The interaction between fish trawling (in NSW) and other commercial and recreational fisheries

Final report to

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by

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1.0 NON-TECHNICAL SUMMARY

Background and research need

1. There is worldwide concern over the potential effects of by-catch and discarding of fish in commercial fisheries, particularly trawling. Although mortalities of discards are highly variable, it is likely that a large proportion of fish discarded at sea by trawlers do not survive. Consequently, discards at sea represent real losses from fish populations. Therefore, stock assessments that ignore the discarded component of catch are biased by an unknown amount, resulting in biomass and yield estimates that may be incorrect.

2. In Australia, the issue of primary concern is the direct mortality resulting from the capture and discard of commercially and recreationally important species by trawlers. This may result in negative impacts on: (i) stocks of fish targeted by the fishery concerned and/or (ii) other commercial or recreational fisheries (interacting fisheries) which catch the species discarded.

3. Fish trawling occurs off the coast of NSW between Crowdy Head and Eden and components of this fishery are managed by NSW Fisheries (north of Barrenjoey headland and less than 3 nm offshore to the south of Barrenjoey) and by the Commonwealth - the South East Fishery (> 3 nm offshore south of Barrenjoey).

4. Prior to the commencement of this project (in 1992): (i) except for anecdotal reports, nothing was known about quantities and sizes of fish discarded by fish trawlers; (ii) no reliable information existed about the quantities and sizes of fish in retained catches for fish trawlers north of Barrenjoey; (iii) quantities and sizes of non-quota species retained by fish trawlers in the SEF were not generally known.

5. Consequently, there was a need to (i) quantify magnitudes and size-compositions of retained and discarded catches of fish trawlers; (ii) facilitate assessment of the impact of by-catch and discards on the fish trawl fisheries in NSW and on interacting fisheries.

Research methodology

6. An observer survey, in which data were collected onboard fishing vessels during normal commercial fishing, was used to study the species composition of catches and estimate quantities and size-distributions of retained and discarded catches by fish trawlers on the NSW coast. Retained and discarded catches of fish trawlers were surveyed in each of 4 quarters in each of 3 years (1993-95), in each of 3 regions ("North": Newcastle/Tuncurry; Ulladulla; Eden).

7. A fishery-independent survey (by FRV Kapala) was used to compare abundances and size-distributions of commercial species on the NSW continental shelf across several spatial

and temporal scales: depths, locations, years, quarters (seasons) and day-time versus night-time.

Results

8. A total of 365 taxa (species or species groups) were identified in catches of commercial trawlers. Of these, 145 were classed as "commercial" species.

9. Mean catch rate (across all components of catch) increased with latitude, there being a significant difference among the mean catch rates (+/- 1 standard error) taken by the fleets of North (632 +/- 33 kg per fisher-day), Ulladulla (2,205 +/- 98 kg) and Eden (4,175 +/- 139 kg). Retained and discarded catches (all species combined) also increased with latitude.

10. Estimates of mean annual catches (across all components of catch) by these fleets were: North, 1,012 +/- 53 t; Ulladulla, 2,653 +/- 118 t; Eden, 8,671 +/- 289 t. Mean annual catch for the combined fleets of these regions was 12,336 +/- 316 t. Making several assumptions (outlined in Section 6.2), it may be estimated that a mean annual catch of approximately 2,000 t was taken by fish trawlers working north of Barrenjoey headland and approximately 18,000 t by fish trawlers south of Barrenjoey, approximately 20,000 t annually by all fish trawlers on the NSW coast.

11. Although rates of catch and annual estimates of retained and discarded catches differed among the 3 regions examined in the survey, an average of 50% of the total catch of fish trawlers was discarded by the combined fleets of North, Ulladulla and Eden. Approximately 30% (by weight) of the total catch of SEF quota species, 34% (by weight) of the total catch of non-quota commercial species and 100% (by weight) of the total catch of non-commercial species were discarded by the combined fleets of North, Ulladulla and Eden.

12. Retained and discarded catches of individual species varied among regions, years and quarters and was species-dependent. There was wide variation among species in both (i) the quantities of retained and discarded catches and (ii) the proportion of total catch discarded. It was estimated that more than 25% (by weight) of the total catch of the following commercial species (for which mean catch rates exceeded 20 kg per fisher-day) was discarded: redfish, barracouta, southern frostfish, piked dogshark, velvet leatherjacket, gemfish, jack mackerel, mirror dory, "offshore" ocean perch and "inshore" ocean perch. Between 10% and 25% (by weight) of the catch of tiger flathead and blue warehou were discarded.

13. For the catches of commercial species, sizes of fish discarded were generally smaller than the sizes of fish retained - the result of size-selective sorting.

14. By (i) comparing observer-based estimates of retained catches with reported landings and (ii) comparing observer-

based size-distributions with an auxiliary survey of size-distributions of landed catches at fishers' co-operatives, it was concluded that observer-based estimates of catch for the Ulladulla and Eden fleets for the 3-year period 1993-95 were accurate. That is, they were not biased by unrepresentative sampling of trawlers or by any significant change in onboard practices when an observer was present.

Conclusions and recommendations

15. This project has provided detailed descriptions of retained and discarded catches by fish trawling along the coast of NSW and variations in catches among the 3 regions, 3 years and 4 quarters sampled. Consequently, this project has provided the necessary data for agencies responsible for interacting fisheries to assess the relative importance of catches by NSW fish trawlers to stock assessment and subsequent management of these fisheries.

16. Discarded catches of inshore species targeted by recreational anglers (such as eastern blue spot flathead, yellowfin bream, tarwhine, snapper, tailor and mulloway) were of most significance in the northern region. It is, however, concluded that fishing mortality on these species due to discarding by fish trawlers is inconsequential compared with other known sources of fishing mortality (commercial landings by all methods, discards from prawn trawl fisheries, recreational catches).

17. The commercial species discarded in greatest quantities were species targeted and commonly retained in the SEF. In particular, several SEF quota species were discarded in large quantities: redfish, gemfish, mirror dory, ocean perches, tiger flathead and blue warehou.

18. Stock assessment techniques currently used for these species rely on analyses of catch-per-unit-effort (CPUE) trends and size/age structure. Discarded catches of each of these species represent a considerable proportion of the total catch of each species. Furthermore, for each of these species, the size-distribution of the retained catch is a poor representation of the size-distribution of the total catch. Consequently, stock assessments based on statistics of landed catch alone will be biased. Moreover, without some ongoing collection of data about discards, there is a danger that future changes in CPUE or size-distributions derived from landed catches may be misinterpreted as reflecting changes in fish stocks when there may simply be a change in discarding practice.

* *Provision should be made for the future collection of data about quantities and sizes of discards (off the coast of NSW and other States).*

19. Potential exists for yields from these stocks (see "17") to increase if the mortality due to capture and discarding was

decreased. The fish currently discarded could possibly be caught at a larger size.

* *There is a need for model-based assessments of the consequences of discarding SEF quota species on long-term yields for the SEF (and the NSW trawl fishery).*

20. Commercial species were discarded for a variety of reasons. Non-commercial species were discarded because, by definition, no market currently exists. Market and economic considerations, or the existence of minimum legal length legislation, determined the discarding of non-quota commercial species and probably also the discarding of most quota species in the SEF. For all quota species except gemfish and redfish, jurisdictional arrangements between the Commonwealth and NSW (the "3 nm loophole") meant that quotas could not be enforced for all but the final 4 months of the period 1993-95. It is considered unlikely that the existence of quotas influenced discarding of most quota species during this period. However, discarding of gemfish (TAC of 0) occurred when catches were made in excess of trip limits (in SEF waters and State waters). There is perhaps a further exception: an increase in discarding and decrease in retention of redfish at Ulladulla following the imposition of trip limits, in 1994, for catches made in State waters (thereby closing the "3 nm loophole"). Increased discarding may occur if quotas are more strictly adhered to.

* *Substantial benefits are likely to be gained from research into the selectivity of existing gears and gear modifications that seek to reduce the catches of unwanted sizes of commercial species (and unwanted species). A fundamental component of such research must be an analysis of the costs and benefits to the fishery of alternative trawl designs.*

* *The potential for increased usage of components of catches that are currently discarded should be evaluated.*

21. The fishery-independent survey by FRV Kapala demonstrated that abundances and size-distributions of several important commercial species were dependent on season, time of day (day versus night), depth and location. Consequently, any change in the pattern of fishing effort by the commercial fleet across these scales will result in changes in catch, CPUE and size (and age) distributions of catches. Without accurate data describing the distribution of effort across such spatial and temporal scales (e.g. reliable logbook data), changes in catch statistics derived from the fishery may be misinterpreted as reflecting changes in abundances and size-distributions of stocks when, in reality, they simply result from a change in the distribution of effort by fleets.

* *The problems associated with the accuracy of SEF logbook (SEF-1) data should be addressed urgently.*

2.0 BACKGROUND AND RESEARCH NEED

2.1 Introduction

There is worldwide concern over the potential effects of the by-catch and discarding of fish in commercial fisheries, particularly trawling (Saila, 1983; Andrew & Pepperell, 1992; Alverson et al., 1994; Kennelly, 1995). By-catch is that part of the gross catch that is captured incidentally to the species toward which there is directed effort and all, some or none of it may be discarded at sea (Saila, 1983). Catches of targeted species may also be discarded, particularly in fisheries managed using minimum legal lengths or output controls such as trip limits or annual quotas (e.g. Pikitch, 1991; Alverson et al., 1994).

Although mortalities of discards are highly variable and depend on biological, environmental and operational factors, it is apparent that a large proportion of fish discarded at sea do not survive (Neilson et al., 1989; Andrew and Pepperell, 1992; Alverson et al., 1994; Richards et al., 1995). Consequently, fish discarded at sea represent real losses from populations, so stock assessments that ignore the discarded component of catch are biased by an unknown amount and the potential biomass and yield from stocks may be reduced (Saila, 1983; Pikitch, 1991; Hilborn and Walters, 1992; Alverson et al., 1994). In addition to such direct effects, the capture and discard of fish may have more complex effects on community structure such as habitat degradation, influences on species interactions, and their consequent cascading effects through the trophic web (e.g. Hutchings, 1990; Sainsbury, 1991).

In many countries, including Australia, the issue of primary concern is the direct mortality of juveniles of commercially and recreationally important species due to trawling and discarding of by-catch (Kennelly, 1995; Liggins and Kennelly, 1996). This may have a negative impact on: (i) stocks of fish targeted by the fishery concerned and/or (ii) other commercial or recreational fisheries which catch the species discarded.

In the last decade, increasing awareness of the problems associated with by-catch and discarding have made these some of the most important and critical issues facing commercial and recreational fisheries throughout the world. The challenge to manage complex multi-species trawl fisheries and interacting fisheries has led to demands for increased research into by-catch and discarding (eg. Green et al., 1991; Alverson et al., 1994). Consequently, there has recently been widespread interest in estimating quantities and compositions of by-catches and discards in trawl fisheries (Alverson et al., 1994; Kennelly, 1995).

Observer-based surveys, in which data are collected onboard commercial fishing vessels during normal commercial fishing, have been widely used to estimate quantities and size/age distributions of by-catches and discarded catches from fish trawling (e.g. Jean, 1963; Jermyn and Robb, 1981; Howell and Langan, 1987; Alverson et al., 1994) and prawn trawling (e.g. Andrew and Pepperell, 1992; Alverson et al., 1994; Kennelly, 1995; Liggins and Kennelly, 1996). Data from such studies is fundamental to assessing: the importance of data about discarding to stock assessment; effects of discarding on populations; losses to fisheries; and potential solutions to these problems (e.g. Saila, 1983; Hilborn and Walters, 1992; Alverson et al., 1994).

It is also important that estimates of rates of discarding are scientifically sound (Saila, 1983). Just as stock assessments may be biased by absence of data about discarding, they may be biased by the inclusion of inaccurate data about discarding. A particular concern with observer surveys is that the process of observation may affect the process being observed: fishers may change their normal practices when being observed.

2.2 Fish trawling and catch statistics in NSW

Fish trawling off the coast of NSW comprises 2 geographic components that are managed separately. To the north of Barrenjoey Point and less than 3 nm offshore south of Barrenjoey Point, fish trawling is under the jurisdiction of New South Wales Fisheries. South of Barrenjoey Point, excluding State waters inside 3 nm, fish trawling occurs within the South East Fishery (SEF) and is managed by the Commonwealth. Figure 1 identifies the major fish trawl ports on the NSW coast, north and south of Barrenjoey Point. The SEF extends further southward, around Victoria and Tasmania and westward to Cape Jervis in South Australia (excluding State waters).

Both the NSW-managed trawl fishery and the SEF catch multiple species across a range of habitats on the continental shelf and slope. In the SEF, a regime of total allowable catches (TACs) and individual transferable quotas (ITQs) exists for 16 species (or species groupings) (see also Tilzey, 1994; Chesson, 1996). In the NSW-managed fishery the only catch regulation is by way of "trip limits" for some of the species subject to TACs in the SEF. Not only is the management of stocks complicated by this regime of dual management, but the catch and effort data routinely collected by NSW Fisheries and the Australian Fisheries Management Authority (AFMA) cannot be easily reconciled or integrated.

In 1993, 67 fish trawlers operating in the NSW-managed fishery reported a minimum of 50 days fished (NSW Fishers' monthly returns database, "Form 19"). Of these vessels, 39 were also endorsed to fish in the SEF and 28 were restricted to the NSW fish trawl fishery. Of the 28 vessels restricted to the NSW trawl fishery, 20 vessels fished mostly in waters to the north of Sydney. Many of these vessels were also licensed to fish in the offshore prawn trawl fishery. In the same year, 1993, 44 trawlers operating in the SEF and landing catch into NSW ports reported a minimum of 50 days fished (AFMA SEF-2 database). Therefore, approximately 70 fish trawlers worked off the NSW coast in 1993.

Catch and effort data are routinely collected from fishers operating in the NSW trawl fishery via mandatory monthly catch returns. However, several problems limit the practical use of these data, particularly with respect to fish trawling: (i) it is generally impossible to isolate catches from the NSW-managed section of the fishery and the SEF; (ii) for fishers who use more than one fishing method in a month, it is not possible to partition catch among methods; (iii) for SEF-endorsed fishers, landings of many species may not be reported individually but combined and reported as "Finfish - unspecified"; (iv) no independent landings data exist for validation of reported catches (Pease and Grindberg, 1995; Scribner and Kathuria, 1996).

Fishers operating in the SEF are required to submit details of catch and effort on a shot-by-shot basis ("SEF-1" logbook returns). However, the accuracy of logbook data since the introduction of quotas in 1992, is questionable. Misreporting of where quota species have been caught has occurred off NSW because of jurisdictional arrangements (Tilzey, 1994; Chesson, 1996). Fishers in the SEF are also required to submit details of weights of quota species landed at the completion of each fishing trip ("SEF-2", Quota monitoring system returns). Catches of quota species in NSW waters (inside 3 nm) are also reported on SEF-2 returns but are recorded separately as State-waters catches. For the same reasons that logbook data was corrupted, it is very likely that some catches taken in the SEF have been reported as State catches on SEF-2 returns.

The problems associated with the reporting of catch through the NSW monthly catch returns mean that very little is known about the composition of catches taken by fish trawlers operating in the NSW fishery, north of Barrenjoey. To the south of Barrenjoey, where most fishing occurs within the SEF, retained catch and effort data is available for quota species. However, little is known about the catches of other commercial species. No data is available for the discarded components of catch for either component of the fishery.

Consequently, in 1992, we were in the position in NSW of: (i) knowing nothing about quantities and sizes of fish in discarded catches of fish trawlers; (ii) having no reliable information about the quantities and sizes of fish in retained catches north of Barrenjoey; and (iii) having no reliable information about the quantities and sizes of fish in retained catches of non-quota species in SEF (the main component of the fishery south of Barrenjoey). This situation was obviously unsatisfactory and effectively precluded sound management of these fisheries (and also interacting fisheries).

2.3 Interacting fisheries

In NSW, many species are caught (as targeted catch or by-catch) by a variety of commercial methods and by recreational anglers. During the year 1992/93, catches of 265 species (or species groupings), by 44 fishing methods, from 84 estuaries and 55 ports were reported to NSW fisheries by commercial fishers (Scribner and Kathuria, 1996; see also Pease and Grindberg, 1995).

The accuracy of stock assessment for any species depends, among other things, on obtaining reliable estimates of total catches (both retained and discarded components) by all methods. Estimates of retained and discarded catches are therefore essential for commercially important species that are caught by fish trawlers or by any other commercial or recreational fishery.

Of major concern in NSW have been complaints regarding prawn and fish trawlers catching and discarding large numbers of juvenile fish that, when larger, are targeted in other commercial and recreational fisheries. Over recent years, this issue has become of increasing concern to commercial and recreational fishers, fisheries scientists and managers, conservationists and State and Commonwealth governments (Green et. al., 1991; Kennelly, 1995).

2.4 Research need

Estimates of the quantities and sizes of fish discarded by fish trawlers on the NSW coast are necessary for the long-term sustainable management of the South East Fishery (SEF), the NSW-managed trawl fishery and other interacting fisheries.

Stock assessments for species caught in these fisheries depend, among other things, on accurate determinations of total catches (both retained and discarded components) and length (and age) distributions of these catches. If discards represent a significant proportion of the total catch of a particular species, then any stock assessment that ignores the magnitude and size distribution of the discarded component of catch is likely to be erroneous. Levels of discarding and high-grading in the SEF are issues of particular concern given the management regime of total allowable catches (TACs) and individual transferable quotas (ITQs), introduced in 1992. High-grading refers to the practice of discarding certain sizes of fish while retaining sizes that receive higher prices.

Qualitative information from fishers, researchers and managers and preliminary surveys of the retained and discarded catches of fish trawlers based in Port Stephens, Ulladulla and Eden (in 1992) provided some information about the discarded catch of fish trawling. These data suggested that: (i) discards represented a significant proportion of total catches; and

(ii) catches contained large quantities of by-catch (non-target species) and juveniles of commercially and/or recreationally-important species.

