120	1150	1011
	909	81995	120	1819	1106
	909	82095	120	2085	1439
	909	82195	120	1928	1389
	910	81095	135	1758	1094
	910	81195	104	2692	1291
	910	81295	110	1750	1073
	910	81395	69	1176	696
	911	81495	121	1230	1210
	911	81595	151	510	509
	911	81695	77	140	140
	911	81795	64	181	181
Jul 95	909	81795	119	2098	1371
	909	82895	119	1342	1122
	910	82995	113	661	640
	910	83095	94	500	500
	911	82295	94	443	443
	911	82395	148	513	513
	911	82495	114	720	720
	911	83195	82	669	669

Table 2. A summary of effort, catch and CPUE data from the CELR system, 1989-95. Estimated weights are in kg, CPUE is in kg/potlift.

Year	Month	AREA 909 Pot lifts	AREA 909 Est wt	AREA 909 Raw CPUE	AREA 910 Pot lifts	AREA 910 Est wt	AREA 910 Raw CPUE	AREA 911 Pot lifts	AREA 911 Est wt	AREA 911 Raw CPUE	ALL CRA3 Pot lifts	ALL CRA3 Est wt	ALL CRA3 Raw CPUE
89	8	1478	378	0.2558	11641	2078	0.1785	9421	3049	0.3236	22540	5505	0.2442
89	9	2903	1607	0.5536	30014	12757	0.4250	16156	6391	0.3956	49073	20755	0.4229
89	10	10968	4501	0.4104	71474	32356	0.4527	28777	18947	0.6584	111219	55804	0.5018
89	11	12410	6803	0.5482	65479	35810	0.5469	30750	29324	0.9536	108639	71937	0.6622
89	12	12517	10039	0.8020	59778	36722	0.6143	30539	27607	0.9040	102834	74368	0.7232
90	1	15402	8513	0.5527	49317	18429	0.3737	35261	22133	0.6277	99980	49075	0.4909
90	2	4638	2046	0.4411	35892	11456	0.3192	14648	6493	0.4433	55178	19995	0.3624
90	3	4072	2288	0.5619	33371	12286	0.3682	6794	3084	0.4539	44237	17658	0.3992
90	4	740	194	0.2622	15749	4721	0.2998	3415	1314	0.3848	19904	6229	0.3130
90	5	880	107	0.1216	13134	2384	0.1815	3075	887	0.2885	17089	3378	0.1977
90	6	3785	1028	0.2716	31651	8448	0.2669	7228	3249	0.4495	42664	12725	0.2983
90	7	12269	5439	0.4433	33479	10831	0.3235	17210	7496	0.4356	62958	23766	0.3775
90	8	5385	1308	0.2429	22369	5000	0.2235	17383	5550	0.3193	45137	11858	0.2627
90	9	6704	2506	0.3738	25646	8265	0.3223	25097	9899	0.3944	57447	20670	0.3598
90	10	11418	5148	0.4509	58896	32807	0.5570	36666	22475	0.6130	106980	60430	0.5649
90	11	11294	7055	0.6247	62077	40296	0.6491	39549	25414	0.6426	112920	72765	0.6444
90	12	9093	6210	0.6829	51258	24714	0.4822	37687	22985	0.6099	98038	53909	0.5499
91	1	5098	3249	0.6373	26665	8439	0.3165	32691	14464	0.4425	64454	26152	0.4058
91	2	7740	2749	0.3552	27512	8452	0.3072	24504	8348	0.3407	59756	19549	0.3272
91	3	1735	526	0.3032	14451	4736	0.3277	15613	3690	0.2363	31799	8952	0.2815
91	4	1420	380	0.2676	22447	6982	0.3110	8784	2251	0.2563	32651	9613	0.2944
91	5	0	0	0.0000	6596	951	0.1442	2713	384	0.1415	9309	1335	0.1434
91	6	5468	1687	0.3085	19413	4517	0.2327	2863	747	0.2609	27744	6951	0.2505
91	7	13395	4017	0.2999	46670	10093	0.2163	22644	6838	0.3020	82709	20948	0.2533
91	8	5494	1371	0.2495	24384	3940	0.1616	31238	8119	0.2599	61116	13430	0.2198
91	9	3707	525	0.1416	19014	2605	0.1370	37450	7820	0.2088	60171	10950	0.1820
91	10	13519	3601	0.2664	53003	15145	0.2857	45162	19113	0.4232	111684	37859	0.3390
91	11	20299	7747	0.3816	65545	25454	0.3883	45328	22787	0.5027	131172	55988	0.4268
91	12	13575	5090	0.3750	57328	19980	0.3485	51616	28617	0.5544	122519	53687	0.4382

Table 2 continued

Year	Month	AREA 909 Pot lifts	AREA 909 Est wt	AREA 909 Raw CPUE	AREA 910 Pot lifts	AREA 910 Est wt	AREA 910 Raw CPUE	AREA 911 Pot lifts	AREA 911 Est wt	AREA 911 Raw CPUE	ALL CRA3 Pot lifts	ALL CRA3 Est wt	ALL CRA3 Raw CPUE
92	1	12194	4186	0.3433	36755	10092	0.2746	43285	15584	0.3600	92234	29862	0.3238
92	2	8930	2713	0.3038	22302	4817	0.2160	22293	5979	0.2682	53525	13509	0.2524
92	3	4424	1844	0.4168	20360	3960	0.1945	17788	3988	0.2242	42572	9792	0.2300
92	4	709	620	0.8745	6418	1181	0.1840	6141	1193	0.1943	13268	2994	0.2257
92	5	200	0	0.0000	2592	385	0.1485	8270	1143	0.1382	11062	1528	0.1381
92	6	5619	1461	0.2600	27311	5992	0.2194	23657	5347	0.2260	56587	12800	0.2262
92	7	6097	1495	0.2452	30942	4969	0.1606	28861	5467	0.1894	65900	11931	0.1811
92	8	9272	2005	0.2162	20291	2860	0.1410	22933	4206	0.1834	52496	9071	0.1728
92	9	3070	556	0.1811	6093	674	0.1106	19502	2559	0.1312	28665	3789	0.1322
92	10	5771	1353	0.2345	26339	5510	0.2092	32863	6727	0.2047	64973	13590	0.2092
92	11	13233	4621	0.3492	53325	17818	0.3341	49665	14411	0.2902	116223	36850	0.3171
92	12	10434	5827	0.5585	45600	17314	0.3797	49064	20278	0.4133	105098	43419	0.4131
93	1	12512	5256	0.4201	37622	12209	0.3245	45685	16586	0.3631	95819	34051	0.3554
93	2	996	291	0.2922	14035	3378	0.2407	26345	7363	0.2795	41376	11032	0.2666
93	3	4627	1344	0.2905	19089	4834	0.2532	21559	5648	0.2620	45275	11826	0.2612
93	4	2533	692	0.2732	8374	2146	0.2563	10579	2989	0.2825	21486	5827	0.2712
93	5	800	163	0.2038	4081	753	0.1845	19725	4300	0.2180	24606	5216	0.2120
93	6	12847	9680	0.7535	45125	27320	0.6054	27140	13928	0.5132	85112	50928	0.5984
93	7	12296	9216	0.7495	43733	19103	0.4368	37101	16205	0.4368	93130	44524	0.4781
93	8	9254	3569	0.3857	27466	5036	0.1834	26054	6911	0.2653	62774	15516	0.2472
93	9	1200	378	0.3150	0	0	0.0000	0	0	0.0000	1200	378	0.3150
93	10	1800	485	0.2694	0	0	0.0000	0	0	0.0000	1800	485	0.2694
93	11	1800	787	0.4372	0	0	0.0000	0	0	0.0000	1800	787	0.4372
93	12	810	344	0.4247	0	0	0.0000	0	0	0.0000	810	344	0.4247

Table 2 concluded.

Year	Month	AREA 909 Pot lifts	AREA 909 Est wt	AREA 909 Raw CPUE	AREA 910 Pot lifts	AREA 910 Est wt	AREA 910 Raw CPUE	AREA 911 Pot lifts	AREA 911 Est wt	AREA 911 Raw CPUE	ALL CRA3 Pot lifts	ALL CRA3 Est wt	ALL CRA3 Raw CPUE
94	1	1200	513	0.4275	0	0	0.0000	0	0	0.0000	1200	513	0.4275
94	2	6796	6010	0.8843	45559	25898	0.5685	23570	22820	0.9682	75925	54728	0.7208
94	3	4589	2368	0.5160	12288	4819	0.3922	1159	633	0.5462	18036	7820	0.4336
94	4	110	40	0.3636	8544	4053	0.4744	9782	7975	0.8153	18436	12068	0.6546
94	5	0	0	0.0000	80	80	1.0000	0	0	0.0000	80	80	1.0000
94	6	6601	13117	1.9871	29159	39552	1.3564	12467	16385	1.3143	48227	69054	1.4319
94	7	5021	5336	1.0627	29924	20447	0.6833	18008	14786	0.8211	52953	40569	0.7661
94	8	6049	4757	0.7864	19806	10420	0.5261	18560	8546	0.4605	44415	23723	0.5341
94	9	1557	466	0.2993	0	0	0.0000	0	0	0.0000	1557	466	0.2993
94	10	1320	631	0.4780	265	180	0.6793	0	0	0.0000	1585	811	0.5117
94	11	880	409	0.4648	0	0	0.0000	0	0	0.0000	880	409	0.4648
94	12	1920	1525	0.7943	0	0	0.0000	0	0	0.0000	1920	1525	0.7943
95	1	950	4220	0.4421	80	80	1.0000	0	0	0.0000	1030	500	0.4854
95	2	1320	773	0.5851	3340	3471	1.0392	6785	8589	1.2659	11445	12833	1.1213

Table 3. A summary of abundance indices from catch sampling in CRA3.

