Fisheries Research Institute

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Final Report of the Redfish Tagging Study, N.S.W. (FIRTA Project 85/71)

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Abstract

Redfish, **Centroberyx affinis**, *were tagged off southern New South Wales from the FRV Kapala and from chartered commercial trawlers between December 1985 and December 1986. The study aimed primarily to determine the rate of fishing mortality applying to the redfish stock, which had been shown from catch curve analysis to have a high rate of total mortality. A total of 30,809 redfish were tagged with small plastic T-bar anchor tags, and released on trawl grounds between Crowdy Head and Eden. The distribution of tagged fish reflected the relative abundance of redfish as determined from the distribution of commercial catches and fishing effort. From experiments conducted in holding cages, initial tagging and handling mortality was estimated to be approximately 20%. The reporting rate for recaptured tagged fish was estimated from tag seeding experiments carried out at the Sydney Fish Market to be consistently low, averaging only 20%.*

To December, 1989, recaptures of 137 tagged redfish were reported. Approximately one-third of the recaptured fish showed significant movements within the study area, but no seasonal migrations were apparent. Analysis of the tag returns confirmed that redfish have a high rate of total mortality (approximately 70% per annum). Using Gulland's (1969) method, the fishing mortality rate F *was estimated to be in the range 0.04 - 0.19, although the result for the population as a whole appeared to be towards the lower end of this range. The results supported previous findings that redfish are relatively slow growing, however growth parameters could not be estimated directly from the tag recapture data.*

Analysis of commercial catch per unit effort and catch length frequency data for redfish for the period 1970 - 1988 showed significant changes in the composition of redfish catches over this period. These changes appear to result from the impact of exploitation, although the relatively low levels of fishing mortality suggested by the results of the tagging study do not support such a conclusion.

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Introduction

Redfish Centroberyx affinis is an important component of the trawl fish catch in New South Wales (N.S.W.). Recent annual landings have been about 1,500 tonnes valued in excess of $1 million.

In March 1984 estimates of growth and total mortality rates for redfish (Diplock, 1984) were discussed at a workshop on Trawl Fish Resources, convened by the Demersal and Pelagic Fish Research Group of the South Eastern Fisheries Committee. From age determinations based on examination of otoliths, redfish were found to be relatively slow growing fish, taking 4-5 years to reach 20cm caudal fork length (LCF). Estimates of the rate of total mortality for the exploited age classes, from 'catch curve' analysis of the age composition data, were considered by the workshop participants to be quite high ($Z = 0.8-1.3$, corresponding to annual survival rates of 27-45%). It was thought that these results may have been indicative of a high rate of exploitation (Allen, 1984), and the Research Group supported a proposal by the N.S.W. delegate to undertake a tag/recapture study of redfish, aimed at estimating the rate of fishing mortality. Included in the tagging study were segments to estimate mortality due to tagging, and the reporting rate applying to recaptured tagged fish. Valuable information on fish movements, stock identity, and possible validation of the otolith-derived growth curve would also be gained from such a study.

The purpose of this report is to describe the methods used for tagging redfish and discuss the results achieved by the various segments of the project. In conjunction with the tagging study, data on commercial catches of redfish, fishing effort and catch length frequency were also analysed, and the results of this work are discussed in relation to exploitation rates estimated by tagging.

Methods

Tagging of redfish was carried out from the Department's research vessel *Kapala* and from chartered commercial trawlers at each of the main ports on the N.S.W. south coast. The geographical distribution of tagged fish was approximately proportional to the relative abundance of redfish as indicated by commercial catches.

Choice of Tag Type

The choice of a suitable tag was influenced by the fact that redfish taken in commercial catches are small fish, 20-25cm caudal fork length (LCF) and about 300g in weight. It was also intended to tag large numbers of trawl caught fish in short periods of time, to try and ensure maximum survival. Small plastic "T-anchor" tags (FD-67 made by the Floy Tag Manufacturing Company, Seattle, U.S.A.) which had been used successfully to tag other trawl fish species (Rowling, 1983) were selected. Davis and Reid (1982) indicated that the FD-67 anchor tags were superior to similar sized 'dart' tags for tagging small fish, and this has been supported by the results of more recent studies (Whitelaw and Sainsbury, 1986). Initial trials aboard *Kapala* confirmed the suitability of the anchor tags for redfish, and helped develop appropriate techniques for handling the fish during tagging. Field tagging of redfish from the *Kapala* commenced in late 1985 using yellow FD-67 tags, with a 30 mm long sleeve bearing the legend "NSW Fish" and a serial number. At about this time, Hallprint Pty Ltd of Adelaide developed a similar tag which was more robust (less susceptable to separation of the sleeve from the anchor) and of lighter construction. Because of these advantages, the Hallprint tag was the major tag used in the study. Tags used were blue in colour (thought to be more obvious against the red background colour of the fish) and bore the wording "NSW Fish" and were numbered R0001 - R25000.

Tagging Procedure

Fish to be tagged were caught by 30 minute - 2 hour duration trawls at depths of 40-197 fathoms. Redfish do not suffer noticeably from swim bladder distention, and it was found to be unnecessary to 'prick' the swim bladder to release excess pressure. Anaesthetics were not used to subdue fish during tagging - rather, the emphasis was placed on careful and expeditious handling of the fish. Only fish which appeared to be in good condition were tagged, although lively fish with slight damage to the scales or with minor cuts were occassionally tagged and released, and the extent of damage noted on the data sheet. Most tagging was carried out at night, due to the more consistent availability of redfish from night time trawls during the period in which tagging was undertaken.

The catch was landed on the deck and lively redfish were quickly placed into 400 litre holding tanks filled with circulating seawater supplied by the vessel's deck hose. Fish were allowed to settle in the tanks for 10 - 15 minutes, then those which appeared to be uninjured and swimming normally were retrieved with a dip net, measured and tagged. On commercial trawlers, fish were measured to the nearest cm below the actual length to the caudal fork, however aboard *Kapala* caudal fork length was measured to the nearest mm.

Tags were inserted into the musculature below the dorsal fin on the left side of the body by means of a trigger operated applicator. The needle of the applicator was inserted between the scales, directed anteriorly at an angle of about 45° between the pterygiophores at the base of the dorsal fin. Care was taken to ensure that the 'T-bar' anchor was locked behind the pterygiophores by a slight rotation of the applicator prior to removal from the fish. Redfish have a solid bone structure which provides good anchorage for this type of tag and correctly inserted tags were difficult to remove by pulling on the protruding tag.

Fish tagged aboard *Kapala* were placed in holding tanks for observation prior to release, but on the commercial trawlers fish were released immediately after tagging. To lessen handling time, some fish from occasional large shots aboard commercial trawlers were tagged and released without being measured, so the number measured was sometimes less than the number tagged.

Assessment of Tagging Mortality and Tag Loss

In any tagging study aimed at estimating mortality rates of fish populations, it is important that the effects of capture, handling and tagging be taken into account in any resultant assessment of mortality rate.

Mortality of redfish caused by the actual implantation of the tag was studied by a specific experiment, which involved observing tagged and untagged fish in specially constructed holding pens for a period of seven days. The methodology and results of this study are outlined in Appendix 2.

The long term (greater than seven days) effects of tagging or the rate of tag loss were not investigated, due to the non-availability of a suitable secondary tag. Opercular strap tags, of the type used in previous studies on jackass morwong (Smith and Rowling, 1986) were considered to be too inconspicuous when used in the small size required to prevent excessive damage to the fish, and would have been very time consuming to apply. Crossland (1976) discontinued double tagging of snapper because of injury being caused to the fish by the additional handling required.

Tag Recovery and Estimation of Reporting Rate

A reward of $5 was paid for the return of each tagged fish together with information on where the fish was found and, if possible, where it was caught. Publicity about the project and how to report recaptured tagged fish involved display of reward posters at fishermen's co-operatives and the Sydney Fish Market. Information was also disseminated in Departmental *Kapala* Cruise Reports which are circulated to licensed trawl fishermen.

Discovery of recaptured tagged fish could take place in several locations: aboard the catching vessel, at the point of landing, at the wholesale market or during later handling or filleting. It was not possible to 'seed' tagged fish into catches before landing on deck, so the true reporting rate during the primary handling stages could not be directly ascertained. It is likely that tagged fish not found during the primary handling stages (perhaps because of bulk handling of the fish) could still be found at a later stage.

The majority of the redfish catch is marketed through the Sydney Fish Market. A series of experiments was therefore carried out, in which tagged fish were distributed amongst consignments of redfish prior to sale, to estimate the reporting rate applicable for redfish passing through this market. These experiments involved the random placement of 10 tagged redfish amongst daily consignments (all ports combined) of 300 to 1000 boxes of redfish, prior to the sale of the fish through the normal auction procedure. The number of tagged fish subsequently reported was noted. On two occasions, the buyers of boxes into which tagged fish had been placed were traced and contacted to ascertain if they had found the tagged fish and if so, why they had not reported it.

Data Analysis

Methods for estimating mortality rates from the results of tagging studies have been detailed by Paulick (1963) and Gulland (1969), and the practical difficulties encountered with commonly used methods were discussed by Jones (1977). Where tagging is carried out on more than one occasion, it is desirable that the different releases be treated independently, however such analyses are not practical in the current study because of the low number and irregularity of returns from individual tagging operations (see Table 1). For the purpose of analysis, the results of this study were 'averaged' across all the tagging episodes, the data being treated as if all the fish had been tagged at the same point in time. The number of recaptures (n_r) in successive time intervals (in this case T = 1 year) can then be used to estimate the instantaneous co-efficients of fishing mortality 'F' and natural mortality 'M' (Gulland, 1969). Mortality rates were also calculated for the tagging operation which resulted in the highest recapture rate, as an indication of the maximum likely exploitation rate for redfish.

An assessment of redfish catch per unit of fishing effort (CPUE) by commercial trawlers was made from landings data available from fishermen's co-operatives and the N.S.W. Fish Marketing Authority. The monthly redfish catch of each trawler was divided by the vessel's underdeck tonnage (a measure of gross tonnage - see Boden, 1966), and the results were averaged across all vessels for which data were available for that month.

Annual length frequency distributions were determined for redfish caught at all the main ports of landing from measurements made at the Sydney Fish Market. Samples for measurement generally consisted of 2 to 4 boxes of fish, randomly selected from consignments to the market.

Results

Release Data

After observation in holding tanks aboard *Kapala*, 98.4% of fish tagged were judged to be suitable for release. Upon release, tagged redfish descended rapidly, swimming strongly toward the sea bed. On several occasions, tagged fish released while the next shot was being towed were recaptured in that shot, indicating a rapid descent to the sea floor.

A total of 30,809 redfish were tagged and released on trawling grounds between Crowdy Head and Eden : 22,395 from the *Kapala* and 8,414 from chartered commercial trawlers (Table 1). Of the fish released from *Kapala* 10,780 were tagged with yellow coloured FD-67 tags. The remaining 11,615 fish tagged aboard *Kapala* and all fish tagged aboard commercial trawlers, were tagged with blue coloured tags made by Hallprint.

Releases of tagged fish were reasonably evenly distributed over the period from December 1985 to December 1986 (Figure 1a). Although tagged fish were distributed from Crowdy Head in the north to Eden in the south, about 87% were released on grounds between Sydney and Ulladulla (Figures 2 and 3). Most (82%) of the fish tagged aboard *Kapala* were released on trawling grounds between Broken Bay and Shoalhaven Bight (Figure 2). Tagging from chartered commercial trawlers was carried out from the ports of Wollongong, Ulladulla, Bermagui and Eden. Although fish were tagged from trawls carried out at depths ranging from 40 to 197 fathoms, about 95% of fish tagged were caught in depths between 50 and 70 fathoms.

The length frequency distributions of fish tagged aboard *Kapala* are set out by area in Appendix 1, while those for redfish tagged from commercial trawlers at each of the main ports are shown in Figure 4.

Assessment of Tagging Mortality and Tag Loss.

The results from the tagging mortality experiment (Appendix 2) indicated that short term mortality of redfish was mainly due to the effects of capture and handling, and mortality attributable to the actual tagging was of lesser importance. During the experiment, mortality of about 15% occurred during the first 24 hours (whether the fish were tagged or not). After one week the observed mortality was 22% for tagged fish and 17% for untagged fish. The deteriorating condition of the fish at this time was probably attributable to their being held in captivity in relatively shallow water and the experiment was terminated. It was assumed that the difference of 5% in these mortality rates was due to the effect of tagging.

Unfortunately, it was not possible to design a suitable experiment to determine the level of mortality due to capture and handling for those fish that were released, because all such experiments would necessarily involve confinement of the fish at a depth suitable for observation. It is likely that the 15% handling mortality observed in the above experiment is greater than that applicable to fish that were released, as the experimental fish were held in tanks aboard *Kapala* for two to three hours and then confined in shallow water for a further week. However, in the absence of more reliable estimates, it is considered appropriate to reduce the number of viable tagged fish released by 15% to compensate for handling mortality, and an additional 5% to compensate for short term tagging mortality. This combined mortality rate of 20% is identical to that found by Leaman *et al* (1979) for short term mortality of tagged juvenile pacific cod, although in that case mortality was found to be entirely due to capture and handling, and was not increased by tagging.

Recapture Information

Recaptures of tagged redfish were reported very soon after tagging commenced, and the rate of recaptures peaked in the spring of 1986 (Figure 1b). The monthly distribution of recaptures shows that peaks occur in recaptures in late Autumn (April-May) and Spring (October-November) of each year, however closure of the gemfish fishery in the July-August 1988 period coincided with an increase in the number of recaptures reported in that period, presumably due to transfer of fishing effort to redfish. Tagged fish continued to be recaptured until November, 1989.

In most cases, only a 'general' area of recapture was available, because the tagged fish was known to have been caught by a trawler which fished from a specific port. The study area was therefore stratified into broad zones corresponding to the areas fished by trawlers from the major ports. To December 1989, recaptures of 137 tagged redfish had been reported and verified. A summary of the time at liberty of these recaptures by location tagged (Table 1) shows wide variation in the temporal pattern of recaptures from individual tagging operations.

Because fish were tagged aboard *Kapala* using both blue and yellow coloured tags made by different manufacturers, the relative recapture rates and the mean number of days at liberty were compared for each tag colour (Table 2). The yellow coloured tags were recaptured at double the rate of the blue tags for fish tagged aboard *Kapala* however this was still only about two-thirds of the recapture rate observed for blue tags used from commercial trawlers. Fish tagged aboard *Kapala* also showed a much shorter average time at liberty before recapture than those tagged aboard commercial trawlers (Table 2). This result is surprising, as fish tagged aboard commercial trawlers were released on regularly worked commercial grounds (often amongst operating trawlers), whereas many of the fish tagged aboard Kapala were released on grounds worked only irregularly by commercial trawlers.

Information on movements of recaptured fish is summarised in Figures 2 and 3. Although most tagged fish were recaptured in the same general area in which they were released, 40 (33% of the total) recaptured fish whose location was reliably known had moved at least to the adjoining area. Of these, 18 tagged fish had moved approximate distances between 200 and 400 Km. The majority of movements were in a southerly direction, but this could be due to the fact that more fish were tagged in the northern part of the range. The lack of apparent relationship between the time at liberty and the distance moved from the point of release (Figure 5) suggests random movement within the study area with no seasonal or cyclical trends.

The size distribution (at tagging) of recaptured fish (Figure 6) is similar to the size distribution of all tagged fish, which indicates no size-related effects of tagging or recapture. However, during one tagging operation (at Bermagui in February 1986) a large proportion (37%) of the fish tagged were less than 18 cm LCF, which was the length of the smallest tagged fish reported recaptured from this operation. This suggests that fish less than 18 cm LCF may not have survived the tagging procedure as well as the larger fish, or that these fish were not fully vulnerable to later recapture.

Nearly 14% of reported recaptures were found aboard the catching vessel (Table 3). A further 5.8% were found at the point of landing (usually a fishermen's co-operative), however the majority (75.9%) of tagged fish were found by buyers and filleters at the Sydney Fish Market. Two fish were reported recaptured by recreational fishermen and one by a professional handline fisherman (these results were excluded from the analysis of recaptures by the trawl fishery).

To date, the longest period observed between release and recapture for a tagged redfish is 1290 days, or 3 years and 7 months (see Figure 7). The mean time at liberty for all recaptures of tagged redfish is in excess of 360 days (Table 2), which indicates good long-term retention of tags in this study.

Evidence for Schooling.

A tendency for tagged redfish to remain together in schools is suggested by the following recaptures:

i) Two fish tagged on 10/2/86 off Montague Island were both recaptured on 29/9/86 by a Bermagui based trawler and found at the point of unloading.

ii) Three tagged fish were found in one box consigned to the Sydney Fish Market by a Sydney based trawler on 14/4/87 - all the fish were tagged aboard *Kapala* off Sydney, two from the same catch on 24/3/86 and the third in the same area on 2/4/86.

iii) Four tagged fish, all tagged from a commercial trawler off Eden on 21-22/4/86 were found in a consignment from an Eden based trawler to the Sydney Fish Market on 16/4/87.

iv) Five redfish, again tagged off Eden from a commercial trawler on 21-22/4/86, were caught together by an Eden based trawler on 15/3/89 in the same general area in which they were tagged.

On the other hand, some simultaneous recaptures provide evidence for aggregation of redfish from diverse tagging operations:

i) Three tagged fish recaptured by a Bermagui based trawler on 15/7/86 had extremely diverse origins - one was tagged from a commercial trawler off Ulladulla on 9/12/85; one was tagged from *Kapala* off Sydney on 24/3/86; and one was tagged from a commercial trawler off Eden on 21/4/86.

ii) Three tagged fish found in a consignment from Bermagui co-op to the Sydney Fish Market on 22/5/87 were tagged aboard *Kapala* off Sydney on 2/4/86 and Wollongong on 13 & 14/10/86. (It is assumed that in this instance the fish were recaptured in the same general location at the same time.)

Other Interesting Recaptures.

i) A tagged redfish released from *Kapala* on 2/10/86 off Wollongong was recaptured on 13/12/86 while tagging aboard a commercial trawler in the same area, and was re-released in good condition.

ii) A tagged redfish originally released from a commercial trawler off Wollongong on 13/3/86 was recaptured in the same area while tagging on 11/12/86 - the tagged fish was not found aboard the vessel, but by a co-op employee after the catch had been landed.

iii) A tagged redfish released from a commercial trawler off Wollongong on 3/3/86, was recaptured by *Kapala* while undertaking further tagging on 16/10/86 in the same area and re-released.

Estimation of Reporting Rate.

The results of the tag seeding experiments are summarised in Table 4. Reporting rates were consistently low, averaging only 20.3%. Only two seedings were carried out using yellow tags, the results of which are considered to be insufficient to allow a valid comparison of the reporting rates of the two tag colours, although the results obtained do not indicate a difference in reporting rate. Although low, this reporting rate is comparable with that of 25% found by Kleiber *et al.* (1987) for purse-seined pacific skipjack tuna tagged with larger dart tags.

When telephone contact was made with buyers who purchased boxes containing tagged redfish that were not reported, all stated that they had not found the tag. It appears that one of the major reasons for the low reporting rate is the small size and inconspicuous nature of the tag. This is probably compounded by the fact that redfish tend to be handled in bulk rather than individually wherever possible, and the fact that they are handled very quickly when being filleted. Indeed, some of the reported tags were only discovered after one side of the fish had been filleted.

Assessment of Growth Rate

For 95 of the recaptured tagged fish, measurements of LCF were available at both release and recapture. Positive increase in length was shown by only 32 (33.7%) of these. Of the remainder, 47 (49.5%) showed no difference in length at release and recapture (even for some fish at liberty for more than two years), and for 16 (16.8%) fish the measured length at recapture was less than the length at release. (The maximum reported "negative" growth was 2 cm.) The results for those fish which showed a growth increment are compared graphically with the growth curve determined from otolith studies in Figure 8.

Estimation of Fishing Mortality Rate

The instantaneous mortality coefficients were estimated for the whole population, and for the tagging operation which resulted in the highest recapture rate, as follows :

A. WHOLE POPULATION

Number of tagged fish released = 30,809
Less 20% {15% for handling mortality
and 5% for tagging mortality } 6,162
Yields number of tagged fish at start
of first recapture period N_0 = 24,647

Recapture period	Year 1	Year 2	Year 3	Year 4
Recaptures reported	85	34	16	2
Corrected n_r	425	170	80	10
$\log_e n_r$	6.052	5.136	3.912	2.303

$\log_e n_r$ is plotted for each recapture period in Figure 9. The calculated linear regression equation is:

$$\log_e n_r = -1.247\, r + 6.2214$$

The instantaneous coefficient of fishing mortality can then be calculated from the intercept on the y-axis which is equal to:

$$\log_e \frac{F\, N_0}{F+M} \{1 - e^{-(F+M)}\}$$

Therefore $\log_e \{F \times 24647 \times 0.699/1.247\} = 6.2214$
resulting in $F = 0.036$ (and $Z = 1.25$).

B. HIGHEST OBSERVED RECAPTURE RATE.

The highest recapture rate for any single tagging operation was observed for redfish tagged from a commercial trawler off Bermagui in February 1986 (Table 1). As noted previously, a significant proportion of fish tagged off Bermagui were very small, and for recaptured fish the smallest length at tagging was 18 cm LCF. Fish less than 18 cm have therefore been excluded from the following calculation of fishing mortality rate, which follows the same method as above:

Number of tagged fish released		=	536
Number >18 cm released		=	336
Less 20% mortality			67
Number of tagged fish at start of recapture period	N_0	=	269

Recapture period	Year 1	Year 2	Year 3
Recaptures	8	3	2
Corrected n_r	40	15	10
$\log_e n_r$	3.689	2.708	2.303

The regression obtained when these results are plotted is:

$$\log_e n_r = -0.693\ r + 3.593$$

which yields estimates of F = 0.187 and Z = 0.693.

It should be noted that the rate of total mortality estimated from these results is much lower than that estimated for the stock as a whole, and is heavily influenced by the small numbers of recaptures in each time period.

Commercial Fishery Data.

The monthly commercial catch of redfish landed at the main fishermen's co-operatives and directly to the Sydney Fish Market for the period 1970 - 1985 is shown in Figure 10. A summary of estimated annual landings of redfish by NSW trawlers (Figure 11) shows that catches peaked at over 2300 tonnes in 1979/80, and have since declined to less than 1500 tonnes per annum.

Large seasonal variations in CPUE are apparent in the earlier years when redfish were taken mostly in the winter as a by-catch of fishing targeted at gemfish (Figure 12). These seasonal fluctuations become much less pronounced after about 1980, and an annual summary of these data (Figure 13) shows mean CPUE slowly declining since catches peaked in 1979/80.

Length frequency distributions of landed catches of redfish for all ports combined are shown in Figure 14 for the years 1974/75 to 1987/88. In the early part of this period the mean length of the annual catch was in the range 24-25 cm LCF, however the last decade has seen a gradual decline in the mean length of the catch to about 22 cm. Although there are differences in the mean size of fish landed at the major ports (see Appendix 3), a decline in the mean length of the redfish catch is apparent for all ports for which data are available. (Eden is an exception to this result, as catches are known to be significantly sorted with the larger fish only being consigned to the Sydney Market).

Discussion

Estimation of Fishing Mortality

Tag/recapture studies are generally considered to be one of the best direct methods of obtaining estimates of fishing mortality rates for exploited fish stocks. However, the scarcity of reports in the recent scientific literature of tagging studies which have resulted in useful estimates of population mortality parameters testifies to the very real practical difficulties which are encountered in such studies. In the current study, some of these difficulties have been overcome, but there are still a number of uncertainties which must be considered in the interpretation of the results.