Consequently, there was a need to estimate the magnitude and size compositions of retained and discarded catches by fish trawlers along the NSW coast and to determine if there are any significant spatial and temporal patterns in these variables. Associated with this was the need to maximise the precision and assess the accuracy of estimates of these components of catch.

3.0 OBJECTIVES

3.1 Original objectives

1. To provide the first detailed description of the catch and by-catch (retained and discarded components), and species composition from fish trawling outside the South East Fishery (SEF) in NSW (north of Barrenjoey).

2. To provided the first detailed description of the by-catch (in particular, the discarded catch) of fish trawling inside the SEF.

3. To assess the importance of by-catch (in particular, the discarded catch), inside and outside the SEF, in the total impact of fish trawling on other commercial and recreational fisheries.

4. To assess the impact of trawling in inshore (nursery) areas on commercial fisheries outside these areas, in particular the SEF.

3.2 Auxiliary objectives

5. To determine the relative accuracy and precision of alternative methods of estimating annual retained and discarded catches by trawl fleets.

6. To assess the accuracy of observer-based estimates of catch. Does the presence of an observer influence fishing practices and so bias observer-based estimates of catch?

4.0 RESEARCH METHODOLOGY

There were 2 basic components to this research.

(i) An observer-based survey, in which catch data were collected onboard fishing vessels during normal commercial fishing, was used to study the species composition of catches and estimate quantities and size-distributions of retained and discarded catches taken by fish trawlers on the NSW coast.

(ii) The NSW Fisheries research vessel "Kapala" completed a stratified randomised survey of the abundances and size distributions of commercial fish species on the continental shelf off NSW. This survey provided data about the distributions, abundances and size-compositions of fish across several spatial and temporal scales: depths, locations, years, quarters and day-time versus night-time.

4.1 Observer survey

4.1.1 Design and execution

Retained and discarded catches of fish trawlers were surveyed on approximately 24 fisher-days during each quarter (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) of each of 3 years (1993, 1994, 1995) in each of 3 regions of the NSW coast: fleets based in "North" (Newcastle and Tuncurry); Ulladulla; and Eden (see Figures 1 and 2). These regions were selected to cover the geographic range of the fishery in NSW. On the south coast, the Eden and Ulladulla fleets were selected because they were the largest. The original survey methodology included sampling of the 3 largest fleets on the north coast (Newcastle, Port Stephens and Tuncurry) but the owners and skippers of trawlers at Port Stephens did not wish to participate in the survey. Fishing trips out of Eden, of intended duration of more than 3 days were excluded from the sampled population of the survey because fishing generally took place far to the south of the study area. Fishing trips targeting royal red prawns, *Haliporoides sibogae*, were also excluded from the sampled population because the survey was designed to estimate catches from fish trawling.

In each region, we attempted to select fisher-days at random for inclusion in the survey. At Eden, where fishing trips were between 1 and 3 days duration, we attempted to select fishing trips randomly until the targeted number of fisher-days had been observed. We assumed that fisher-days on multi-day trips at Eden were independent because trawlers generally stayed out for the pre-planned number of days and there was no obvious relationship between catch rates and decisions to reduce or extend the duration of trips.

The number of fisher-days sampled during each quarter, in each year, averaged 23.2 for North, 23.8 for Ulladulla and 23.8 for

Eden (Figure 2). During the 3 years surveyed, 88, 93 and 97 fisher-days were observed at Newcastle/Tuncurry. These represented sampling fractions of 5.5%, 5.8% and 6.1%, respectively, of the estimated total number of fisher-days completed by the Newcastle/Tuncurry fleets (see Section 4.1.2.1). At Ulladulla, 97, 93 and 96 fisher-days were observed, with sampling fractions of 7.5%, 7.5% and 8.8%, respectively. At Eden, 96, 94 and 96 fisher-days were surveyed during the 3 years, with sampling fractions of 4.6%, 4.6% and 4.5%, respectively.

For each tow of each fisher-day sampled, observers recorded weights and numbers of the retained and discarded catches of each commercial species and size-distributions for each commercial species present in the discards. Commercial species are identified in the list of taxa in Appendix B. Size-distributions of retained catches were recorded opportunistically as time permitted. Operational data (location, depth, time, duration of tow) and a list of non-commercial species present in the catch were also recorded.

Retained weights of each species were estimated by weighing each box of fish or a subsample of boxes and counting the total number of boxes. On occasions when fishers graded species into separate size-classes for marketing purposes, the average weight of fish was estimated from a subsample of each grade of each species (usually a 30 - 40 kg box of fish) and used to estimate the total number of each species of each grade, and consequently, the total number of each species retained. The total weight of discards was estimated using one of two methods. If the catch was relatively small, total weight of discards was estimated from the catch remaining on deck after the crew had sorted out the fish to be retained. If the catch was relatively large, the crew discarded fish as the catch was sorted. In these circumstances, the weight of total catch was estimated and an estimate of total discards was calculated by subtracting the estimated total weight of retained catch from estimated weight of total catch. Composition and abundances of species and size-distributions were estimated from a subsample of discards (usually a 30-40 kg box) and an estimate of the sampling fraction. All species present in the discards were recorded.

4.1.2 Observer-based estimates of catch rates

Estimates of mean retained and discarded catches per fisher-day and estimates of annual retained and discarded catches by whole fleets required auxiliary data about effort (in units of fisher-days) and/or retained (landed) catches by fleets, in each region, year and quarter.

4.1.2.1 Reported catch and effort data

All fishers in the SEF are required to report landed catches of quota species and the duration of each fishing trip (dates of departure and return to port) to the Australian Fisheries Management Authority (on "SEF-2", "Quota monitoring system" returns). Only those fishing trips that conformed to the criteria for the sampled population of the observer survey were included in calculations of fishing effort and landed catch (i.e. trips of less than 3 days' duration and trips not targeting royal red prawns). Number of fisher-days and total landings of each SEF quota species were calculated for the Ulladulla and Eden-based fleets, in each quarter of each year.

Quarterly fishing effort (in units of fisher-days), for the ports of Ulladulla and Eden, was calculated as follows: (i) trips for which the reported dates of departure and return to port were identical each contributed 1 fisher-day of effort; (ii) trips for which the dates of departure and return to port differed by *d* days contributed an estimated $d - 0.5$ fisher-days.

Annual weights of landed catches of each quota species were calculated from the data reported by fishers making landings into Ulladulla and Eden. Landed weights that were reported for "processed" fish (gutted, or headed and gutted) were converted to "whole" weights using approximate conversion factors (1.1 for pink ling, 1.25 for gemfish, 1.5 for blue grenadier).

Obtaining landed catch and effort data for the northern sector of the fishery was more problematic. Due to time delays with entry of data into the NSW fishers' monthly returns database, complete statistics were only available for 1993 (not 1994 or 1995). Furthermore, limitations of the data collected on NSW fishers' monthly returns meant that it was not generally possible to obtain reliable data for landed catches, specifically from fish trawling, for the North region (Newcastle and Tuncurry). Newcastle and Tuncurry fishers reported an effort of 2,426 fisher-days in 1993. This figure is not considered reliable and it almost certainly overestimates true effort. During the 3 years of observer work at Newcastle and Tuncurry we consistently worked on 8 trawlers and occasionally on several others that trawled for fish part-time. Assuming that an average of 8 trawlers worked for an average of 17 fisher-days each month, fishing effort would be approximately 400 days per quarter. All observer-based estimates of retained and discarded catches by fish trawlers in region "North" are based on the assumption that the fleet completes 400 fisher-days per quarter, a total of 1600 fisher-days per year. The consequences of making this assumption are discussed in Section 5.1.6.

4.1.2.2 Components of catch

Estimates of mean catches per fisher-day were calculated annually (1993, 1994, 1995) for each region (North, Ulladulla, Eden), for total catch and 7 partitions of total catch, each comprising multiple species:

- total catch
  - retained catches of all species combined
    - retained SEF quota species
    - retained non-quota commercial species
  - discards of all species combined
    - discarded SEF quota species
    - discarded non-quota commercial species
    - discarded non-commercial species

Estimates of mean retained and discarded catches per fisher-day were also calculated for all individual commercial species (SEF quota species and non-quota commercial species).

4.1.2.3 Relative accuracy and precision of alternative estimators of catch

The relative accuracy and precision of stratified mean-per-unit, combined ratio and combined regression estimators of catch were compared in an auxilliary study. The rationale, methods, results and conclusions from this study are described in the manuscript *"Observer-based estimates of discarded and total catch: relative reliability of mean-per-unit, ratio and regression estimators"* (in Appendix C).

Based on the study described above, "stratified mean-per-unit" estimators were used to estimate catch rates and annual retained and discarded catches of all components of catch with 2 exceptions: discards of tiger flathead and jackass morwong at Ulladulla and Eden. The "combined ratio" estimator produced estimates with better precision (lower coefficients of variation) than the stratified mean-per-unit estimator for these species. Each of these estimators is described below and in further detail in Appendix C.

4.1.2.4 Application of estimators

Stratified mean-per-unit estimator

(used to estimate catch per fisher-day and annual catches of all components of catch except discards of tiger flathead and jackass morwong at Ulladulla and Eden)

With a simple random sample of fisher-days taken in each quarter of each year, the estimated mean catch (discarded retained catch) per fisher-day (for a region), y, and its estimated variance, $s^2(y)$, were calculated using the stratified mean-per-unit ("SMPU") estimator as follows: which can also be expressed in the form:

$$\overline{y}_{SMPU} = \sum_{q=1}^{4} W_q . \overline{y}_q \tag{1}$$

$$s^2(\overline{y}_{SMPU}) = \sum_{q=1}^{4} \frac{W_q^2 . (1-f_q)}{n_q} . \frac{\sum_{i=1}^{n_q} (y_{qi}-\overline{y}_q)^2}{(n_q-1)} \tag{2}$$

$$s^2(\overline{y}_{SMPU}) = \sum_{q=1}^{4} \frac{W_q^2 . (1-f_q)}{n_q} . s^2(y_q) \tag{3}$$

in which $W_q = N_q/N$ is the relative size of the stratum, y_q is the mean retained or discarded catch), y_{qi} is the retained or discard catch taken on the i'th fisher-day, $s^2(y_q)$ is the variance of discarded catch, n_q is the sample size, N_q is the number of fisher-days by the fleet, and $f_q = n_q/N_q$ is the sampling fraction, in quarter q of the year. N is the number of fisher-days completed by the fleet in the year.

Combined Ratio estimator

(used to estimate catch per fisher-day and annual catches of discarded tiger flathead and jackass morwong at Ulladulla and Eden)

The combined ratio estimator, Rc uses the ratio of the SMPU estimate of discarded catch to an auxilliary variable (the SMPU estimate of the retained catch of that species), R_C, to estimate mean discarded catch per fisher-day, y_{RC}, and its estimated variance, $s^2(y_{RC})$, by:

$$\hat{R}_C = \frac{\overline{y}_{SMPU}}{\overline{x}_{SMPU}} \tag{4}$$

$$\overline{y}_{RC} = \hat{R}_C . \overline{X} \tag{5}$$

$$s^2(\overline{y}_{RC}) = \sum_{q=1}^{4} \frac{W_q^2 . (1-f_q)}{n_q} . \frac{\sum_{i=1}^{n_q} (y_{qi} - \hat{R}_c . x_{qi})^2}{(n_q-1)} \tag{6}$$

which can also be expressed as:

$$s^2(\bar{y}_{Rc}) = \sum_{q=1}^{4} \frac{W_q^2 . (1-f_q)}{n_q} . [s^2(y_q) + \hat{R}_c^2 . s^2(x_q) - 2 . \hat{R}_c . s(y_q, x_q)] \quad (7)$$

in which y_{qi} and x_{qi} are catches taken on the i'th fisher-day, $s^2(x_q)$ is the variance of the retained catch and $s(y_q, x_q)$ the covariance of the sample in each quarter q. X is the mean landed catch (per fisher-day), obtained from SEF-2 returns, for the species.

Estimates of mean catches (per fisher-day) for combinations of years and regions

Mean catches (and associated variances) calculated for each year, in each region, were used to calculate mean catches (i) during the period 1993-95 for each region; (ii) for the combined fleets of North, Ulladulla and Eden, in each year; and (iii) for the 3 years and 3 regions combined. Using an SMPU estimator, estimates of mean catch, y_h, and variance, $s^2(y_h)$, in each year for each region were combined to estimate mean catch, y, and associated variance, $s^2(y)$, over k strata, as follows:

$$\bar{y} = \sum_{h=1}^{k} W_h . \bar{y}_h \quad (8)$$

$$s^2(\bar{y}) = \sum_{h=1}^{k} W_h^2 . s^2(\bar{y}_h) \quad (9)$$

in which W_h is the proportion of fishing effort contributed to the total by stratum h. For estimates of mean catch across the 3 years for each region and across the 3 regions for each year, k = 3. For estimates of mean catch across the 3 regions and the 3 years, k = 9.

Estimates of retained and discarded catches by whole-fleets

Estimates of catch per fisher-day were scaled to provide annual estimates of catch by whole-fleets using the known total effort (in units of fisher-days) by the fleet in each year.

Estimates of size-distributions of annual catches

Quarterly size-distributions of retained and discarded catches of each commercial species were calculated for each region after weighting the size-frequency distributions (relative frequencies) obtained from each observed tow by the relative catch (relative number of fish) of each tow.

Annual size-distributions (relative frequencies) for each region were calculated by weighting quarterly size-distributions (relative frequencies) by the relative catches (estimated number of fish caught) taken by fleets in each quarter.

Annual size-distributions (relative frequencies) for each region and year were combined to produce size-distributions: (i) across the 3 regions for each year; (ii) across the 3 years for each region; and, (iii) across the 3 regions and the 3 years. In each case, annual size-distributions (relative frequencies) were weighted by the relative catches (number of fish caught) in each region/year.

4.1.3 Comparisons of catch rates among regions, years and quarters

Analyses of variance (ANOVA), followed by Student-Newman-Keuls multiple comparisons when appropriate, were used to detect significant differences in mean catch rates (per fisher-day). These differences were tested between regions (North, Ulladulla, Eden; fixed factor), years (1993, 1994, 1995; fixed factor) and quarters (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec; fixed factor). To provide balanced ANOVAs, 21 fisher-days were selected randomly from the fisher-days surveyed in each quarter of each year in each region. Catch data were transformed by $log_e(x+1)$ to normalise the data and stabilise variances.

4.1.4 Accuracy of observer-based estimates of catch

Observer-based estimates of quantities and size-distributions of by-catches and discarded catches may be biased by non-representative selection of sampling units (fisher-days) or by changes in fishing practices onboard trawlers when observers are present. In an auxiliary study, the accuracy of observer-based estimates of catch was examined for the fleets of Ulladulla and Eden. Observer-based estimates of magnitudes and size-distributions of retained catches were compared with independent, unbiased estimates that were available for a subset of species (SEF quota species) caught in the fishery. Weights of landed catches of SEF quota species were calculated from SEF-2 returns. An auxiliary survey of the size-distributions of catches landed at Ulladulla and Eden was completed during May/June and September/October of 1994 and 1995 at fishing co-operatives in Ulladulla and Eden. Conclusions about bias in estimates of other components of catch (especially discards) are based on the premise that bias is unlikely to affect these estimates without also affecting estimates of retained catches of quota species.

Further background to this study and a detailed description of the methods used are provided in the manuscript *"Detection of bias in observer-based estimates of retained and discarded catches from a multi-species trawl fishery"* (in Appendix D).

4.2 Fishery-independent survey

During 1993 and 1994 the NSW Fisheries research vessel "Kapala" conducted a stratified randomised survey of the abundances and size distributions of commercial fish species on the continental shelf off the NSW coast between Newcastle and Eden. Quarterly surveys were completed in each of the two years (1993, 1994), in each of 3 depth strata (30-60m, 90-125m, 125-160m). Three locations were chosen from the trawlable ground within each depth stratum for inclusion in the survey. Two tows of 60 minutes duration were completed during pre-dawn (night) and post-dawn (day) periods on each of 2 days during each quarter, in each year, at each location, in each depth stratum. The starting position and direction of each tow were selected at random within the defined location on each day of the survey.

Gear configuration was similar to that used by many of the large commercial trawlers operating in the fishery, with the exception of a 45 mm cod-end liner. The cod-end liner was included to retain smaller sizes of fish than would have been retained using the standard 90 mm cod-end mesh.

Data collected from each tow included weights, numbers and size-distributions of each commercial finfish species present in the catch. Operational data recorded included the depth range of the tow and ambient sea and weather conditions.

Prior to the commencement of this survey some preliminary survey work was completed to: (i) measure the fishing dimensions of the trawling gear; and, (ii) test the feasibility of the sampling procedures, in different depths. It was important to conduct such preliminary trials to determine appropriate operational factors (warp lengths, warp length : depth ratios) so that the spread of the gear could be standardised across the depths. The trials and subsequent doorspread estimates indicated that the spread of the gear in depths of 30 m and 120 m were within 5-10% (see Kapala Cruise Report No. 113).

Further details about the execution of the survey are contained in the cruise reports for the 1993 and 1994 surveys (Kapala Cruise Reports, No. 114 and 115).

5.0 RESULTS

5.1 Observer survey

5.1.1 Catch rates - Major partitions of catch

Mean catch (kg) per fisher-day did not vary significantly among the 3 years surveyed (1993, 1994 and 1995) for any of the 3 fleets (North, Ulladulla and Eden). There was, however, a significant difference among the catch rates taken by the fleets of North, Ulladulla and Eden. Mean catch per fisher-day (+/- 1 se) increased with latitude: 632 +/- 33 kg for North, 2,205 +/- 98 kg for Ulladulla and 4,175 +/- 139 kg per fisher-day for Eden trawlers (Figure 3.1, Table 1). Regardless of region or year, catch rate was maximal in the 3rd quarter of the year, July - September (Figure 4.1, Table 1). Mean catch per fisher-day for the combined fleets of these regions was 2,528 +/- 65 kg.

Retained catches (mean kg per fisher-day, +/- 1 se) increased with latitude (376 +/- 20 kg for North; 1,377 +/- 16 kg for Ulladulla; 1,856 +/- 39 kg for Eden trawlers). Quantities of retained catch were similar from year to year (Figure 3.2, Table 1). Retained catches were usually lowest during the first quarter of each year and highest in the 3rd quarter. Catches during the 2nd and 4th quarters of each year were generally between these extremes (Figure 4.2, Table 1).