Month	Stat area	days sampled	legal males per pot	males >=54mm per pot	sublegal males per pot	females per pot
Nov 89	909	2	1.67	0.58	1.28	0.78
	910	1	2.22	0.31	3.59	1.00
Nov 90	909	1	0.68	0.23	1.23	1.42
	910	3	4.79	0.82	7.56	6.55
Nov 91	909	2	1.46	0.57	1.90	2.37
	910	3	5.54	0.89	7.98	6.74
Nov 92	909	3	0.67	0.41	0.45	0.89
	910	2	2.79	0.37	6.56	4.95
Jun 93	910	4	3.18	0.44	7.54	1.18
Jul 93	910	8	1.72	0.26	7.99	1.72
Aug 93	909	2	0.95	0.35	4.69	1.01
	910	7	0.69	0.22	2.79	0.94
	911	9	0.79	0.39	0.84	0.77
Nov 93	910	6	5.96	1.53	9.64	5.21
	911	3	0.75	0.39	0.26	0.69
Feb 94	909	3	4.24	1.26	5.30	0.85
	910	5	4.67	1.65	4.69	2.66
	911	7	2.67	1.87	0.54	1.29
Jun 94	910	8	3.75	0.85	8.50	1.11
	911	4	2.39	1.52	0.56	0.53
Jul 94	910	8	2.04	0.38	5.73	0.86
	911	7	1.66	1.07	1.10	1.02
Aug 94	909	3	2.93	1.20	5.11	0.38
	910	6	0.90	0.29	4.46	1.06
Nov 94	910	6	8.61	2.45	11.62	3.91
Feb 95	910	2	5.87	2.54	4.09	0.49
	911	7	3.46	2.28	0.96	3.31
Jun 95	909	4	7.99	3.76	6.25	0.31
	910	4	7.72	3.15	9.39	0.53
	911	4	3.00	1.98	0.95	1.04
Jul 95	909	2	7.09	3.26	6.73	0.64
	910	4	2.15	1.46	4.28	1.08
	911	4	2.75	2.04	1.25	1.35

Table 4. Estimates of required effort and annual biomass from the forward simulations described in the text. The highlighted column is the option preferred by the CRA3 users' group.

	MLS = 52				MLS = 54			
Catch	1.00	1.25	1.33	1.50	1.00	1.25	1.33	1.50
Rect	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Effort 0	119540	119540	119540	119540	119540	119540	119540	119540
Effort 1	87725	111451	119542	136029	117930	150728	161566	185196
Effort 2	69632	91424	99192	115586	88478	118650	129289	153771
Biomass 0	727025	727025	727025	727025	727025	727025	727025	727025
Biomass 1	969324	928112	914366	886834	956901	909180	893822	861034
Biomass 2	1201888	1121403	1094486	1040461	1184255	1091602	1061557	996983

Catch	1.00	1.25	1.33	1.50	1.00	1.25	1.33	1.50
Rect	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Effort 0	132234	132234	132234	132234	132234	132234	132234	132234
Effort 1	107884	137668	147894	168848	141110	181323	195288	224156
Effort 2	91328	121848	132978	156934	115948	159003	175366	211891
Biomass 0	619416	619416	619416	619416	619416	619416	619416	619416
Biomass 1	756868	715983	702342	675018	744624	697890	682208	650672
Biomass 2	889183	808905	782026	728016	869368	777092	745772	682111

Catch	1.00	1.25	1.33	1.50	1.00	1.25	1.33	1.50
Rect	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Effort 0	148355	148355	148355	148355	148355	148355	148355	148355
Effort 1	140073	180115	194037	222844	175671	227719	246059	284454
Effort 2	132467	182449	201567	244499	167471	239996	269518	340305
Biomass 0	512528	512528	512528	512528	512528	512528	512528	512528
Biomass 1	546015	505643	492166	465175	535178	489953	474763	444018
Biomass 2	578372	498425	471583	417160	557946	466160	434688	368960

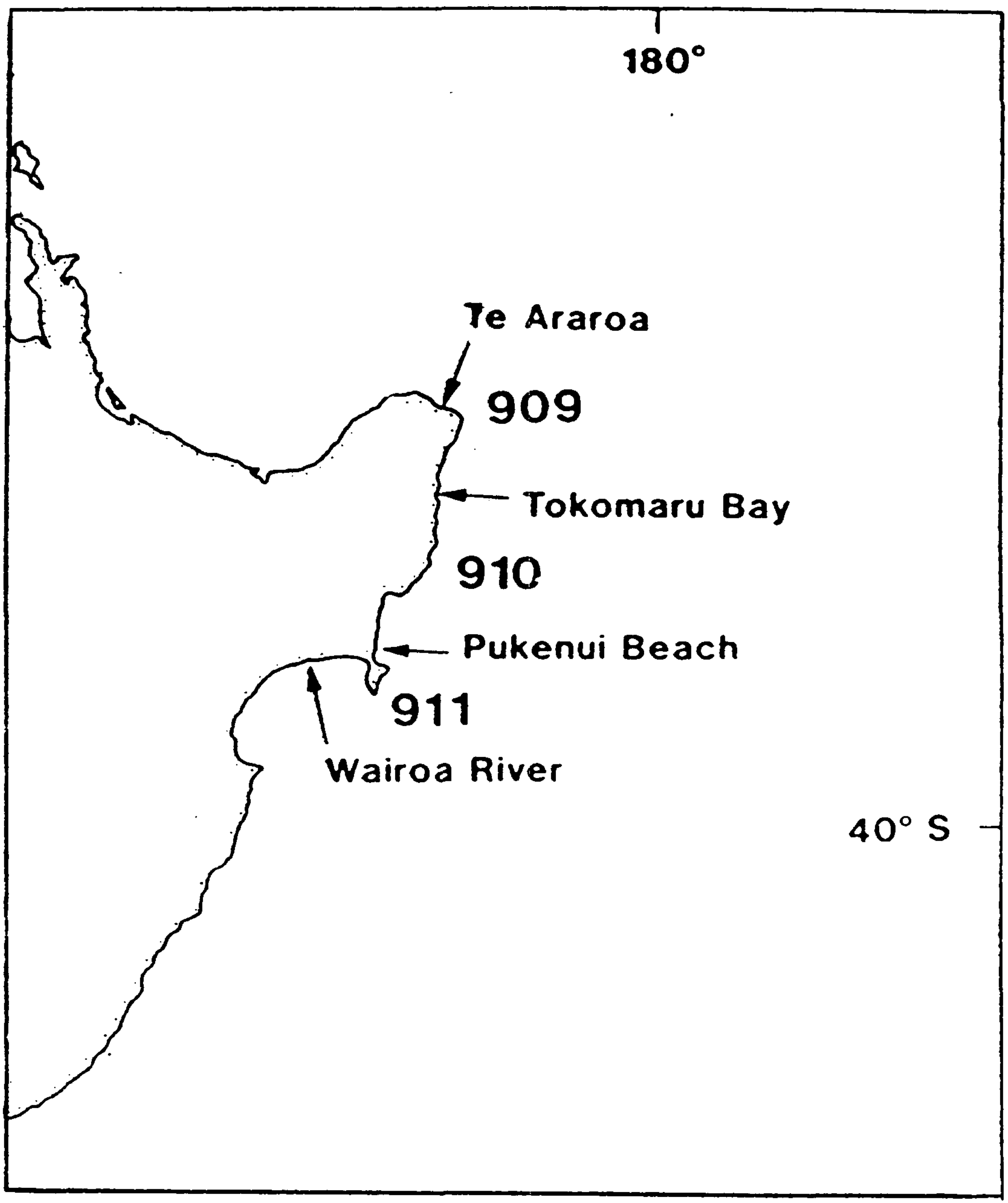


Figure 1: Map of the CRA3 management area showing the three statistical areas used in the CELR system and in this report. The area to the north of statistical area 909 is in CRA2, and the area to the south of statistical area 911 is in CRA4.

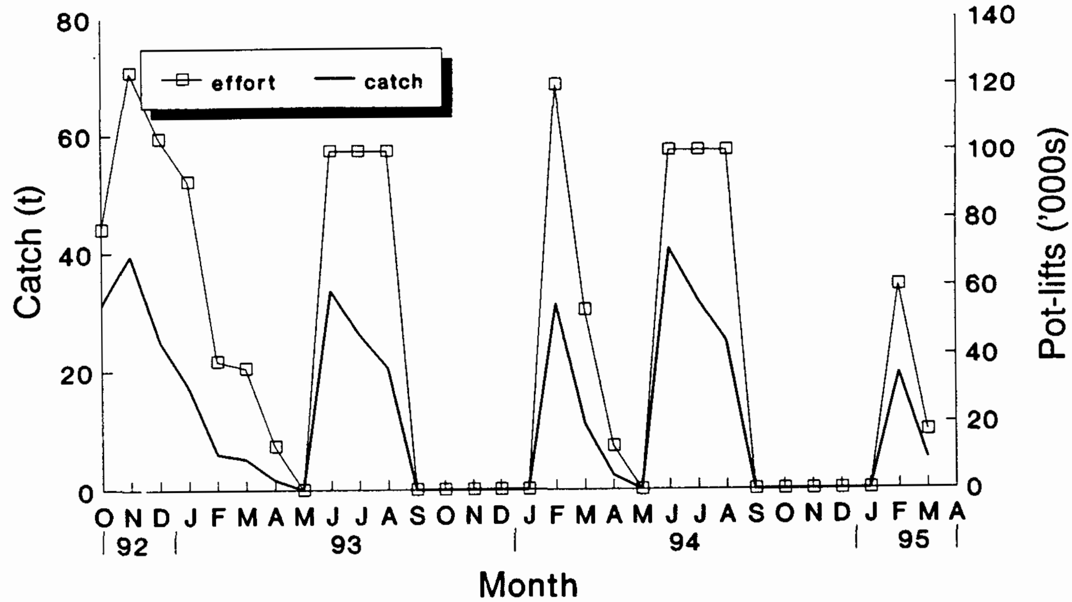


Figure 2: Predicted effort and catch for CRA3, October 1992 through March 1995 (from Breen, unpub. report to the Minister of Fisheries, 1993). Heavier lines are catch, lighter lines with square points are effort.