The major aim of the redfish tagging study was to estimate the rate of fishing mortality applicable to the redfish stock, and to determine if fishing mortality contributes significantly to the very high rate of total mortality which has been estimated for the stock. All methods of calculating mortality rates from the results of tagging studies involve a number of assumptions. The assumptions made in this study, and their effect on the reliability of the conclusions, are as follows:

i) Sufficient numbers of fish were tagged to ensure a reasonable level of recaptures, and the tagged fish were proportionately distributed throughout the whole population: In the project proposal it was anticipated that approximately 25,000 fish would be tagged per year, and this figure was in fact achieved. Efforts were made to distribute the tagged fish throughout the range of the fishery for redfish, and roughly in proportion to abundance as reflected by fishing effort expended and commercial catches.

ii) The size range of fish tagged was the same as that in the population being studied: Redfish to be tagged were selected from trawl catches according to the condition of the fish - the size distribution of fish tagged was very similar to that of the commercial catch and the results therefore apply only to that portion of the redfish stock recruited to the commercial fishery.

iii) Tagged fish were assumed to have the same survival rates as untagged fish and to exhibit the same patterns of behaviour and movement: Implicit in this assumption is that tagging did not cause fish to be more (or less) likely to be recaptured, and it seems unlikely that the anchor tags used in this study would result in such an effect. However, if the mortality rate of tagged fish was greater than that of untagged fish for the duration of the study, then it is likely that the total mortality rate has been overestimated (but the estimate of fishing mortality rate may not necessarily be biased).

iv) It was assumed that the initial mortality caused by the tagging procedure could be estimated: And therefore, that the number of tagged fish alive at the start of the study was accurately known. The reliability of the estimate of fishing mortality depends directly on the extent to which this assumption is satisfied.

v) It was assumed that there was no loss of tags from tagged fish: A continuous loss of tags from tagged individuals over the study period would produce the same effect as an increased mortality rate i.e. would lead to a biased estimate of the total mortality rate, but not necessarily the fishing mortality rate. Loss of a proportion of tags very soon after tagging would have the same effect as initial mortality, reducing the number of tagged fish in the population and leading to bias in the estimate of the fishing mortality rate.

vi) It was assumed that the proportion of recaptured tagged fish which escaped detection (or were not reported) could be reliably estimated: Non-reporting of recaptured tagged fish can significantly bias estimates of the fishing mortality rate. In this study, where the majority of the catch passes through a central marketing outlet, it is considered that the reporting rate has been reliably estimated. Bias due to non-reporting can therefore be minimised by applying a correction factor to the number of recaptures reported.

The implications of each of these assumptions are now discussed in relation to the results of the study:

Clearly, there was not complete homogeneous mixing of the tagged fish throughout the whole stock, as evidenced by the different recapture rates of groups of redfish tagged at different times and locations. These differing recapture rates appear to result from a combination of the schooling habits of the fish and variations in vulnerability on both geographic and temporal scales. Such variability could also explain the observed differences in recapture rates and mean times at liberty between fish tagged aboard commercial trawlers and those tagged aboard the research vessel *Kapala*. However, tagged fish were distributed throughout the range of the fishery, and the results of the tagging study indicate a significant degree of mixing within the geographic boundaries of the stock. There is no reason, therefore, to suggest that the tagged fish were more (or less) vulnerable to being captured than untagged fish.

Various authors (e.g. Eames and Hino, 1983) have remarked on the need to ensure that the 'T bar' anchor is properly positioned behind the pterygiophores, and it appears that satisfactory retention of the tags is obtained if this condition is met. Carline and Brynildson (1972) found 94-98% retention of FD-67 tags by 16-19 cm long brook trout over a period of seven months, while Ebener and Copes (1982) found a retention rate of about 80% for anchor tagged whitefish of 33-79 cm total length which were at liberty for two to three years. These figures contrast with the more rapid shedding of anchor tags by barramundi less than 35 cm in length, where a tag loss rate of 17% over a period of 100 days was found (Davis and Reid, 1982), and by 30-100 cm striped bass where 58% of tags were shed during the first year (Dunning *et al*, 1987). However, all these studies were carried out on freshwater or riverine species. Few estimates of tag shedding rates have been reported for deepwater demersal marine species similar to redfish. Leaman *et al* (1979) interpreted the results of double tagging of Pacific cod *Gadus macrocephalus* to indicate no significant shedding of anchor tags over a period of 12 months. In the present study, care was taken to ensure correct placement of the anchors behind the pterygiophores, and redfish have a heavy bone structure which provides good anchorage for this type of tag. Redfish held in cages in the tagging mortality experiment showed no shedding of anchor tags during a period of 7 days after tagging. As no estimate of long term shedding rate was available, it has not been incorporated in the analysis of the returns.

The maximum period at liberty observed for tagged redfish compares favourably with other tagging studies which have been reported in the literature. Ebener and Copes (1982) reported times at liberty of 3 to 4 years for anchor tagged whitefish in Lake Michigan, however the maximum period at liberty recorded for anchor tagged striped bass released in the Hudson River was only about 1 year (Dunning *et al*, 1987). In Australian studies, Smith and Rowling (1986) observed a maximum period at liberty of just over 3 years for tagged jackass morwong (this has since been extended by a recent recapture to a maximum period at liberty of just over 5 years), while Pepperell (in press) found maximum periods at liberty of about 300 days for small yellowtail kingfish tagged by recreational fishermen with anchor tags. Russell and Garrett (1988) report a maximum period at liberty of 1299 days (3.5 years) for tagged juvenile barramundi, however it is not clear if this fish was tagged with an anchor or a dart tag.

The mean time at liberty found for tagged redfish was over 360 days. This, together with the (expected) exponential decline in the number of recaptures reported for successive 100 day intervals, suggests that tag loss or long term increased mortality of tagged fish are not serious problems. The increase in recaptures between 200 and 300 days after tagging (Table 1) may be evidence of the 'recruitment' effect referred to by Paulick (1963, p 50), which is thought to be due to behavioural effects delaying the return to full availability of tagged fish, however the result for this period is also strongly influenced by the recovery over a short period of 8 tagged fish from the small number tagged off Bermagui. The estimate of total mortality rate from the results of the tagging study (Z = -1.2) is within the range previously estimated by catch curve analysis, which also supports the conclusion that the results of the tagging study are not subject to undue bias due to long term increases in mortality of tagged fish or tag shedding.

The consistency of the results of the tag seeding experiments supports the conclusion that, although low, the reporting rate for recaptured tagged fish has been adequately estimated. Therefore, the major factors influencing the accuracy of the estimate of the fishing mortality rate are the level of initial mortality and whether or not there was any initial tag shedding. Study of fish held in enclosures in shallow water for one week provided estimates of short-term handling and tagging mortality, however it was not possible to directly estimate the mortality rate applying to fish released back into their environment immediately after tagging.

The results of the analysis of tag returns indicates that, although large temporal and spatial variations probably occur in fishing mortality of redfish, the stock as a whole is subject to an instantaneous fishing mortality rate of about 0.04. Although the accuracy of this estimate depends directly on an (assumed) initial mortality/tag shedding rate of 20%, sensitivity analyses indicate that the relative magnitude of this result is not critically dependent on the initial mortality estimate. If it is assumed that 50% of the tagged fish die or shed their tags soon after tagging, the resulting estimate of F is only 0.059, which is still less than 10% of the estimated total mortality rate.

The highest observed recapture rate for any of the releases yields an estimate of F of 0.187, however the corresponding estimate of Z is only 0.693, which is at the extreme lower end of the previously estimated range of Z for redfish. The small numbers of recaptures involved in this analysis also reduce the level of confidence in the resulting estimate of F. It is therefore concluded that, based on the tagging results, the most likely value of F for redfish lies within the range 0.04 - 0.06.

Movements and Growth of Redfish

Secondary aims of the tagging study were to determine movements or migrations of redfish, to aid in delineation of stock boundaries, and to provide independent verification of the previously reported growth estimates for the species.

Although exact locations of recapture could not be determined for most of the reported recaptures, the majority could be sourced to the area surrounding a particular port. The results indicated significant movement within the study area. The majority of movements were in a southerly direction, however this is likely to be due to the fact that more tagged fish were released in the northern segment of the range. No pattern in recaptures indicating regular migrations within the stock was found. The results are consistent with the existence of a single unit stock of redfish within the study area. Redfish are known to range both north and south of this area, however redfish abundance is quite low on grounds south of about Gabo Id (Wankowski and Moulton, 1986) and the same is apparently the case north of about Crowdy Head (Gorman and Graham, 1979). The tagging study covered almost the entire range of redfish on the east coast of Australia, and the results of the study should therefore be applicable to the east coast stock as a whole. {*n.b.* The same species Centroberyx affinis has also been reported from waters of the Great Australian Bight (Last *et al*, 1983) and it would seem on current evidence that redfish from this area should be considered as a separate stock to those off the east coast.}

It has been accepted for many years that tag/recapture studies provide a useful means of validating ageing techniques which rely on assessment of age from bony structures such as otoliths or scales. Indeed, tag/recapture was the major means of validation recommended by Beamish and McFarlane (1983, p741). However, Francis (1988) has recently shown that estimates of growth parameters derived from the results of tag/recapture studies are not necessarily comparable to estimates derived from study of hardparts, and he recommends that such comparisons be avoided until better models become more widely used. It appears that tagging can be usefully employed for validating the interpretation of patterns on hardparts when used in conjunction with fluorescent labelling of the parts at the time of tagging. Such work would require a dedicated and properly designed experiment, and was not within the scope of the current study.

In this study, measurement of fish lengths at tagging and recapture was subject to a number of errors. The majority of fish tagged were very lively, and they were measured quickly with a minimum of handling. Also most tagging was done at night. These factors made it difficult to obtain accurate measurements. Recaptured fish were generally iced aboard the catching vessel, and most tagged fish had been frozen prior to being returned. It is likely that such handling would have resulted in a significant (and variable) degree of shrinkage. Given that otolith studies indicate growth rates of only 2 - 2.5 cm per year for 20 -25 cm fish, and the mean time at liberty observed for tagged redfish was only just over 1 year, it is perhaps not surprising that a large proportion of the recaptured fish exhibited little measurable change in length. In light of the many possible sources of error mentioned above, the results for fish which showed evidence of growth lend a good deal of support to the reported observation from otoliths that redfish are relatively slow growing.

Comparison with Commercial Fishery Data

The commercial fishery data are presented to provide a background against which the results of the tagging study can be assessed. Redfish have comprised a significant proportion of the catch since the inception of the trawl fishery in 1915, however in the years prior to the second world war much of the redfish catch was discarded due to low market acceptability (Blackburn, 1978). Redfish were landed in increasing quantities as tiger flathead catches declined in the late 1940's and the anual catch of redfish peaked at over 2300 tonnes in 1949 (Houston, 1955). Blackburn (1978) found evidence of a decline in mean length of the redfish catch and a decline in average redfish catch per trawler during the 1950's. These declines were contemporaneous with the highest annual levels of fishing effort and were attributed by Blackburn to the impact of exploitation on the redfish stock. There is evidence that the condition of the redfish stock improved after the steam trawlers ceased operating in the late 1950's, however the fishery was then dominated by Danish seiners which did not catch significant quantities of redfish. Landings did not increase again until the early 1970's, when modern diesel powered trawlers entered the fishery. Redfish were taken as an incidental catch of fishing operations targeted at gemfish during the winter months, however prices received for redfish were only low (averaging 20c/Kg) and gluts of unsold fish occurred frequently. In the late 1970's, as market acceptance increased, redfish began to be specifically targeted, and significant catches were landed on a year round basis.

The recent decline in mean length of the redfish catch may have been influenced by increased retention of smaller fish, which were previously discarded. Results of mesh selectivity studies (Diplock, 1984) suggest a 50% retention length of at least 20 cm LCF for redfish caught in legal otter trawls (minimum codend mesh size 90 mm); therefore the component of the catch less than 20 cm which was obviously sorted from catches in the years 1974/75 to 1976/77 was probably not great. Small fish of 15 - 20 cm LCF began appearing in marketed catches in 1977/78, and during subsequent years it is likely that the incidence of catch sorting, and its impact on the measured length frequency, declined substantially. Additionally, the modal length of the catch declined from 23 - 24 cm LCF in the years prior to 1980/81, to 21 - 22 cm in recent years. All these factors indicate that the decline in mean length of the landed catch has not resulted simply from marketing of small fish that were previously discarded, and probably indicates a real decline in the abundance of larger fish.

CPUE also showed a declining trend over the period 1980 - 1985, although the significance of this result is difficult to ascertain because the measure of CPUE (catch per trawler-ton-month) is not very sensitive and may mask significant changes in targeted daily fishing effort.

The data available for the commercial fishery certainly suggest that there have been significant changes in the composition of the redfish stock since catches increased in the mid 1970's. The relatively low rates of fishing mortality suggested by the tagging study would probably not be expected to have led to a major impact on the stock. However, redfish are apparently a long lived, slow growing species whose schooling habit may result in increased vulnerability to fishing at certain times. To more fully analyse the changes in the composition of the redfish stock, and allow a better understanding of the likely effects of a fishing mortality rate of 0.04 - 0.06, it is recommended that an age structured model of the redfish stock be developed. This could be done using data currently available on age composition, length frequency distributions and commercial catches of redfish, and would allow a more quantitative assessment of the state of the redfish stock, and the conditions required to produce optimum yield from the stock.

Summary of Conclusions.

The conclusions which can be drawn from the results of the tagging study are as follows:

i) Stock Identity - The area between Crowdy Head and Eden appears to support a single unit stock of redfish, within which there is a significant degree of random internal movement.

ii) Growth - Accurate estimates of the growth parameters of redfish are difficult to make from the results of the tagging study. The findings, although limited, are consistent with redfish having a relatively slow growth rate, similar to that indicated by previous studies of growth using otoliths.

iii) Total Mortality - The results of the tagging study confirm that the redfish stock is subject to a high rate of total mortality, estimated to be in the vicinity of 70% per annum.

iv) Fishing Mortality - The results of the tagging study indicate that fishing mortality rate for the redfish stock is low in comparison with the rate of total mortality. While there is evidence that localised fishing mortality rates may be as high as F = 0.19, the fishing mortality rate applicable to the redfish stock as a whole appears to be lower, in the range F = 0.04 - 0.06.

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References

Allen, K.R. 1984 Report on 'Workshop on Trawl Fish Resources, Sydney 27-29 March 1984'. Annex A, Minutes 43rd Meeting, South Eastern Fisheries Committee, 18th February 1985 : Dept. Primary Industry, Canberra.

Beamish, R. J. and McFarlane, G. A. 1983 The forgotten requirement for age validation in fisheries biology. *Transactions of the American Fisheries Society* 112(6): 735-43

Blackburn, M. 1978 Changes in size composition, indicative of stock conditions in the New South Wales trawl fishery, from 1945/46 to 1966/67. *CSIRO Division of Fisheries and Oceanography Report No.* 97, 76 pp.

Boden, C.E. 1966 Proposals regarding measurements of Australian fishing vessels. In "Proceedings of the Technical Meeting on Fishing Boats, Broadbeach, Queensland, March 1966" (Fisheries Branch, Dept. Primary Industry, Canberra).

Carline, R.F. and Brynildson, O.M. 1972 Effects of the Floy anchor tag on the growth and survival of brook trout (Salvelinus fontinalis). *Journal of the Fisheries Research Board of Canada* **29**: 458-60

Crossland, J. 1976 Snapper Tagging in North East New Zealand, 1974: Analysis of methods, return rates, and movements. *New Zealand Journal of Marine and Freshwater Research* 10(4): 675-86

Davis, T.L.O. and Reid, D.D. 1982 Estimates of tag shedding rates for Floy FT2 and FD67 anchor tags in Barramundi, Lates calcarifer (Bloch). *Australian Journal of Marine and Freshwater Research* **33** : 1113-17

Diplock, J.H. 1984 A synopsis of available data on Redfish Centroberyx affinis from NSW waters. Working Papers, D.P.F.R.G. Workshop on Trawl Fish Resources, Sydney 27-29 March 1984, South Eastern Fisheries Committee : Dept. Primary Industry, Canberra.

Dunning, D.J., Ross, Q.E., Waldman, J.R. and Mattson, M.T. 1987 Tag retention by, and tagging mortality of, Hudson River striped bass. *North American Journal of Fisheries Management* 7: 535-8

Eames, M.J. and Hino, M.K. 1983 An evaluation of four tags suitable for marking juvenile chinook salmon. *Transactions of the American Fisheries Society* 112: 464-68

Ebener, M.P. and Copes, F.A. 1982 Loss of Floy anchor tags from lake whitefish. *North American Journal of Fisheries Management* 2: 90-3

Francis, R.I.C. 1988 Are growth parameters estimated from tagging and age-length data comparable? *Canadian Journal of Fisheries and Aquatic Sciences* 45: 936-42

Gorman, T. B. and Graham, K. J. 1979 FRV Kapala Cruise Report No. 53. New South Wales State Fisheries, Sydney.

Gulland, J.A. 1969 Manual of methods for fish stock assessment. I. Fish population analysis. *F.A.O. (U.N.) Manuals in Fisheries Science No.* 4, 154 pp.

Houston, T. W. 1955 The New South Wales trawlfishery: review of past course and examination of present condition. *Australian Journal of Marine and Freshwater Research* 6: 165-208

Jones, R. 1977 Tagging : Theoretical methods and practical difficulties. In 'Fish Population Dynamics' Ed. by J. A. Gulland. J. Wiley and Sons Ltd, Chichester, pp 46-66

Kleiber, P., Argue, A.W. and Kearney, R. E. 1987 Assessment of Pacific skipjack tuna (Katsuwonus pelamis) resources by estimating standing stock and components of population turnover from tagging data. *Canadian Journal of Fisheries and Aquatic Sciences* 44: 1122-34

Last, P. R., Scott, E. O. and Talbot, F. H. 1983 Fishes of Tasmania. Tasmanian Fisheries Development Authority, Hobart. 563 pp.

Leaman, B. M., Nagtegaal, D. A. and Smith, J. E. 1979 A pilot tagging study of pacific cod in the Strait of Georgia, January 17 - February 2, 1978. *Canadian Fisheries and Marine Service Manuscript Report No.* 1516, 57 pp.

Paulick, G. J. 1963 Estimates of mortality rates from tag recoveries. *Biometrics* **19**: 28-57

Pepperell, J. G. (in press) Australian cooperative gamefish tagging program, 1973-1987 : status and evaluation of tags. Procedings of the International Symposium and Educational Workshop on Fish-Marking Techniques, University of Washington, Seattle, 27 June - 1 July, 1988. American Fisheries Society.

Rowling, K.R. 1983 N.S.W. trawl fish tagging study successful. *Australian Fisheries* **42**(1): 14-16

Russell, D. J. and Garrett, R. N. 1988 Movements of juvenile barramundi, Lates calcarifer (Bloch), in north-eastern Queensland. *Australian Journal of Marine and Freshwater Research* **39**: 117-23

Smith, D.C. and Rowling, K.R. 1986 Analysis of jackass morwong tagging experiments. *N.S.W. Department Agriculture, Fisheries Research Institute, Cronulla, Internal Report No.* 10, 17 pp.

Wankowski, J. W. and Moulten, P. L. 1986 Distribution, abundance and biomass estimates of commercially important demersal fish species in eastern Bass Strait, Australia. *Victorian Department of Conservation, Forests and Lands, Marine Science Laboratories Technical Report No.* 62, 57 pp.

Whitelaw, A.W. and Sainsbury, K.J. 1986 Tag loss and mortality rates of a small tropical demersal fish species Lutjanus carponotatus (Pisces:Lutjanidae) tagged with dart and anchor tags. *Australian Journal of Marine and Freshwater Research* **37** : 323-7

	Area	Date	No. of Tagged Fish Released	Days at Liberty 1-100	101-200	201-300	301-400	401-500	501-600	601-700	701-800	801-900	901-1000	1001-1100	1101-1200	1201-1300	Total Recaptures to Dec.'89	(%)
Kapala Tagged Fish	Newcastle	Feb-Oct'86	2276	1	2												3	0.13
	Sydney	""	11411	9	13	17	4	4	2	5		1				1	56	0.49
	Wollongong	""	6932	5	3	2		3	2	1						1	17	0.25
	Ulladulla	""	1776	3								1					4	0.23
	Kapala Total		22395	18	18	19	4	7	4	6		2				2	80	0.36
Commercial Trawler Tagged Fish	Wollongong	March '86	999	3	2	2	1		2								10	1.00
	Wollongong	Dec '86	2181														0	0
	Ulladulla	Dec '85	1224	2	1	1	1		1					2			8	0.65
	Ulladulla	Nov '86	2181			2			1	1							4	0.18
	Bermagui	Feb '86	536			8		1	1	1			2				13	2.43
	Eden	April '86	1293	1	2		6	1	1		3	2		6			22	1.70
	Commercial Total		8414	6	5	13	8	2	6	2	3	2	2	8			57	0.68
	TOTAL		30809	24	23	32	12	9	10	8	3	4	2	8		2	137	0.45

Table 1. Summary by area of the numbers of tagged redfish released, and recaptures during successive 100 day periods.

		Number Released	Number Reported Recaptured	Unadjusted Recapture Rate	Mean Time at Liberty (days)
Kapala Tagged Fish	Blue	11615	27	0.23%	221
	Yellow	10780	53	0.49%	318
	Combined	22395	80	0.36%	286
Commercial Tagged Fish	Blue	8414	57	0.68%	470
All Fish Tagged		30809	137	0.44%	362

Table 2. Comparison of recapture rates and mean times at liberty for different tag colours, and research vessel versus commercial trawler tagged redfish.

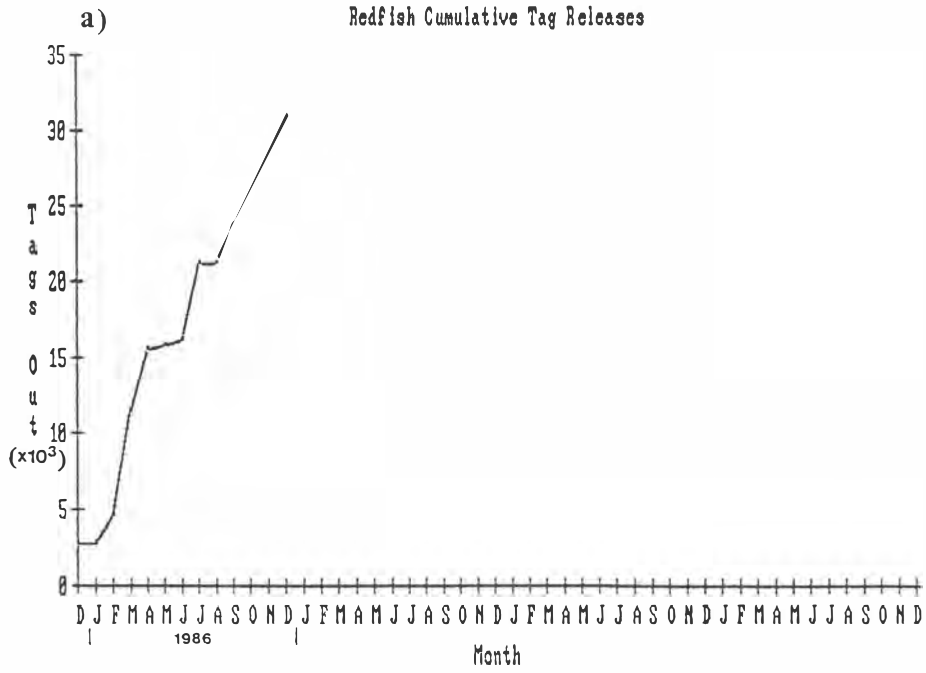
	Number of Recaptures Reported				
	Code 1	Code 2	Code 3	Code 4	Total
Kapala Tagged Fish	4 5.0%	7 8.7%	67 83.8%	2 2.5%	80
Commercial Trawler Tagged Fish	15 26.3%	2 3.5%	38 66.7%	2 3.5%	57
Total	19 13.9%	9 6.6%	105 76.6%	4 2.9%	137

Table 3. Distribution of recaptures of tagged redfish by location found.

Code 1: Tagged fish found aboard catching vessel.
Code 2: Tagged fish found at the point of landing prior to being consigned to market or otherwise sold or processed.
Code 3: Tagged fish found by buyers or filleters at the Sydney Fish Market.
Code 4: Other. Tagged fish recovered by amateur fisherman, professional handliner or at retail premises.

Date	Tag Colour	No. of Tagged Fish Seeded	No. Recaptures Reported	(%)
14.7.86	Blue	10	4	40%
11.9.86	Yellow	10	2	20%
2.10.86	Blue	10	2	20%
17.10.86	Yellow	10	0	0
14.1.87	Blue	9	1	11%
1.6.87	Blue	10	2	20%
23.9.87	Blue	10	4	40%
26.4.88	Blue	10	1	10%
Total		79	16	20.3%

Table 4. Results of tag seeding experiments conducted at the Sydney Fish Market to estimate the reporting rate for recaptured tagged fish.