The quantities of fish discarded (mean kg per fisher-day) also increased with latitude (257 +/- 18 kg for North; 828 +/- 97 kg for Ulladulla; 2,319 +/- 134 kg per fisher-day for Eden). Discarded catches were significantly greater during the 3rd quarter of each year in each region (Figure 4.2, Table 1).

The retained catch of SEF quota species, by the Ulladulla fleet, was less in 1994 (997 kg) and 1995 (967 kg) than in 1993 (1,280 kg). Retained catches of SEF quota species were similar in each year for the North and Eden fleets (Figure 3.3). Retained catches of SEF quota species by the Ulladulla fleet were lower during January-March than during the other 3 quarters. At Eden, catches were greater during April-June and July-September than during January-March and October-December (Figure 4.3).

Various interactions between the factors Region, Year and Quarter were significant in ANOVAs for discarded catches of SEF quota species (Figures 3.3 and 4.3, Table 1), retained and discarded catches of non-quota commercial species (Figures 3.4 and 4.4, Table 1) and discarded catches of non-commercial species (Figures 3.5 and 4.5, Table 1). Catch per fisher-day for these partitions of catch generally increased with latitude and were similar from year to year. Patterns of catch across the 4 quarters of each year were less consistent.

Figure 5 depicts the proportional contribution of the major partitions of catch to total catch: in each region in each year; for the combined regions in each year; for the 3 years combined for each region; and for the 3 years and 3 regions combined. As described in the paragraphs above, catch compositions differed between regions but were generally similar among years within each region. Eden trawlers discarded a greater proportion of their catch (56% discarded) than North and Ulladulla trawlers (41% and 38% respectively). The retained catch of SEF quota species represented a greater proportion of the total catch at Ulladulla (49%) than at North (26%) or Eden (30%).

Contributions of the major partitions of catch to total catch varied across the spatial and temporal scales examined in this survey (regions, years, quarters). However, the summary figures below, averaged across all regions and years, provide an overview of the scale of retained and discarded catches by fish trawlers on the NSW coast. Mean catch per fisher-day by the combined fleets of North, Ulladulla and Eden, during the period 1993-95 was 2,528 +/- 65 kg. This total catch comprised:

TOTAL CATCH:	**2,528 +/- 65 kg**	
Retained catch:	**1,253 +/- 18**	**(50%)**
SEF quota species:	858 +/- 4	(34%)
non-quota species:	394 +/- 18	(16%)
Discarded catch:	**1,275 +/- 62**	**(50%)**
SEF quota species:	372 +/- 39	(15%)
non-quota commercial spp:	207 +/- 18	(8%)
non-commercial spp:	697 +/- 34	(28%)

5.1.2 Species composition of catches

A total of 365 taxa (species or higher taxonomic groups) were identified during the observer survey and 145 of these were defined as "commercial" species (see Appendix B).

Of the 309 finfish species identified, 121 were classified as "commercial" (ie. species often retained in this fishery or in other commercial fisheries). Thirty-four crustacean taxa were identified, of which 17 were classed as "commercial". Of the 12 mollusc taxa identified, 7 were "commercial". Four echinoderm, 3 cnidarian, 1 annelid, 1 mammal and 1 reptile taxa were also identified.

A complete taxonomic listing is contained in Appendix B. this list contains family, scientific and common names of species/taxa identified in catches during the observer survey.

5.1.3 Catch rates, retained and discarded - individual species

Detailed information about retained and discarded catch rates (per fisher-day) and variations among regions, years and quarters are provided in Appendix A for each of 35 commercial species.

Figure 6 provides a summary of retained and discarded catches (per fisher-day) for the combined fleets of North, Ulladulla and Eden across the 3 year period 1993-95 and across all quarters. There is wide variation among species in both (i) the quantities of retained and discarded catches and (ii) the proportion of total catch discarded. Of the species with total catches in excess of 20 kg per fisher day (those shown on page 1 of Figure 6), in excess of 25% of the total catch (by weight) was discarded for redfish (52%), barracouta (44%), southern frostfish (59%), piked dogshark (55%), velvet leatherjacket (57%), gemfish (72%), jack mackerel (80%), mirror dory (44%), "offshore" ocean perch (40%) and "inshore ocean perch" (85%). Between 10% and 25% of catches of tiger flathead (13%) and blue warehou (15%) were discarded. Less than 10% of the total catches of spotted trevalla, silver trevally, pink ling, arrow squid, jackass morwong, john dory, Deania spp. dogsharks and angel shark were discarded.

In the northern region, the 10 commercial species retained in greatest quantities by trawlers contributed 67% of the retained catch weight of all species combined (ie. 67% of 376 +/- 20 kg per fisher-day): silver trevally (29%), tiger flathead (6%), shovelnose ray (6%), piked dogshark (6%), redfish (4%), john dory (4%), angel shark (3%), sawsharks (3%), long-nosed whaler (3%). The 10 species discarded in greatest quantities contributed 70% of the total weight of discarded commercial species (ie. 70% of 44 +/- 5 kg per fisher-day): redfish (27%), tiger flathead (10%), snapper (7%), piked dogshark (6%), eastern blue-spot flathead (4%), tailor (4%), whaler sharks (3%), rubberlip morwong (3%), "inshore" ocean perch (3%) and eagle ray (3%).

At Ulladulla, the 10 commercial species retained in greatest quantities contributed 86% of the total retained catch of commercial species (ie. 86% of 1,377 +/- 16 kg per fisher day): redfish (47%), tiger flathead (9%), pink ling (6%), piked dogshark (4%), silver trevally (4%), mirror dory (4%), angel shark (3%), "offshore" ocean perch (3%), john dory (3%), arrow squid (2%). The 10 commercial species discarded in greatest quantities contributed 98% of the discarded catch of commercial species (98% of 413 +/- 75 kg per fisher-day): redfish (74%), gemfish (13%), tiger flathead (3%), southern frostfish (3%), "inshore" ocean perch (1%), mirror dory (1%), "offshore" ocean perch (1%), silver dory (< 1%), rubberlip morwong (< 1%) and barracouta (< 1%).

At Eden, the 10 commercial species retained in greatest quantities contributed 77% to the total retained catch of commercial species (ie. 77% of 1856 +/- 39 kg per fisher-day): spotted trevalla (19%), tiger flathead (10%), redfish (8%), pink ling (7%), barracouta (7%), jackass morwong (6%), blue warehou (6%), arrow squid (6%), silver trevally (4%), *Deania spp.* dogshark (3%). The 10 commercial species discarded in greatest quantities contributed 87% of the weight of discarded commercial species (ie. 87% of 1087 +/- 96 kg per fisher-day): redfish (35%), barracouta (9%), southern frostfish (8%), piked dogshark (7%), jack mackerel (7%), velvet leatherjacket (5%), "inshore" ocean perch (5%), gemfish(4%), mirror dory (3%) and "offshore" ocean perch (3%).

For the combined fleets of North, Ulladulla and Eden, the 10 commercial species retained in greatest quantities contributed 71% to the total retained catch of commercial species (ie. 71% of 1253 +/- 18). The top 20 species contributed 86% of 1,253 +/- 18 kg per fisher-day: redfish (18%), spotted trevalla (12%); tiger flathead (10%), silver trevally (6%), pink ling (6%), arrow squid (4%), barracouta (4%), jackass morwong (4%), blue warehou (4%), piked dogshark (2%), john dory (2%), southern frostfish (2%), Deania spp. dogshark (2%), offshore ocean perch (2%), mirror dory (2%), angel shark (2%), velvet leatherjacket (2%), blue grenadier (1%), octopus (1%), gemfish (1%). The 10 commercial species discarded in greatest quantities contributed 88% to the total discarded weight of commercial species (ie. 88% of 579 +/- 45 kg per fisher-day): redfish (42%), barracouta (7%), southern frostfish (7%), piked dogshark (6%), jack mackerel (5%), gemfish (5%), velvet leatherjacket (4%), "inshore" ocean perch (4%), tiger flathead (3%), mirror dory (3%).

Figure 7 provides a summary of quarterly retained and discarded catches (per fisher-day) of 20 species, for the combined fleets of North, Ulladulla and Eden for the period 1993-95. Differences in the quantities of fish retained during each quarter were species-dependent. Similarly, the patterns of discarded quantities across quarters were species dependent. (Figure 7, Table 2, Appendix A).

Note that references in the above paragraphs to proportions or percentages of catches discarded were all in units of weight. For most species, the proportion of catch discarded in units of number of fish exceeds the proportion of catch discarded in units of weight (see Appendix A). This occurs because sizes of fish discarded are generally smaller than the sizes of fish retained.

5.1.4 Size distributions of retained and discarded catches

Size-distributions of retained and discarded catches of individual species, by the fleets of North, Ulladulla and Eden, in each year surveyed, are provided in Appendix A.

Figure 8 provides a summary of sizes of fish discarded by the combined fleets of North, Ulladulla and Eden during the 3 year period 1993-95. Sizes of fish discarded were generally smaller than the sizes of fish retained for each of the 18 species shown in this figure, except gemfish. This is indicative of size-selective sorting and, depending on the species, results from the existence of a minimum legal length (MLL) for the species (tiger flathead, jackass morwong, rubberlip morwong, eastern blue-spot flathead, yellowfin bream, tarwhine and snapper) or the practice of high-grading (discussed in Section 6.3). Note that fork lengths were measured in this study (for species with forked caudal fins) and minimum legal lengths refer to total lengths. Consequently, the length at which fish subject to MLLs are retained (as shown in Figure 8 and Appendix A) may be less than the MLL because of the difference between fork length and total length for some species (e.g. morwongs, yellowfin bream, tarwhine and snapper).

Discards make a major contribution to the size distribution of the total catch (retained and discarded) for many of these species (redfish, tiger flathead, gemfish, mirror dory, "offshore" and "inshore" ocean perch, rubberlip morwong, eastern blue-spot flathead and snapper. For these species, the size-frequency distribution of retained catch alone is a poor representation of the size-frequency distribution of the total catch.

5.1.5 Estimates of annual retained and discarded catches

Estimates of annual catches, for each of the major partitions of catch, by survey region and year, are shown in Tables 3 and 4.

For individual species, estimates of annual catches (total, retained, discarded; by weight and by number) by the fleets of North, Ulladulla and Eden for 1993, 1994 and 1995 are provided in Appendix A.

Tables 5 - 8, summarise mean annual catches of individual species for the combined fleets of the 3 regions (Table 5) and for each region separately.

5.1.6 Accuracy of observer-based estimates of catch

It was concluded that estimates of catch, based on the 3-year period 1993-95, were unaffected by significant bias (Appendix D). Observer-based estimates of magnitudes of retained catches did not differ significantly from reported landings for: 6 out of 7 species and the combined catch of quota species (CQS) for the Ulladulla fleet; 11 out of 11 species and CQS for the Eden fleet; and 10 out of 11 species and CQS for the combined fleets of Ulladulla and Eden. There was, however, some evidence of bias in estimates of catch for each fleet in 1 of the 3 years examined (1994 for Ulladulla, 1995 for Eden). Observer-based size distributions were not significantly biased. Further details about the results and conclusions derived from this analysis are provided in Appendix D.

Because of limitations associated with the catch and effort data collected on NSW fishers' monthly returns the same validation procedure could not be used to validate estimates of catches for North. Assumptions associated with the calculation of estimates of catches for North must be noted. Estimates of annual retained and discarded catches per fisher-day assume that effort (in units of fisher-days) was the same in each quarter of the year. If effort and catch rates differed from quarter to quarter, estimates of mean catch per fisher-day may be biased. If the assumed annual fishing effort of 1600 fisher-days (400 fisher-days per quarter) over- or underestimates the true effort, estimates of annual catches by the fleets of Newcastle and Tuncurry will be biased accordingly. Thus, estimates of annual catches for North must be considered less accurate than those derived for Ulladulla and Eden.

5.2 Fishery-independent survey

Detailed descriptions of catch compositions, catch rates and size-distributions of catches are contained in Kapala cruise reports covering the 1993 and 1994 components of the survey (Kapala Cruise Reports No. 114 and 115). A brief summary is given here.

The total catch taken over the 2 years consisted of about equal quantities of commercial and non-commercial species (Kapala Cruise Report No. 115 - Table 5). The total catch of commercial finfish species was 172 t and comprised 71 species. Only 36 species each contributed more than 100 kg to the total catch. Redfish (38%) and tiger flathead (22%) contributed the bulk of the catch of commercial fish. Another 12 species each contributed between 1 and 10% of the total catch of commercial fish (Kapala Cruise Report No. 115 - Table 6). In addition, 11.5 t of cephalopods were caught: cuttlefish (36%), arrow squid (34%), southern calamary (16%) and octopus (13%).

Distributions, abundances and size-distributions of many important commercial species differed across the spatial and temporal scales examined: years, seasons, day versus night, depth and location (see Kapala Cruise Reports No. 114 and 115 for details).

The occurrence, relative abundances and/or size compositions of several species were related to depth. Redspot whiting, eastern blue spot flathead, inshore angel sharks, banjo sharks, eagle rays and southern calamary were caught almost exclusively on inshore grounds. Over 80% of the catches of barracouta, ocean perches and latchet (sharp-beaked gurnard) were taken on outer-shelf grounds. Abundances of redfish, tiger flathead, offshore angel sharks, eastern sawsharks and arrow squid increased with depth. Abundances of velvet leatherjacket and shovelnose rays decreased with depth. Sizes of redfish and silver trevally increased with depth. Further details about the sizes of redfish in different depths are provided in the manuscript *"Modelling the length-dependent offshore distribution of redfish, Centroberyx affinis"* (in Appendix E). The proposed model provides an approach to incorporating a size-dependent offshore distribution of fish into models of fish population dynamics and stock assessment.

For several species, there were differences in diurnal catchabilities, especially on inshore grounds. On the inshore grounds, night-time catches of redfish and redspot whiting were greater than day-time catches during most survey periods. In contrast, silver trevally were more abundant in day-time tows on inshore grounds. On the deeper grounds, catchability of pink ling was greater at night and john dory and barracouta were more catchable during the day.

Relative abundances of commercial species also varied seasonally. Commercial fish, redfish in particular, were most abundant during winter. Barracouta, blue warehou and spotted warehou (spotted trevalla) and jack mackerel were most abundant in autumn and winter catches.

Catches of recreationally-important species were low. Sand (eastern blue spot) flathead was the most abundant species and the majority caught were greater than the minimal legal length of 33 cm.

6.0 DISCUSSION

6.1 Description of retained and discarded catches

Quantifying magnitudes and size-distributions of retained and discarded catches is fundamental to examining issues associated with by-catch and discarding. Fishery derived data on catches and catch compositions underpins stock assessments in the SEF and, prior to this project, little was known of the quantities and size-distributions of: (i) retained and discarded catches by fish trawlers operating in the NSW fishery north of Barrenjoey; (ii) retained catches of non-quota species and discarded catches of all species from the SEF. This project has provided detailed descriptions of retained and discarded catches in these areas and examined the variability of catch rates, annual catches and size-distributions across several spatial and temporal scales: regions, years and quarters. The importance of running the observer survey during each quarter of each of 3 years in each of 3 regions cannot be over-emphasised. Recent reviews of the international literature concerning issues of by-catch and discarding have noted an increase in the use of observer-surveys to collect catch data but point out that few datasets are based on extended sampling over seasons and years (Alverson et al., 1994). In our survey, quantities and size-distributions of retained and discarded catches of numerous individual species and partitions of catch varied considerably among the 3 regions, the 3 years and the 4 quarters sampled.

The variation in catch rates (retained and discarded catches) of individual species across these scales was species-dependent. Although rates of catch and annual estimates of retained and discarded catches differed across the 3 regions examined in the survey, on average, 50% of the total catch of fish trawlers was discarded (a discard ratio of 1:1). Similar discard ratios have been observed in fish trawl fisheries around the world and discard ratios are much higher in several fisheries, for example: Northwest Atlantic fishtrawl, 5.3:1; Bering Sea rock sole, 2.6:1; British Columbia cod trawl, 2.2:1 (Alverson et al., 1994).

Approximately 30% (by weight) of the catch of SEF quota species and 34% (by weight) of the catch of non-quota commercial species were discarded by the fleets of North, Ulladulla and Eden during the period 1993-95. There was wide variation in the proportions of catches of individual commercial species that were discarded. Discards exceeded 25% of total catch (by weight) for the following species: redfish (52% by wt, 66% by number), barracouta (44% by wt, 57% by num), southern frostfish (59% by wt, 79% by num), piked dogshark (55% by wt, 72% by num), velvet leatherjacket (57% by wt, 69% by num), gemfish (72% by wt, 67% by num), jack mackerel (80% by wt), mirror dory (44% by wt, 72% by num), "offshore" ocean perch (40% by wt, 70% by num), "inshore" ocean perch (85% by wt, 93% by num). Even for those species with discard ratios between 10% and 25% (by weight), considerable proportions of the total catch in units of numbers of fish were discarded: tiger flathead (13% by wt, 31% by num) and blue warehou (15% by wt, 32% by num).

Size-selective retention (and discarding) of catches occurred for each of these species with the size of retained fish being larger than discarded fish, with the single exception being gemfish (see Section 6.3).

6.2 Expansion of estimates of catch to other regions of NSW

Assuming that the survey regions of North, Ulladulla and Eden are generally representative of fish trawling along the NSW coast; results of this project may be generally applied to fish trawling on the coast of NSW. Furthermore, estimates of annual retained and discarded catches may be expanded to include catches by fleets in non-surveyed ports as follows.

Fishing effort by the Ulladulla and Eden fleets during the period 1993-95 (excluding trips targeting royal red prawns and trips > 3 days duration) totalled 9840 fisher-days (SEF-2 database). Fishing effort for all SEF trawlers landing catches into NSW ports (excluding trips targeting royal red prawns and trips > 3 days duration) totalled 15,586 fisher-days (SEF-2 database). If catches by the Ulladulla and Eden fleets are representative of catches by SEF trawlers in other ports then estimates of annual catches for the combined fleets of Ulladulla and Eden may be scaled to estimate the SEF catches across all ports using the multiplier 1.6 (ie. 15,586 / 9840).