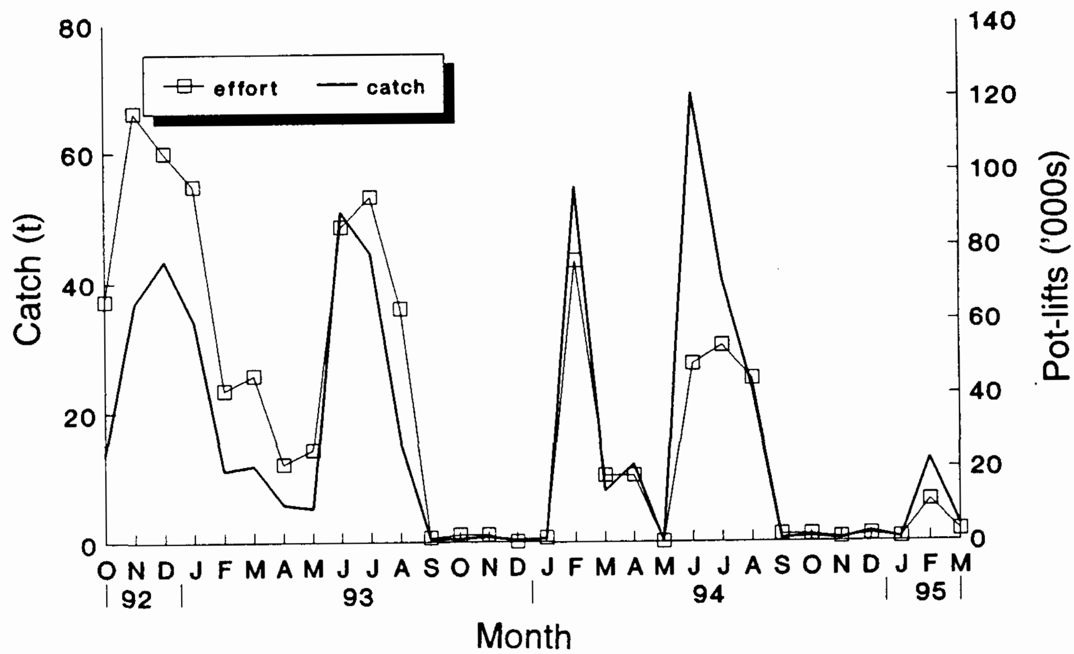


Figure 3: Catch and effort from CRA3, October 1992 through March 1995, from the QMS and CELR systems. Heavier lines are catch, lighter lines with square points are effort.

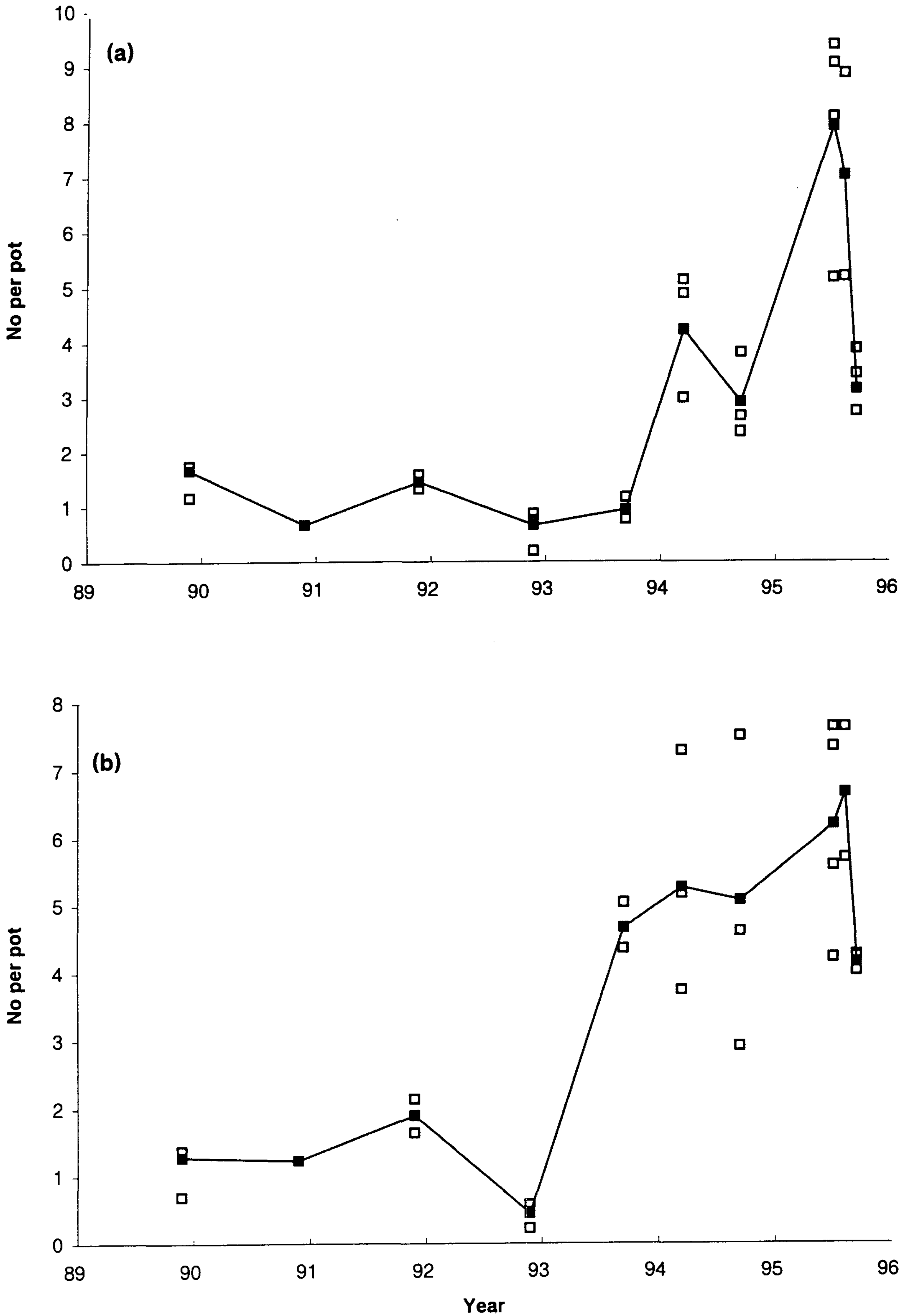
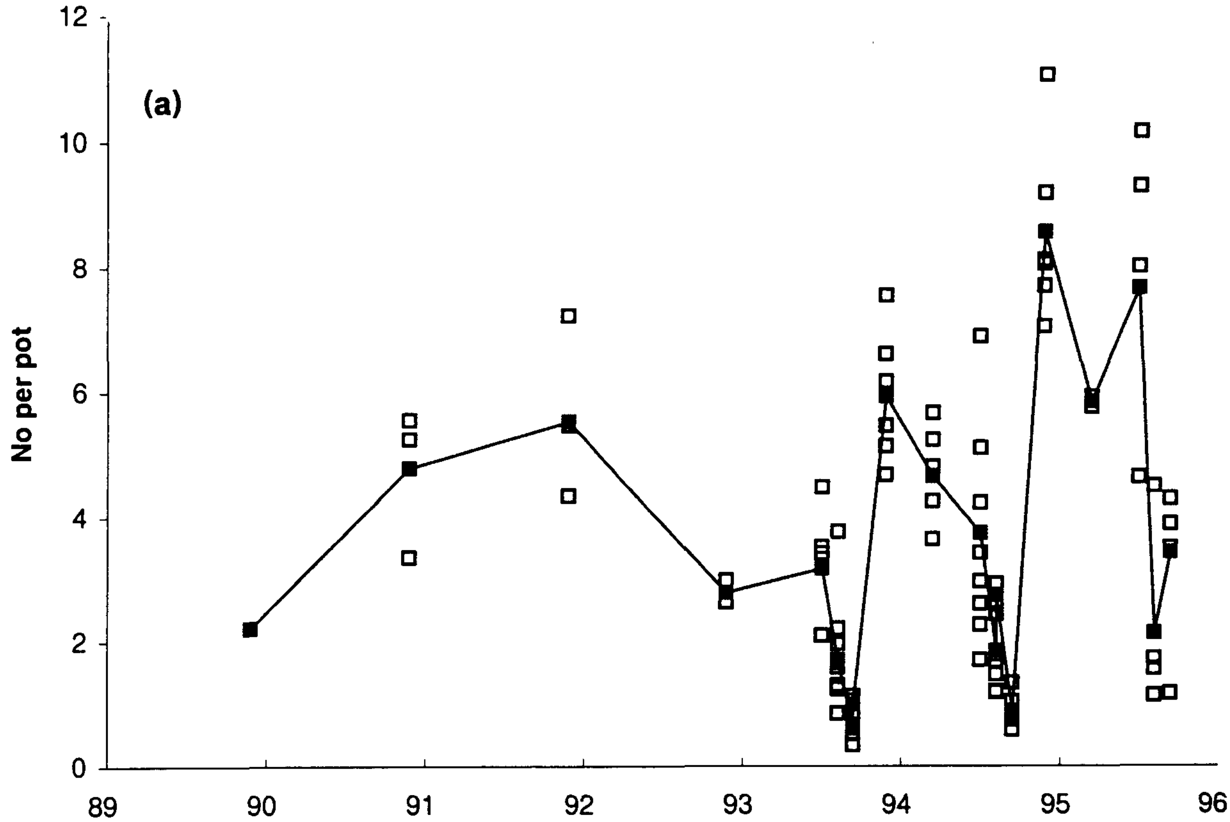


Figure 4: Male abundance indices (number per pot-lift) estimated from catch sampling as described in the text, area 909. a) legal males (i.e. equal to or greater than 52.0 mm TW); b) sublegal males (i.e. less than 52.0 mm).