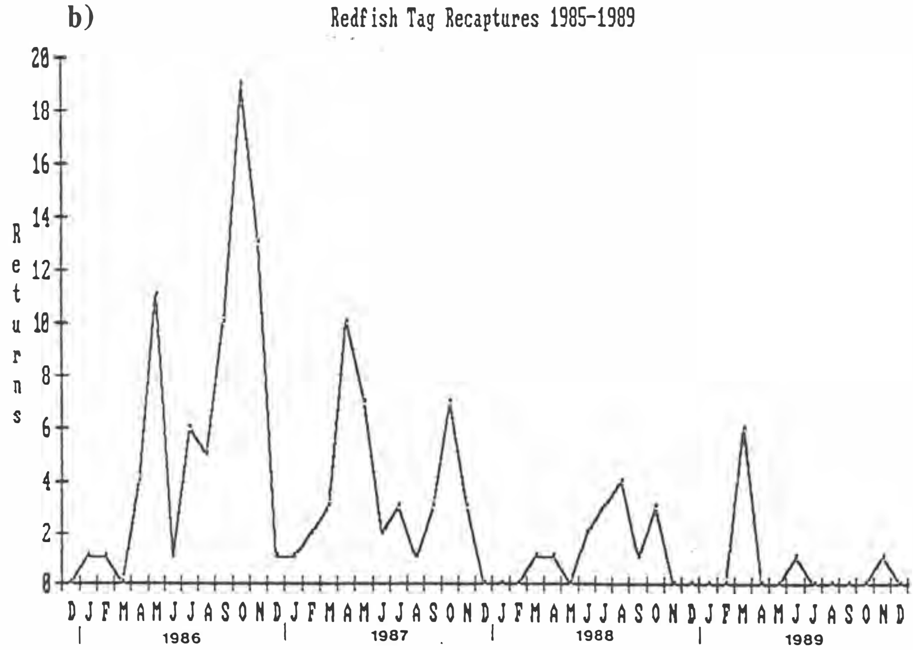


Figure 1. (a) Cumulative releases of tagged redfish, December 1985 to December 1986.

(b) Monthly distribution of recaptures of tagged redfish reported from January 1986 to November 1989.

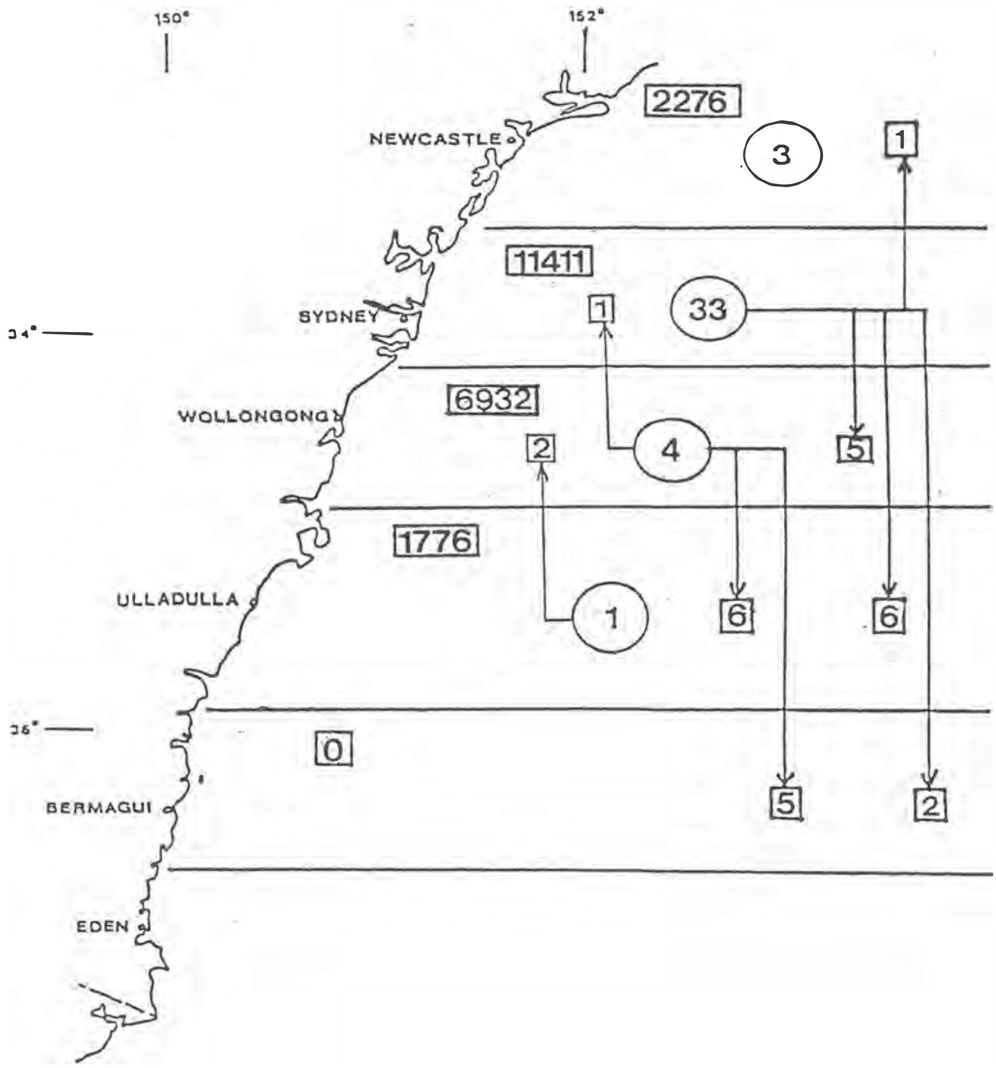


Figure 2. Number of tagged redfish released from FRV Kapala in each area (rectangles), and number of recaptures within the area of release (circles) and in other areas (squares).

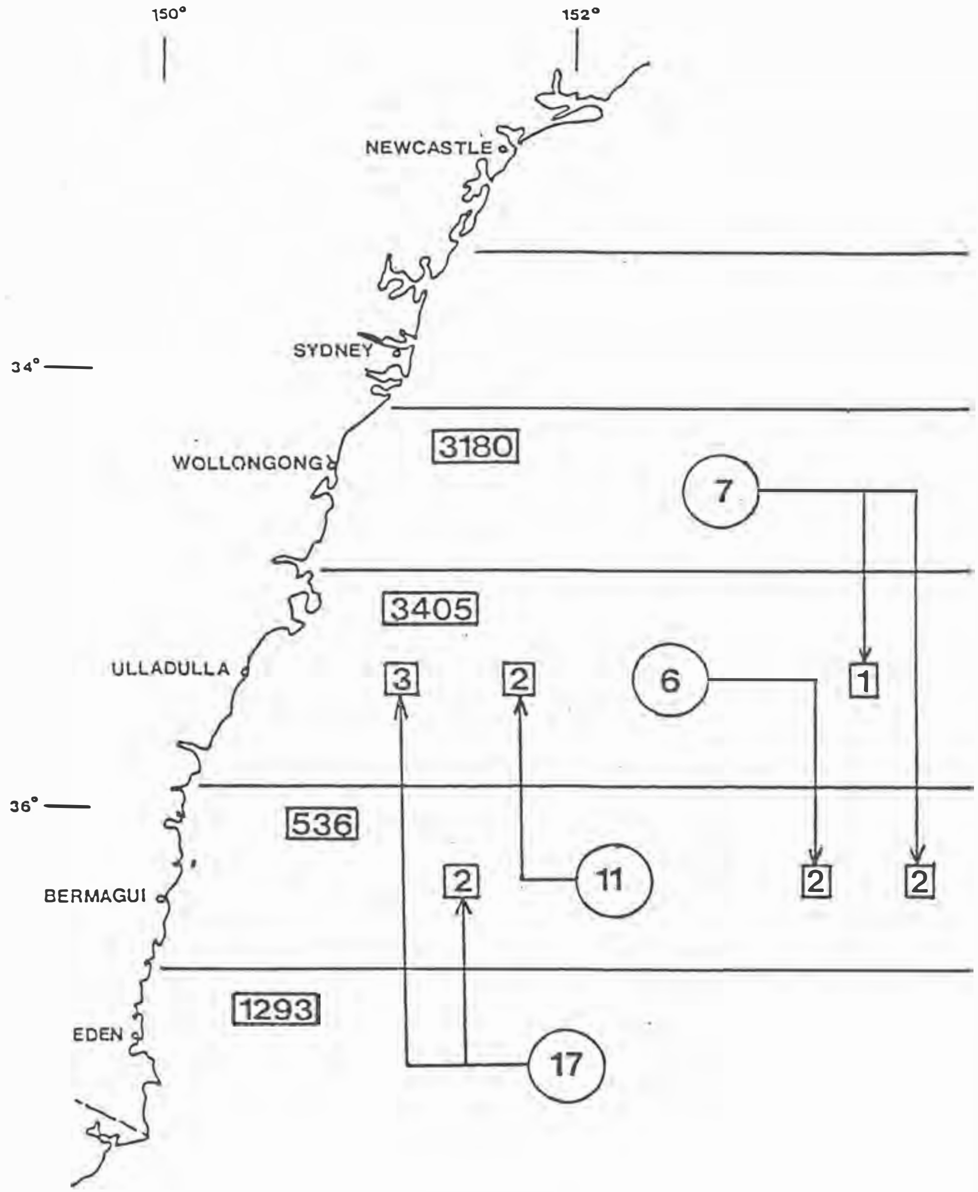


Figure 3. Number of tagged redfish released from commercial trawlers in each area (rectangles), and number of recaptures within the area of release (circles) and in other areas (squares).

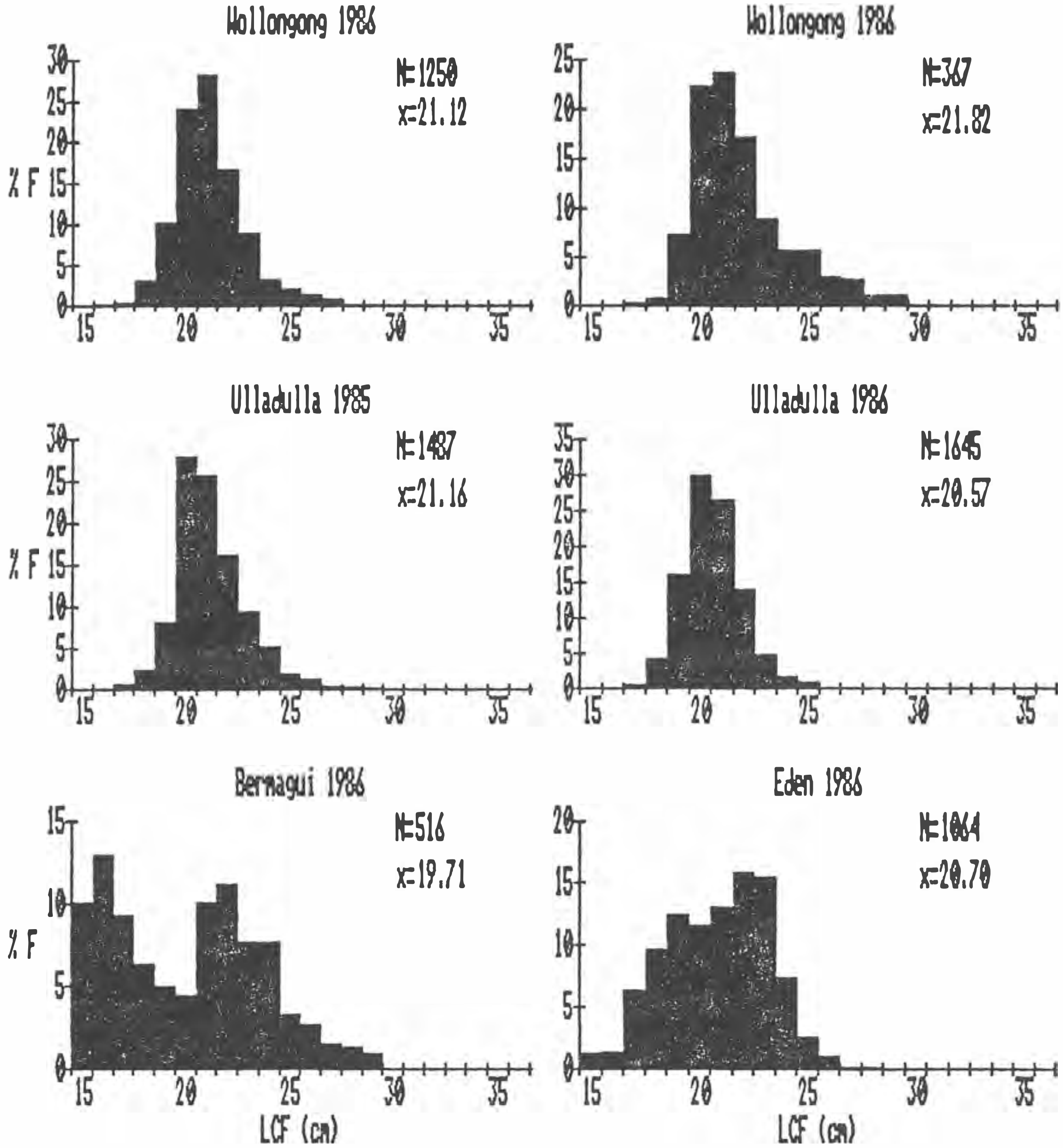


Figure 4. Length frequencies of redfish tagged from commercial trawlers.

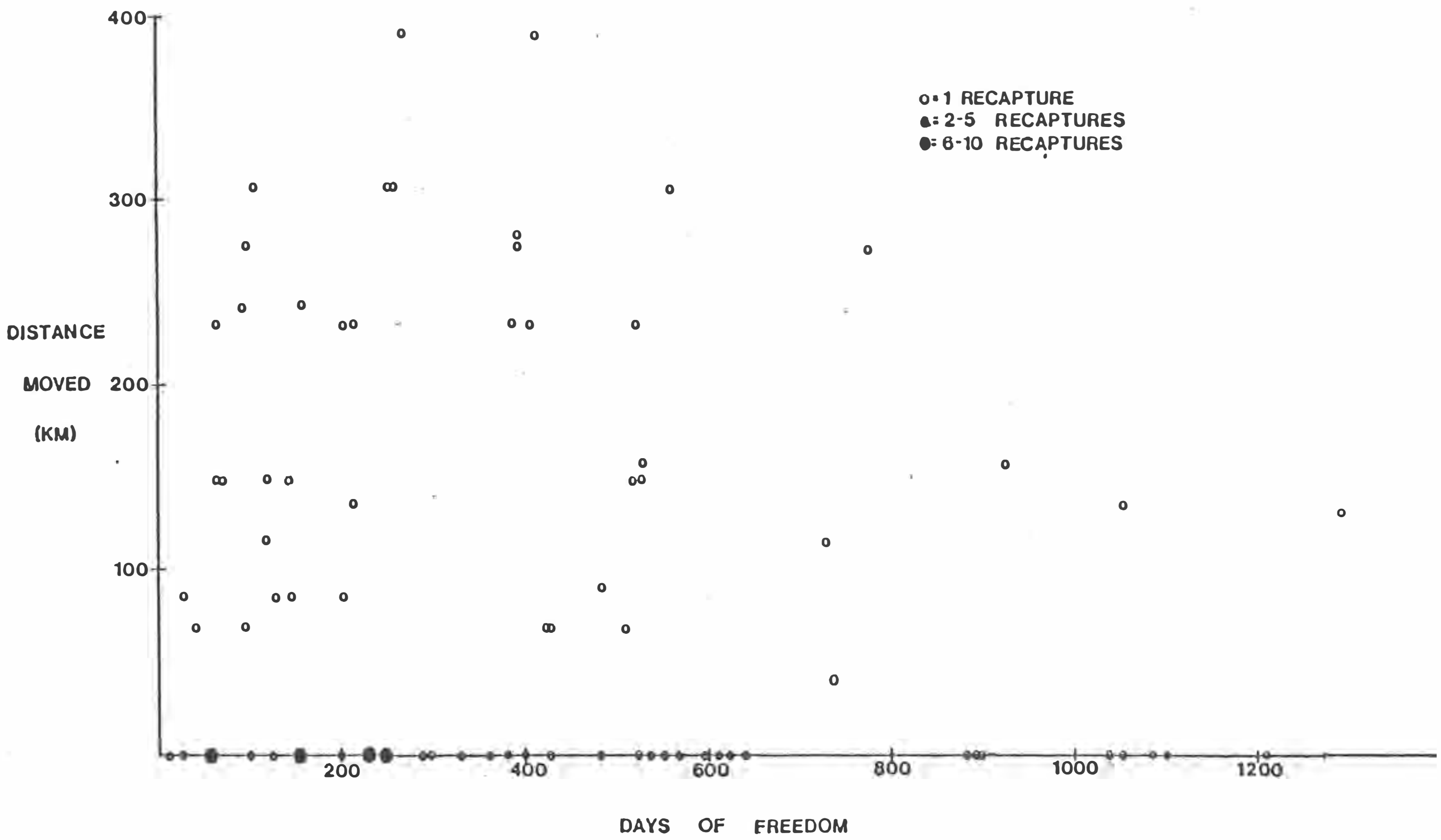


Figure 5. Approximate distances moved compared with time at liberty (days) for recaptured tagged redfish.

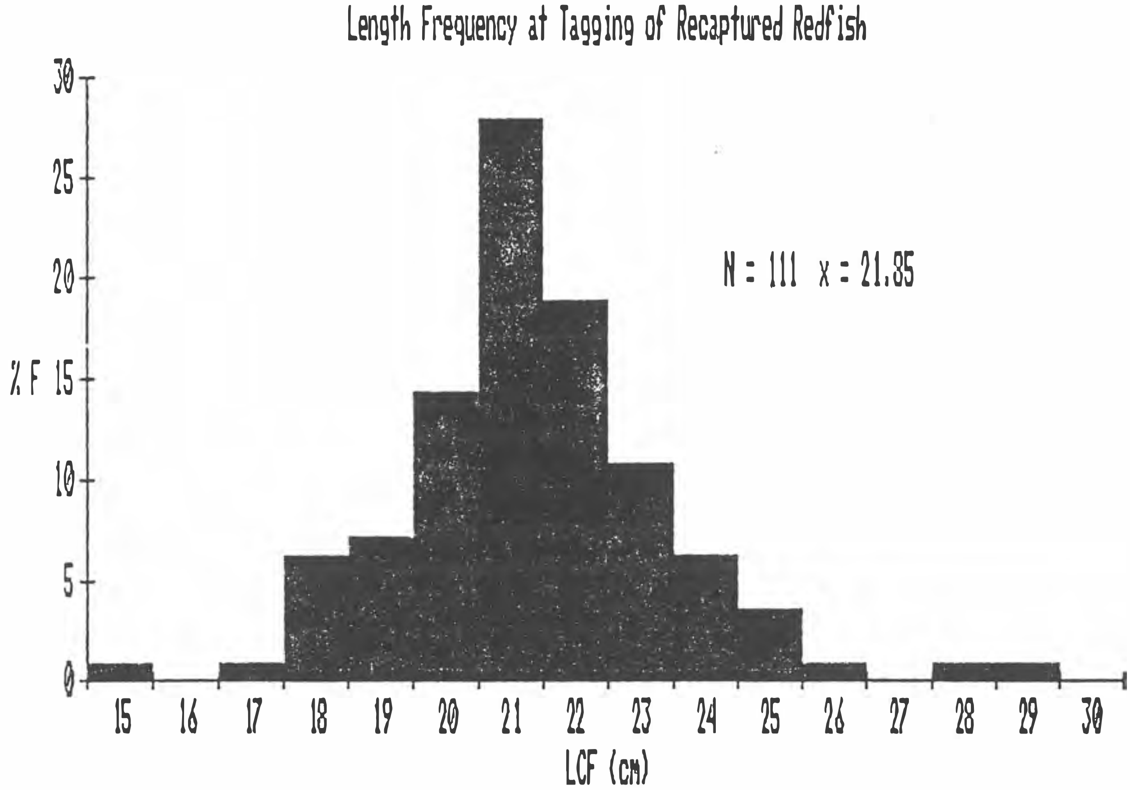


Figure 6. Length frequency (at tagging) of recaptured tagged redfish.

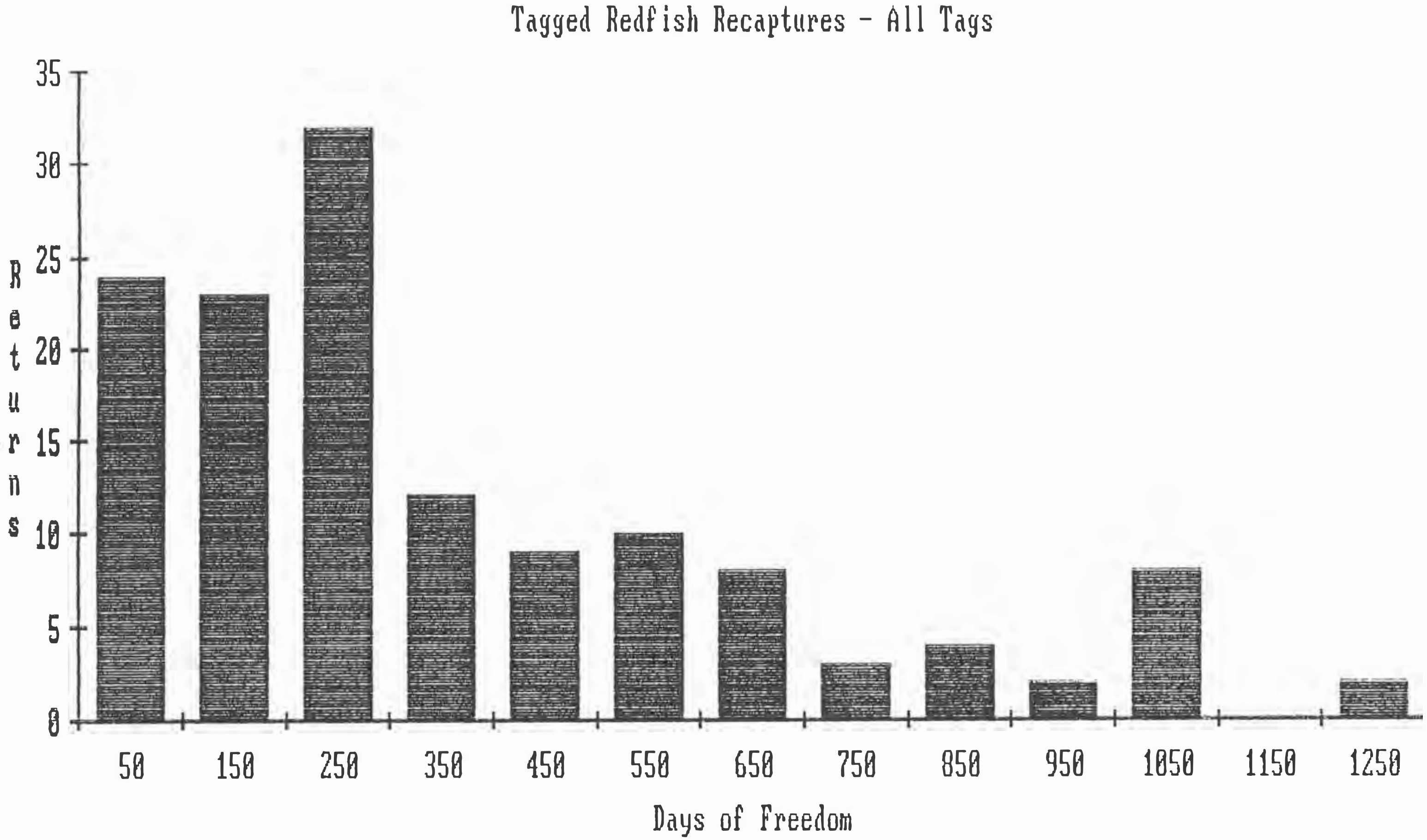


Figure 7. Distribution of times at liberty for recaptured tagged redfish, grouped into 100 day intervals.