Of course, this procedure is not necessary for estimating retained catches of quota species as this data is known from SEF-2 returns. Table 9 shows that the combined fleets of Ulladulla and Eden caught 68% of the total retained catch of quota species by SEF trawlers in NSW during the period 1993-95. Note that this suggests an expansion factor of 1.5 (100% / 68%) for estimating catches by SEF trawlers across all ports - very close to the expansion factor of 1.6 described in the paragraph above. For individual quota species, the percentage of the total retained catch by SEF trawlers in NSW that was contributed by the fleets of Ulladulla and Eden varied between 54% (gemfish) and 96% (spotted trevalla). Estimates of discards of SEF quota species, across all SEF trawlers, may also be made using the observed ratio of discards to retained catch of each species and applying this ratio to known landed catch.

Retained and discarded catches of all fish trawlers north of Barrenjoey may be estimated as follows. Estimates of annual catches by Newcastle and Tuncurry trawlers were based on an assumed annual effort of 1600 fisher-days. In 1993, the total number of fisher-days reported for fish trawling by trawlers landing catches into ports north of Sydney was 3375. Assuming catches by Tuncurry and Newcastle trawlers were representative of catches by all fish trawlers north of Sydney, estimates of annual catches for survey region North may be scaled to estimate annual catches by all trawlers using the multiplier 2.1 (ie. 3375 / 1600).

Use of the expansion factors, described above, to estimate catches by fish trawlers across all NSW ports are approximate and assume that estimated catch rates for the 3 regions surveyed are broadly representative of catch rates in non-surveyed regions. Note that these calculations do not include catches by non-SEF fish trawlers fishing south of Barrenjoey (relatively few operators). Results of the calculations described above are not included in this report. They are described here simply to demonstrate that, with several assumptions, estimates of catch for the entire coast of NSW can be calculated.

6.3 Reasons for discarding

It is convenient to consider reasons for discarding with respect to the different partitions of catch: non-commercial species; non-quota commercial species; and, SEF quota species. By definition, discarding of non-commercial species occurs because there is no market for these components of catch. These species are a by-catch of the fishery targeted at other species and are 100% discarded.

Discarding of non-quota commercial species in the SEF, and SEF quota species in the northern sector of the fishery (north of Barrenjoey where SEF quotas do not apply) is primarily driven by market and economic considerations. Discarding of several species in this category is driven by minimum legal length legislation (e.g. eastern blue spot flathead, snapper, yellowfin bream and tarwhine). Note that, south of Barrenjoey in the SEF, catches of all species of flathead are subject to a TAC. However, catches of eastern blue spot flathead at Ulladulla and Eden were inconsequential (see Appendix A) - hence, the discussion of this species in this paragraph.

It is not trivial to analyse the reasons behind discarding of quota species in the SEF. For most of the survey period, the existence of the so-called "3 nm loophole" meant that ITQs could not practically be enforced in NSW. It is recognised that many fishers reported catches that were actually taken in SEF waters (outside 3 nm) as having been taken in NSW waters (inside 3 nm). These fish were not subtracted from the ITQ held by these fishers. In general it is believed that ITQs did not limit landings during this period. Minimum legal lengths are legislated for 2 quota species in NSW (tiger flathead and jackass morwong) and discarding of these species is explained by this alone - fish were only discarded if they were below legal length. Discarding of gemfish occurred when in excess of the trip limit (which varied between 100 kg and 300 kg during the period 1993-95) was caught. Because of the existence of the "3 nm loophole", it is likely that discarding of the other quota species was mainly driven by market/economic factors rather than by the direct effects of TACs/ITQs limiting retained catches. There may, however, be an exception.

In 1993, at Ulladulla, the mean catch of redfish was 980 +/- 46 kg per fisher-day of which 839 kg was retained and 141 +/- 46 kg was discarded. In 1994, NSW Fisheries introduced a trip limit for redfish caught inside 3 nm. This trip limit (initially 300 kg per day then 500 kg per day) reduced the capacity of fishers to exploit the "3 nm loophole". Mean catch rate for redfish in 1994 was 929 +/- 160 kg per fisher-day (similar to 1993) but the retained catch of 522 kg was lower than in 1993 and the discarded catch of 407 +/- 160 kg per fisher-day was higher than 1993 (see Appendix A, Figure 1.1). Furthermore, there was an increase in the size at which redfish were discarded (see Appendix A, Figure 1.4). These observations are consistent with the following explanation: (i) catches of redfish were not limited by TACs/ITQs in 1993 because of the "3 nm loophole"; (ii) the combination of TAC/ITQs and the NSW trip limit effectively limited the retained catch of redfish at Ulladulla in 1994; and (iii) resulted in a decrease in the proportion of catch retained and an increase in the proportion of catch discarded and a consequent increase in the sizes of discarded fish. This then, may be an example of a direct influence of TACs/ITQs on discarding practices.

In addition to the reasons for discarding discussed above, discarding also occurs for a much broader reason - because the unwanted fish are caught in the first place. While this statement may seem obvious, it does emphasise the influence of gear selectivity on the quantities and sizes of fish caught and subsequently, the quantities and sizes of fish retained and discarded.

6.4 Impacts of discarding and stock assessment

It is simplistic to assume that because estimates of weights or numbers of fish discarded appear high, that discarding is having a significant effect on the stock being fished. Assessment of the impact on fish stocks must take into account the quantities and sizes (and ages) of fish discarded, the survival of discarded fish, and measure the loss to the stock from discarding against: (i) losses resulting from retained catches; (ii) losses from natural mortality; (iii) the biomass of the stock; and (iv) the positive effects of growth and recruitment on stock biomass (e.g. Hilborn and Walters, 1992). It has been demonstrated that the inclusion of data about discards in stock assessments can, in some cases, drastically alter perceptions of the status of exploited stocks and, in particular, changes in yields that could potentially result from changes in regulations (e.g. Saila, 1983; Pikitch, 1991; Alverson et al., 1994).

Retrospective assessments that combine estimates of catch at age (or length) with relative indices of stock abundance (from fishing vessels or research vessels) produce trends in stock size and fishing mortality rates. If discards are primarily juveniles and are not included in assessments of this type, fishing mortality will be underestimated, as will the stock size of small fish. Inclusion of discards of adult fish will have positive effects on estimates of stock biomass and stock numbers-at-age. The importance of discards to model-based predictions for a fishery depends on the types of predictions being made. Long term calculations such as equilibrium yield or yield per recruit, particularly under conditions of variable discard proportions, are the most sensitive to the inclusion of accurate estimates of discarded catches in assessments. Furthermore, lack of data about discards is particularly serious when attempting to assess impacts of changes in gear selectivity on yields (ICES, 1986).

6.5 Interaction with other commercial fisheries

Many of the species caught by fish trawlers in NSW are also caught (as targeted catch or by-catch) in sectors of the SEF off Victoria and Tasmania and in other commercial fisheries in south eastern Australia (e.g. Commonwealth and State trap, drop line, longline and gill net fisheries) (Kialola et al., 1993; Chesson, 1996). This project has provided the necessary data for agencies responsible for these interacting fisheries to assess the relative importance of catches by NSW fish trawlers to stock assessments and subsequent management in these fisheries. Furthermore, this study underlines the need for similar assessments in these other fisheries.

6.6 Interaction with recreational fisheries

Several of the major target species of the fish trawl fishery are also taken by recreational anglers (redfish, tiger flathead, silver trevally, jackass morwong, ocean perches and john dory) (Steffe, In prep.). However, in recent years, the major conflict between the recreational sector and commercial sector concerns the capture and discard by trawlers of juveniles of inshore species targeted by recreational anglers. Species in this category include: eastern blue spot flathead, yellowfin bream, tarwhine, snapper, tailor, mulloway and rubberlip morwong.

With the exception of rubberlip morwong, discarded catches of these species were confined to the northern survey ports (Newcastle and Tuncurry). Estimates of mean annual discards of these species by the combined fleets of Newcastle and Tuncurry were: snapper, 5 +/- 1 t, 31,000 +/- 4,000 fish; eastern blue spot flathead, 3 +/- 0 t, 17,000 +/- 3,000 fish; tailor, 3 +/- 1 t, 22,000 +/- 7,000 fish; tarwhine, 2 +/- 0 t, 12,000 +/- 4,000 fish; mulloway, 2 +/- 1 t; and yellowfin bream, 0.5 +/- 0 t, approx. 2000 fish (see Table 6). These estimates may be scaled to estimate discarded catches by all fish trawlers north of Barrenjoey using an expansion factor of 2.1

(discussed in Section 6.2). Regardless of the accuracy of this calculation, it is concluded that fishing mortality on these species due to discarding by fish trawlers is inconsequential compared with other sources of fishing mortality (see below).

Reported commercial landings of each of these species in NSW are of the order of hundreds of tonnes annually (Pease and Grinberg, 1995). For the most recent year for which NSW catch statistics have been published, 1992/93, landed catches by the commercial sector were as follows: snapper, 610 t; eastern blue spot flathead, 137 t; tailor, 102 t; tarwhine, 61 t; mulloway, 154 t; and yellowfin bream, 623 t (Scribner and Kathuria, 1996). Of course, large quantities of these species are also taken by recreational anglers (see West and Gordon, 1994; Steffe et al., 1996; Steffe, In prep.). Moreover, by-catches (and discards) of these species by prawn trawlers (Kennelly et al., 1992; Kennelly, 1993; Liggins and Kennelly, 1996; Liggins et al., In press) exceed, generally by an order of magnitude, the estimated discarded catches of fish trawlers in NSW.

6.7 Consequences for stock assessment and impacts of discarding in the SEF and NSW fish trawl fishery

This project has demonstrated that fish trawlers operating along the NSW coast discard large quantities of commercial species (30% of catches of SEF quota species and 34% of non-quota commercial species). Discards of several SEF quota species (redfish, gemfish, mirror dory, "offshore" ocean perch, "inshore" ocean perch, tiger flathead and blue warehou) exceeded 15% (by weight) and 30% (by number of fish) of total catch.

The stock assessment techniques currently used for these species rely on analysis of CPUE trends and size/age structure (Chesson, 1996). Each of the analyses is very dependent on the quality of catch, CPUE and size-distribution data collected from the fishery. It is clear from this project (see Figures 6 and 8; and Appendix A for further detail) that discarded catches of these species represent a significant proportion of the total catch, CPUE and size (and age) distributions for these species. The stock assessment techniques currently used for these species are based on the assumption that CPUE is indicative of abundance of fish and that shifts in CPUE or size-distributions are indicative of changes in abundance and changes in size-structures of stocks. If, for any reason (e.g. market forces, alteration of TAC, imposition or removal of trip limits), there is a change in the relative quantities of fish retained and discarded, the relationship between CPUE and abundance is corrupted. With a combination of catch statistics obtained from landed (retained) catches and observer-based estimates of quantities and sizes of fish discarded at sea, CPUE and size-distributions of the total (actual) catch by trawlers can be estimated. Without estimates of the discarded component of catch, changes in CPUE and size-distributions may be interpreted as changes in abundances or size-distributions of fish when these changes actually result from changes in discarding practices. Hence, there is an important need for data about discarded catches.

Of the species mentioned above (first paragraph), the status of the stocks of mirror dory, tiger flathead and ocean perch are considered "fully exploited - with a high degree of uncertainty". The status of the stock of gemfish (eastern gemfish) is classified as "overexploited - with a moderate degree of uncertainty". The stocks of redfish and blue warehou are classified as "status uncertain" (Chesson, 1996). Assuming that these classifications are accurate, or approximately so, and given that significant proportions of the catches of these species are discarded in the fishery, it is likely that yields from these stocks would be increased if the mortality due to capture and discard was decreased. The fish currently discarded could be caught at larger size. Gains in yields would, of course, be dependent on natural mortalities (and fishing mortalities by other methods) during the time taken for these fish to grow to sizes that would be retained.

These concepts underline the importance of several lines of future research: (i) model-based assessment of the benefits of reducing the discards of these species; (ii) a comparative study of selectivities of existing trawl gears and modified gears (different mesh sizes, codend designs, etc); and, thereafter, (iii) an assessment of the positive and negative effects of alternative trawl gears on quantities and size-distributions of catches. Research along these lines, with the cooperation of the fishing industry, may also provide a means of reducing discards of non-quota commercial species and non-commercial components of catch.

The results of Kapala's fishery-independent survey of variations in abundances and sizes of commercial species across depths, locations, seasons and time of day also have consequences for stock assessment. These results suggest that CPUE and size composition data collected from the commercial fishery will be altered whenever the commercial fleet shifts its effort across these spatial and temporal scales. Consequently, there is a danger that changes in fishery-derived catch, CPUE or size compositions may be attributed to changes in fish stocks when, in reality, the changes result from distribution of effort. Without data describing the distribution of fishing effort across such spatial and temporal scales (as could be gained from reliable logbook data) changes in commercial catch statistics may be misinterpreted as reflecting changes in abundances and size-distributions of stocks.

7.0 RECOMMENDATIONS

1. There is a need for model-based assessments of the consequences of discarding SEF quota species on long-term yields for the SEF (and the NSW trawl fishery).

Assessment of impacts of discarding on fish stocks must take into account the relative magnitudes of losses resulting from retained catches, losses from natural mortality, stock biomass and the positive effects of growth and recruitment on stock biomass (see Section 6.4). This study has provided estimates of discards for trawlers operating off NSW. In conjunction with similar data from the Scientific Monitoring Program (for Victoria and Tasmania), there is a need to assess the significance of discarding in the calculation of yields for trawled species and to incorporate data on discards into current stock assessments.

2. Substantial benefits are likely to be gained from research into the selectivity of existing gears and gear modifications that seek to reduce the catches of unwanted sizes of commercial species (and unwanted species). A fundamental component of such research must be an analysis of the costs and benefits to the fishery of alternative trawl designs.

Such a research program would identify the feasibility of reducing the catch of unwanted fish using modified trawl designs (in particular, codend designs). Of course, the benefits of reducing the capture of unwanted species and sizes of fish would need to be measured against any costs to the fishery by way of reduced catches of wanted species.

3. Provision should be made for the future collection of data about quantities and sizes of discards (off the coast of NSW and other States).

It is likely that management interventions (e.g. changes to TACs/ITQs or trip limits) may cause temporal changes in quantities and sizes of retained and discarded components of catches. In the absence of data about discards, there will be difficulty in determining whether post-intervention changes in retained catches, retained CPUEs or size-distributions of retained catches result from changes in discarding practices or changes in total catches by the commercial fleet.

4. The potential for increased usage of components of catches that are currently discarded should be evaluated.

The opportunity to increase the use of components of catch currently discarded is dependent on expanding existing, or establishing new markets for these components of catch. Analysis of the economics of landing and marketing these components of catch is of obvious importance.

5. The problems associated with the accuracy of SEF logbook (SEF-1) data should be addressed urgently.

Kapala's fishery-independent survey demonstrated that abundances and size-distributions of important commercial species (on trawl grounds) were dependent on season, time of day (day versus night), depth and location. Consequently, any change in the pattern of commercial fishing effort across these scales, may result in changes in catch, CPUE and size-distribution data derived from the commercial catch. Without accurate data describing the distribution of effort across such spatial and temporal scales (as could be gained from reliable logbook data) changes in commercial catch statistics may be misinterpreted as reflecting changes in abundances and size-distributions of stocks.

8.0 ACKNOWLEDGMENTS

This project could not have proceeded without the co-operation and good-will of fishers in the ports of Tuncurry, Newcastle, Ulladulla and Eden. Fishers in these ports provided input to the design of the observer survey and provided on-going support for the survey by allowing scientific observers onboard their vessels.

Technical staff (Mark Bradley, Jeff Nemec, Keith Chilcott, Cris Ashby, Norm Lenehan, Greg Collins, Matt Broadhurst) worked tirelessly and with attention to detail when collecting survey data onboard trawlers, in fishers' co-operatives or processing data in the office. In collecting the large quantities of data upon which this project is based, their contribution to this project was immense. Ken Graham, Jutta Wildforster, Brendan Wood and the crew of FRV Kapala made a major contribution in completing the 2 year fishery-independent survey.

The Bureau of Resource Sciences provided additional funding to the observer survey as part of the SEF Scientific Monitoring Program (SMP). The involvement of Dr Derek Staples, Dr Jean Chesson, Mr John Garvey and members of the SMP steering committee provided major benefits to this project. The assistance of the Australian Fisheries Management Authority is also acknowledged. In particular, we thank John Davis, Thim Skousen and Shane Spence for their prompt and efficient preparation of subsets of data from the SEF-2 database.

During various phases of the project many others contributed to the design, analysis and discussion of project data. In particular, Dr Steve Kennelly and Kevin Rowling (of NSW Fisheries) and Professor Tony Underwood (University of Sydney) contributed to the design of the surveys, analyses of data and provided many hours of valuable discussion and criticism.