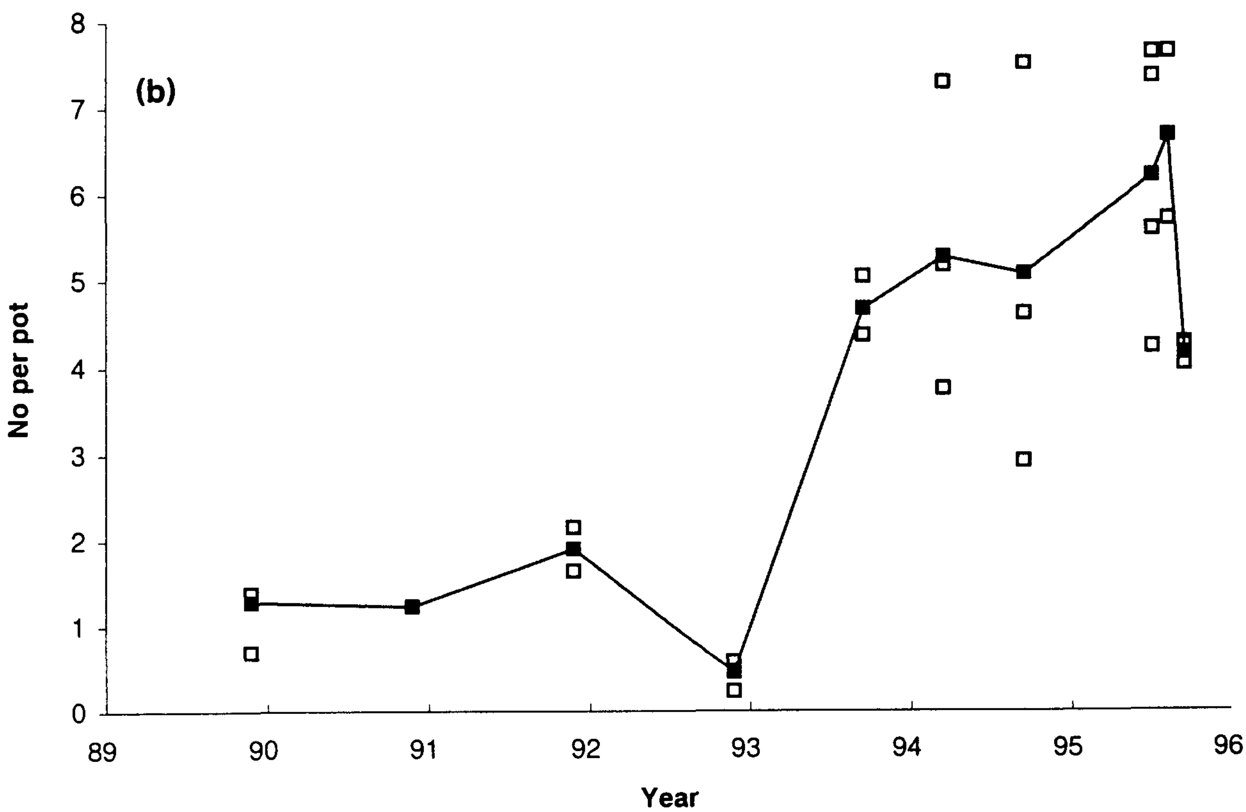


Figure 5: Male abundance indices (number per pot-lift) estimated from catch sampling as described in the text, area 910. a) legal males (i.e. equal to or greater than 52.0 mm TW) b) sublegal males (i.e. less than 52.0 mm).

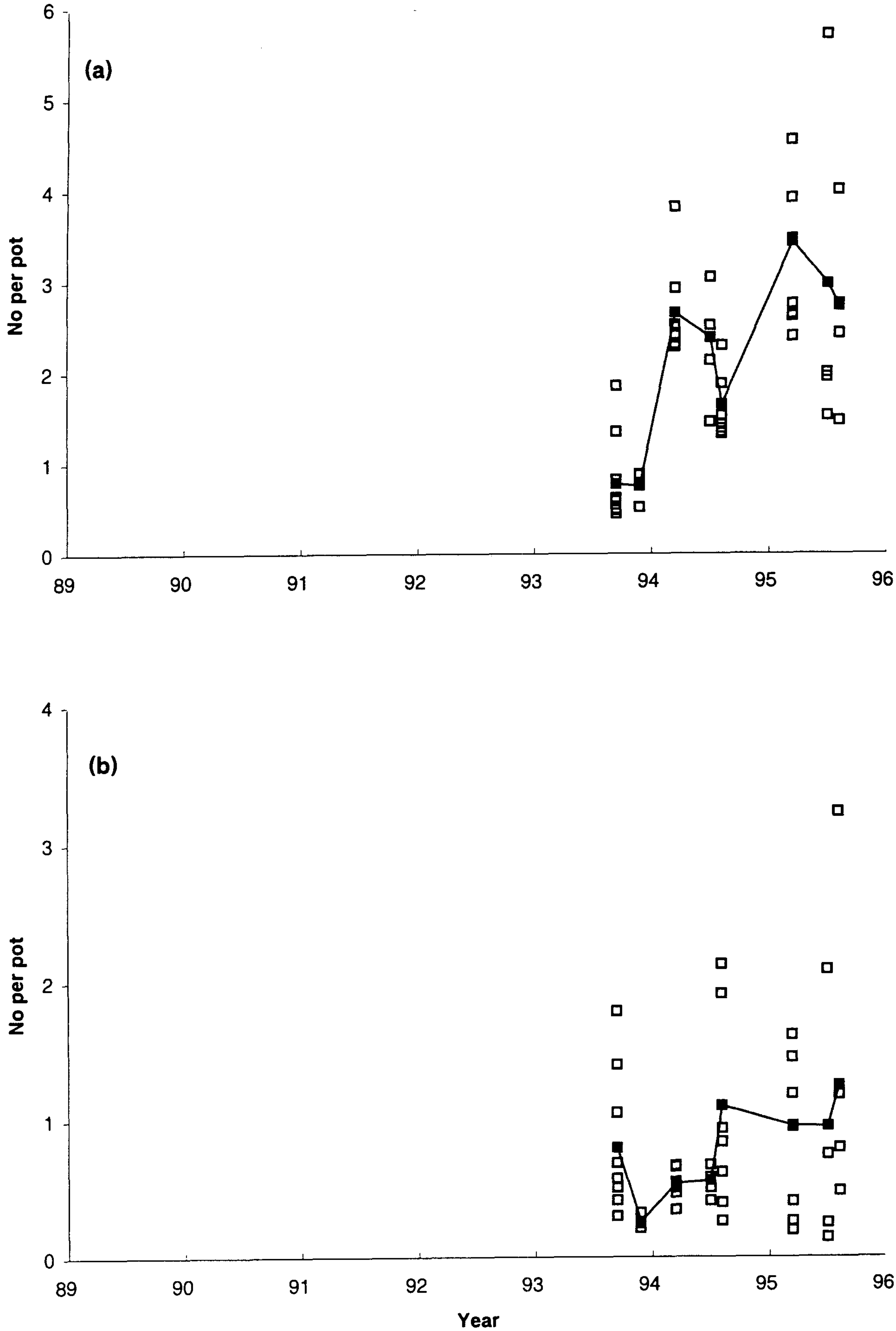


Figure 6: Male abundance indices (number per pot-lift) estimated from catch sampling as described in the text, area 911. a) legal males (i.e. equal to or greater than 52.0 mm TW) b) sublegal males (i.e. less than 52.0 mm).