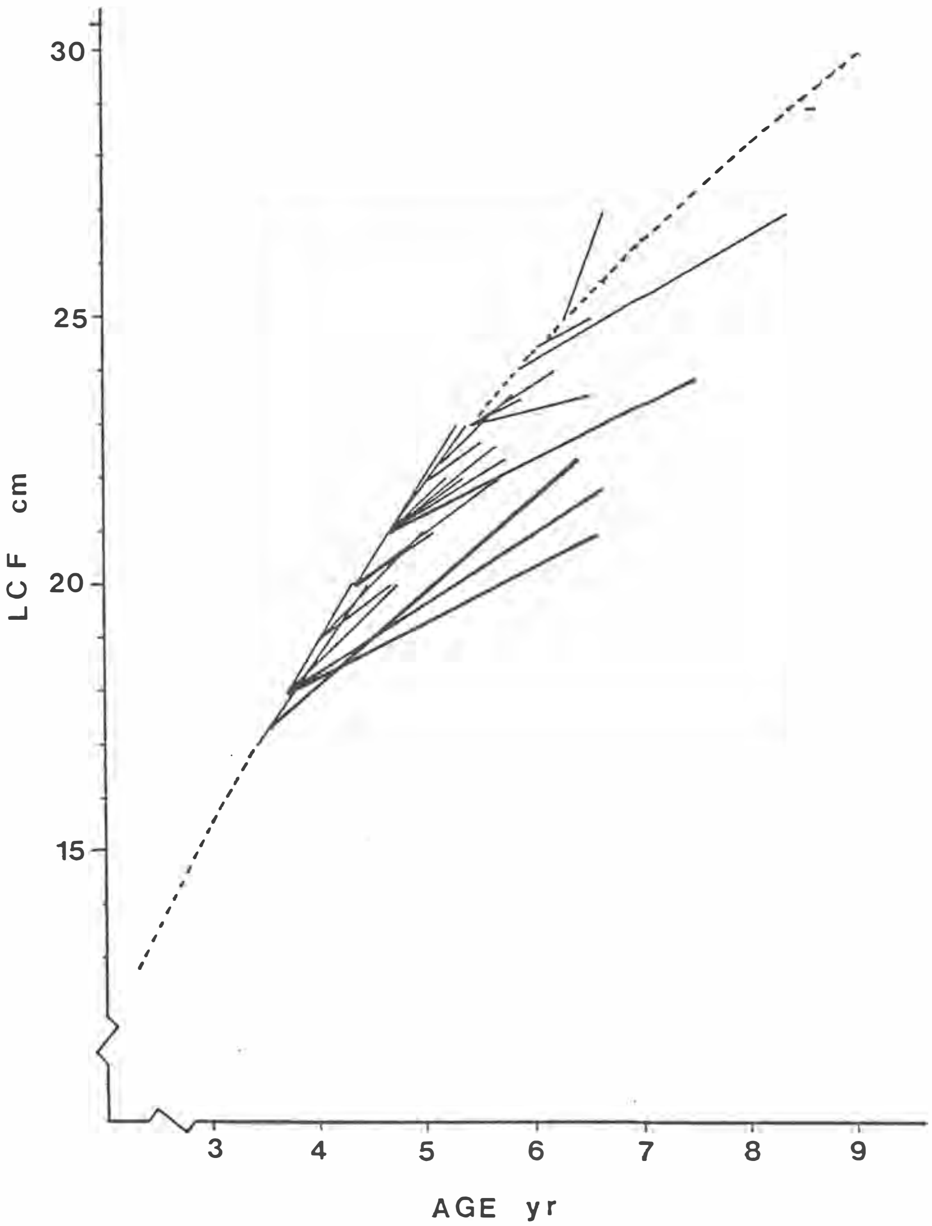
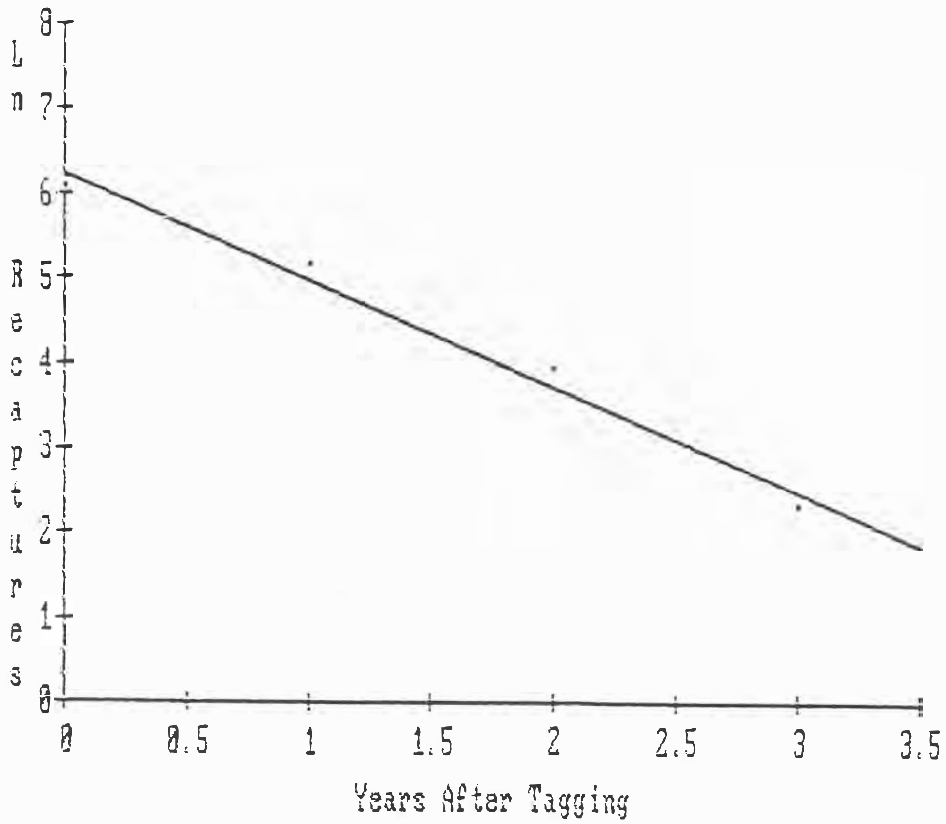


Figure 8. Comparison of observed length increments of recaptured tagged redfish (solid lines) with the von Bertalanffy growth curve calculated from otolith studies of female redfish (Diplock, 1984):

$$L_t = 40.35\ (i - e^{-0.146(t + 0.35)})$$

In each case the length of the fish at tagging was assumed to lie on the calculated growth curve.



	Category	Value
1	R-Square	0.9848
2	Adjusted R-Square	0.9771
3	Std. Err. of Prediction	0.2453
4	Correlation Coefficient	-0.992
5	Value of Coefficient A0	6.2214
6	Std. Err. of Coefficient A0	0.2052
7	T-Stat. of Coefficient A0	30.312
8	Value of Coefficient A1	-1.247
9	Std. Err. of Coefficient A1	0.1097
10	T-Stat. of Coefficient A1	-11.37

Figure 9. Plot of the logarithm of the number of recaptures of tagged redfish in successive 12 month periods after tagging, and the calculated linear regression.

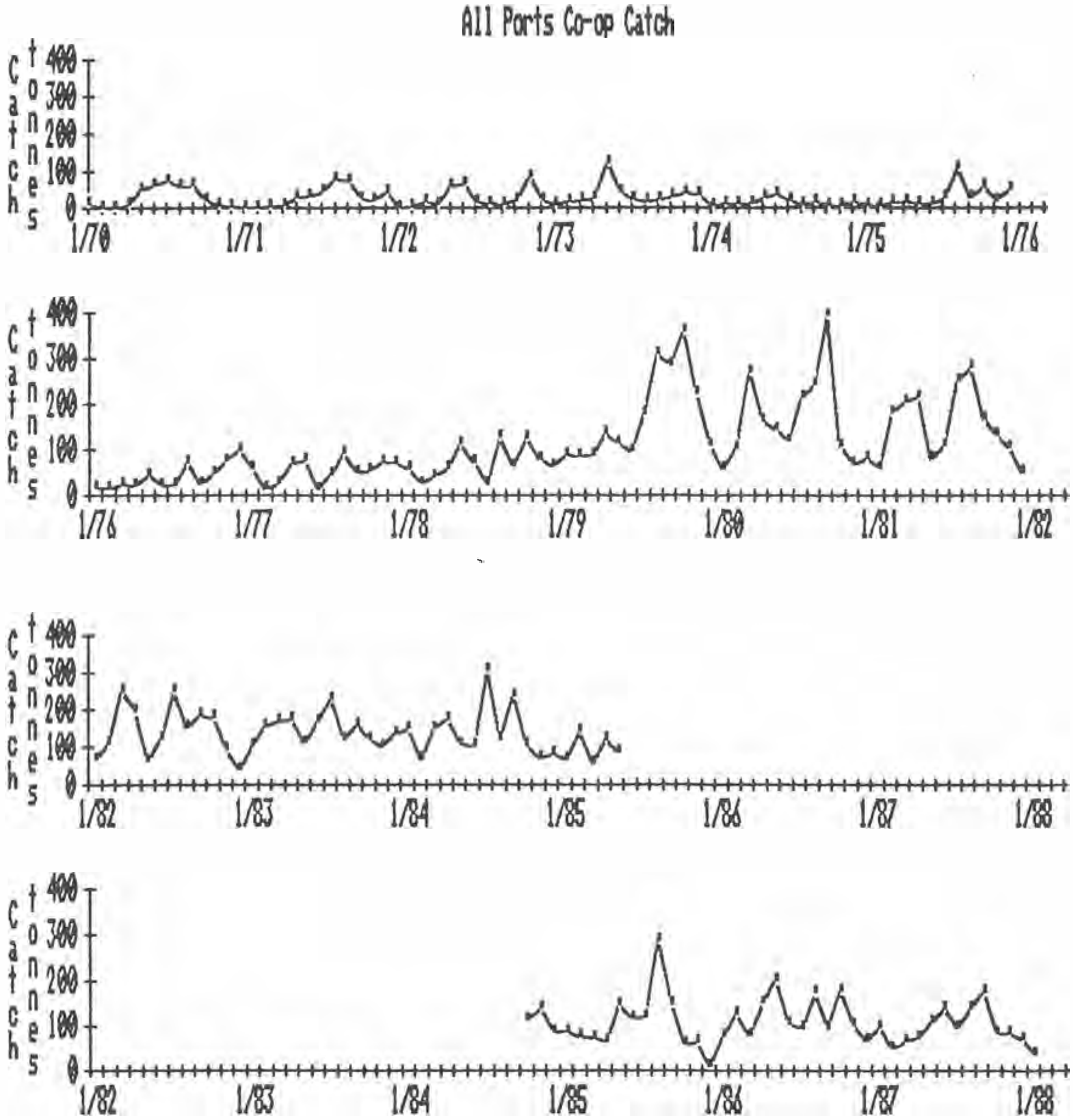


Figure 10. Monthly commercial catches (tonnes) of redfish from records of the main fishermen's co-operatives (1970-1985) and the NSW Fish Marketing Authority (1985-1988).

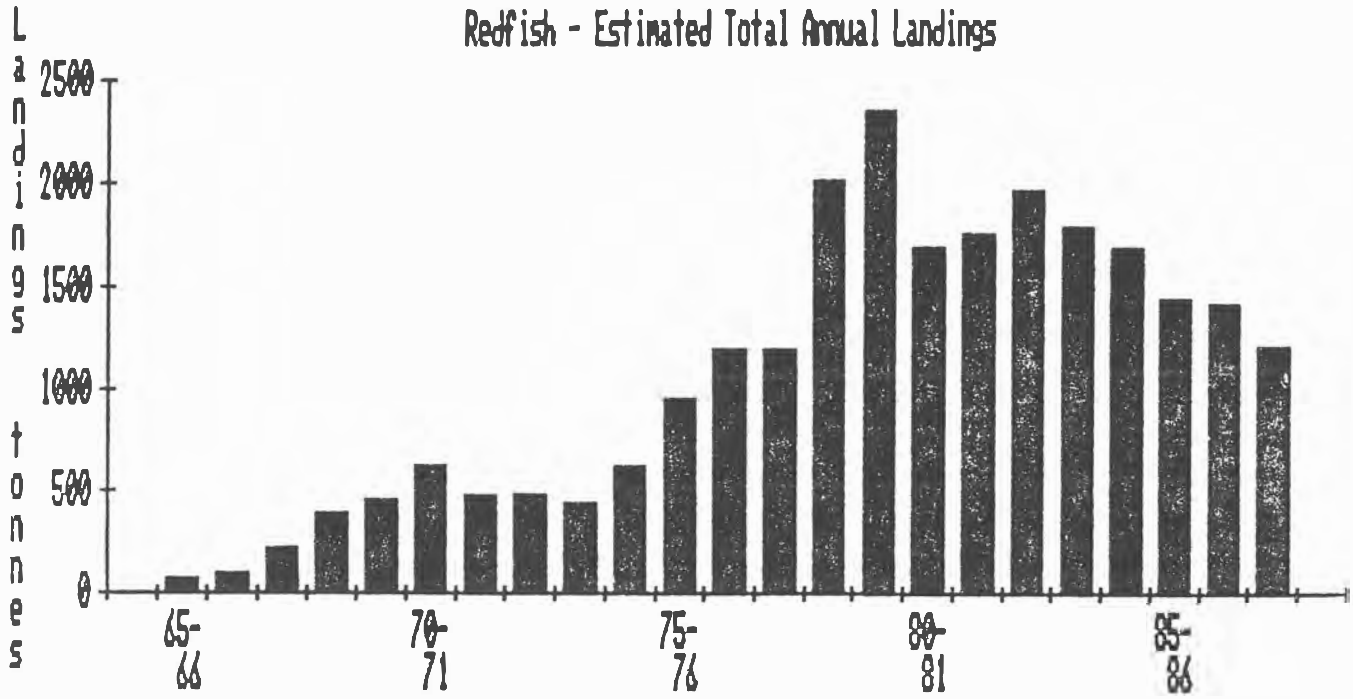


Figure 11. Estimated total annual landings (tonnes) of redfish in New South Wales, 1965/66 to 1987/88.

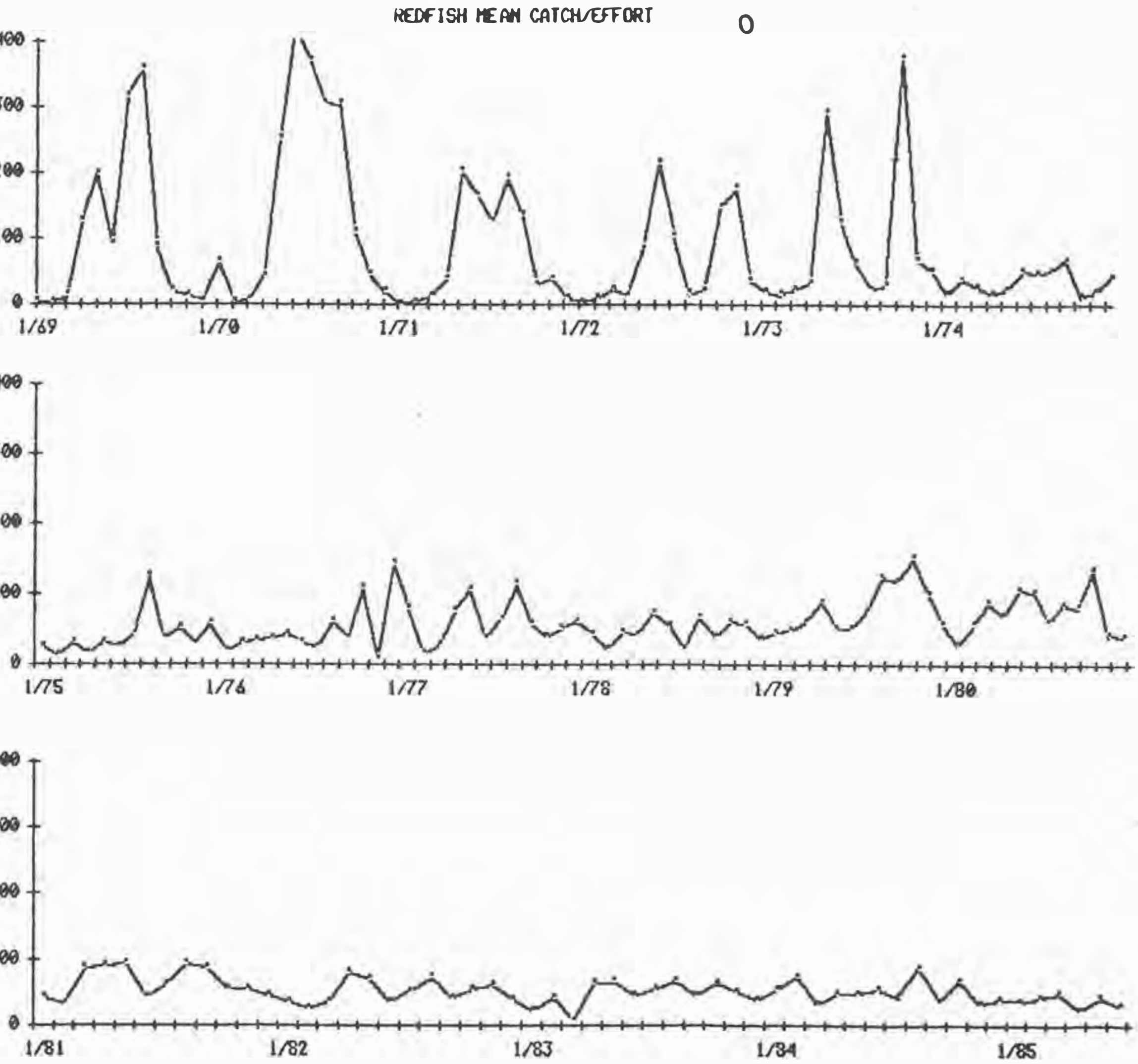


Figure 12. Monthly average catch per unit effort (Kg per trawler-ton-month) of redfish, 1969-1985. Data for the main ports are combined.

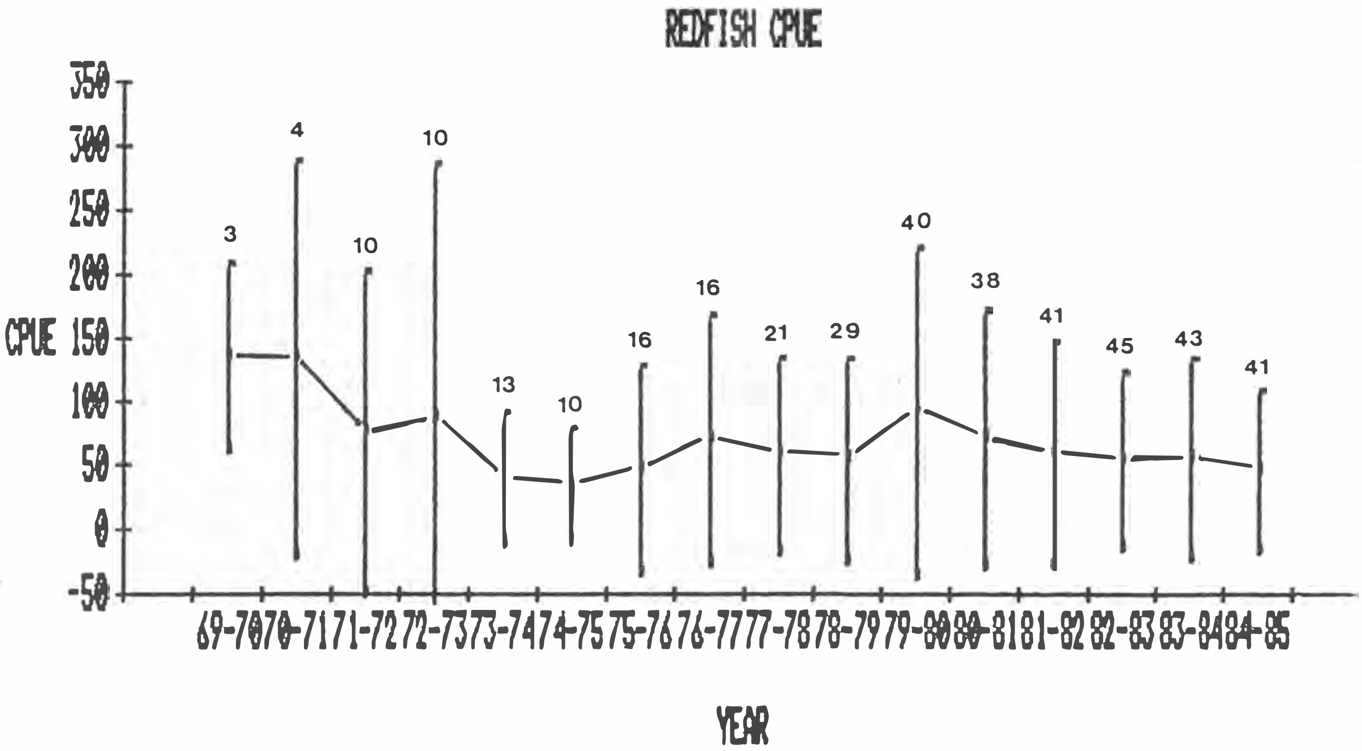


Figure 13. Mean annual catch per unit of effort (Kg per trawler-ton-month) of redfish, 1969/70 to 1984/85. Vertical bars denote one standard deviation about the mean, and the number of vessels for which data were available is shown for each year.

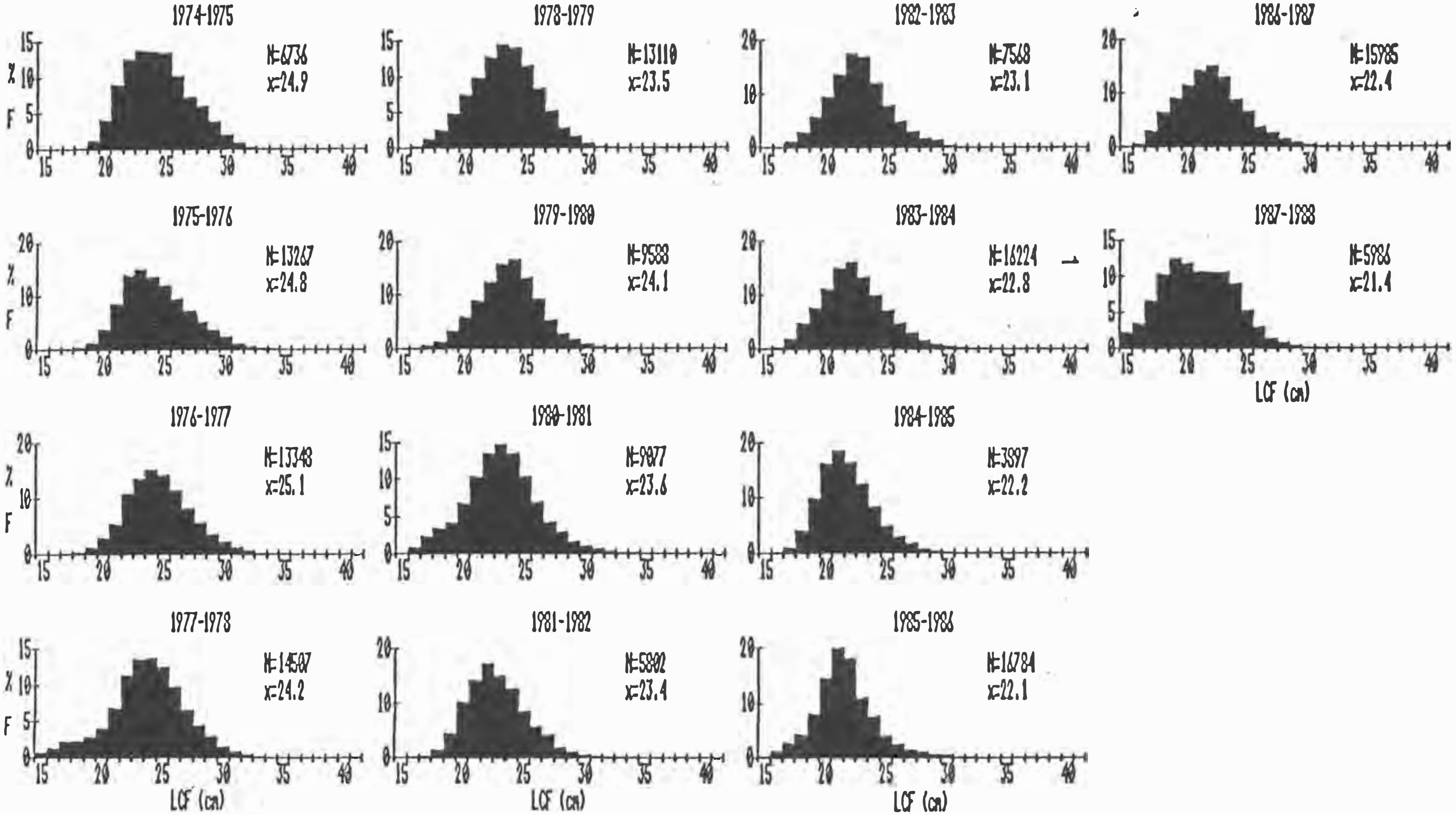


Figure 14. Annual length frequencies of the commercial catch of redfish, measured at the Sydney Fish Markets (all ports combined). Sample size (N) and mean length (x) are shown for each year.

APPENDIX 1

KAPALA CRUISE REPORT

NO.99

Division of Fisheries
Department of Agriculture New South Wales

KAPALA CRUISE REPORT NO. 99

by T.B.Gorman and K.J.Graham

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NEW SOUTH WALES

KAPALA CRUISE REPORT NO. 99

Report on redfish tagging conducted during Cruises 86-14 to 86-28 in June - October, 1986.

by T.B.Gorman and K.J.Graham

OBJECTIVE

To tag redfish (*Centroberyx affinis*) in shelf waters between Crowdy Head and Moruya.

(Redfish tagging by *Kapala* is a contribution by the Division of Fisheries to the redfish tagging program funded by the Fishing Industry Research Trust Account).

GEAR

* 28 m headline Boris box trawl rigged with a rock-hopper footrope, 50 m bridles and towed with 2.0 m Vee doors.

* 21 m headline Boris box trawl rigged with a rock-hopper footrope, 30 m bridles and towed with 1.8 m Vee doors.

REDFISH TAGGING METHODS

Most trawls were conducted at night. Trawling time ranged from 30 to 120 minutes, depending on the density of redfish on the ground; most trawls were for about 60 minutes. The catch was landed directly into deck tanks with circulating seawater and live redfish were quickly sorted into clean tanks. The redfish were then tagged and held for release, usually at the completion of the next trawl.