Geoff Liggins (Principal investigator)

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Figure 1

Fish trawl ports in NSW

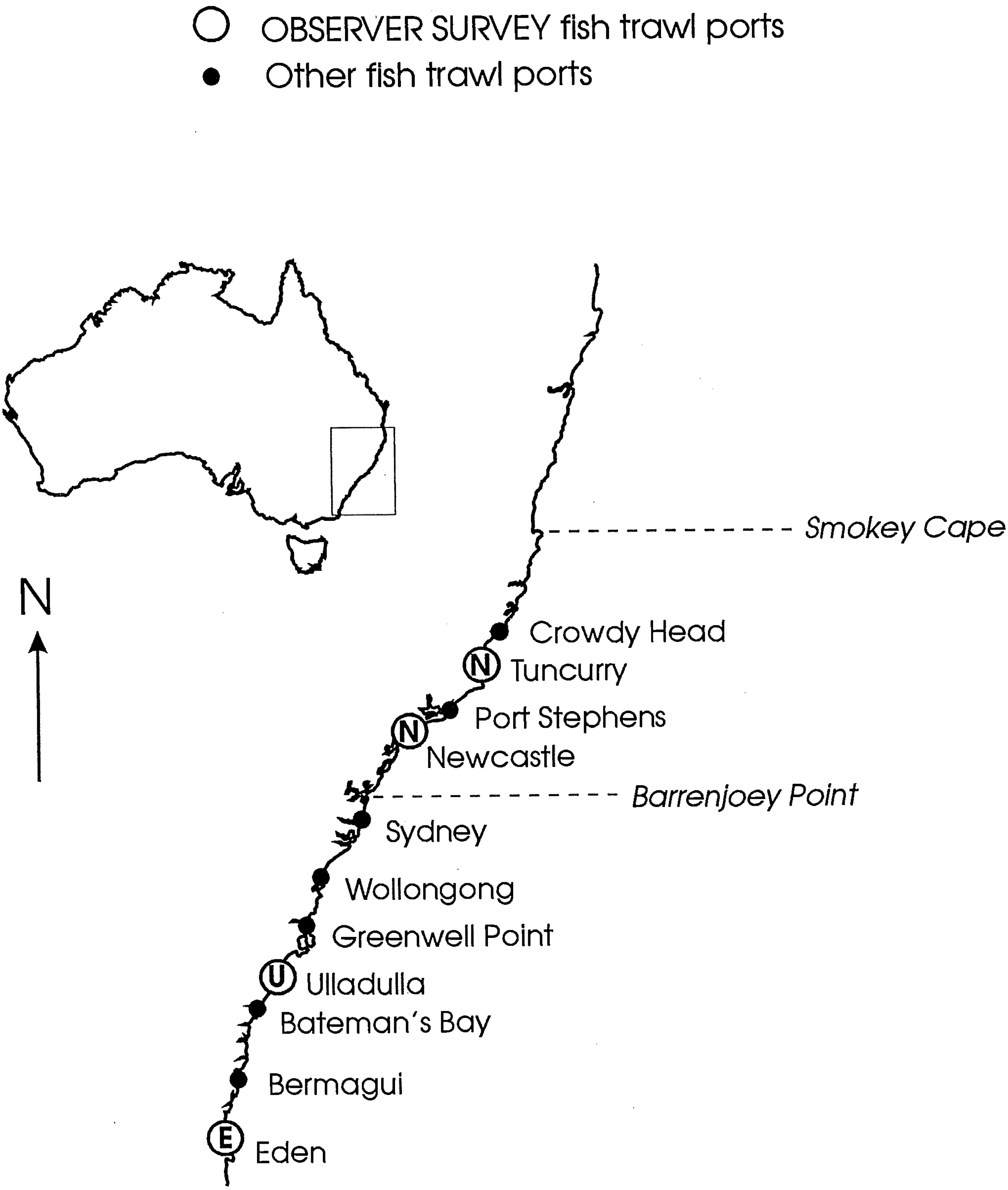
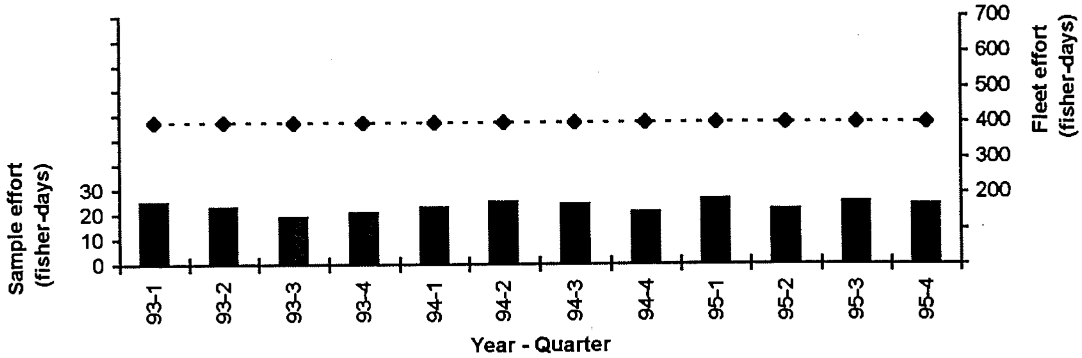


Figure 2

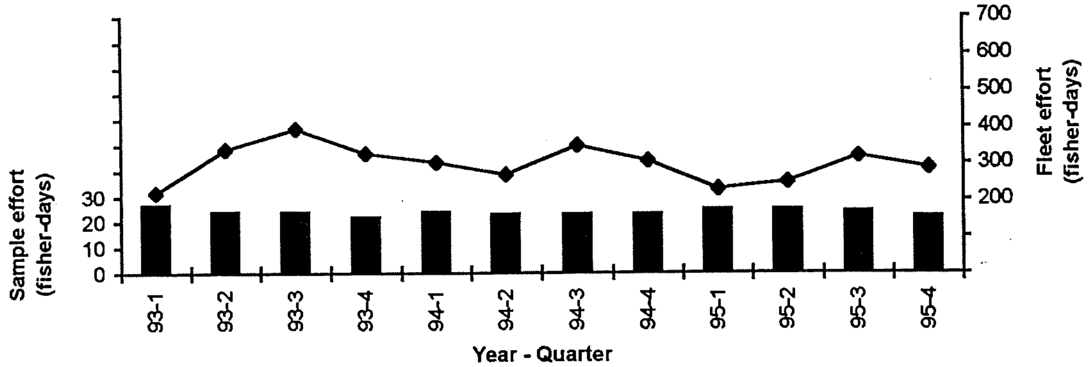
Quarterly sampling effort and fishing effort, by region

Fishing effort data for Ulladulla and Eden derived from Commonwealth "SEF-2" data
Fishing effort for North based on assumption of 400 fisher-days per quarter

North



Ulladulla



Eden

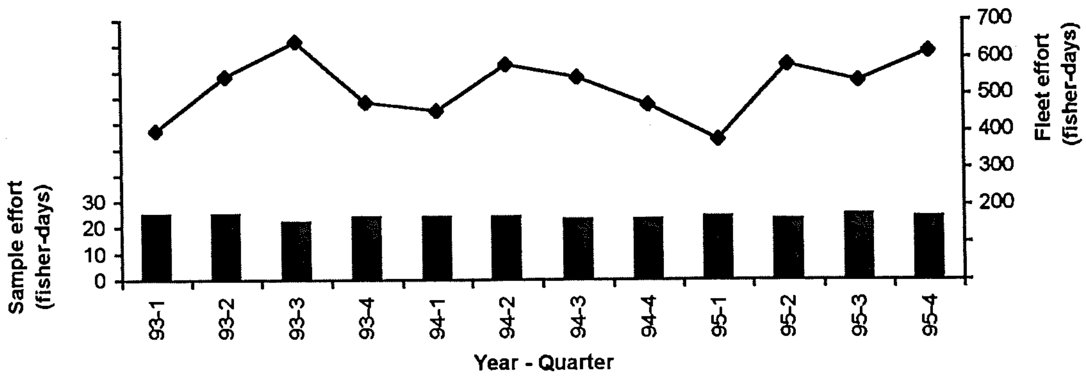


Figure 3.1

Total catches (kg per fisher-day)
by Year, by Region

(mean kg. per fisher-day, +/- 1 se)

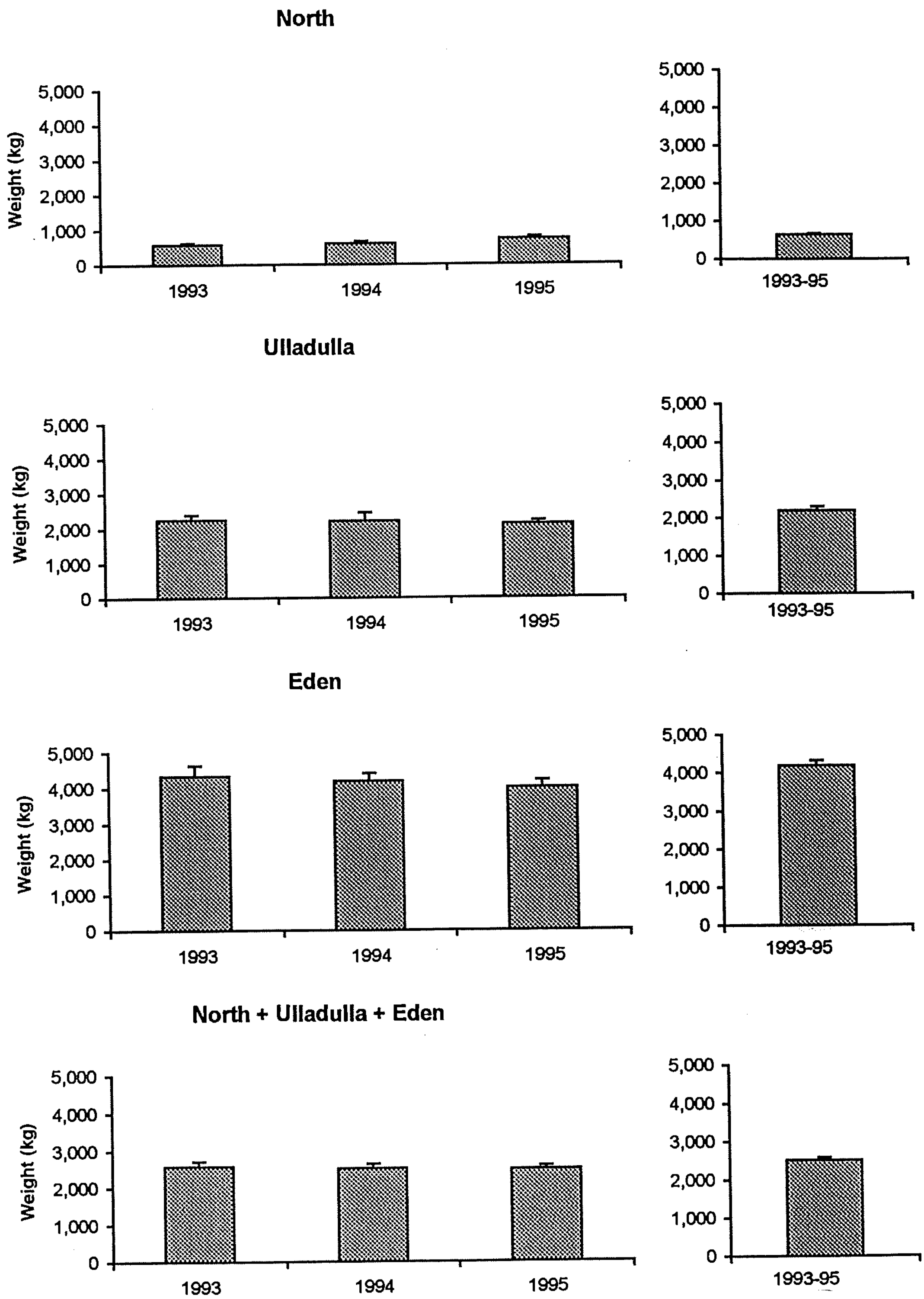


Figure 3.2

Retained and discarded catches (kg per fisher day)
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

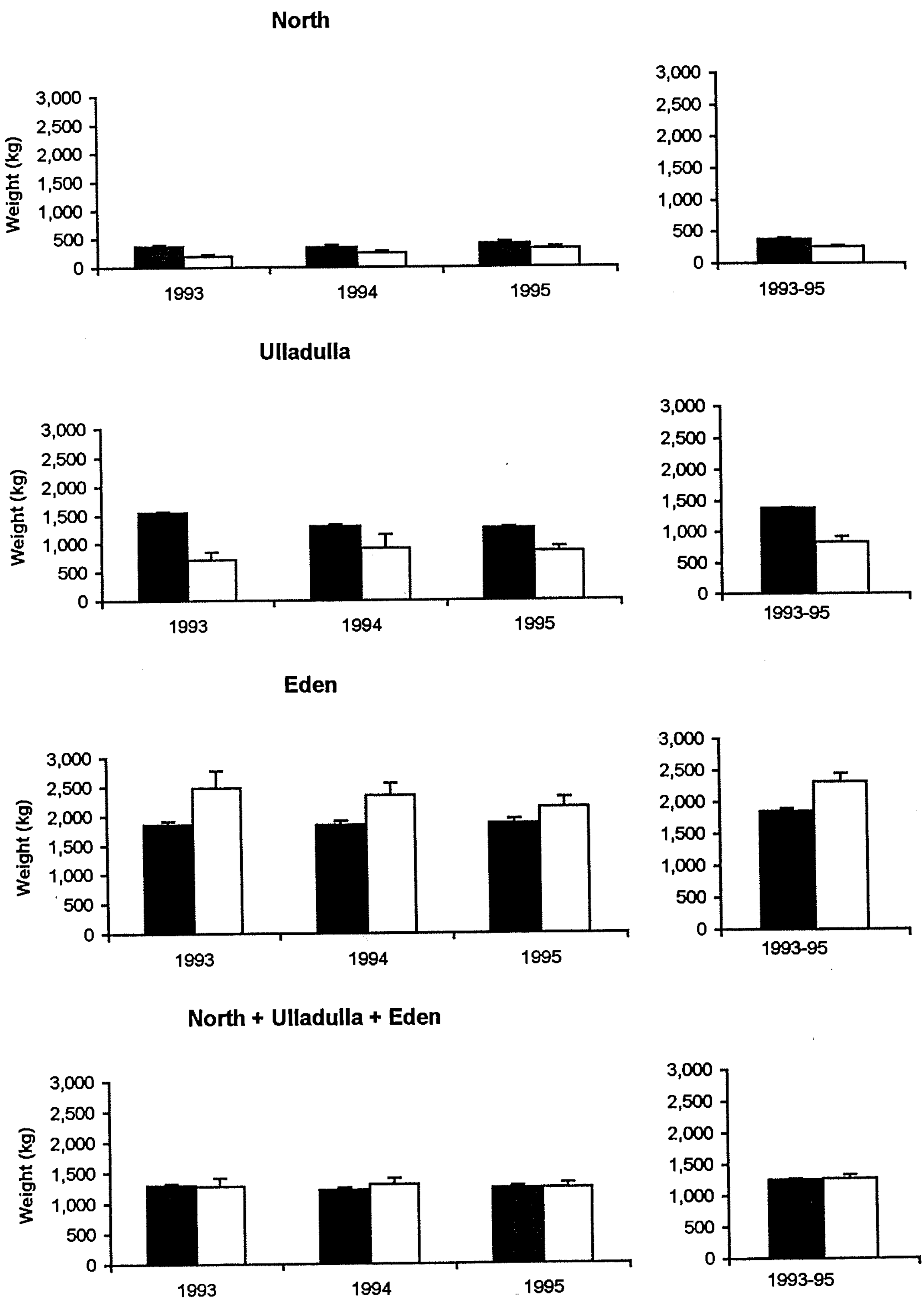


Figure 3.3

Retained and discarded catches of SEF quota species (kg per fisher-day)
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

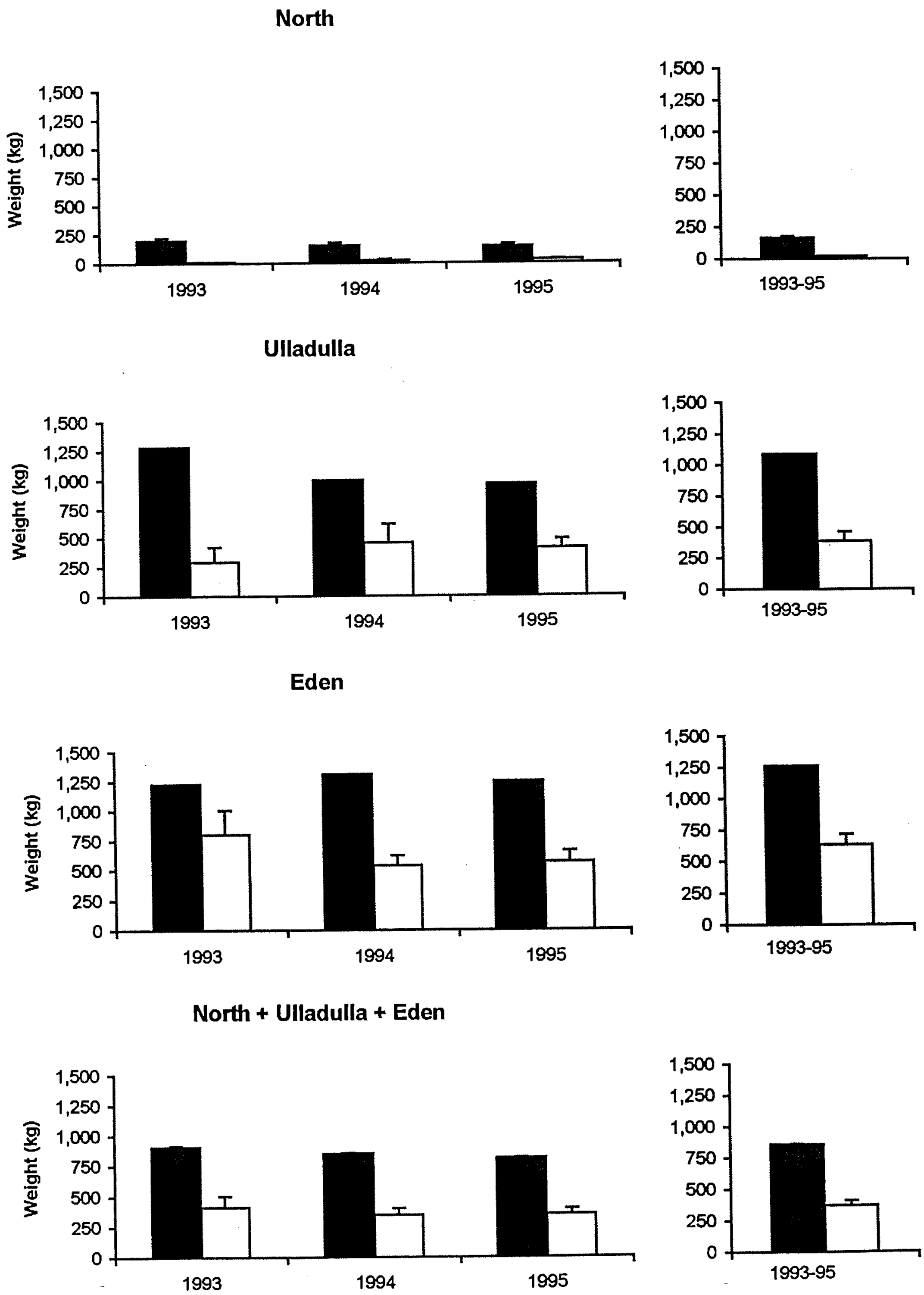


Figure 3.4

Retained and discarded catches of non-quota commercial species
(kg per fisher-day) by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