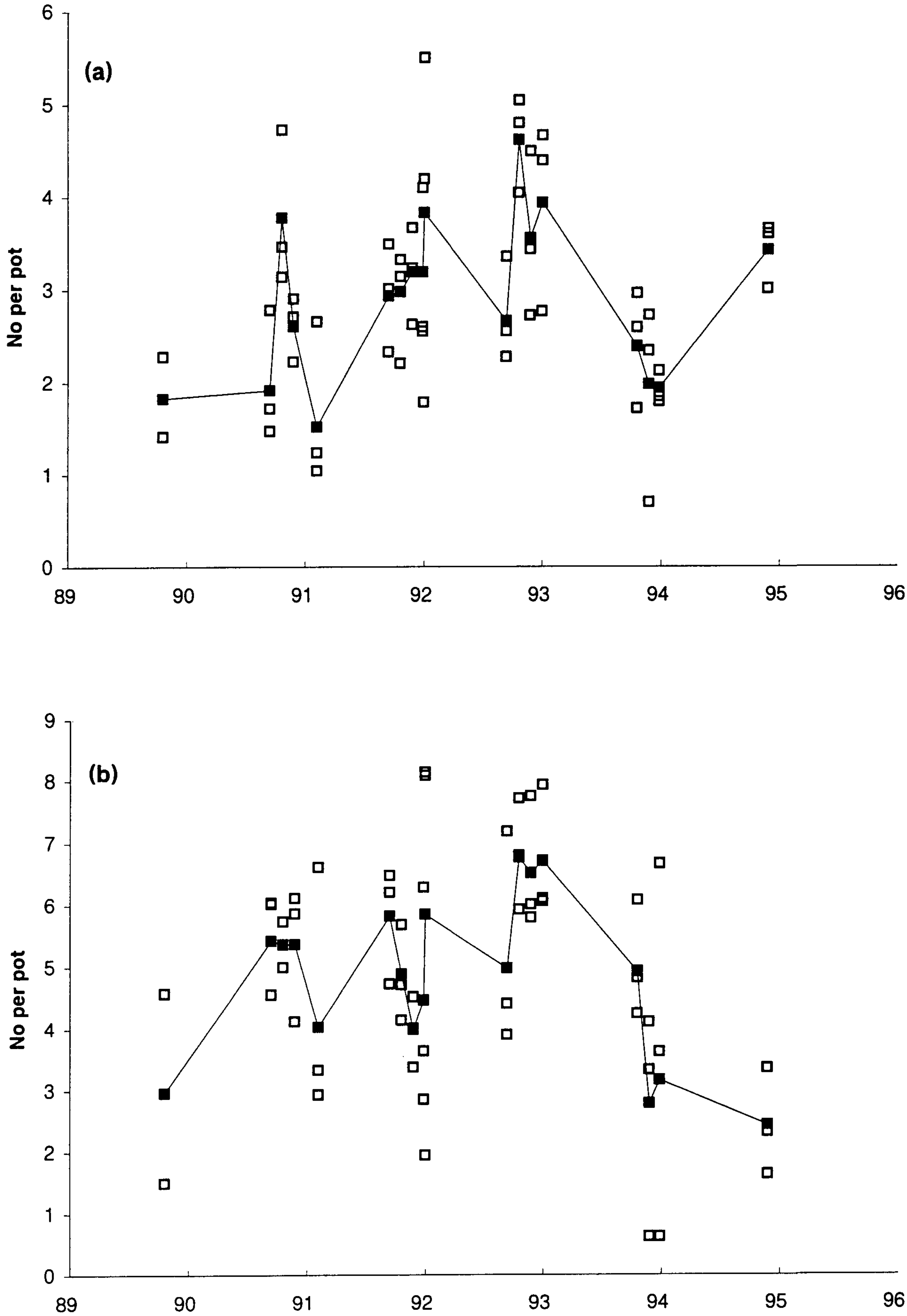


Figure 7: Male abundance indices (number per pot-lift) estimated from catch sampling as described in the text for area 912 in CRA4. a) legal males (i.e. equal to or greater than 52.0 mm TW) b) sublegal males (i.e. less than 52.0 mm).

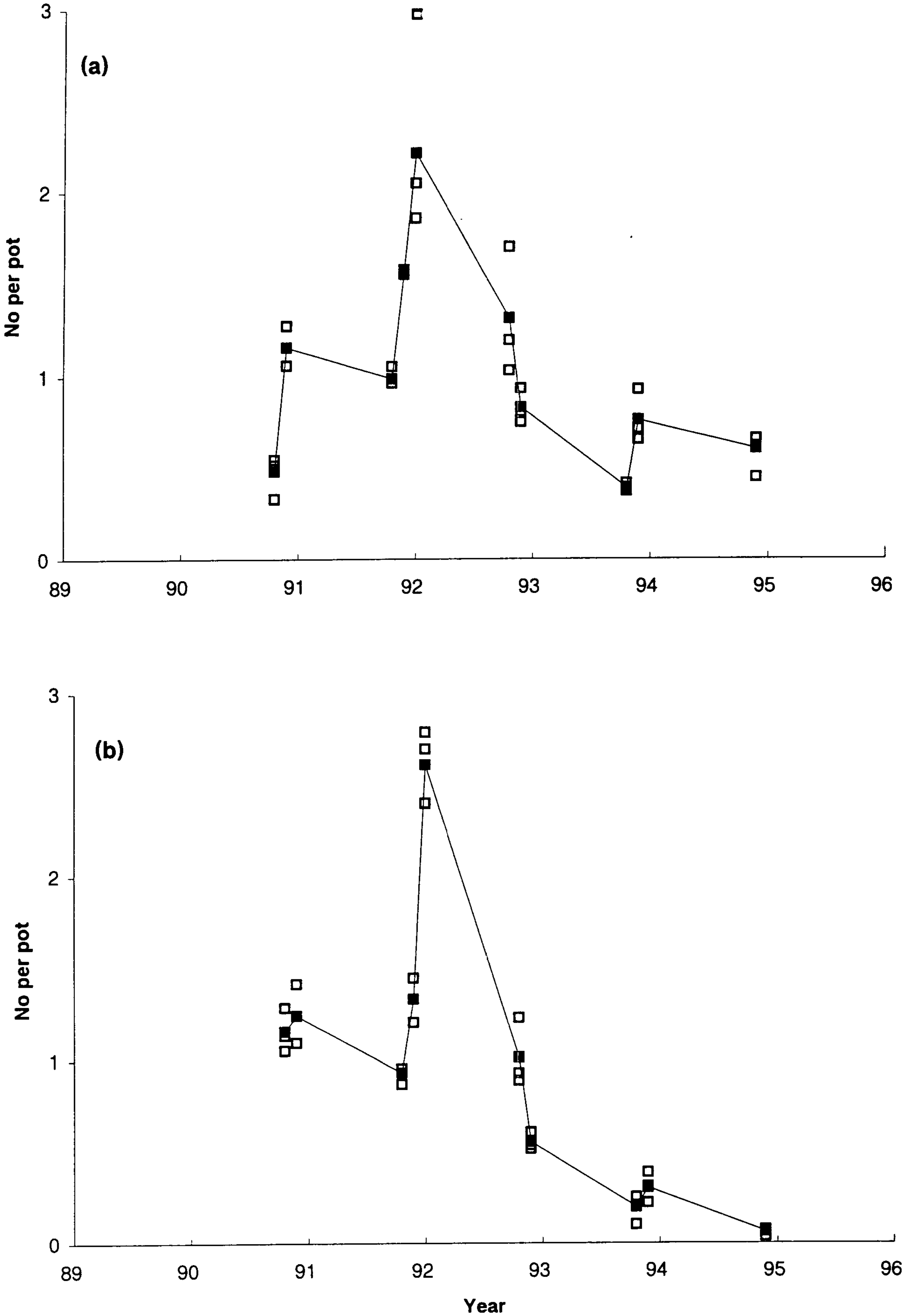


Figure 8: Male abundance indices (number per pot-lift) estimated from catch sampling as described in the text for area 913 in CRA4. a) legal males (i.e. equal to or greater than 52.0 mm TW) b) sublegal males (i.e. less than 52.0 mm).

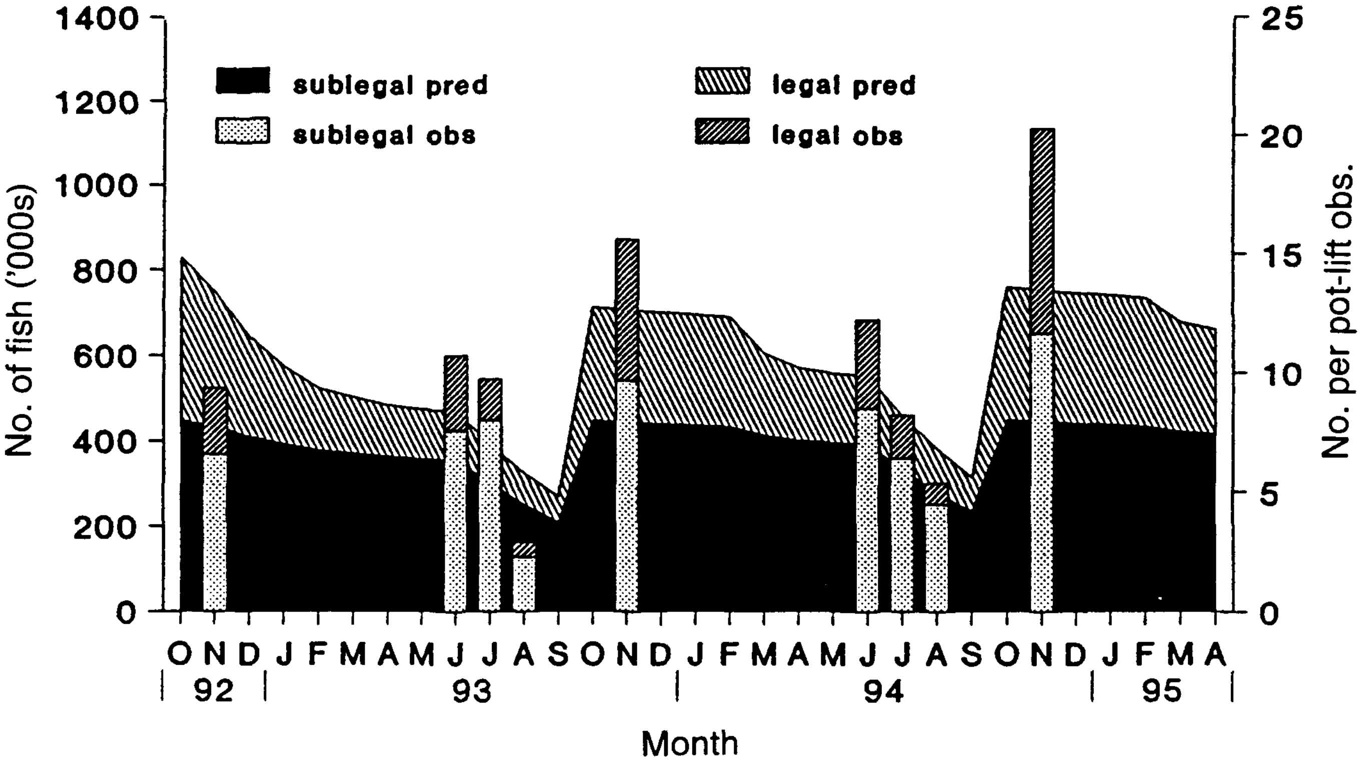


Figure 9: Background: the predicted abundance of legal and sublegal lobsters (Breen, unpub. report to the Minister of Fisheries, 1993). Bars: the abundance of legal and sublegal lobsters observed in catch sampling in area 910 during the winter and November months during the same period. The vertical scale of the bars is kg per potlift; the scale of predicted values is in model fish and has been adjusted arbitrarily.