All redfish greater than 160 mm were tagged and measured (fork length, mm); redfish which did not survive capture, and other incidentally caught commercial species were also measured.

Blue coloured anchor tags were used. The tags were inscribed with N.S.W. FISH REWARD and a number; a reward of $5.00 is paid for returned tags (and preferably the fish), with details of size, location and date of capture.

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TRAWLING AREAS AND CATCHES

Trawling was conducted between Crowdy Head and Moruya mainly on mid-shelf grounds. Six trawls were also conducted on the upper slope (150 - 180 fathoms) between Port Kembla and Brush Island where large catches of redfish had been taken in previous years.

Most redfish were caught during the night trawls on the shelf; very few were caught on the upper slope or during daytime trawls on the shelf.

Tables 2-4 show the operation details of all trawls conducted for redfish during Cruises 86-14 to 86-28.

TAGGING RESULTS

Table 1 and the charts show the number of redfish tagged in each area during Cruises 86-14 to 86-28, and give the total redfish tagged by *Kapala* in 1986.

In total, 11 654 tagged redfish were released between Crowdy Head and Moruya during Cruises 86-14 to 86-28, and a total of 22 395 for 1986.

The number of recaptures has been low. To date (April 1987) 55 *Kapala* redfish tags have been returned. The number of returns of redfish tagged in each area is included in Table 1.

Most of the tags have been returned from the Sydney Fish Markets or by fish retailers, and reliable recapture data has been difficult to obtain for some of the returns. Of the 55 recaptures, 36 were caught in the same area as they were tagged and 9 were returned with no capture data.

Ten recaptures indicated significant movement by the redfish, all to the south of their release area. Seven redfish tagged off Port Jackson-Broken Bay were recaptured off Wollongong (3), Ulladulla (3) and Bermagui (1). The three other movements were Wollongong to Ulladulla , Kiama to Bermagui and the Shoalhaven to Bermagui.

The recaptured redfish had been at liberty from 10 to 386 days and 11 of the 20 tagged redfish recovered since October had been at liberty for more than 220 days.

LENGTH FREQUENCY DATA

Figures 1 to 4 show the length frequency distributions for redfish, tiger flathead and john dory caught between Crowdy Head and Moruya.

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Redfish caught between Broken Bay and Moruya showed little variation in size: the mean size and modes of the length distributions were about 21 cm fork length. Larger redfish were taken off Newcastle-Port Stephens: mean and mode 23 cm, while redfish from the shallower grounds (50-60 fathoms) between Cape Hawke and Crowdy Head were smaller: mean 19.9 cm and mode 18-19 cm fork length.

Tiger flathead were on average small with over 40 percent of the fish less than the legal minimum length of 33 cm. Between Crowdy Head and Botany Bay, catches of john dory consisted mainly of small fish (less than 25 cm); south of Botany Bay, most john dory were between 25 and 35 cm total length.

Table 1: Summary of redfish tagging operations by *Kapala* during Cruises 86-14 to 86-28, the total tagged redfish for 1986, and number of returns of fish tagged in each area.

Area		No. of Trawls	Tagged Redfish	Release Depth(fm)	Total Tagged (1986)	Tag Returns
Crowdy Head	31° 30'- 32° 00'	6	848	50-75	848	-
Cape Hawke	32° 00'- 32° 30'	5	500	42-48	500	1
P.Stephens	32° 30'- 33° 00'	7	487	49-56	559	2
Newcastle- Broken Bay	33° 00'- 33° 30'	-	-	-	369	-
Broken Bay- Botany Bay	33° 30'- 34° 00'	10	1677	66-74	9632	36
Botany Bay- Port Kembla	34° 00'- 34° 30'	21	3604	62-79	3653	10
Port Kembla- Jervis Bay	34° 30'- 35° 00'	20	3335*	66-76	5058	4
Jervis Bay- Brush Is.	35° 00'- 35° 30'	3	207	63-68	230	-
Brush Is. Moruya	35° 30'- 36° 00'	10	1546	62-64	1546	1
Total			11654		22395	

* Includes one release of 149 redfish in 163 fm.

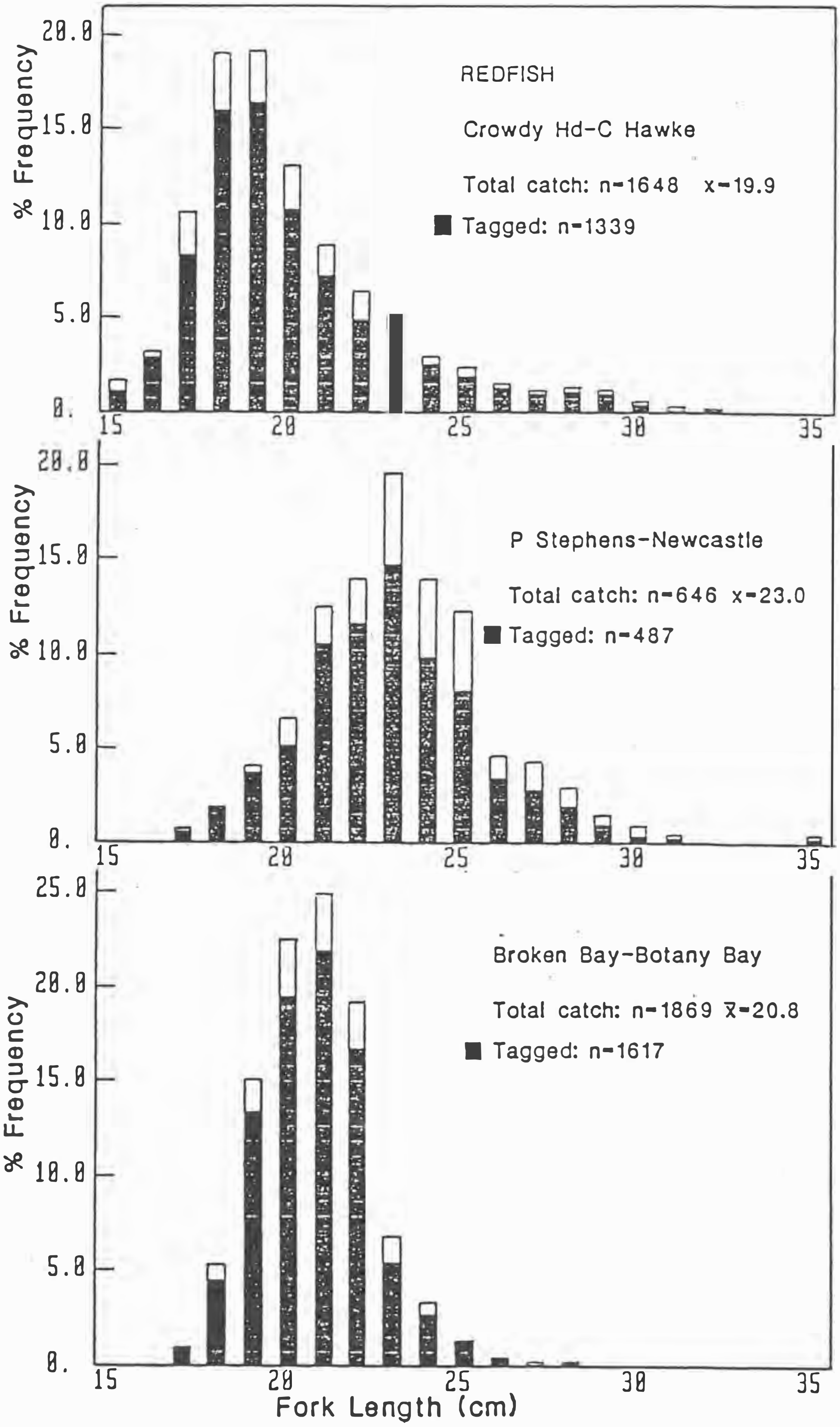


Figure 1: Length frequency histograms for redfish caught and tagged between Crowdy Head and Botany Bay.

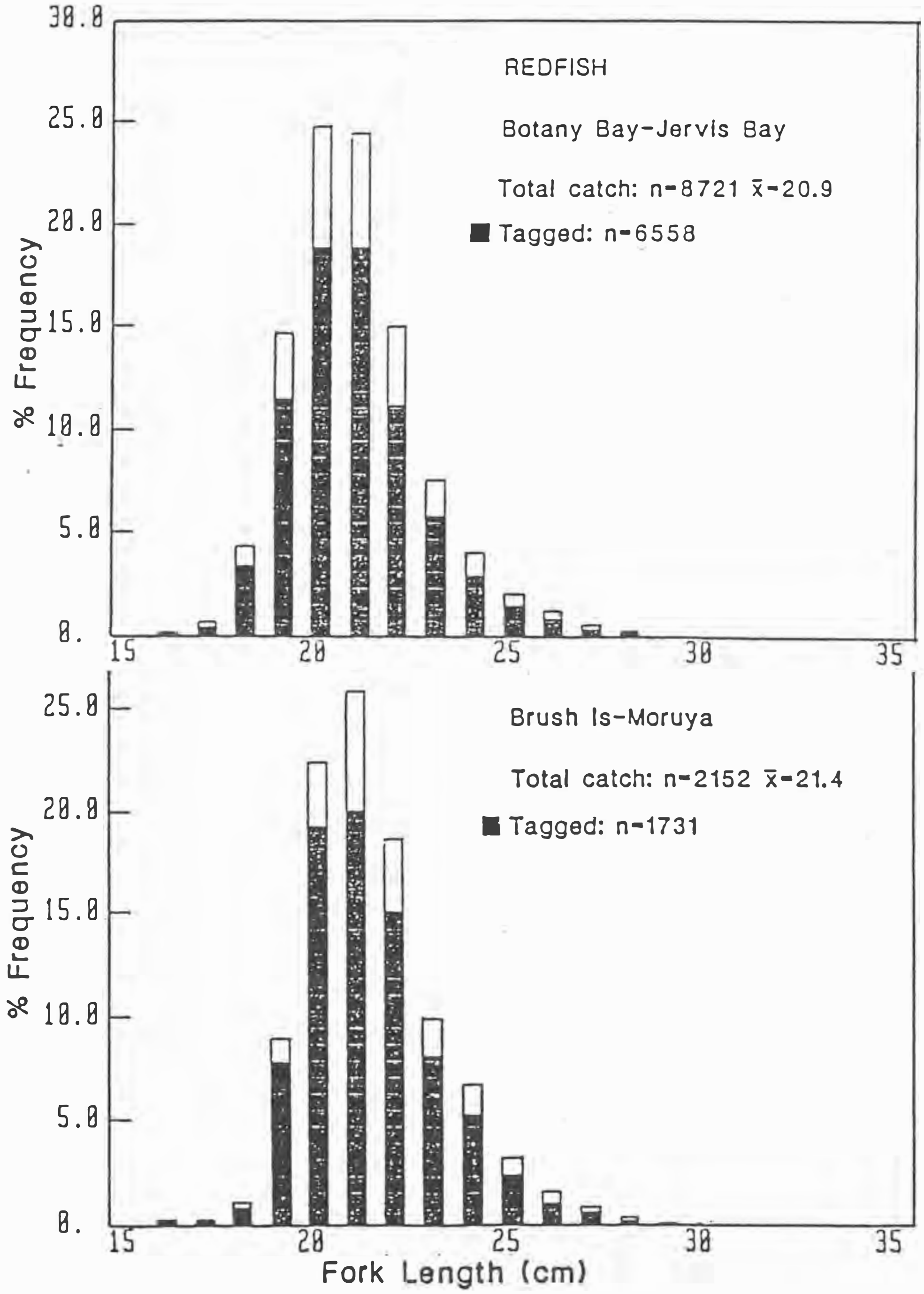


Figure 2: Length frequency histograms for redfish caught and tagged between Botany Bay and Moruya.

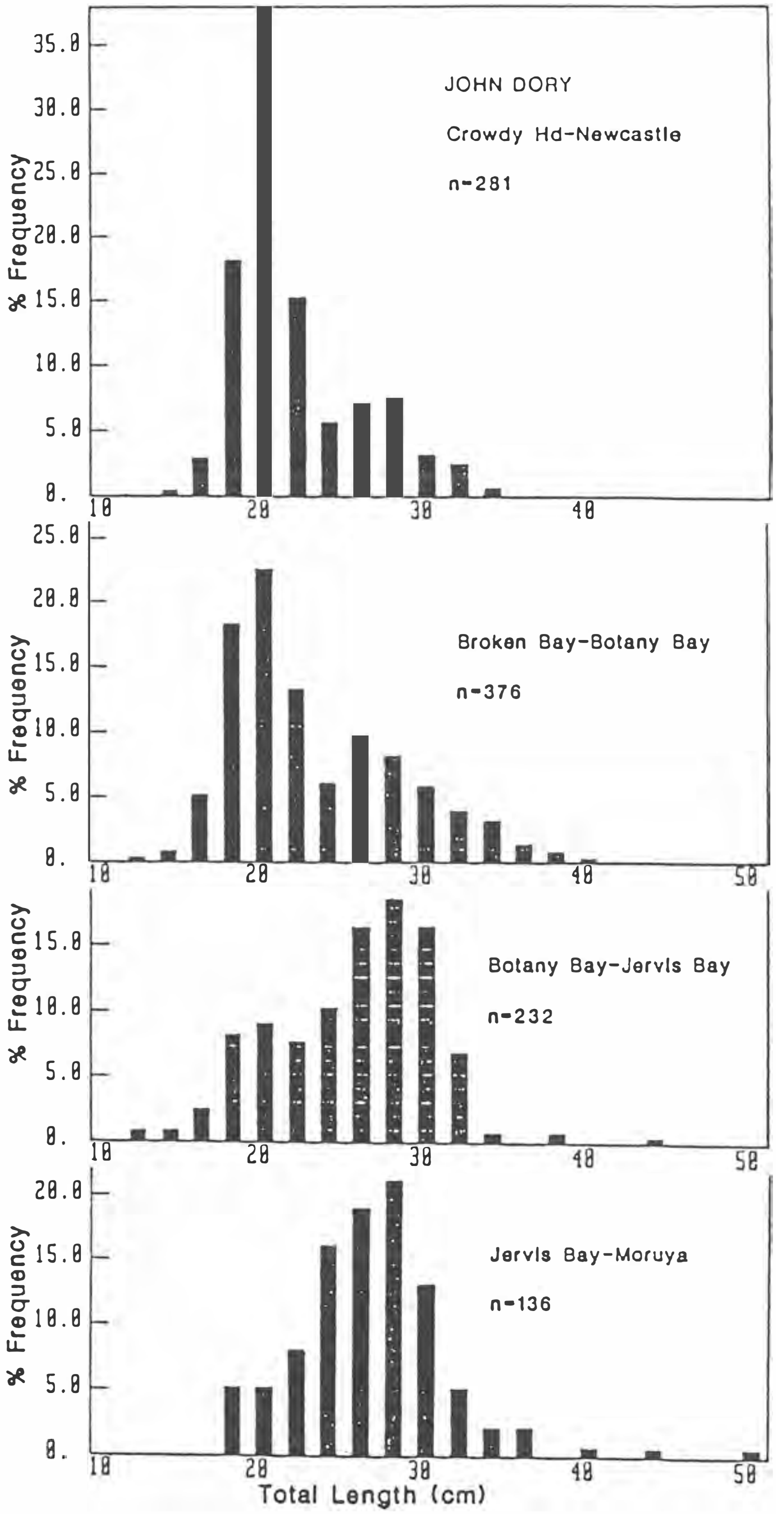


Figure 3: Length frequency histograms for john dory caught between Crowdy Head and Moruya.

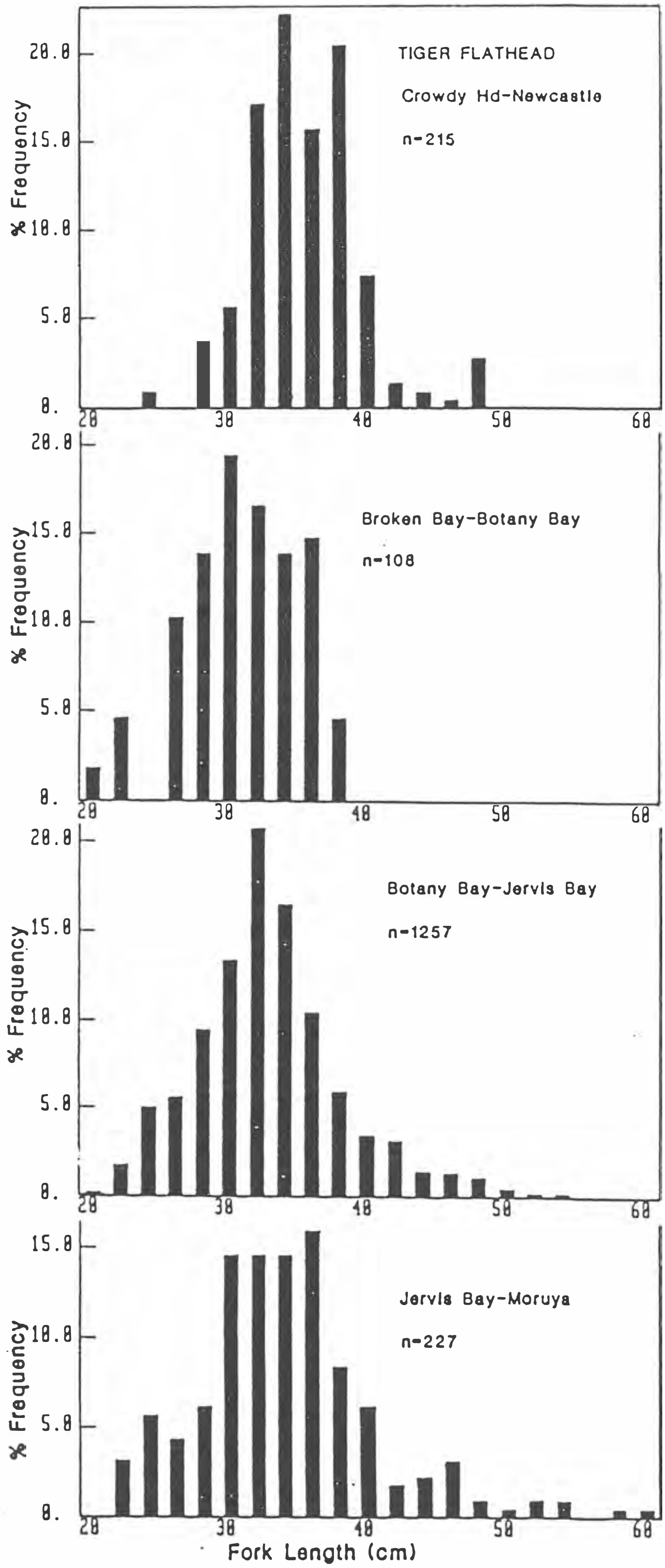


Figure 4: Length frequency histograms for tiger flathead caught between Crowdy Head and Moruya.

Table 2: Operation and catch data for trawls conducted during Cruises 86-14 and 86-15.

Trawl	Date	Start Time	Position Start	Position Finish	Depth (fm)	Trawl Time (mins)	Redfish Catch (kg)
86-14-01	30-6-86	2000	33° 48'151° 31';	33° 44'151° 30'	70-65	60	110
02	"	2225	33° 41'151° 32';	33° 39'151° 35'	65-70	60	40
03	1-7-86	0010	33° 39'151° 36';	33° 36'151° 40'	70-72	60	80
04	"	0145	33° 35'151° 41';	33° 33'151° 44'	74	80	02
05	"	0341	33° 33'151° 42';	33° 35'151° 40'	73-72	60	-
06	"	0518	33° 36'151° 39';	33° 37'151° 36'	72-71	60	-
07	"	0650	33° 38'151° 35';	33° 41'151° 32'	69-67	100	-
08	"	1000	33° 45'151° 29';	33° 48'151° 28'	63-67	90	-
09	"	1355	33° 49'151° 41';	33° 49'151° 34'	88-75	120	15
10	"	1725	33° 48'151° 28';	33° 45'151° 28'	68-65	60	10
11	"	1850	33° 44'151° 29';	33° 43'151° 31'	65-68	60	70
12	"	2020	33° 43'151° 33';	33° 41'151° 35'	69-70	60	2
13	"	2220	33° 44'151° 32';	33° 45'151° 30'	68-66	60	150
14	2-7-86	0005	33° 46'151° 30';	33° 43'151° 33'	66-69	75	150
15	"	0220	33° 43'151° 32';	33° 46'151° 29'	69-66	75	25
16	"	0415	33° 47'151° 28';	33° 50'151° 29'	68	75	5
17	3-7-86	2010	34° 04'151° 17';	34° 06'151° 17'	68-72	60	10
18	"	2140	34° 09'151° 16';	34° 11'151° 14'	72-68	60	5
19	"	2315	34° 12'151° 12';	34° 16'151° 11'	66-70	60	240
20	4-7-86	0045	34° 16'151° 11';	34° 12'151° 13'	70-69	90	50
21	"	0252	34° 10'151° 14';	34° 07'151° 16'	69-71	90	3
86-15-01	7-7-86	1940	34° 19'151° 09';	34° 22'151° 10'	71-75	60	30
02	"	2110	34° 24'151° 10';	34° 26'151° 11'	76-79	60	45
03	"	2240	34° 27'151° 11';	34° 30'151° 09'	79	60	25
04	8-7-86	0015	34° 31'151° 08';	34° 31'151° 05'	77-72	60	65
05	"	0146	34° 32'151° 03';	34° 35'151° 02'	68-69	60	90
06	"	0316	34° 36'151° 02';	34° 39'151° 01'	69-70	60	65
07	"	0447	34° 38'151° 01';	34° 35'151° 02	70-69	60	35
08	"	0620	34° 34'151° 02';	34° 30'151° 06'	69-72	90	--
09	"	0940	34° 33'151° 14';	34° 39'151° 12'	150-157	120	1
10	"	2025	35° 08'150° 53';	35° 11'150° 53'	71	60	30
11	"	2200	35° 13'150° 53';	35° 15'150° 52'	71-72	60	35

Table 3: Operation and catch data for redfish trawls conducted during Cruises 86-16, 86-17 and 86-23.