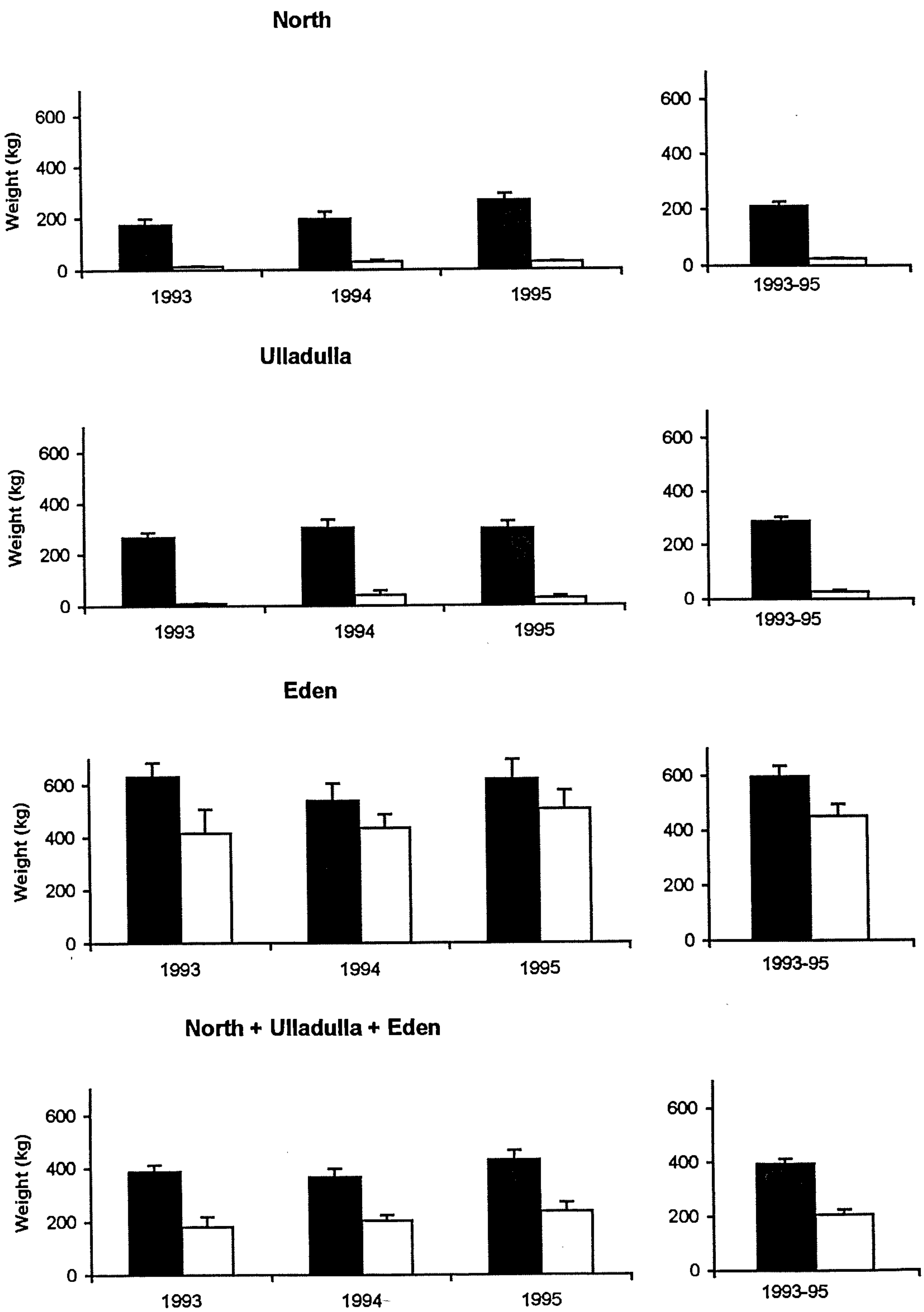
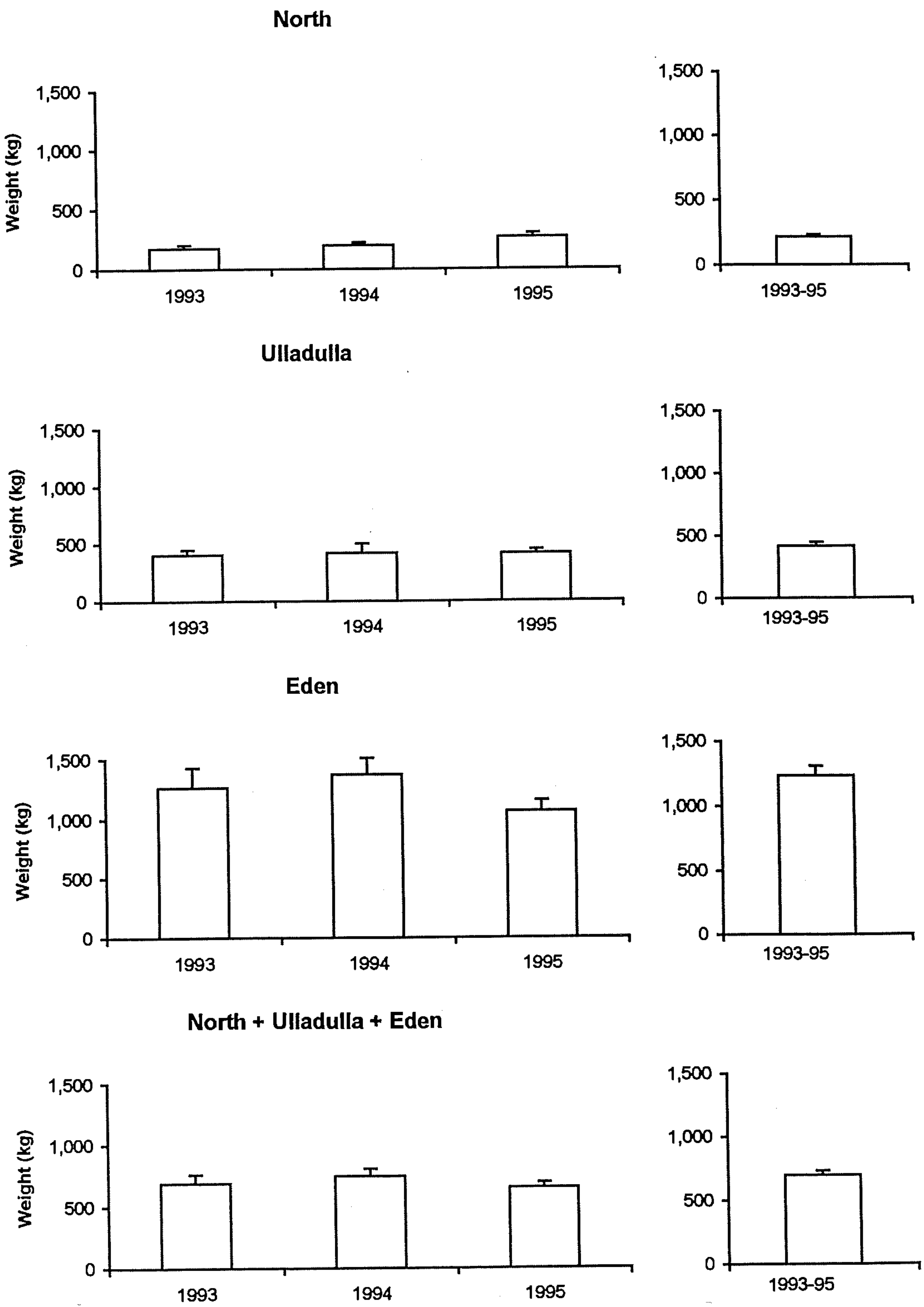


Figure 3.5

Discarded catches of non-commercial species (kg per fisher-day)
by Year, by Region

(mean kg. per fisher-day, +/- 1 se)



Figures 4.1 and 4.2

Quarterly mean catch rate (kg per fisher-day, +/- 1 se) of partitions of total catch

Figure 4.1

Total catch

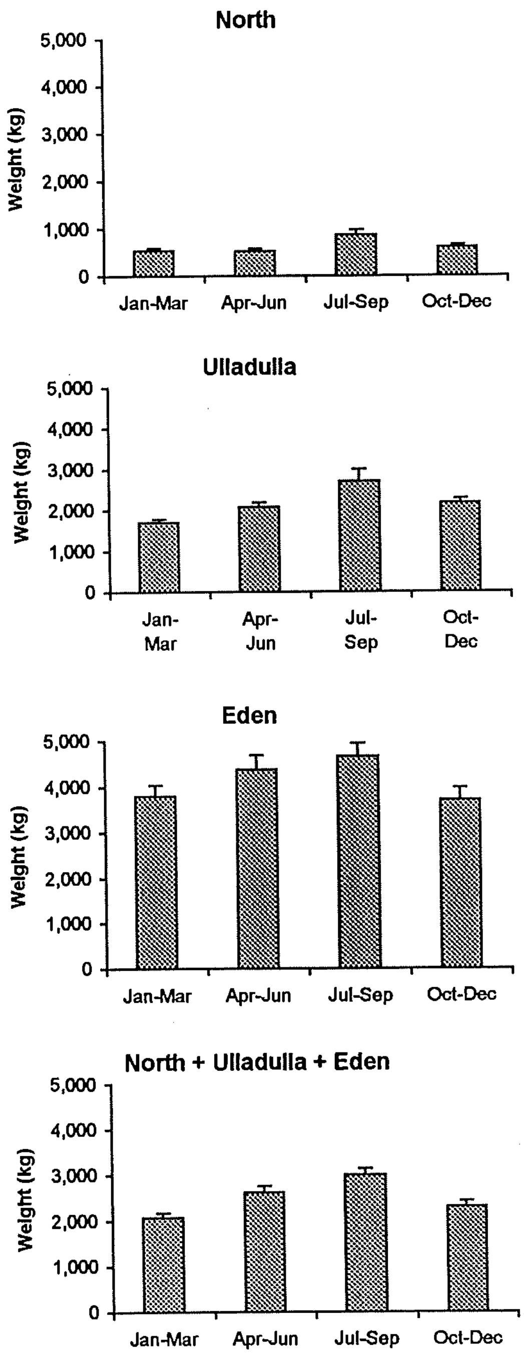
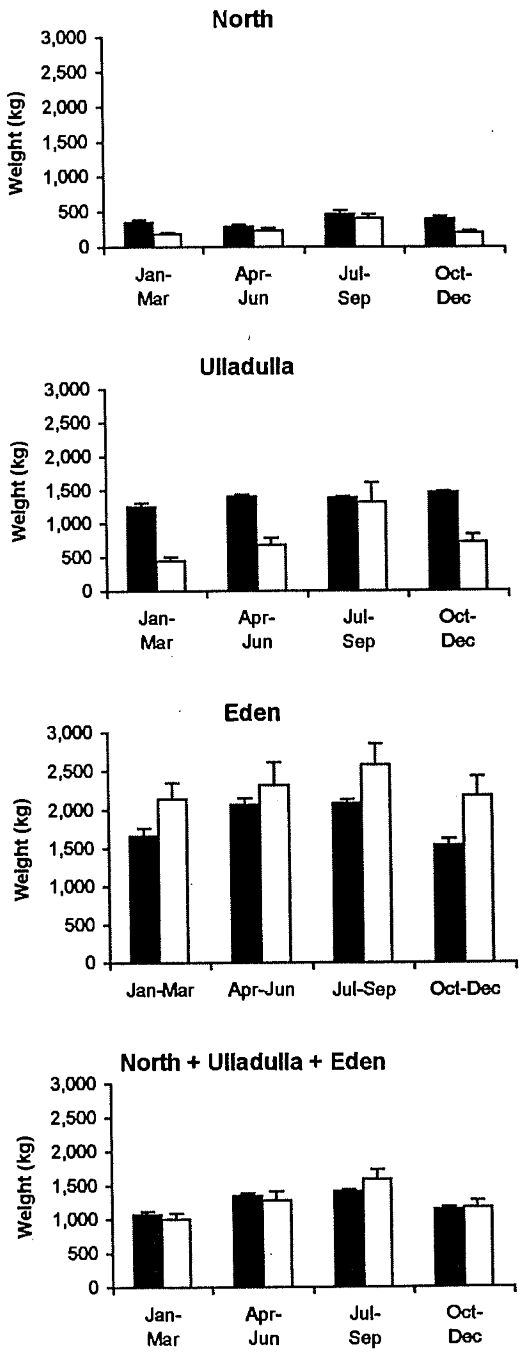


Figure 4.2

Retained and discarded catch

black: retained, white: discarded catch



Figures 4.3 and 4.4

Quarterly mean catch rate (kg per fisher-day, +/- 1 se) of partitions of total catch

Figure 4.3

Retained and discarded quota species

black: retained, white: discarded catch

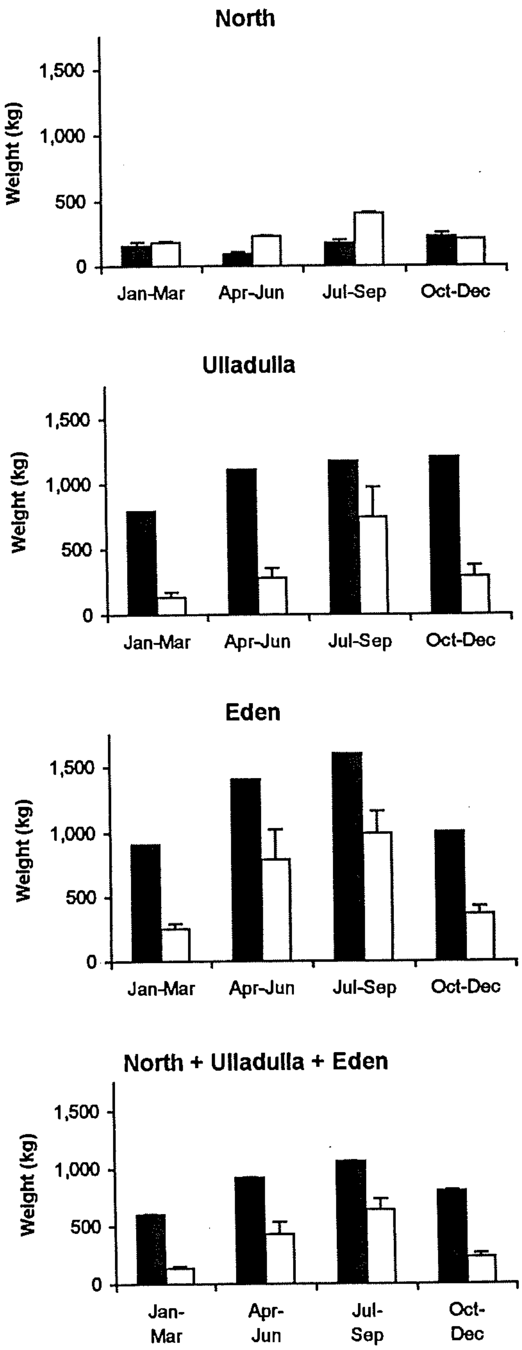


Figure 4.4

Retained and discarded non-quota commercial spp.

black: retained, white: discarded catch

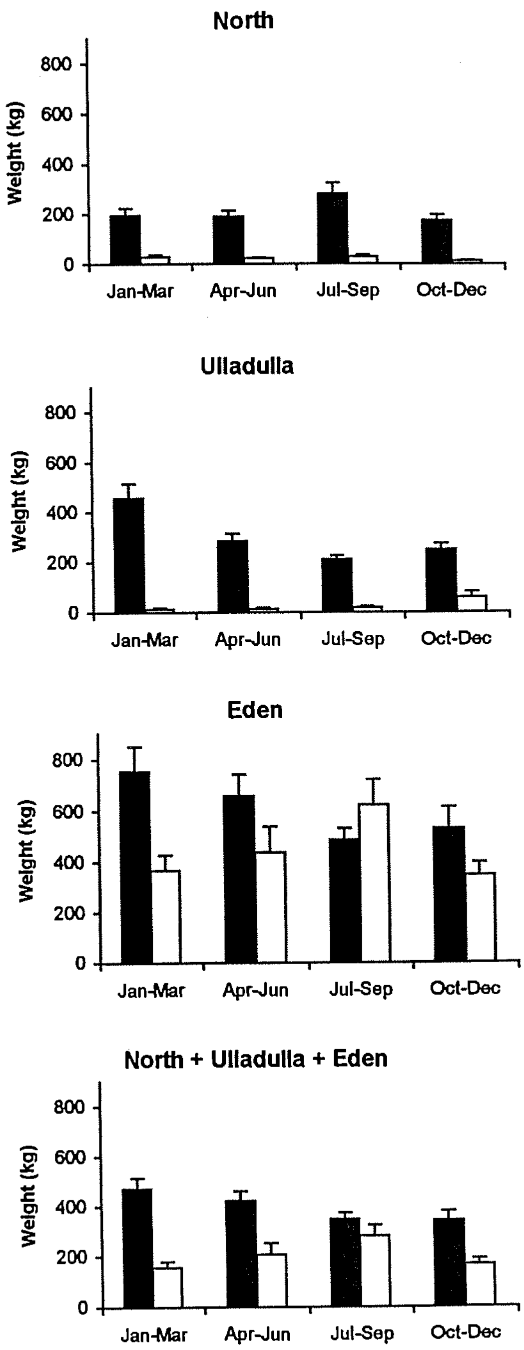


Figure 4.5

Quarterly mean catch rate (kg per fisher-day, +/- 1 se) of partitions of total catch

Discarded non-commercial spp.