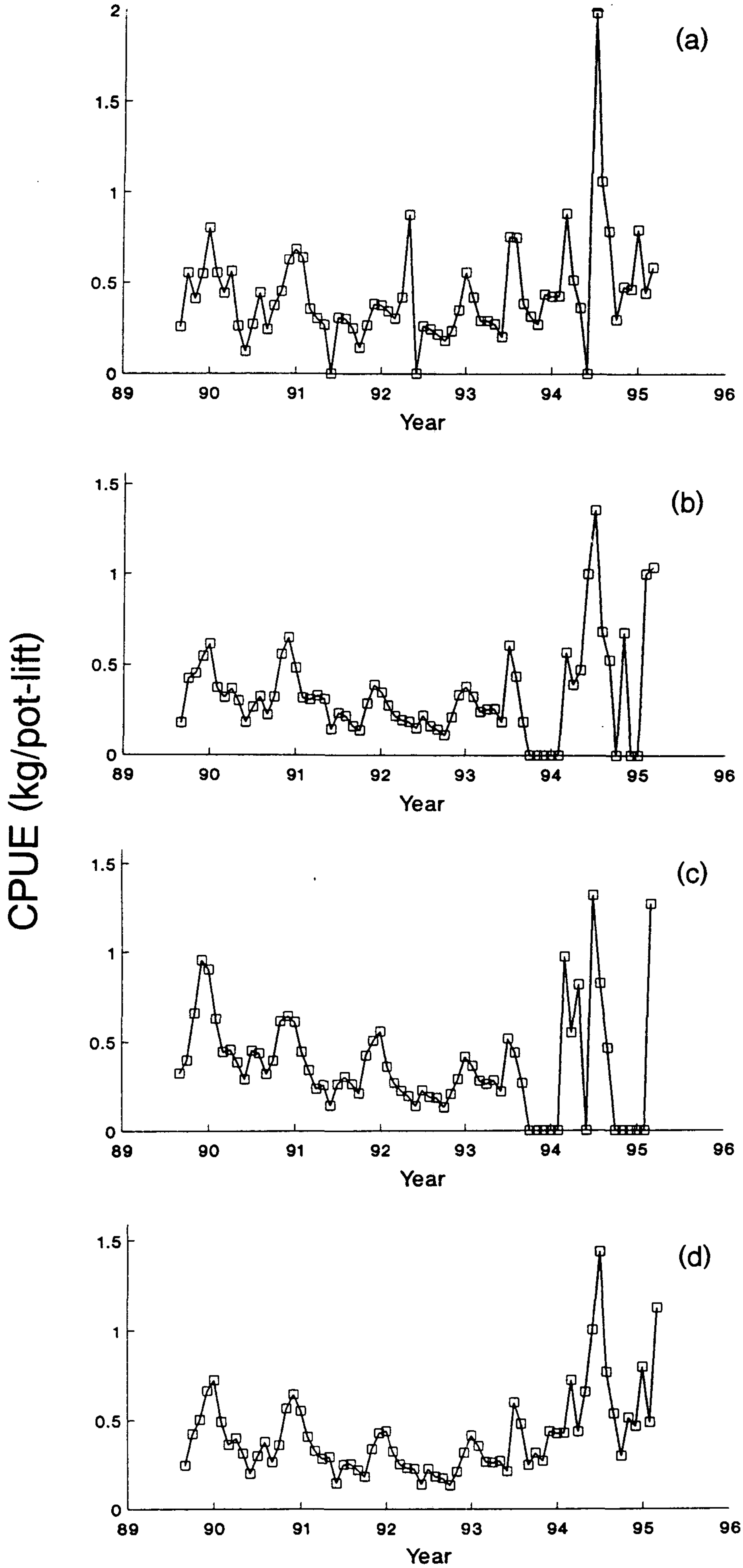


Figure 10: CPUE (kg/pot-lift) from the CELR system, 1989-94. a) statistical area 909, b) statistical area 910, c) statistical area 911, d) all three areas combined (CRA3).

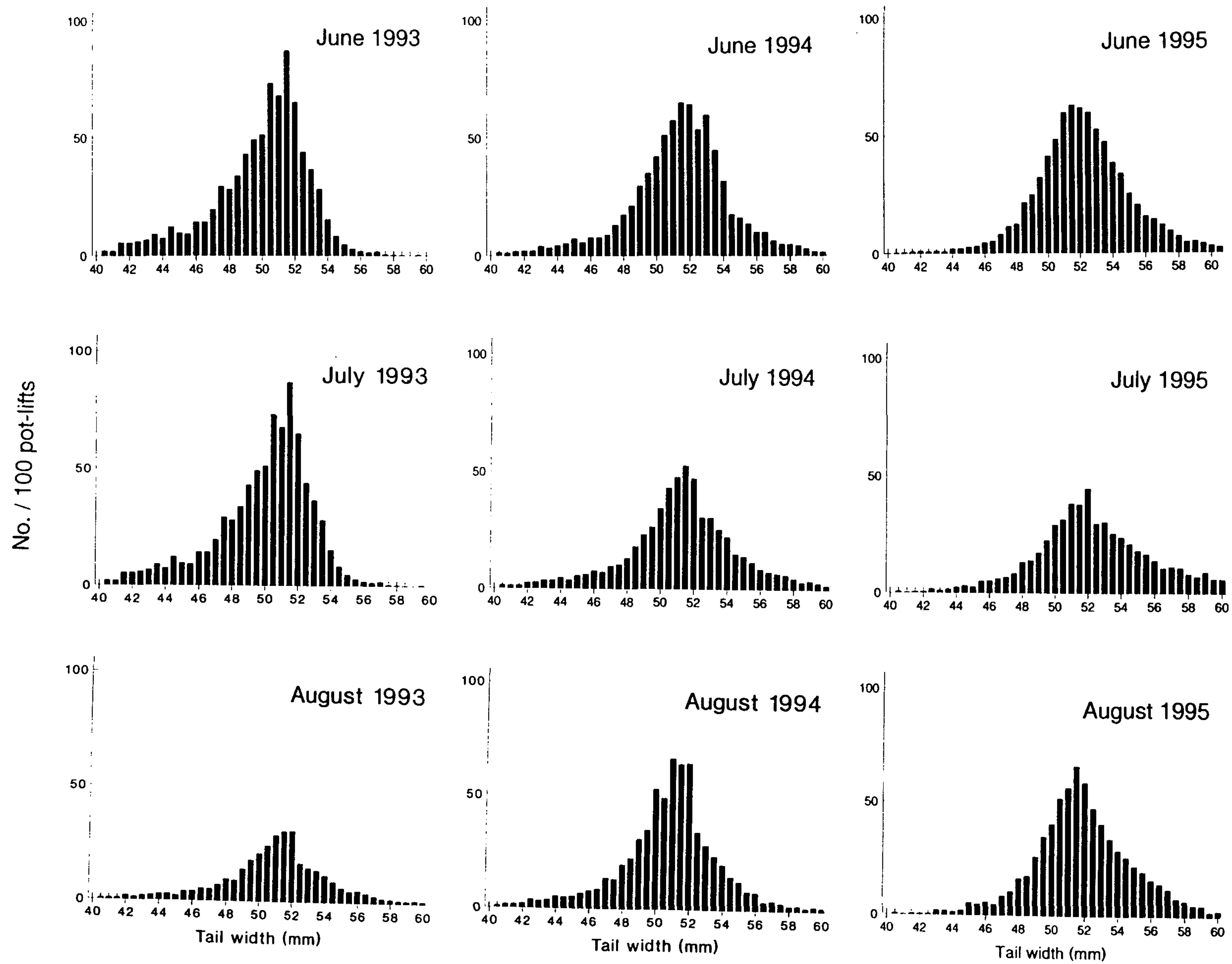
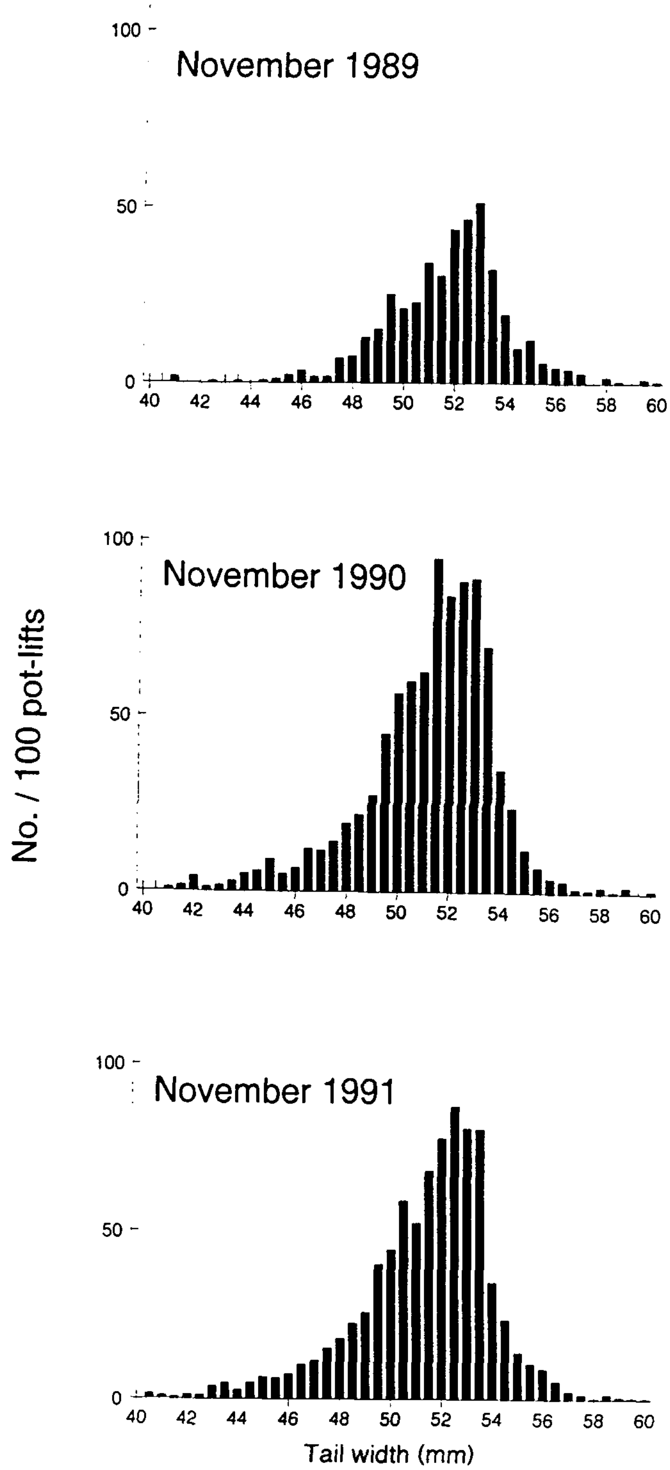