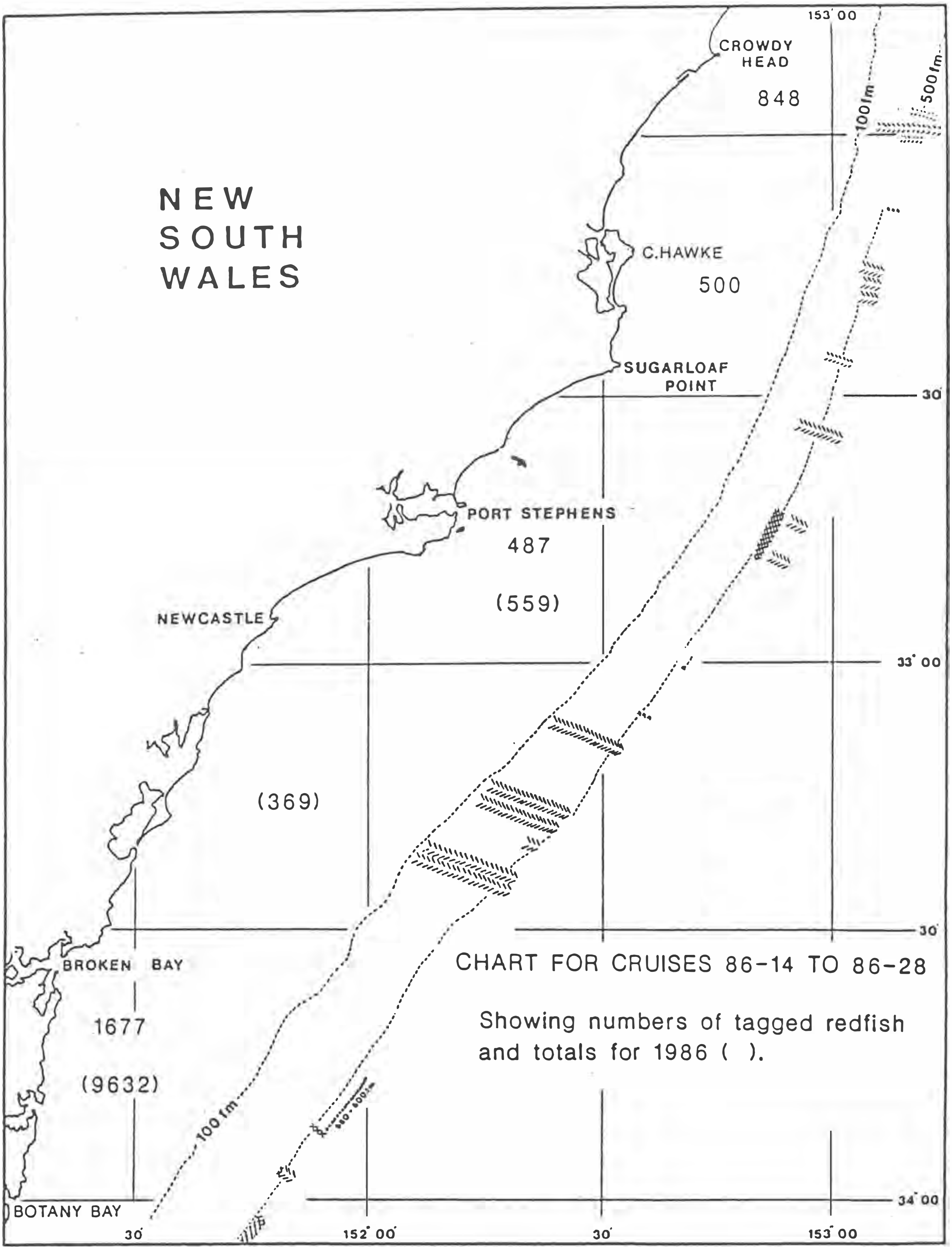
Trawl	Date	Start Time	Position Start	Finish	Depth (fm)	Trawl Time (mins)	Redfish Catch (kg)
86-16-01	14-7-86	1920	34°14'151°13';	34°16'151°11'	68-69	60	150
02	"	2150	34°20'151°09';	34°23'151°09'	69-73	60	50
03	"	2320	34°25'151°10';	34°28'151°09'	74-76	60	50
04	15-7-86	0055	34°29'151°09';	34°32'151°06'	76	70	65
05	"	0250	34°33'151°05';	34°37'151°04'	72-70	65	15
06	"	0430	34°38'151°02';	34°41'151°02'	69	60	10
07	"	0600	34°40'151°01';	34°37'151°01'	69-68	90	12
08	"	0940	34°39'151°12';	34°36'151°15'	152-165	120	75
09	"	1925	35°15'150°44';	35°18'150°43'	63-65	60	40
10	"	2145	35°23'150°38';	35°25'150°35'	64	55	100
11	16-7-86	0114	35°38'150°28';	35°41'150°27'	67-66	60	85
12	"	0343	35°42'150°25';	35°45'150°24'	62-65	60	10
13	"	0523	35°46'150°23';	35°49'150°22'	63-64	60	1
86-17-02	21-7-86	2140	33°01'152°01';	32°58'152°01'	67-68	60	150
03	"	2320	32°57'152°02';	32°54'152°03'	66-50	60	35
04	22-7-86	0100	32°53'152°04';	32°53'152°07'	50-59	60	7
05	"	0234	32°53'152°09';	32°53'152°11	65-69	60	60
06	"	0407	32°53'152°14';	32°51'152°18'	72-75	60	-
11	"	2305	32°06'152°46';	32°04'152°46'	48-52	60	53
12	23-7-86	0030	32°04'152°46';	31°59'152°47'	47	70	20
13	"	0216	31°57'152°48';	31°55'152°50'	46-48	60	45
14	"	0346	31°54'152°51';	31°51'152°52'	48-45	60	44
15*	"	0514	31°50'152°51';	31°49'152°52'	42	35	75
19	"	2000	32°06'152°46';	32°08'152°43'	50	60	50
20	"	2135	32°09'152°43';	32°12'152°43'	50	60	25
21	"	2305	32°13'152°43';	32°16'152°42'	52-49	60	8
22	24-7-86	0030	32°18'152°42';	32°21'152°42'	50-51	60	12
23	"	0200	32°22'152°41';	32°25'152°40'	55-56	60	40
24	"	0333	32°25'152°41';	32°23'152°42'	57-55	60	25
25	"	0517	32°23'152°42';	32°26'152°42'	55-56	60	-
86-23-01	9-9-86	1953	34°03'151°19';	34°06'151°16'	67	60	60
02	"	2121	34°08'151°16';	34°11'151°14'	68	60	55
03	"	2254	34°12'151°13';	34°16'151°12'	69	60	50
05	10-9-86	1924	35°37'150°28';	35°40'150°26'	65-64	60	130
06	"	2127	35°42'150°25';	35°46'150°24'	64	70	60
07*	"	2311	35°48'150°23';	35°51'150°21'	64	45	-

* Gear fouled; net badly damaged.

Table 4: Operation and catch data for redfish trawls conducted during Cruises 86-24 to 86-28.

Trawl	Date	Start Time	Position Start	Position Finish	Depth (fm)	Trawl Time (mins)	Redfish Catch (kg)
86-24-01	16-9-86	2005	34° 03'151° 18'	34° 07'151° 15'	66-67	60	45
02	"	2143	34° 09'151° 14'	34° 12'151° 13'	66	60	70
03	"	2316	34° 15'151° 12'	34° 18'151° 11'	67-68	60	20
85-25-01	22-9-86	2042	34° 04'151° 19'	34° 06'151° 16'	69-66	60	8
02	"	2211	34° 07'151° 15'	34° 09'151° 14'	65-64	60	40
03	"	2341	34° 10'151° 13'	34° 13'151° 12'	64	60	60
04	23-9-86	1028	35° 15'150° 45'	35° 18'150° 43'	64	60	-
05	"	1410	35° 29'150° 46'	35° 31'150° 45'	156-157	60	1
06	"	1613	35° 33'150° 43'	35° 35'150° 41'	84	60	25
07	"	1917	35° 37'150° 29'	35° 39'150° 27'	63	60	60
08	"	2050	35° 40'150° 26'	35° 43'150° 25'	64	60	35
09*	"	2218	35° 45'150° 25'	35° 46'150° 24'	63	30	20
10	25-9-86	1430	35° 12'150° 57'	35° 11'150° 57'	85-90	05	45
11	"	1600	35° 05'151° 03'	35° 02'151° 04'	168-197	60	01
12	"	1855	34° 56'150° 59'	34° 53'151° 00'	67-68	60	90
13	"	2030	34° 52'151° 02'	34° 50'151° 03'	67-70	60	70
14	"	2210	34° 49'151° 02'	34° 47'151° 03'	69	60	95
86-26-01	30-9-86	1916	34° 02'151° 19'	34° 05'151° 17'	67	60	18
02	"	2048	34° 07'151° 16'	34° 09'151° 13'	66-62	60	40
03	"	2220	34° 10'151° 12'	34° 13'151° 11'	61-64	60	50
04*	"	2352	34° 15'151° 11'	34° 16'151° 09'	63-62	38	30
05	2-10-86	1051	35° 20'150° 53'	35° 16'150° 56'	167-161	104	1
06	"	1408	35° 14'150° 58'	35° 12'150° 59'	176-180	32	-
07	"	1548	35° 10'151° 00'	35° 08'151° 01'	178-182	48	-
08	"	2042	34° 42'151° 03'	34° 38'151° 02'	69-68	60	75
09	"	2217	34° 37'151° 02'	34° 35'151° 02'	66-67	60	70
10	"	2352	34° 33'151° 03'	34° 30'151° 05'	67	60	80
86-27-01	8-10-86	1932	34° 04'151° 18'	34° 07'151° 17'	68	60	18
02	"	2101	34° 09'151° 15'	34° 12'151° 14'	67-68	60	22
03	"	2232	34° 13'151° 13'	34° 16'151° 11'	67	60	25
86-28-01	13-10-86	1928	34° 03'151° 19'	34° 05'151° 17'	69-68	60	15
02	"	2105	34° 09'151° 16'	34° 13'151° 14'	67	60	45
03	"	2240	34° 14'151° 13'	34° 18'151° 11'	67-69	60	95
04	14-10-86	0020	34° 20'151° 11'	34° 24'151° 10'	69-72	76	50
05	"	0209	34° 26'151° 10'	34° 29'151° 09'	73-74	60	105
06*	"	0353	34° 31'151° 08'	33° 32'151° 08'	74	10	10
08	16-10-86	2025	34° 40'151° 01'	34° 37'151° 01'	64-66	60	105
09	"	2156	34° 36'151° 01'	34° 31'151° 04'	66-70	60	130

* Gear fouled and/or damaged at finish position.


153° 00
CROWDY
HEAD
848
100fm
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NEW
SOUTH
WALES
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SUGARLOAF
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PORT STEPHENS
487
(559)
NEWCASTLE
33° 00
(369)
30'
BROKEN BAY
1677
(9632)
100fm
BOTANY BAY
34° 00
30'
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153° 00
CHART FOR CRUISES 86-14 TO 86-28
Showing numbers of tagged redfish
and totals for 1986 ( ).

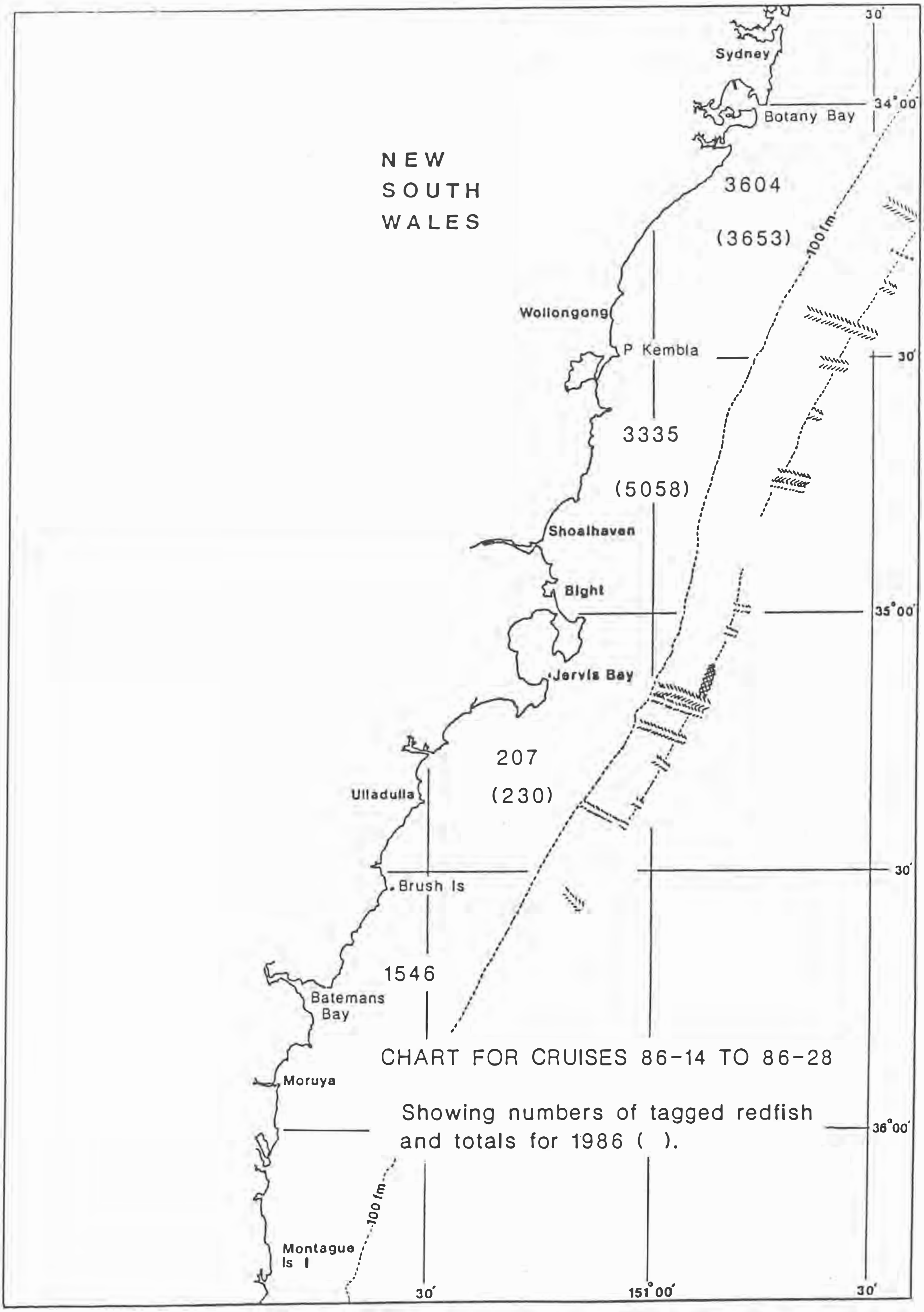

CHART FOR CRUISES 86-14 TO 86-28

Showing numbers of tagged redfish and totals for 1986 ( ).

APPENDIX 2

Redfish Tag Mortality Study

by J. H. Diplock

Internal Report No. 5 - December, 1985

Fisheries Research Institute
P.O. Box 21 Cronulla NSW 2230
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Redfish Tag Mortality Study

Aim

To investigate methods for handling and tagging redfish (*Centroberyx affinis*) and to evaluate the effects of tagging on survival.

Methods and Procedures

1. Holding Cages.

Two circular floating cages were constructed to contain experimental fish. The cages were designed to be collapsible to facilitate transport and to permit re-use. Four 4 metre lengths of 30mm PVC conduit connected by wooden inserts and split-pins at the joints composed the upper and lower supporting rings. To these were stitched two 100 mesh lengths of 1 1/2" 14 ply prawn netting. The netting was pursed at the bottom in this instance and weighted with a 20Kg weight to keep the cage open. Fifteen 5Kg purse seine floats were slipped onto the upper ring for flotation. The cages were tethered from the pursed lower end to a line between two anchors. After prefabrication in Sydney the cages were erected on the beach at Honeymoon Bay, towed into Jervis Bay and anchored in 5 fathoms of water near the entrance.

2. Fish

Redfish were trawled by FRV "Kapala" in approximately 60-70 fathoms. Lively and undamaged fish from the catch were placed in the vessel's brine tanks in continuously circulating seawater for transport back to Jervis Bay. Fish were dipped directly into 1 metre circular floating cages from the brine tanks and towed by boat or diver to the holding cages.

3. Tagging

The tagging operation was performed onboard a runabout tied to the holding cages. Fish were scooped from the transfer cages, measured and tagged, then released directly into the holding cages. Two separate tagging exercises were carried out as fish were brought in from two successive day's fishing. The first day's catch was used to compare mortality in tagged and untagged fish and the second to compare the effects of the two different tag types.

From the catch of the first day 41 fish were measured and tagged with numbered Floy "anchor" tags below the dorsal fin. The tags were locked between the interior processes of the dorsal spines. Another 41 fish were measured and released into the holding cages untagged.

The second day's catch was treated differently to avoid confusion with the first day's catch. Fish tagged with numbered "anchor" tags totalled 14 and another 14 fish were tagged with opercular (chicken-wing strap) tags.

All tagging and handling performed off the "Kapala" was done on the afternoon of the day of capture.

4. Monitoring

The cages were kept under continuous observation during daylight hours for the first four days. Dead fish were removed by diver twice a day to minimise stress. Fish were not fed during the experiment. Monitoring continued for seven days. At the conclusion of the experiment the cages were towed into shallow water and the remaining fish removed.

Results

Table 1 below gives a summary of results. An initial mortality occurred in the first 24 hours with little or no mortality over the subsequent six days. The rates of mortality were similar for both day's catches with little difference between tagged and untagged fish. After 24 hours the ratio of deaths to initial numbers (both day's data combined) is very similar. The ratio for the total number of tagged fish is slightly lower at 13% than that for the untagged at 14.6%.

There was an increase in mortality after three days with three tagged and one untagged fish from the first day's catch dying during the last four days. From the second day's catch only one tagged fish died during the last four days.

The experiment was terminated after seven days. All fish were in poor condition with infections on the head, fins and anterior parts of the body.

Discussion

1. Cages

The holding cages proved to be extremely portable and easy to erect. The conduit construction resulted in a flexible structure which rode comfortably over waves of up to a metre and withstood winds of 25-30 knots. The anchoring system permitted the cages to move freely in the current and despite a considerable battering by bad weather and high tides the cages sustained no damage over the study period.

2. Fish

The cage design proved suitable for redfish. The fish rapidly schooled up and maintained a steady position facing the current in the funnel-shaped lower parts of the cage.
Occasionally fish moved about in midwater but for the most part confined themselves to the lowest regions of the cage. Distressed and dead fish sank and lodged in the bottom of the cage making it unnecessary to cover the top of the cage. Other species of fish with different behaviour patterns may require the presence of a roof of netting to protect the fish from predators or prevent escape.

Within twelve hours some fish displayed bacterial infections on the head and body and several showed a cloudiness in one or both eyes. There was a gradual deterioration in the skin and eye condition of all fish over the seven day period. By the final day all remaining fish were effected to a serious extent and the vigor of all had decreased markedly. It is considered probable that injuries caused during capture were exacerbated by confinement in the holding cages. High water temperatures may also have been a contributing factor.

It should be remembered that the treatment received by these fish was much more severe than that expected in a normal tagging operation. Allowing for this several conclusions may be drawn. There is an initial mortality during capture due to trauma in the net. Lively fish recovered from the deck do survive well and may be transported considerable distances onboard ship. The trauma and injury from this treatment coupled with that of subsequent handling and tagging produces a significant mortality rate within 24-48 hours. The effect of tagging appears insignificant to this short term handling mortality.

The combined effects of capture, handling and confinement in this sort of cage begin to produce increased mortality after seventy two or more hours. It is possible that an altered cage design could eliminate some or all of this subsequent mortality. When facilities become available it is intended to repeat this experiment with fish confined in a large seawater pool to eliminate damage caused by contact with the netting walls.

It is concluded that redfish are robust and hardy fish which with careful handling can be expected to show a very low initial tagging mortality. Further study is needed to show the long term effects of tagging and this will be undertaken when further funds and facilities become available.

Table 1.

Date	5/12	6/12	7/12	8/12	12/12
First Tagging					
Anchor Tagged					
Dead	0	5	1	0	3
Alive	41	36	35	35	32
Untagged					
Dead	0	6	0	0	1
Alive	41	35	35	35	34
Second Tagging					
Opercular Tagged					
Dead		0	1	0	0
Alive		14	13	13	13
Anchor Tagged					
Dead		0	2	0	1
Alive		14	12	12	11

Appendix 3

Length frequencies of commercial catches of redfish for the major NSW ports of landing.

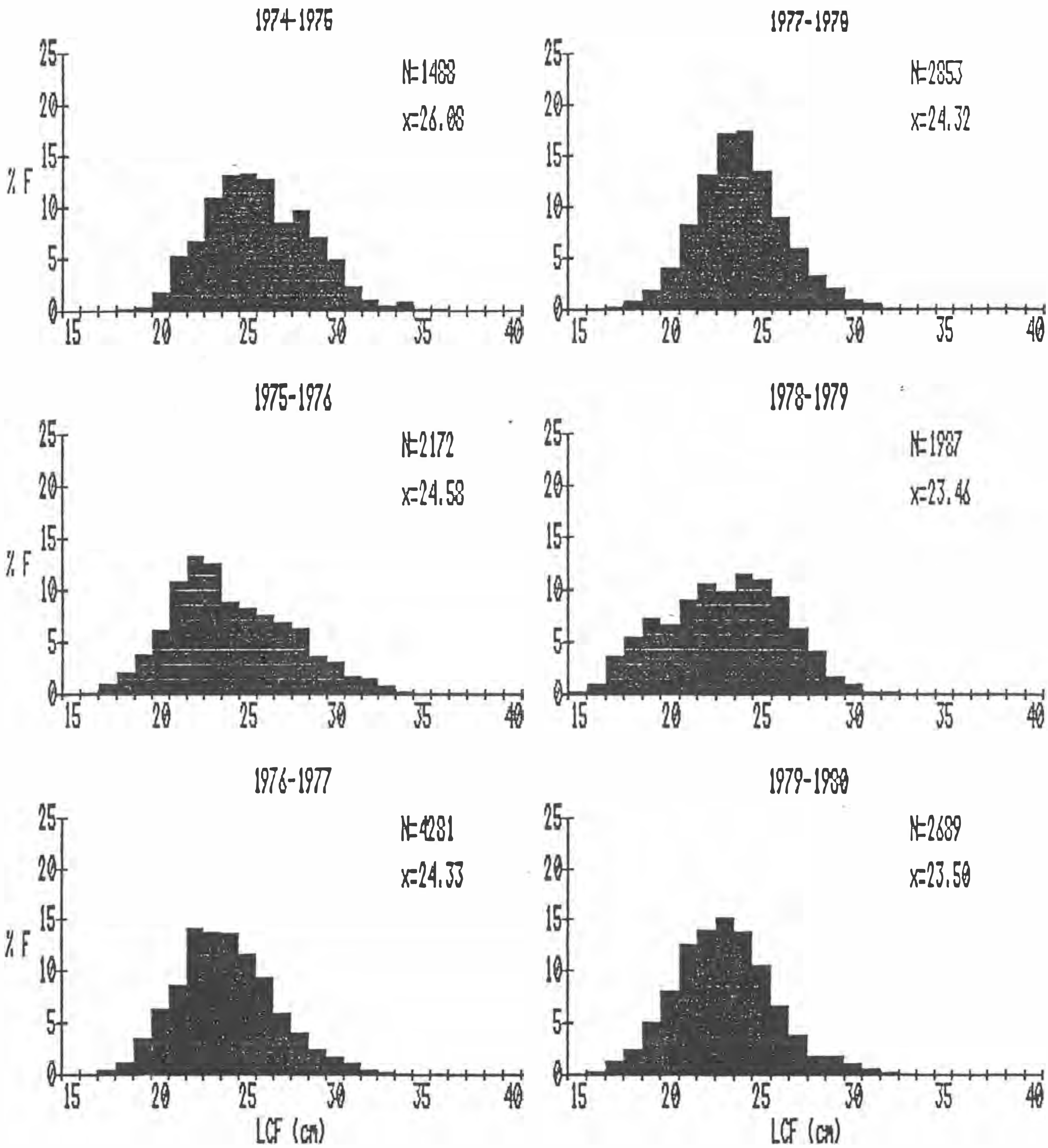


Figure 1. Length frequencies of commercial catches of redfish from the Newcastle area.