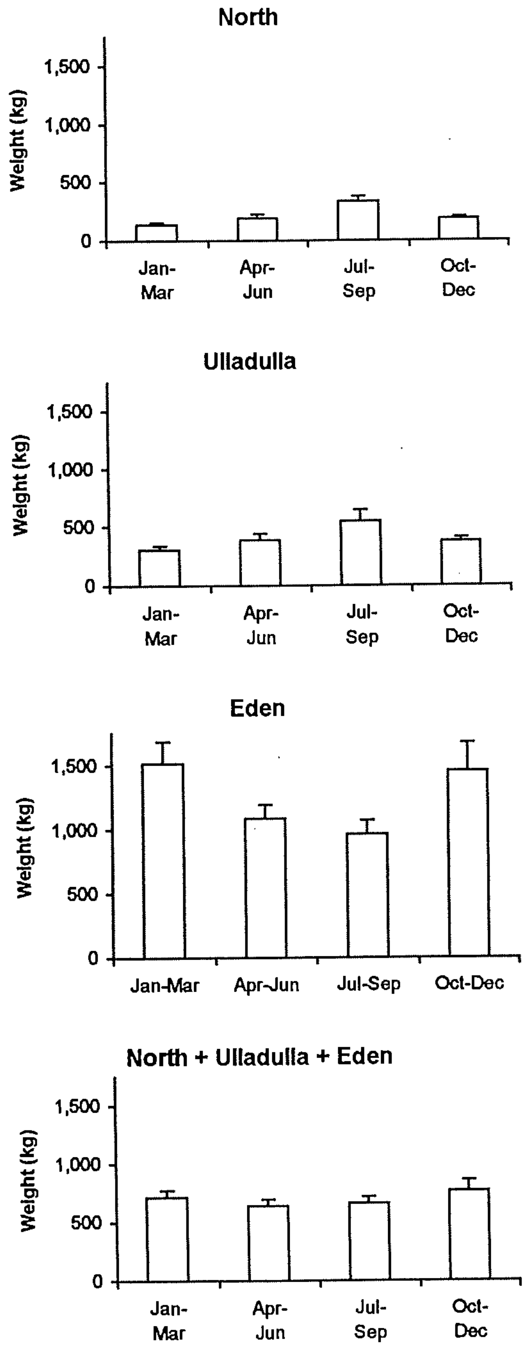


Figure 5, page 1

Retained and discarded components of annual catches (% of total catch weight), by region, by year

black: SEF quota species; white: non-quota commercial species; grey: non-commercial species

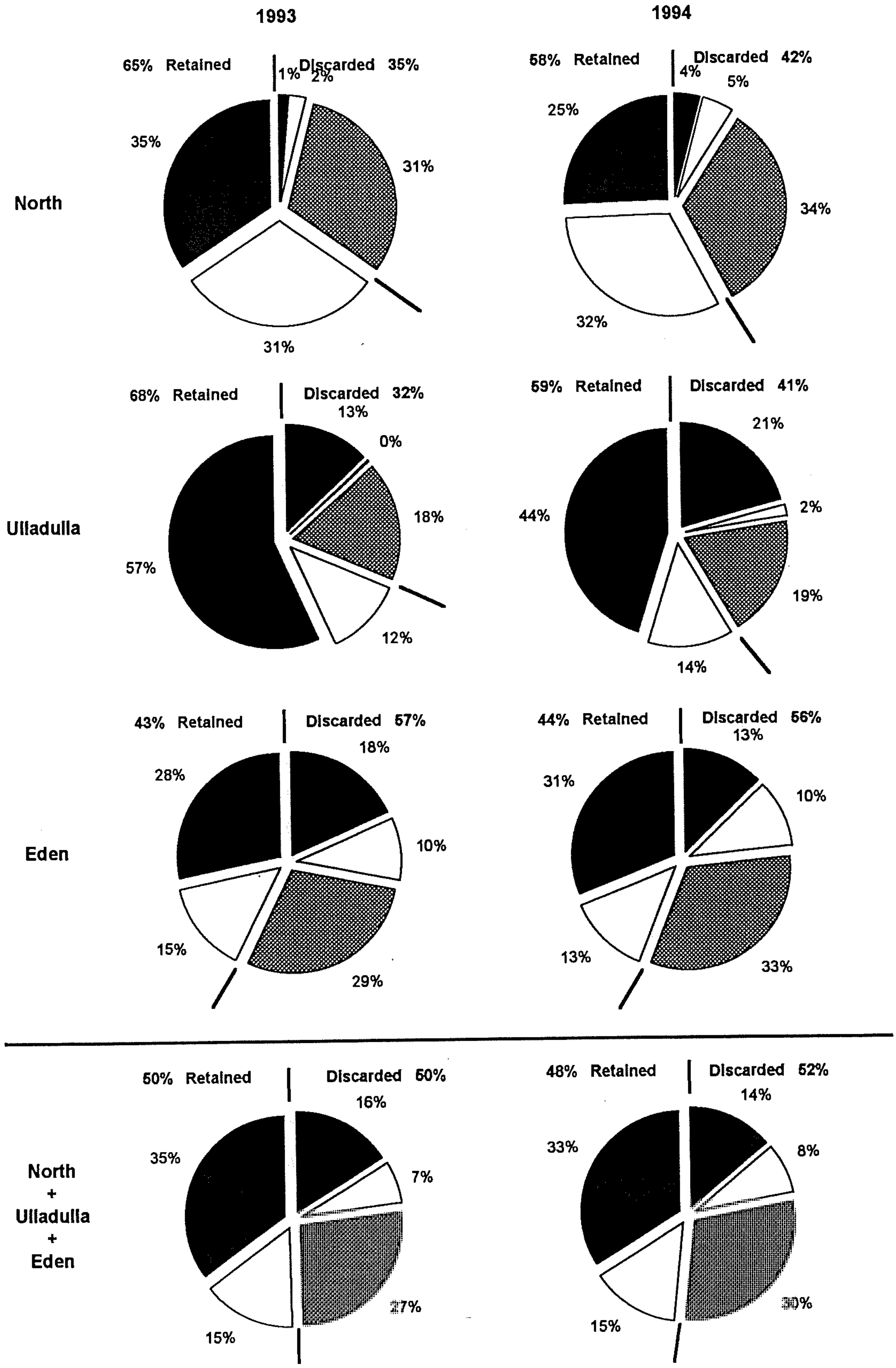


Figure 5, page 2

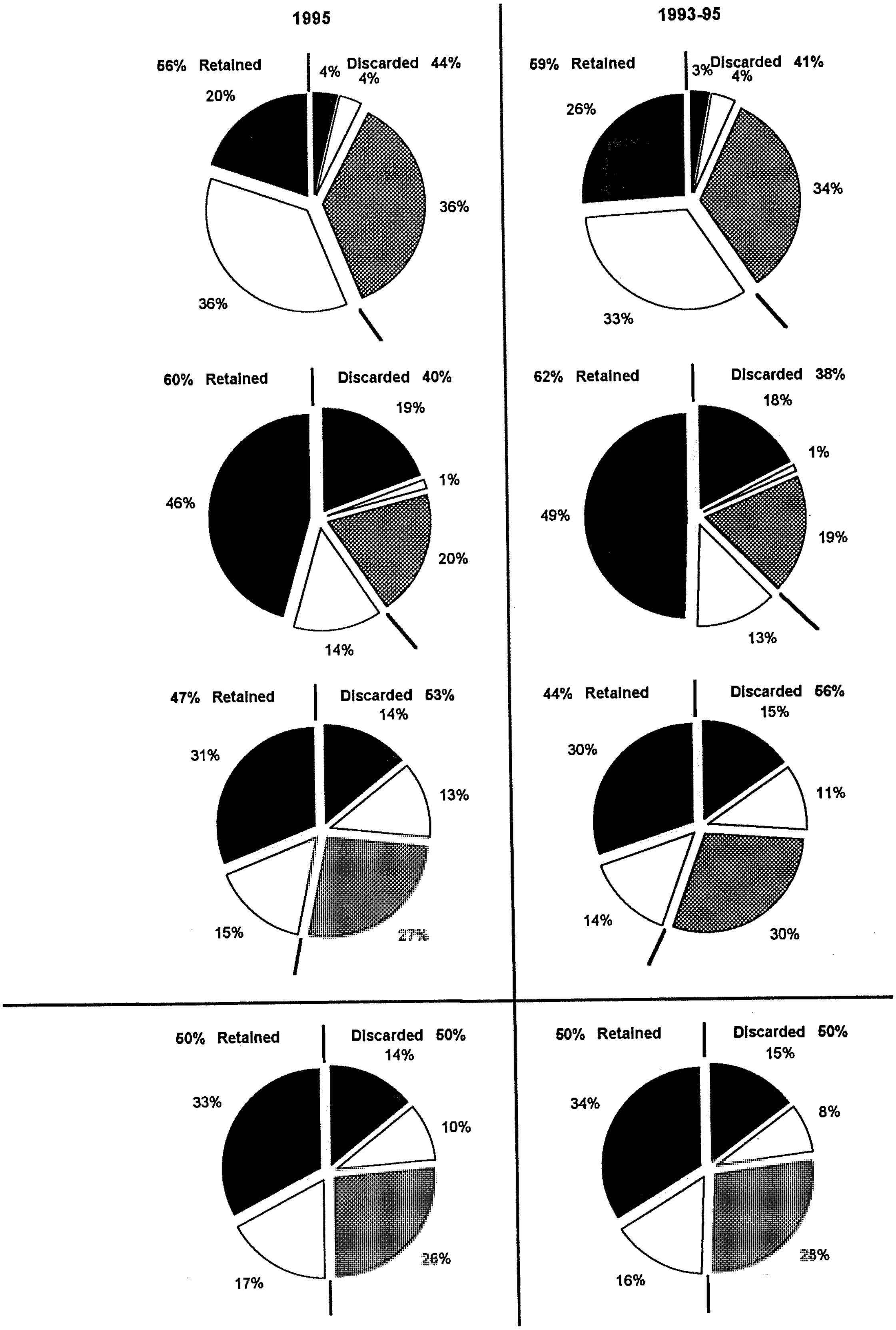


Figure 6, page 1

Estimates of mean-catch rates (per fisher-day, +/- 1 SE) - retained and discarded catches, for the combined fleets of North, Ulladulla and Eden, during 1993-95, 40 species (or species groups)

% of catch discarded shown above each graph, species ordered by decreasing total catch
(black bars: retained catch, white bars: discarded catch)

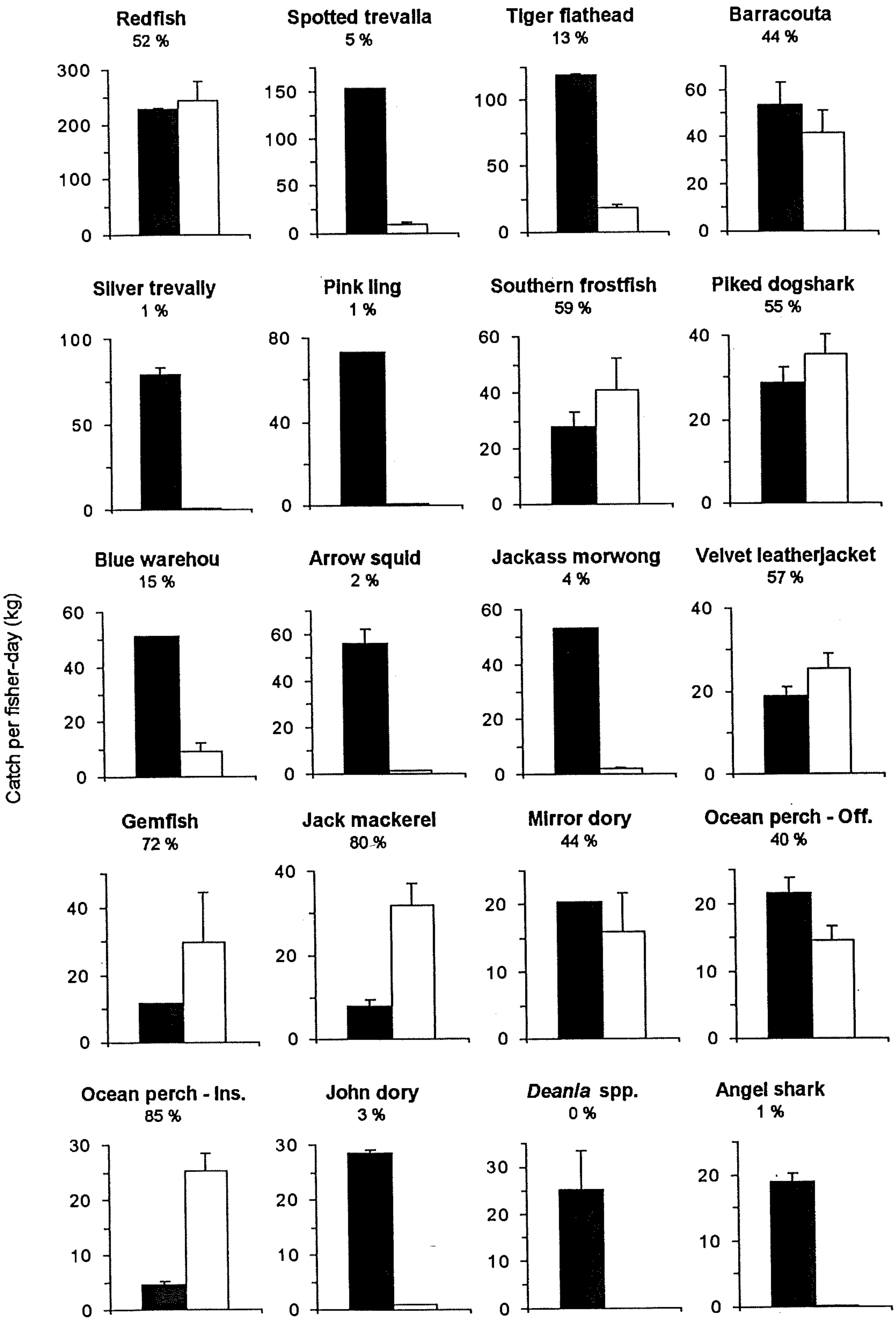


Figure 6, page 2

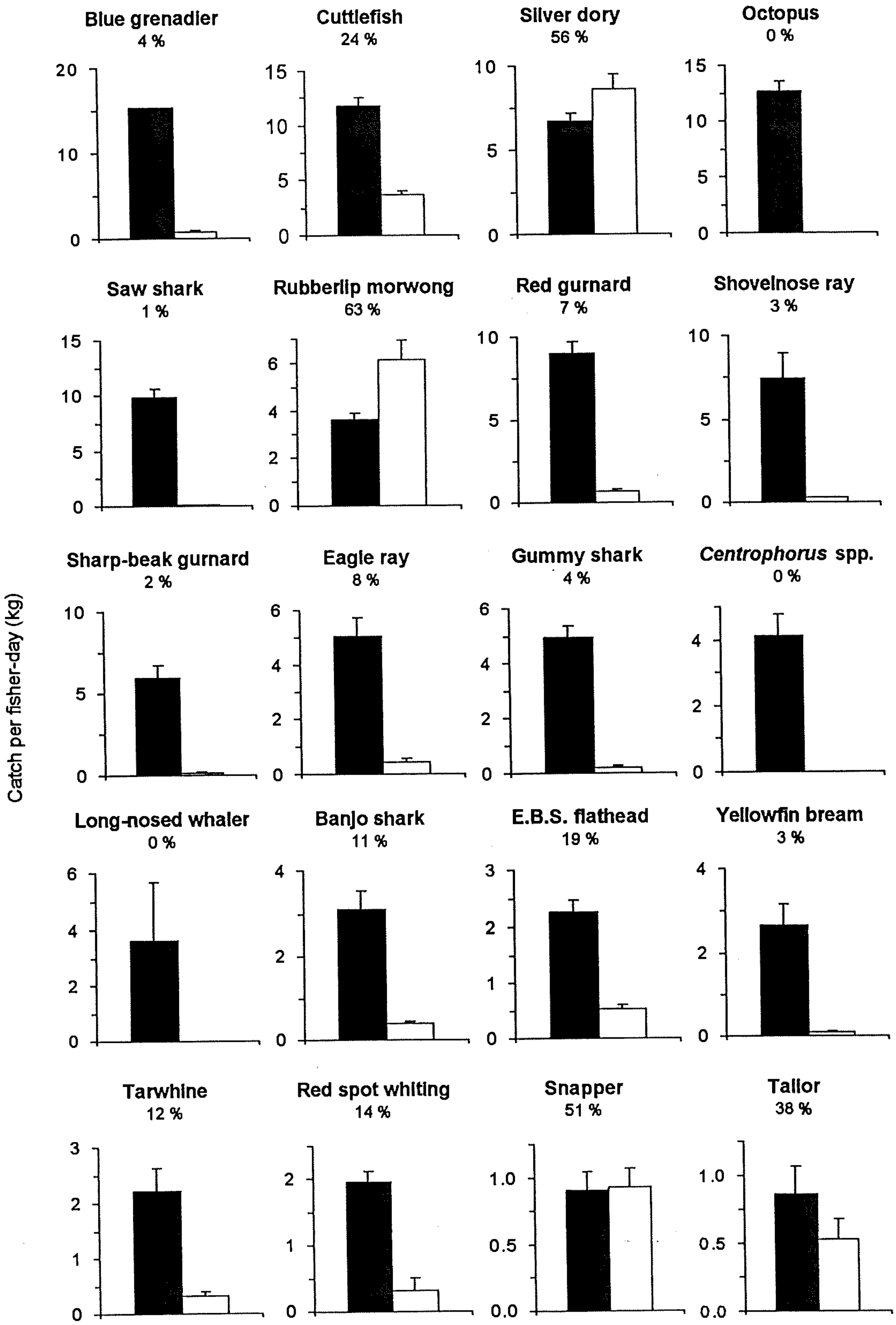


Figure 7, page 1

Estimates of mean catch rates (per fisher-day, +/- 1 SE), by quarter, retained and discarded catches, for the combined fleets of North, Ulladulla and Eden, during 1993-95, 20 species (or species groups)

species ordered by decreasing total catch
(black bars: retained catch, white bars: discarded catch)