Figure 11: Size distributions of male fish, 1993-95, from the combined CRA3 samples measured in the months June through August (the winter fishery). Plotted are the numbers of lobsters, in each 0.5 mm increment of tail width, per 100 pot-lifts in which fish were measured.



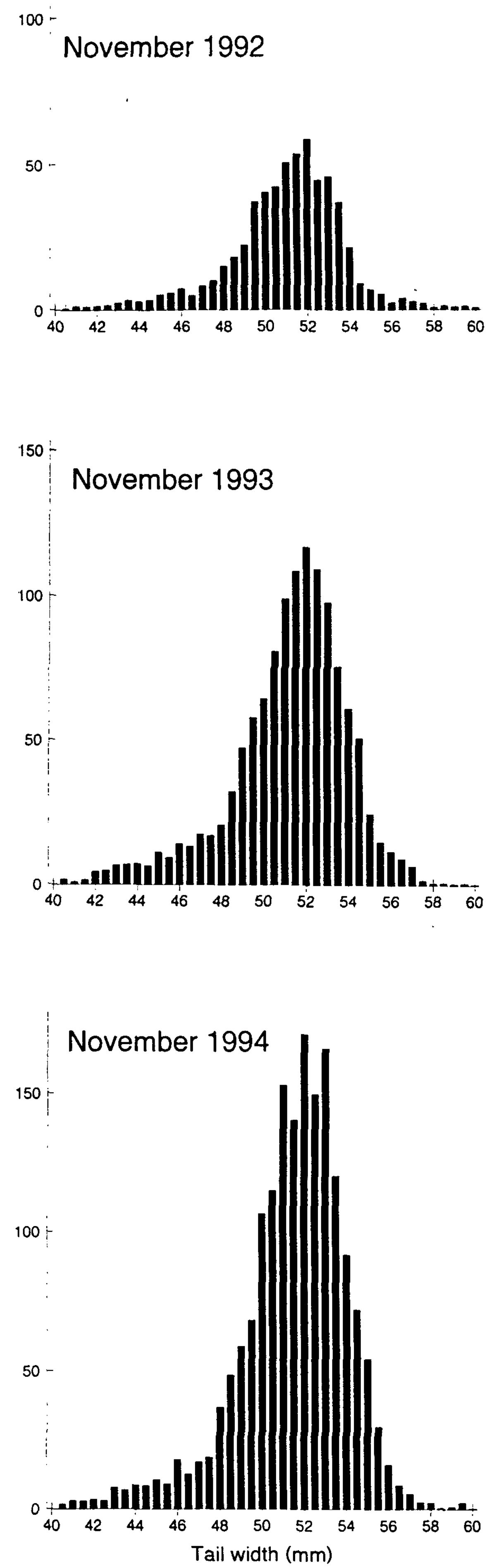


Figure 12: Size distributions of all male fish in November samples, 1989 through 1994. Plotted are the numbers of lobsters, in each 0.5 mm increment of tail width, per 100 pot-lifts in which fish were measured.

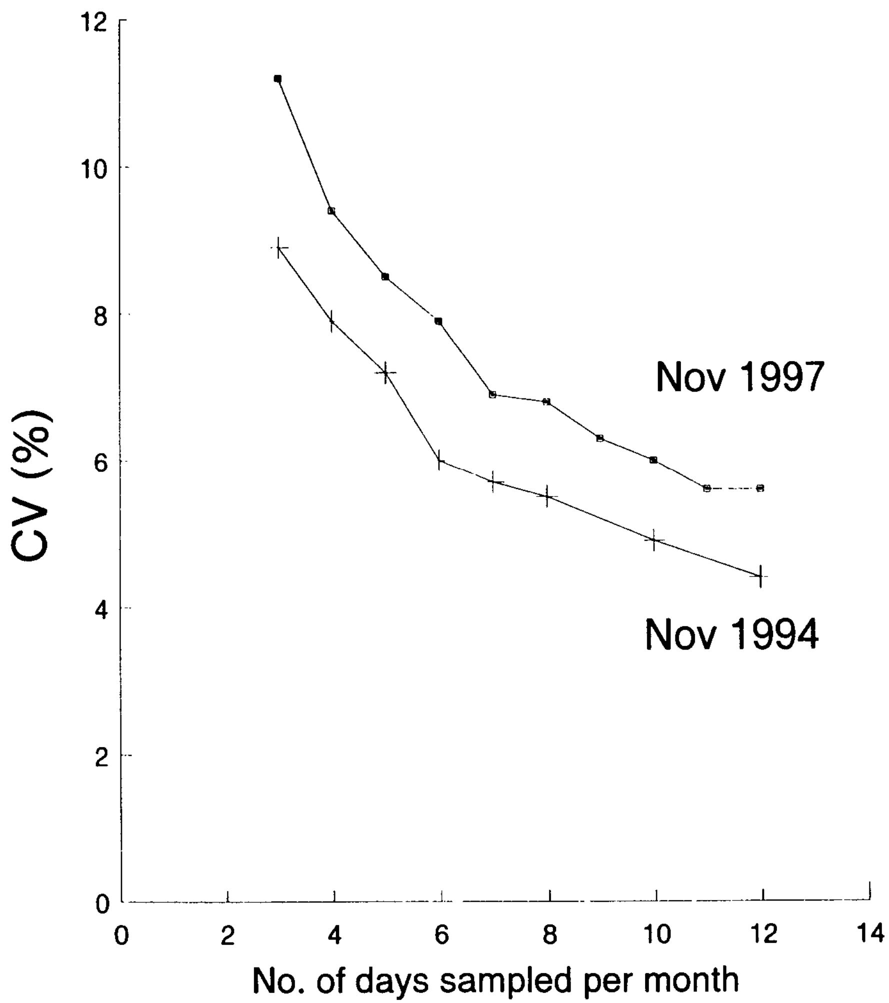


Figure 13: The coefficient of variation of sampling (CV, in %) estimated from bootstrapping of area 910 data, plotted against the number of days sampled per month.