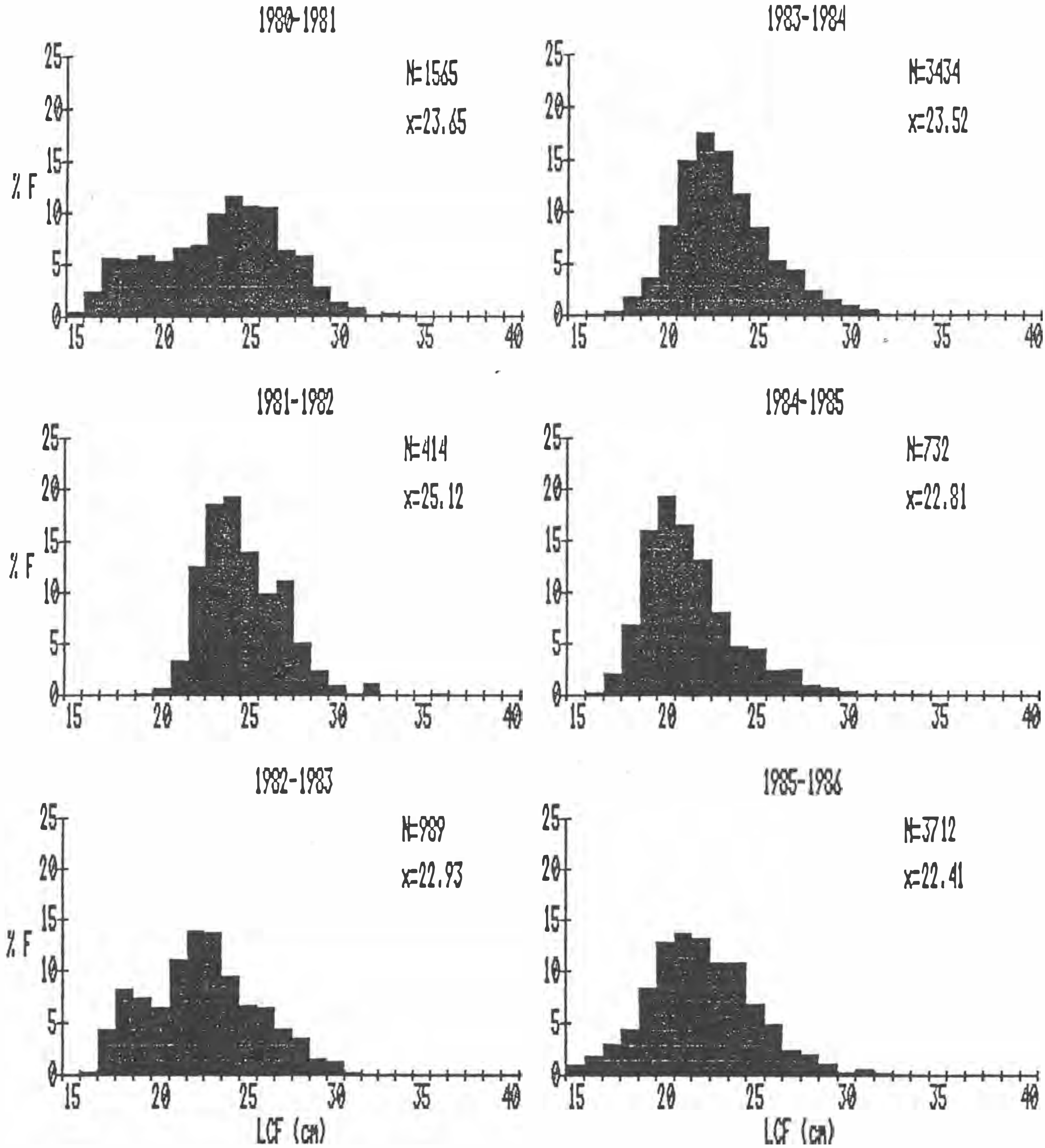


Fig. 1 continued

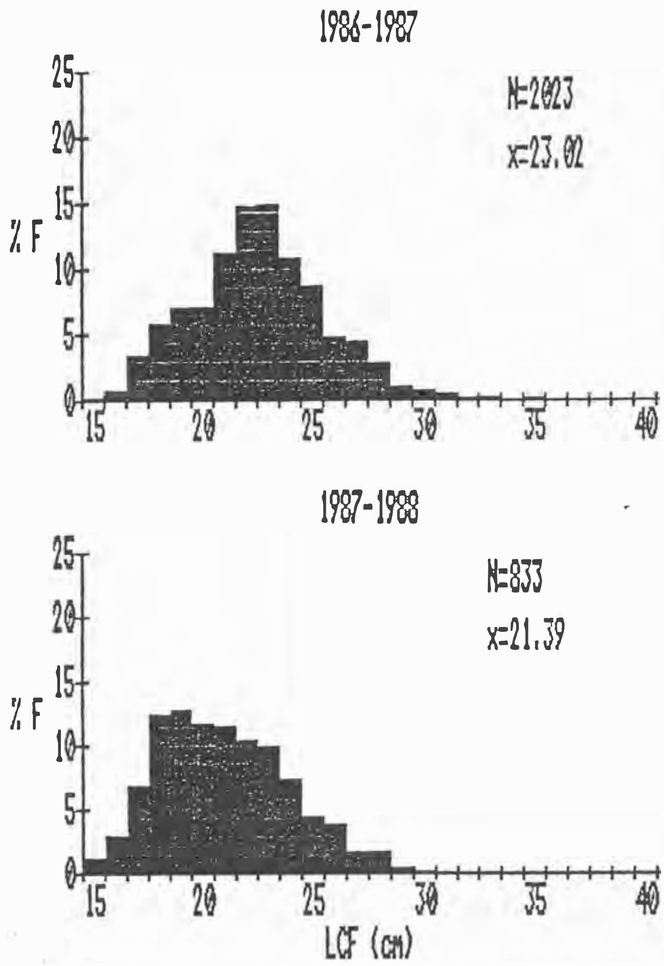


Fig. 1 continued

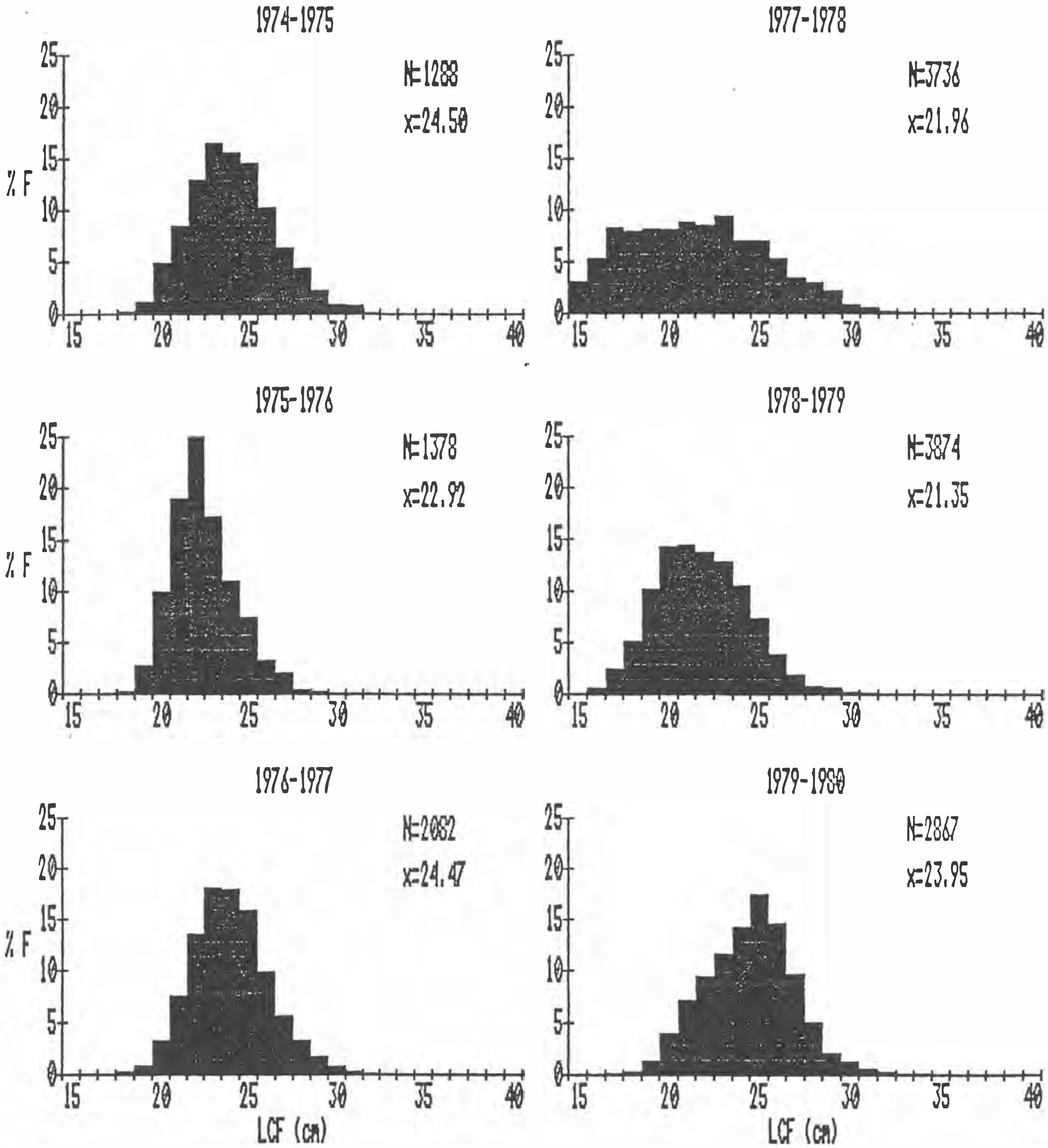
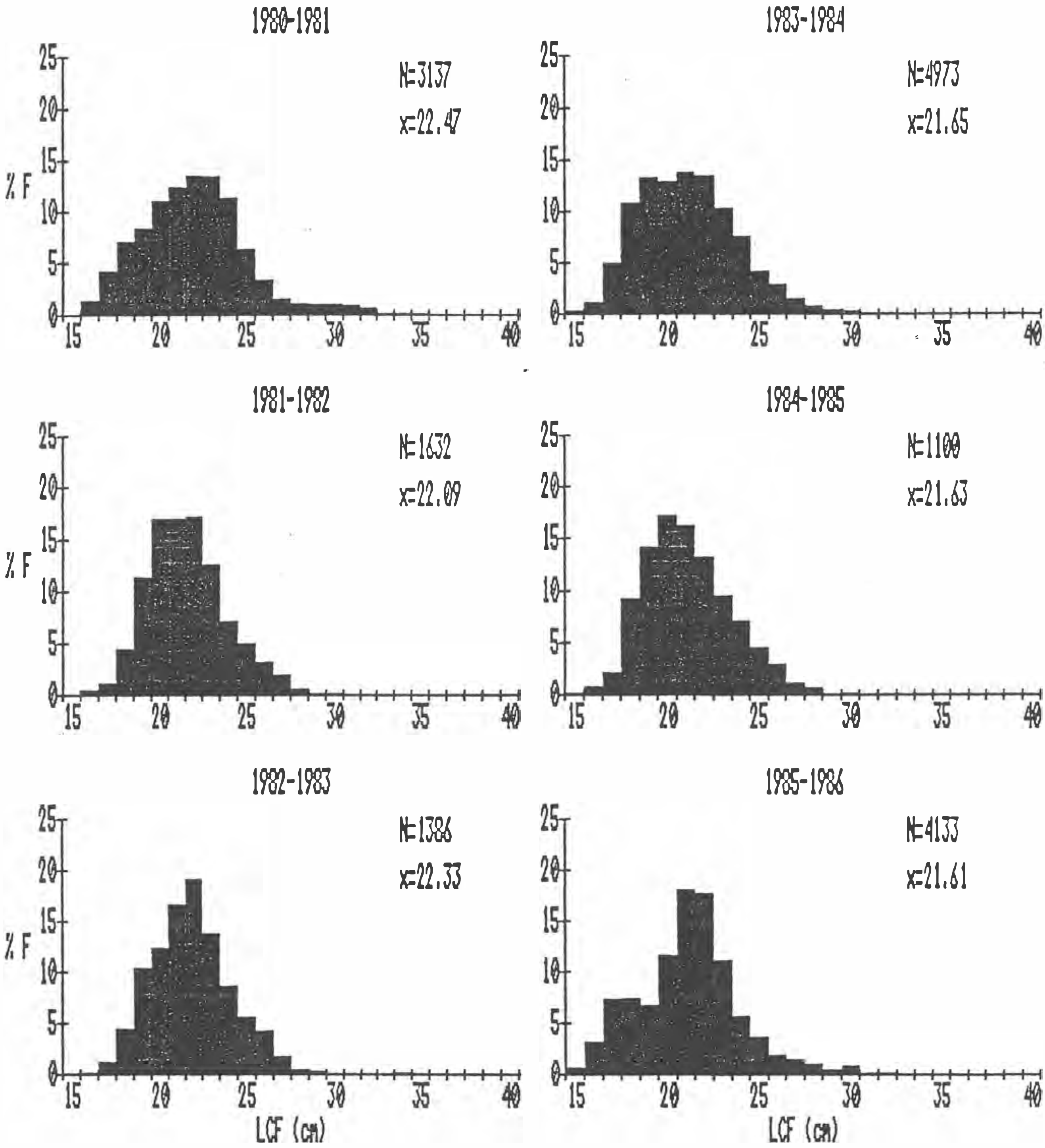


Figure 2. Length frequencies of commercial catches of redfish from the Sydney area.



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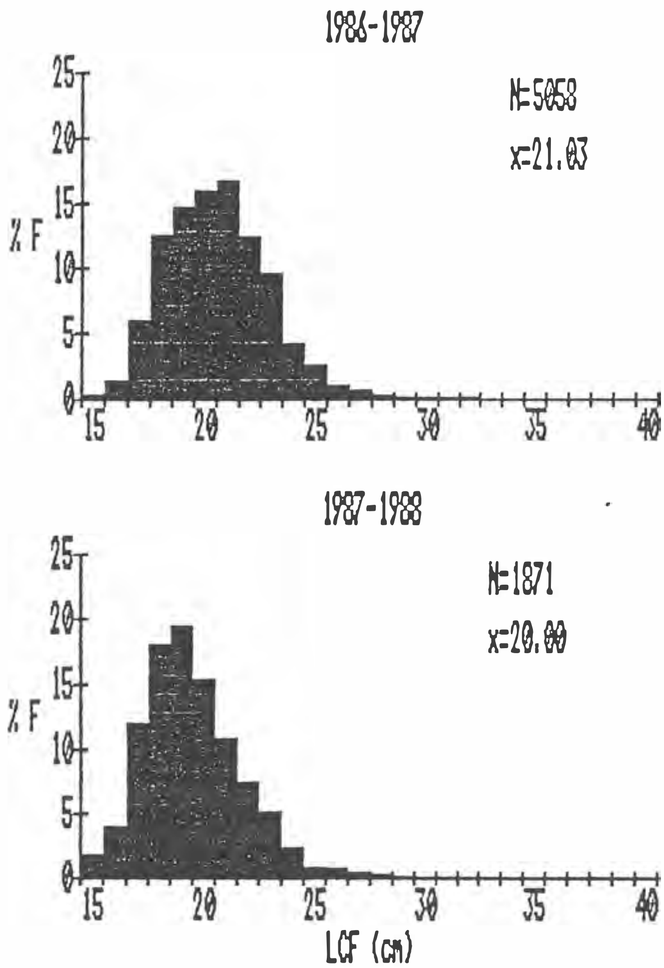

Fig. 2 continued

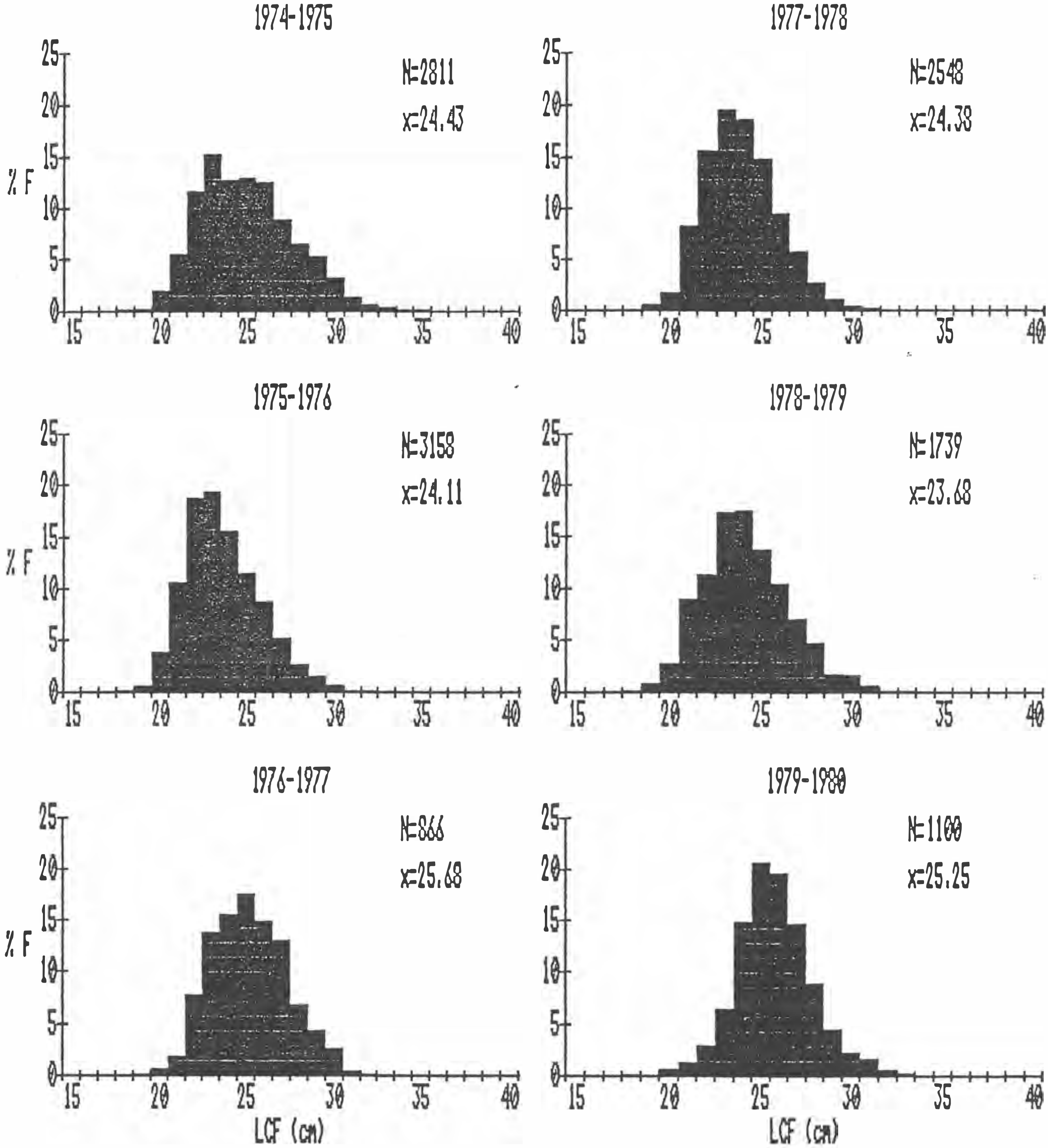

Figure 3. Length frequencies of commercial catches of redfish from the Wollongong area.

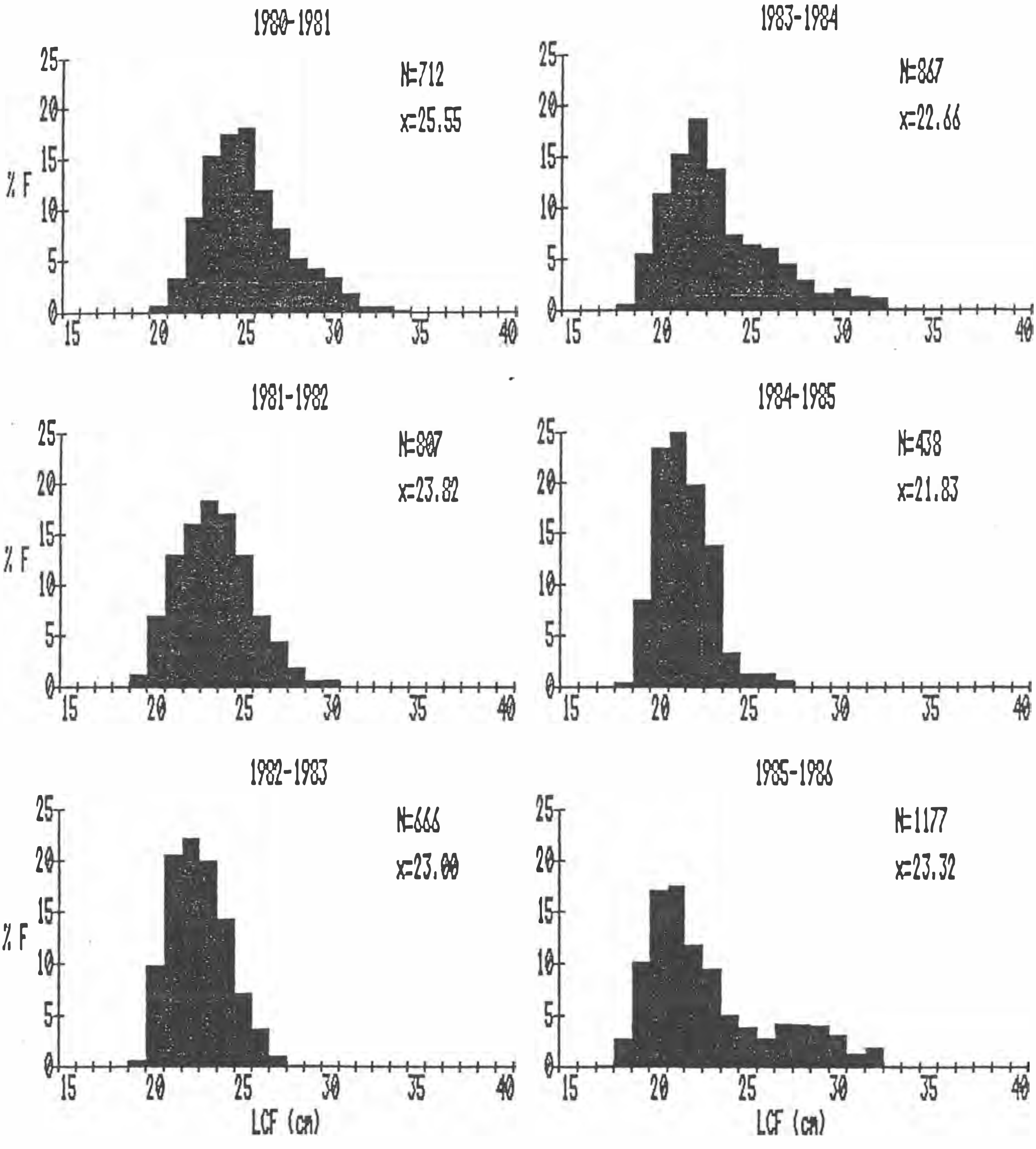

Fig. 3 continued

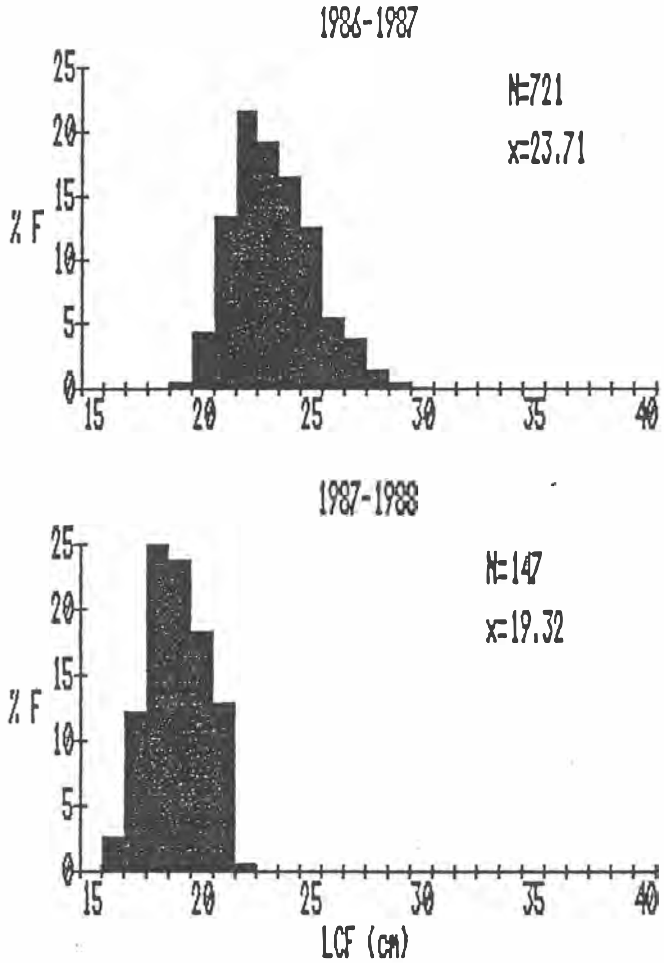

Fig. 3 continued

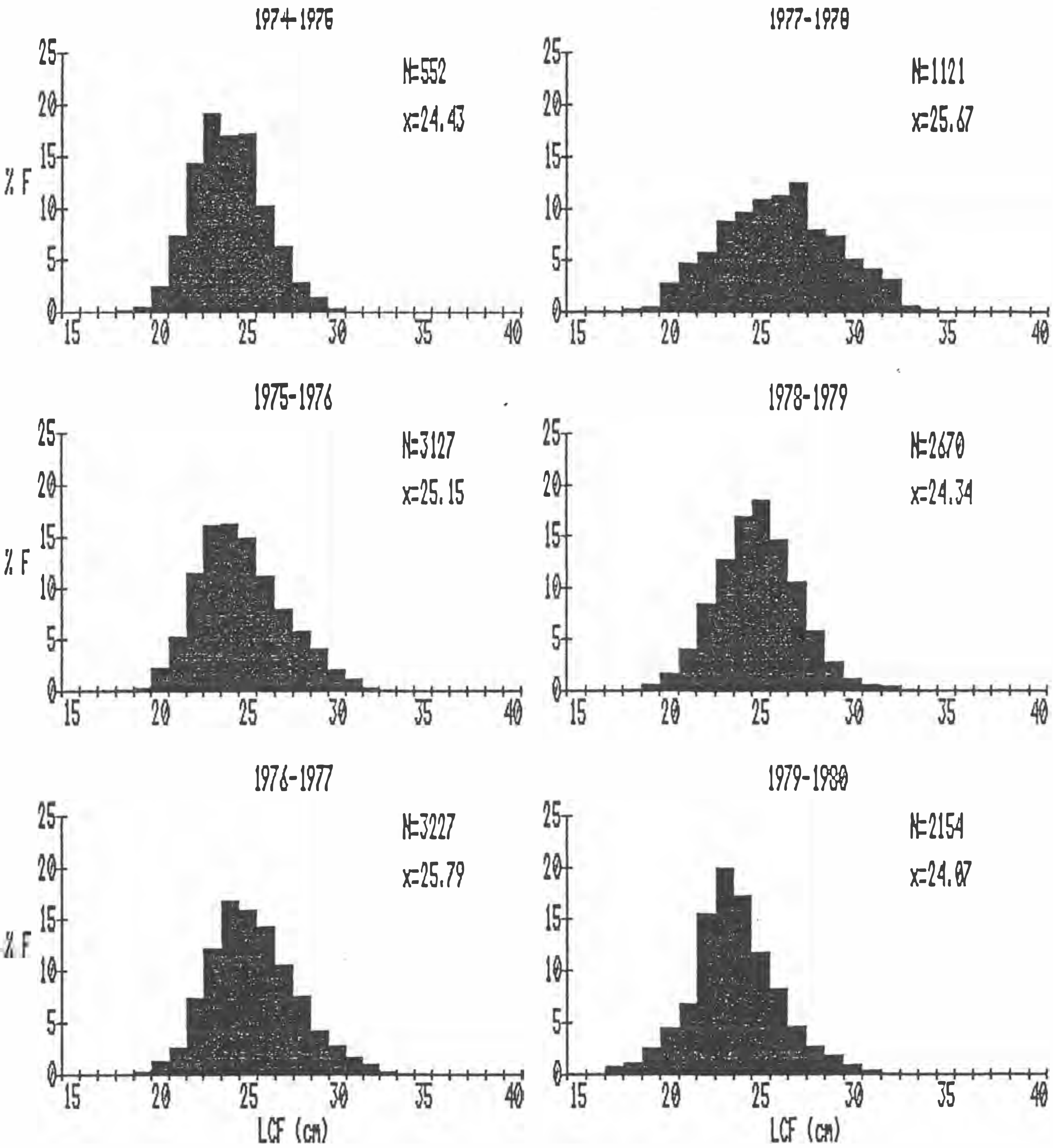

Figure 4. Length frequencies of commercial catches of redfish from the Ulladulla area.

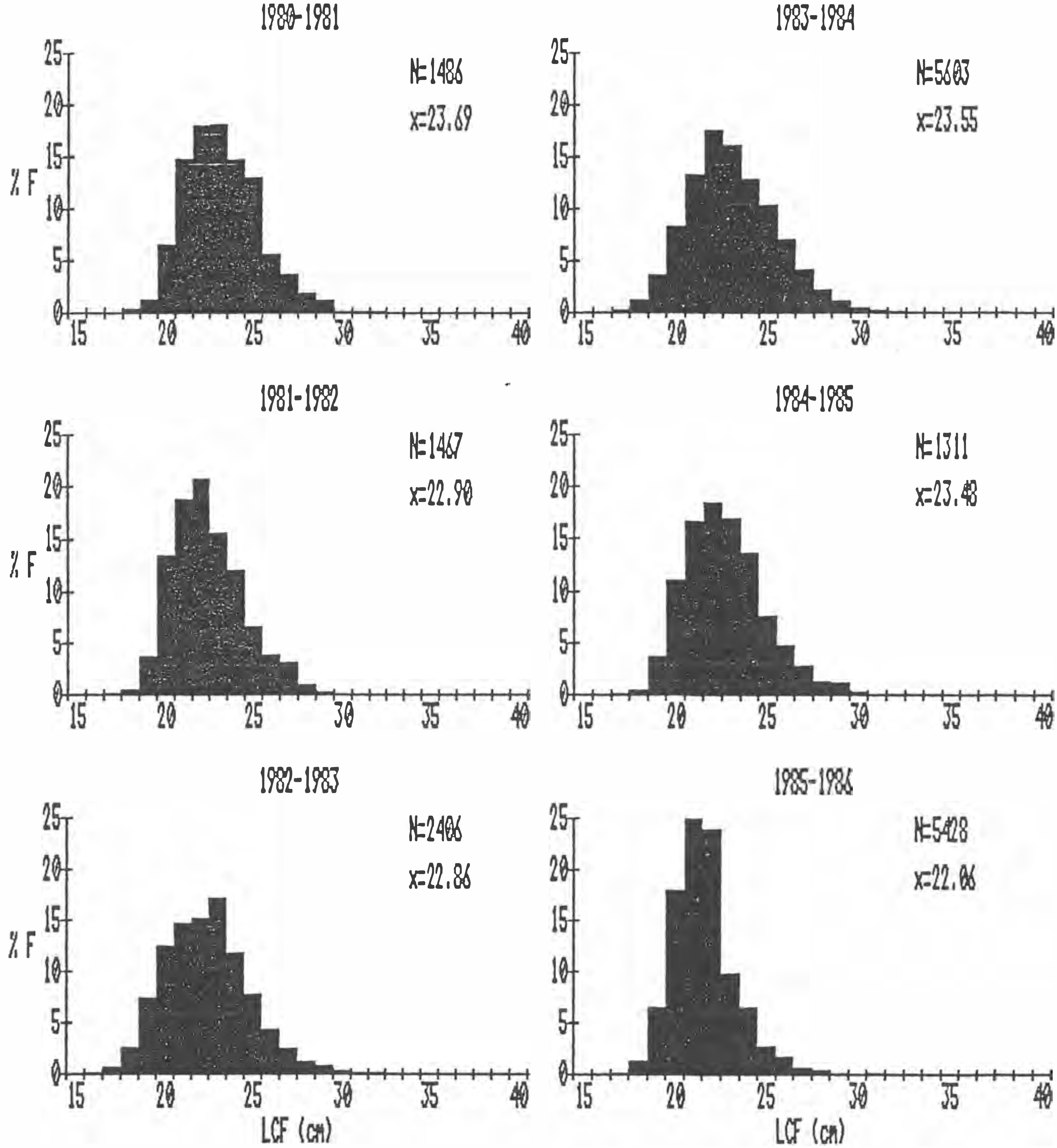

Fig. 4 continued

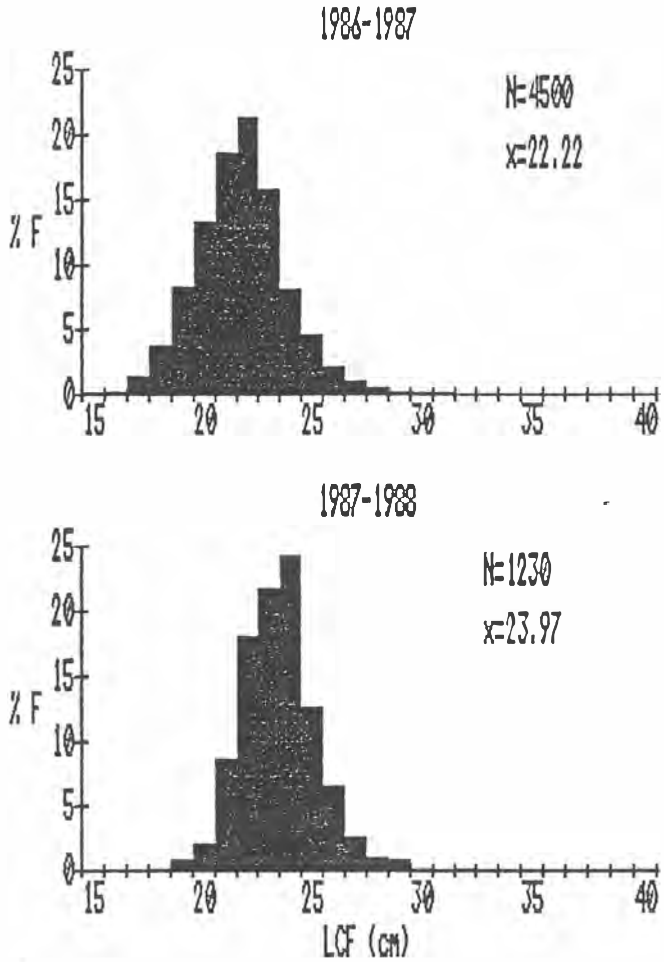

Fig. 4 continued

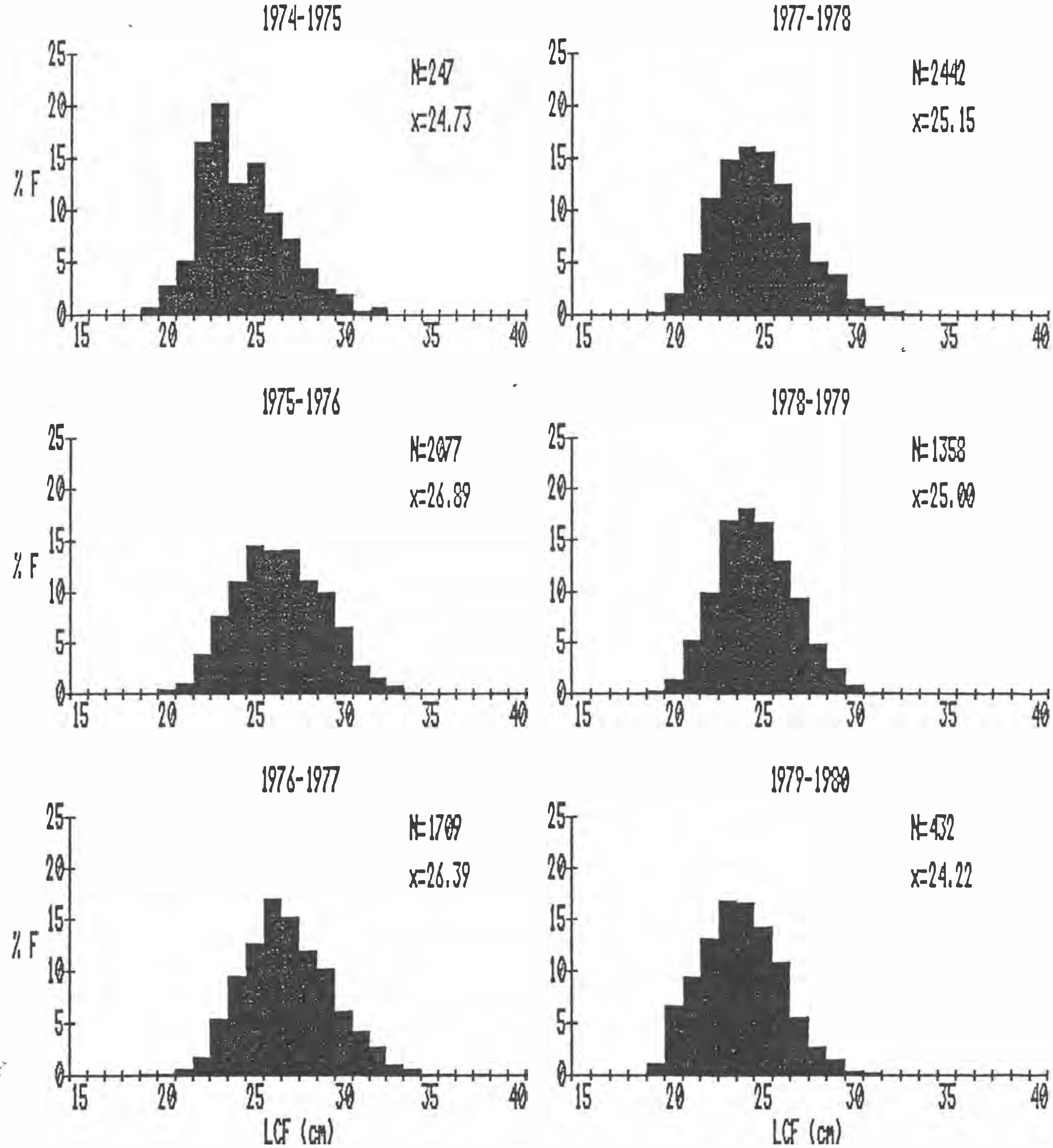

Figure 5. Length frequencies of commercial catches of redfish from the Bermagui area.

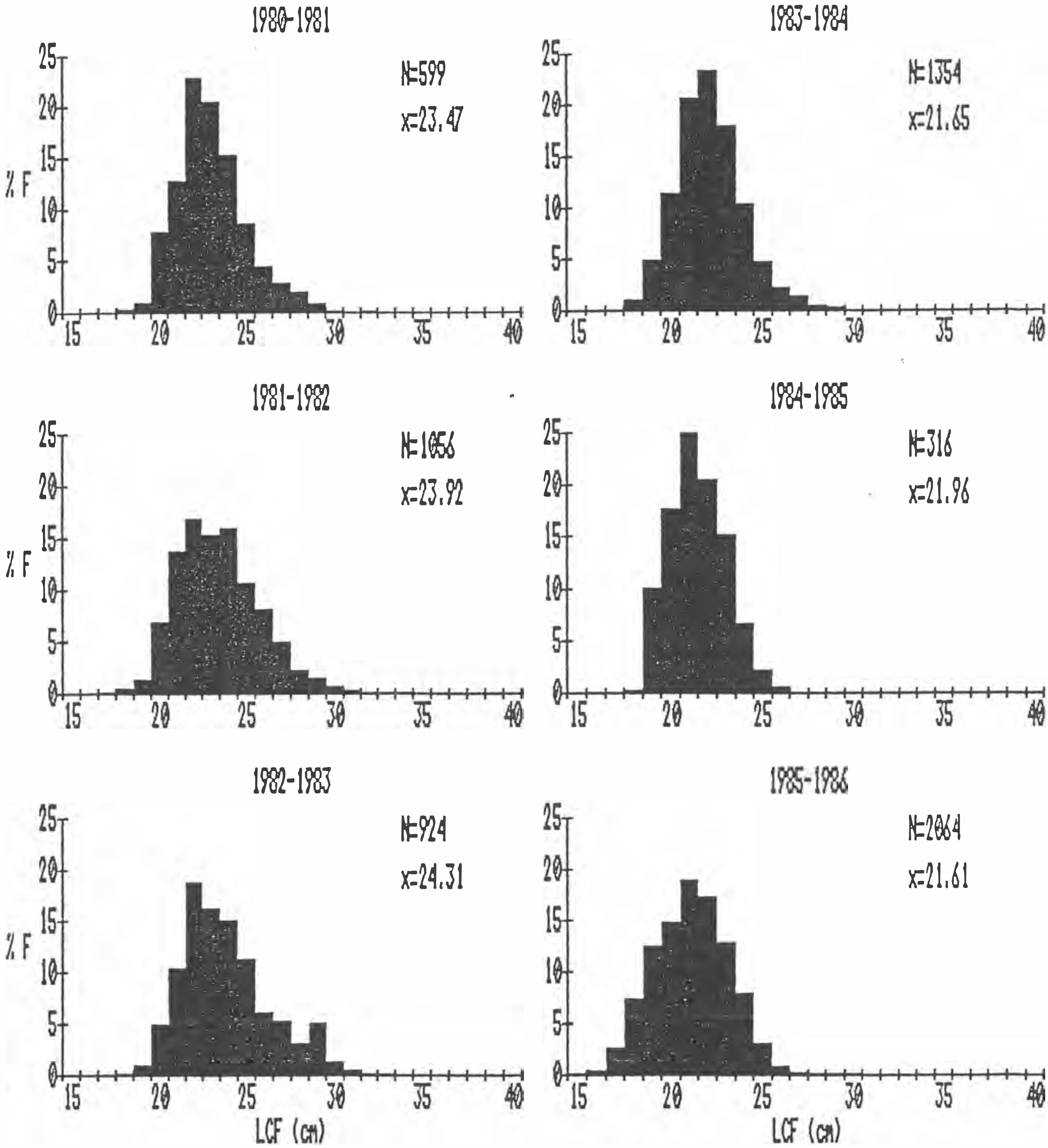

Fig. 5 continued

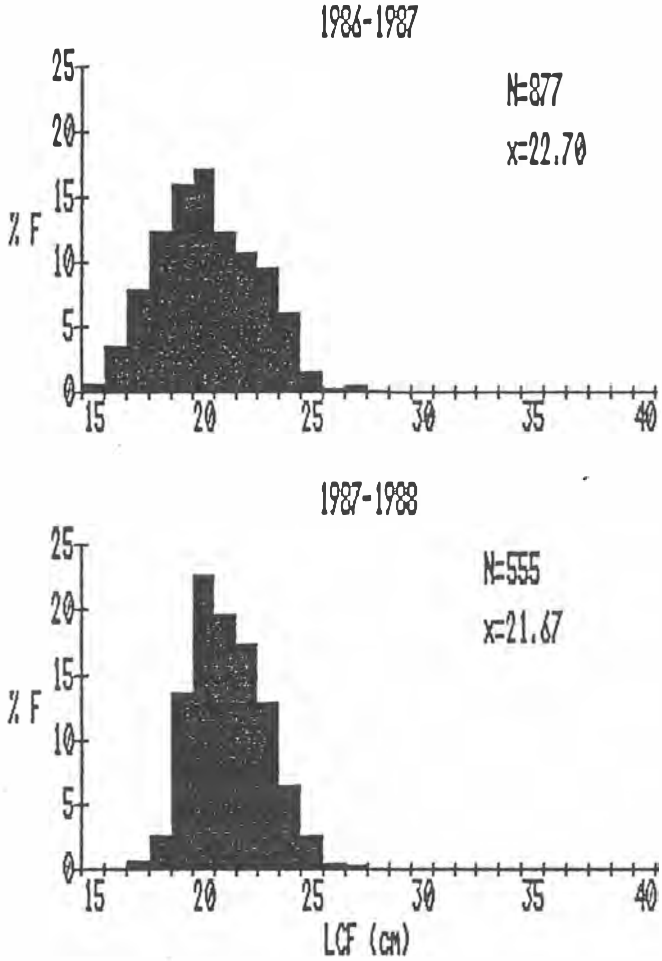

Fig. 5 continued

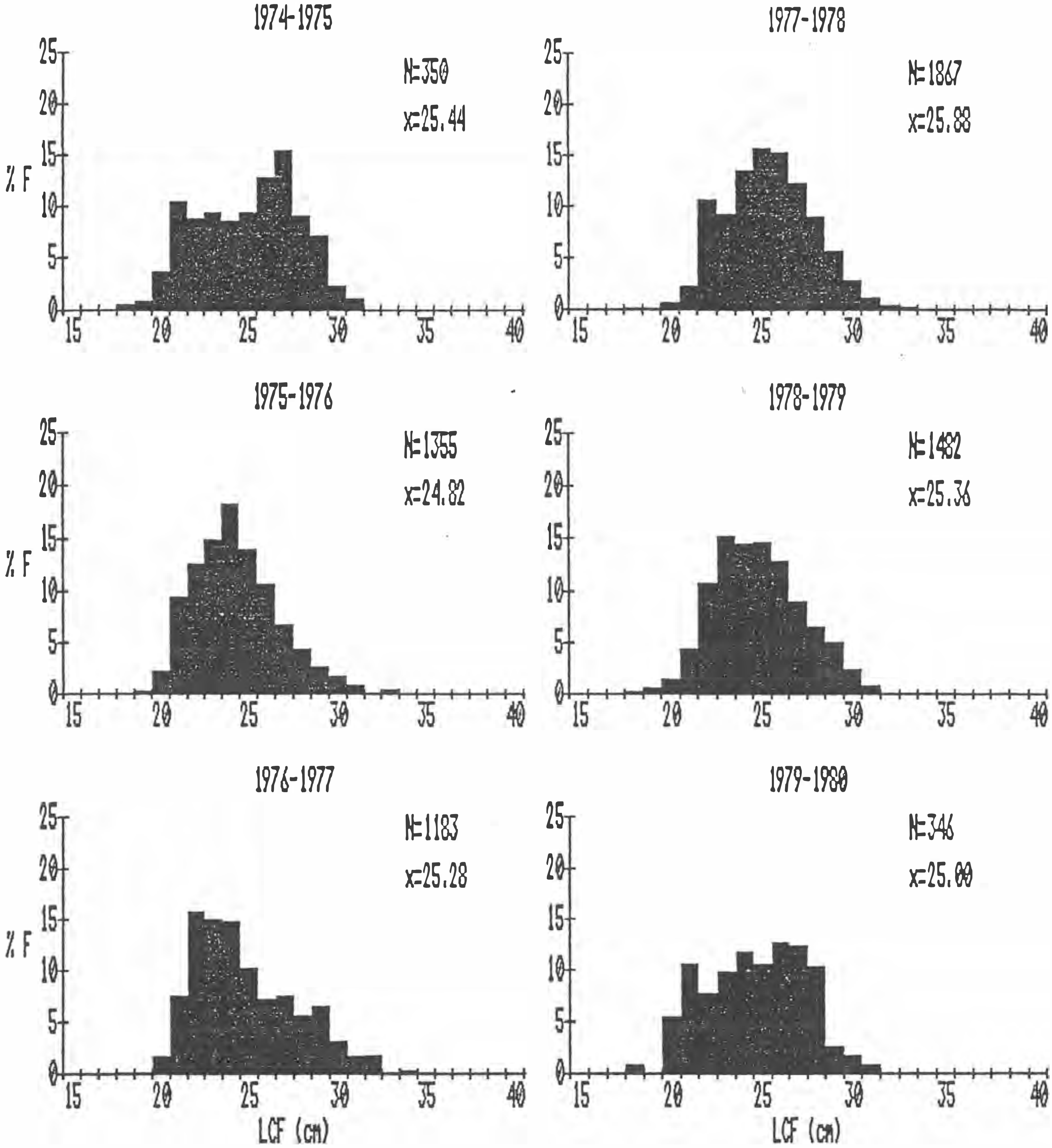

Figure 6. Length frequencies of commercial catches of redfish from the Eden area.

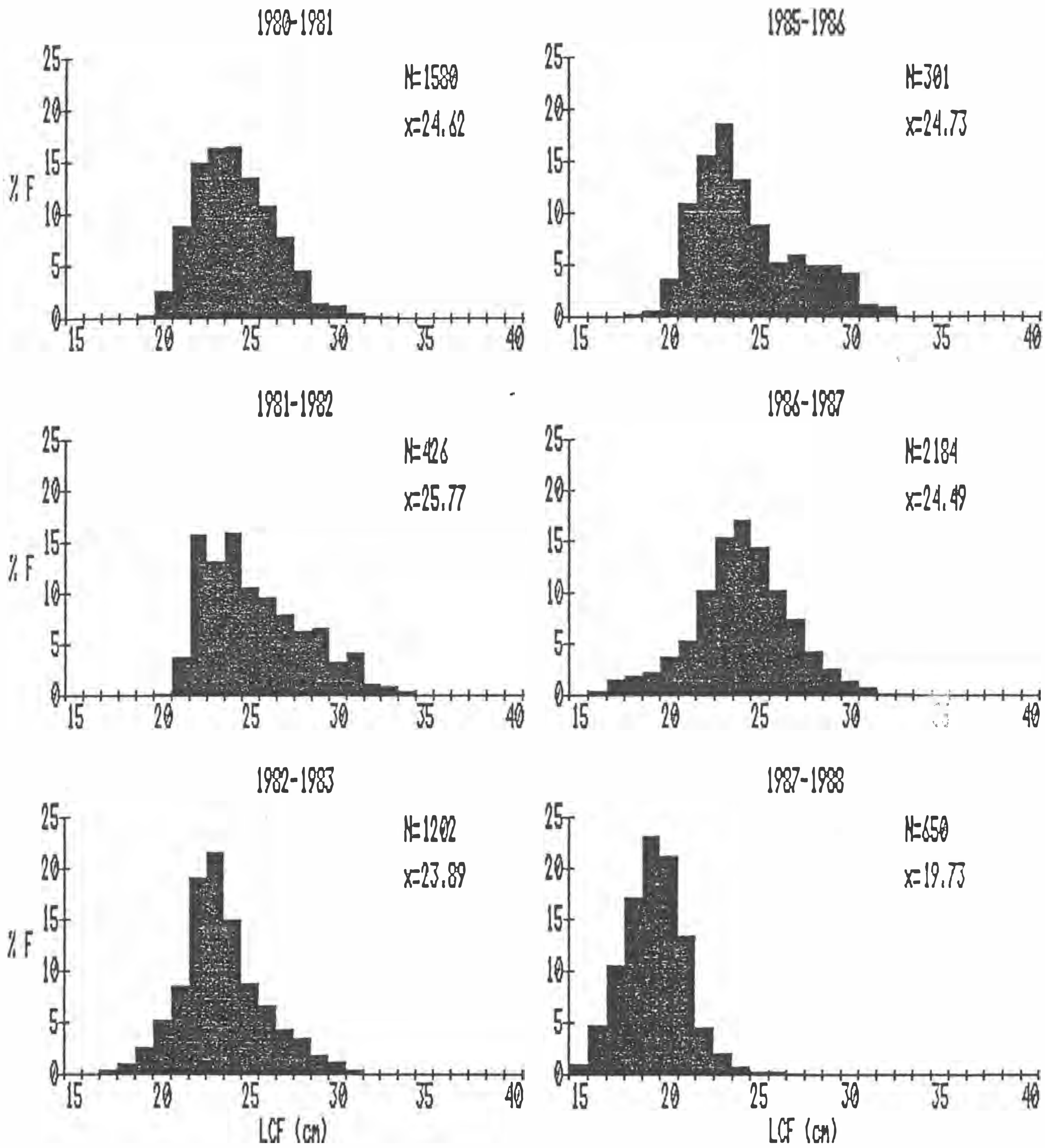

Fig. 6 continued. N.B. No data available for 1983/84 and 1984/85.