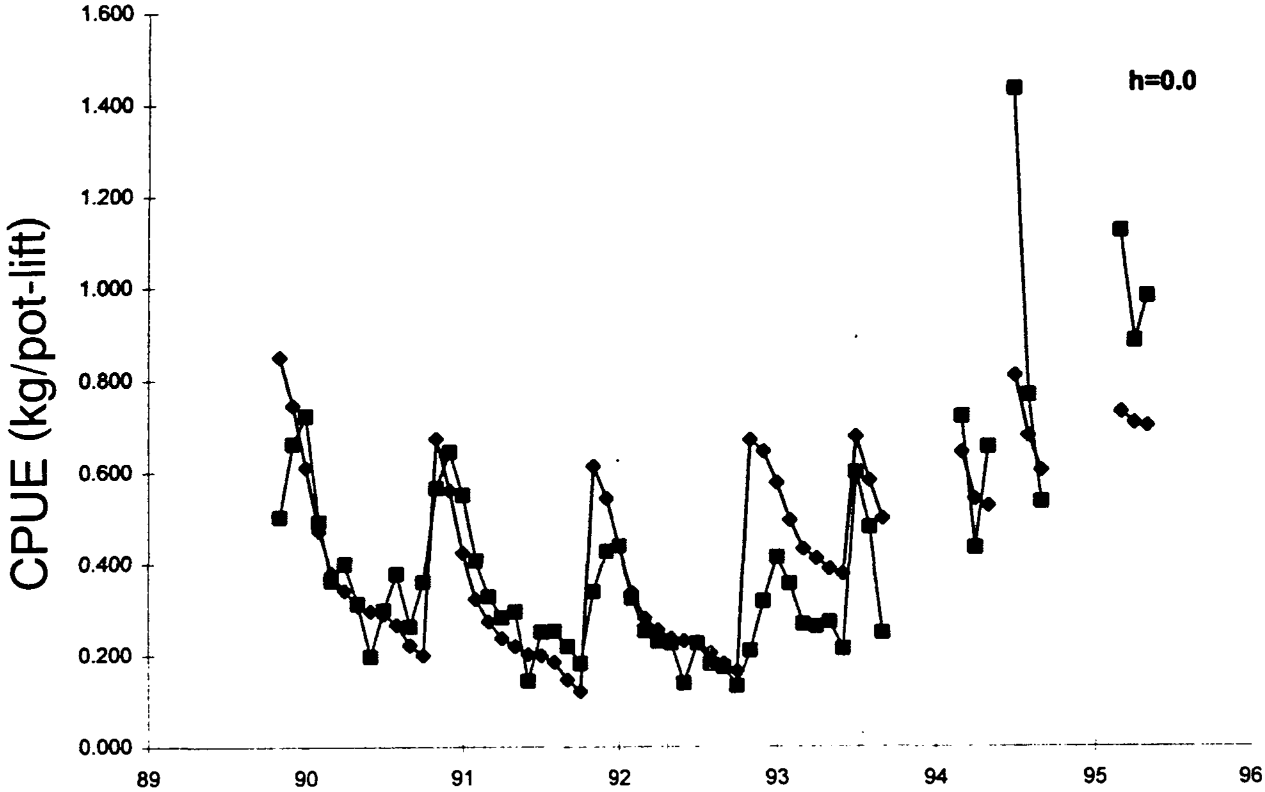


Figure 14: The fit of CPUE from the model described in the text (filled squares) to CPUE data from the CELR system (open squares), October 1989 through May 1995. The fit here is with the associated mortality coefficient, h, set to 0.0.

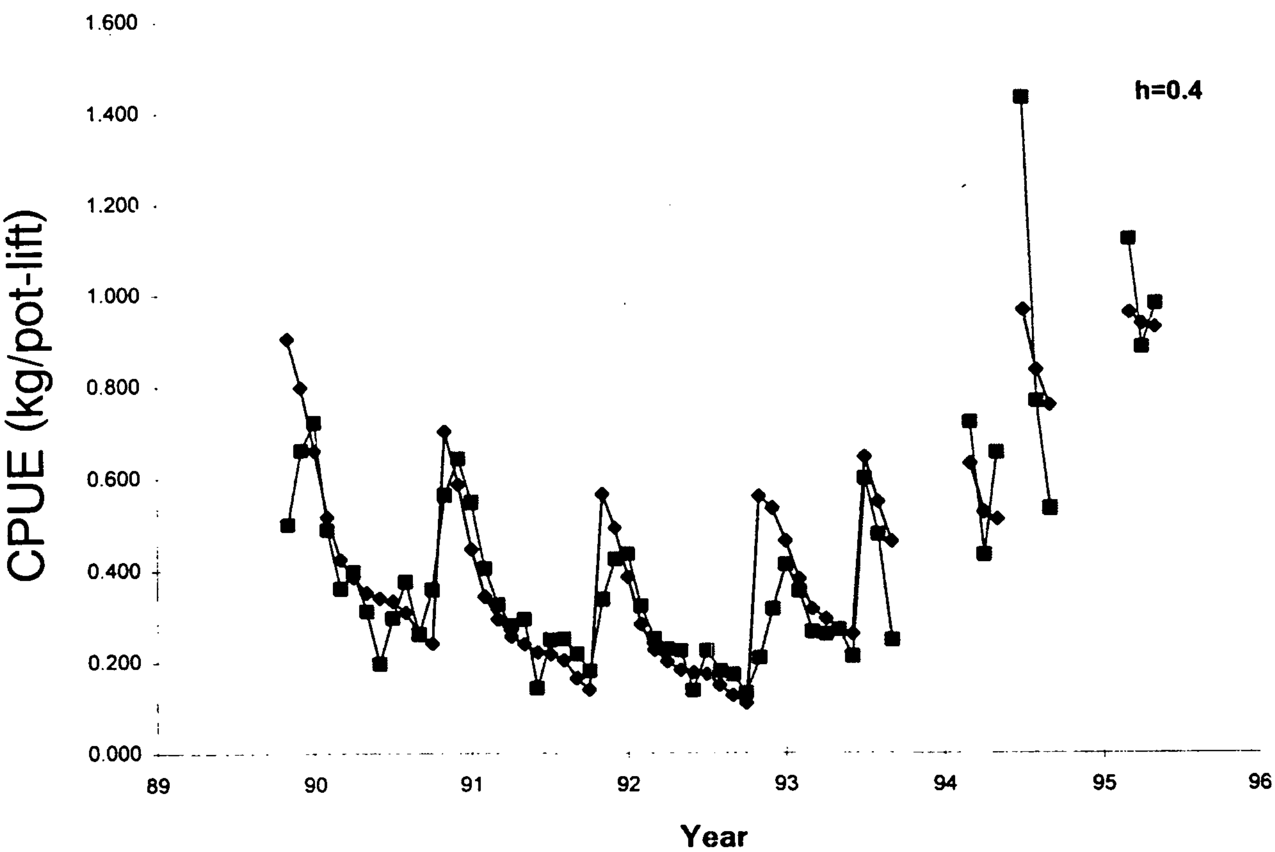


Figure 15: The fit of CPUE from the model described in the text (filled squares) to CPUE data from the CELR system (open squares), October 1989 through May 1995. The fit here is with the associated mortality coefficient, h, set to 0.4.

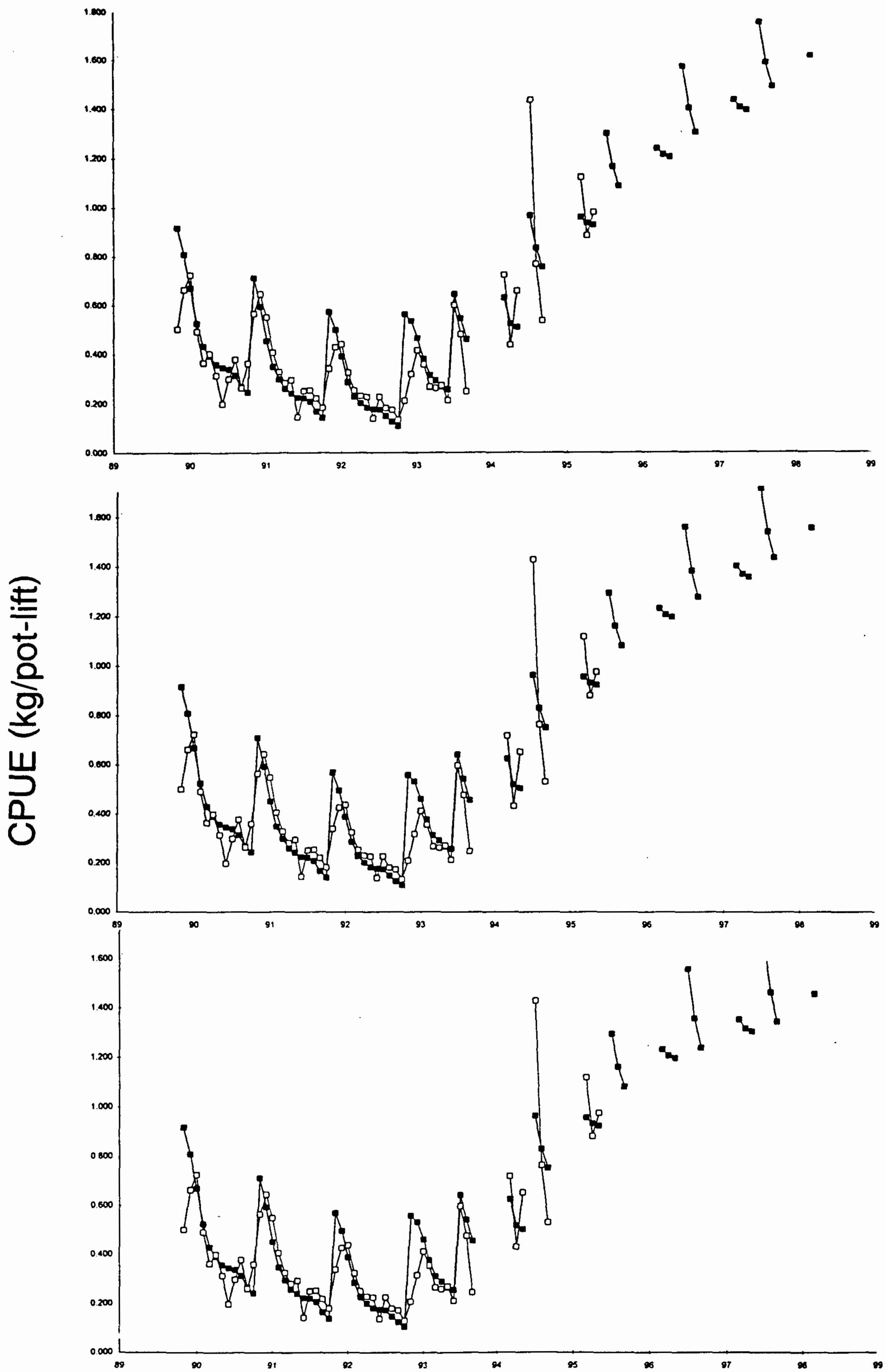


Figure 16: Forward projections of model biomass (filled squares) through March 1998, made with annual recruitment set at 75% R_0. The three figures from top bottom show the catch set at 100%, 125% and 133% of present catches respectively.