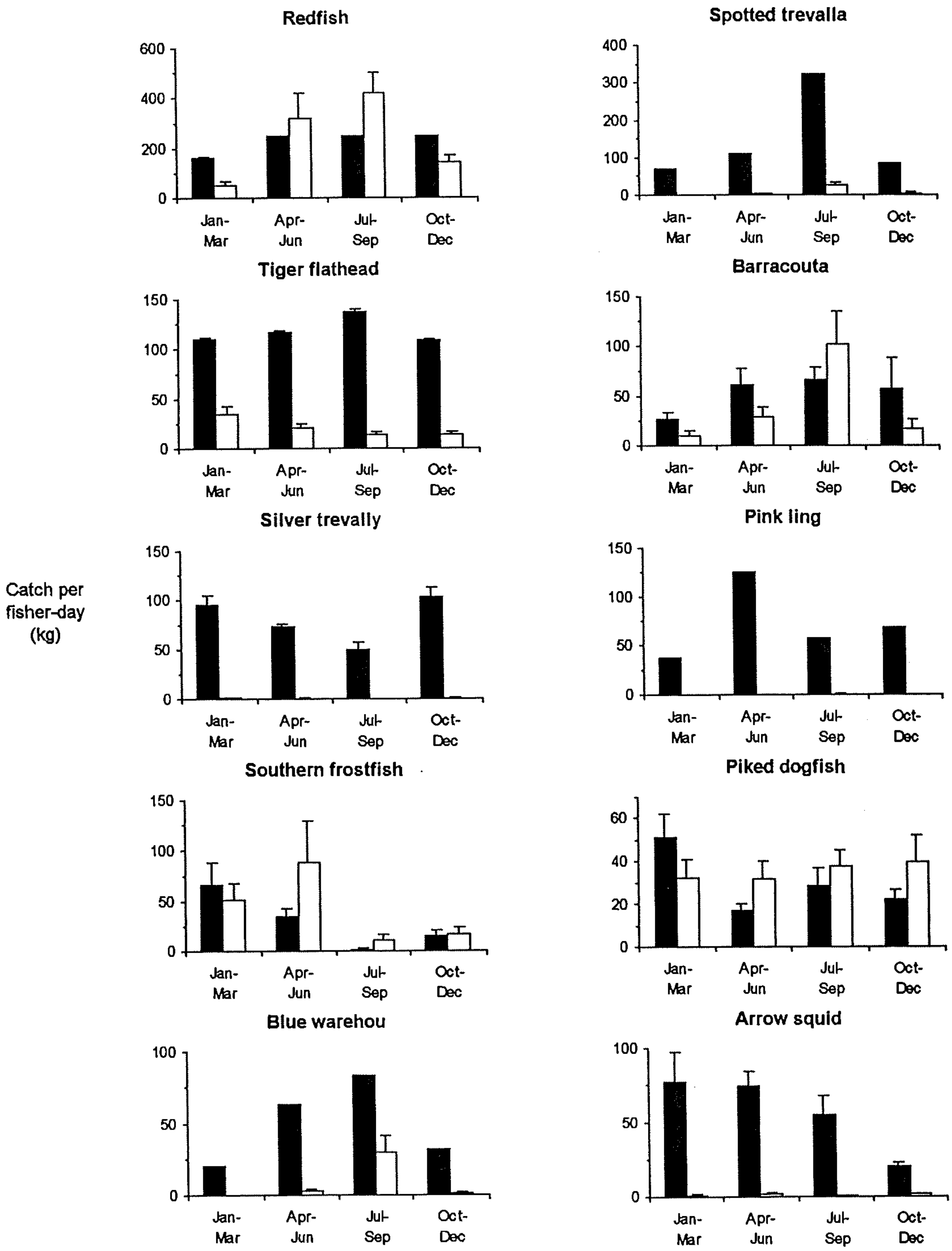


Figure 7, page 2

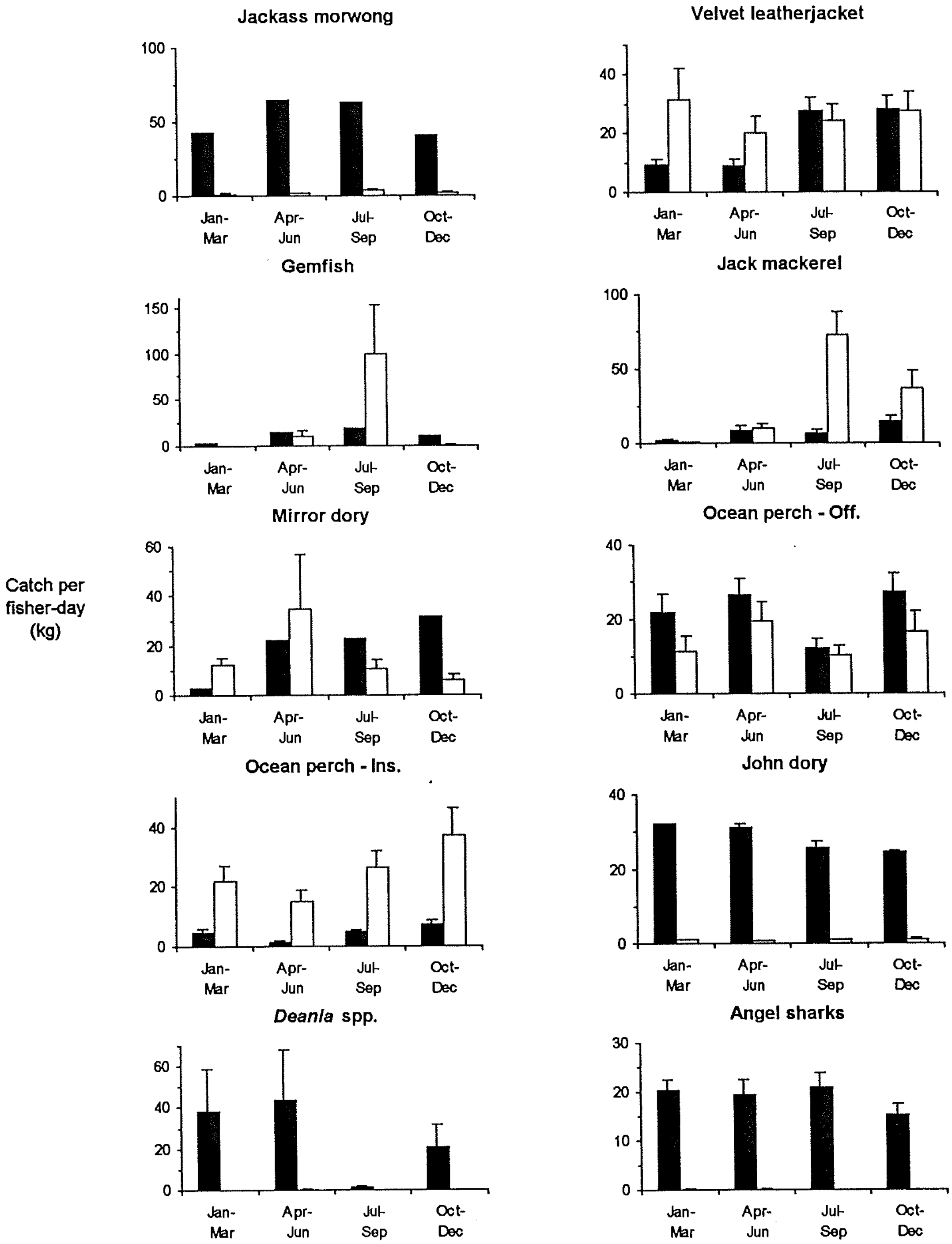


Figure 6, page 1

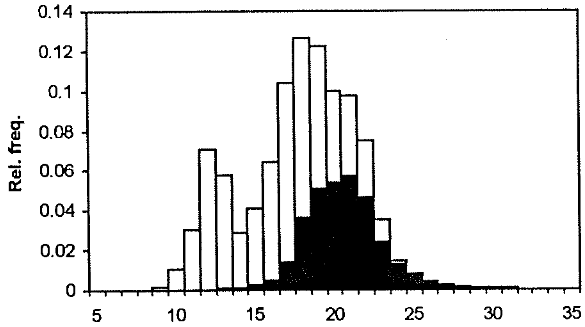
Length-frequency distributions of - retained and discarded catches, for the combined fleets of North, Ulladulla and Eden during 1993-95, 18 species

(black bars: retained catch, white bars: discarded catch)

Sample sizes: x(y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op. survey)

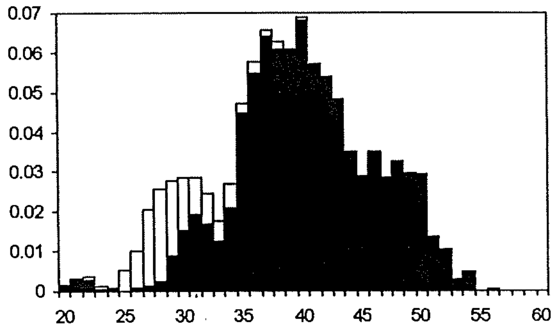
Redfish

	Retained	Discarded	Total
Obs:	7575 (60)	12452 (278)	
Co-op:	9152 (55)		
Mean L:	21.1	17.0	18.3



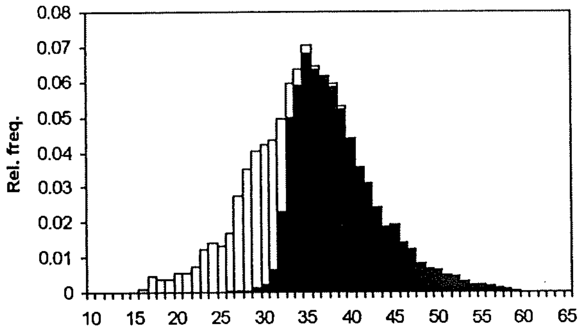
Spotted trevalla

	Retained	Discarded	Total
Obs:	4086 (53)	655 (86)	
Co-op:	2716 (23)		
Mean L:	41.0	30.0	39.5



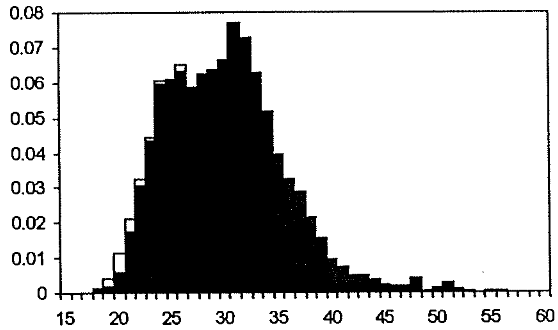
Tiger flathead

	Retained	Discarded	Total
Obs:	22508 (348	8772 (749)	
Co-op:	10668 (83)		
Mean L:	39.1	28.4	35.8



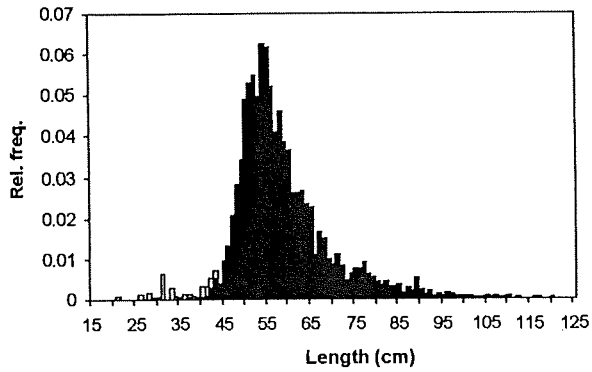
Silver trevally

	Retained	Discarded	Total
Obs:	11031 (197	332 (43)	
Co-op:	2649 (20)		
Mean L:	30.6	21.8	30.5



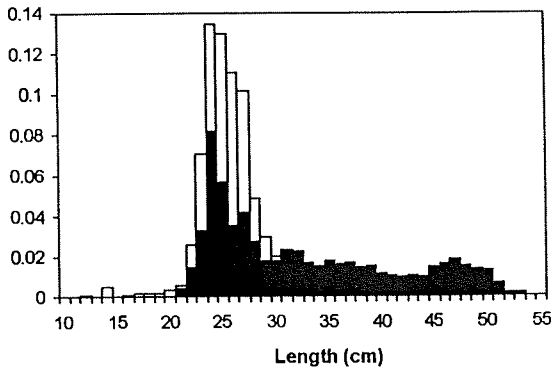
Pink ling

	Retained	Discarded	Total
Obs:	3549 (74)	40 (35)	
Co-op:	3288 (53)		
Mean L:	59.5	35.9	58.8



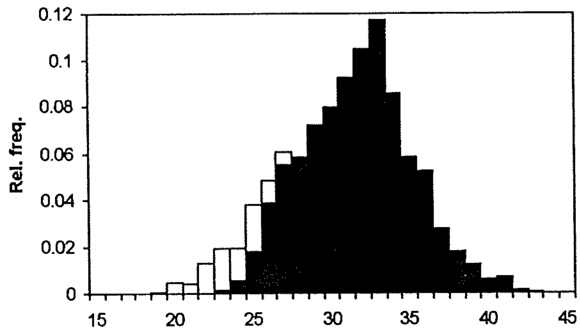
Blue warehou

	Retained	Discarded	Total
Obs:	2587 (30)	547 (74)	
Co-op:	3010 (26)		
Mean L:	33.1	25.6	30.4



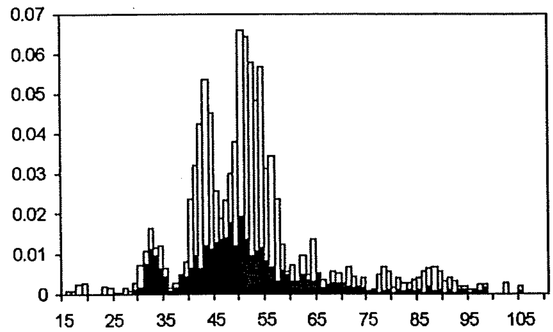
Jackass morwong

	Retained	Discarded	Total
Obs:	3762 (74)	433 (94)	
Co-op:	7623 (53)		
Mean L:	32.2	24.3	31.5



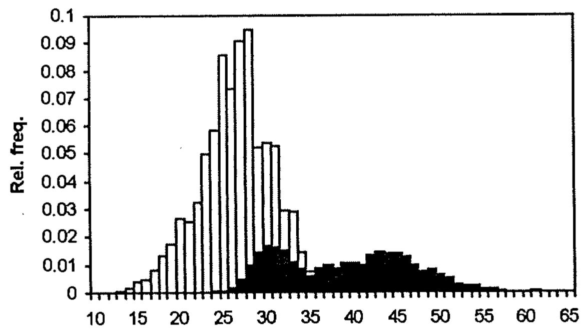
Gemfish

	Retained	Discarded	Total
Obs:	1814 (63)	613 (59)	
Co-op:	78 (5)		
Mean L:	51.9	53.0	52.6



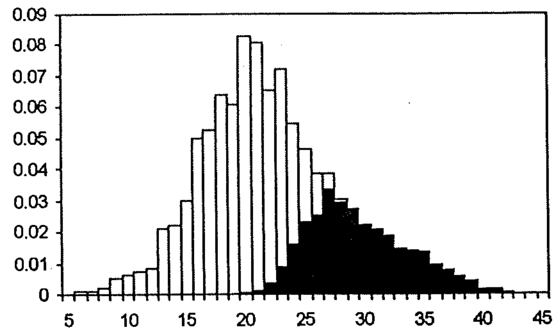
Mirror dory

	Retained	Discarded	Total
Obs:	2480 (64)	3407 (353)	
Co-op:	1663 (30)		
Mean L:	39.5	26.3	29.9



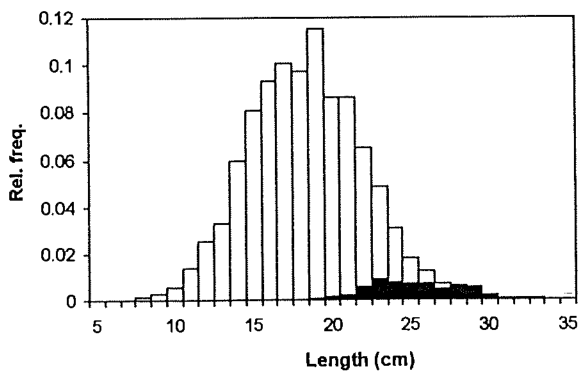
Ocean perch - Offshore

	Retained	Discarded	Total
Obs:	5332 (69)	4518 (366)	
Co-op:	1652 (18)		
Mean L:	30.0	19.8	22.9



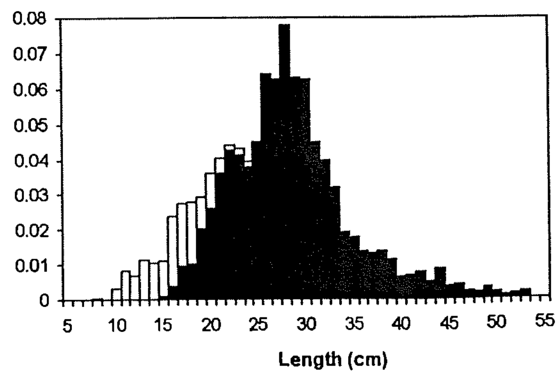
Ocean perch - Inshore

	Retained	Discarded	Total
Obs:	747 (19)	9042 (594)	
Co-op:	213 (3)		
Mean L:	25.9	18.5	18.9



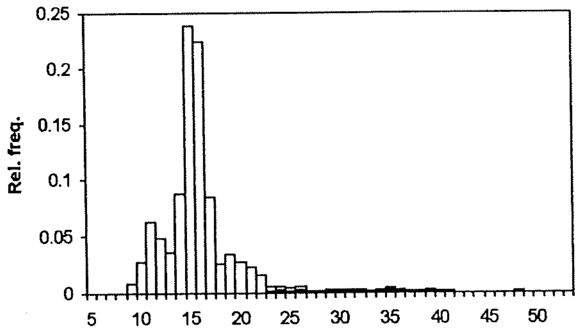
John dory

	Retained	Discarded	Total
Obs:	8000 (216)	966 (270)	
Co-op:	885 (15)		
Mean L:	29.0	16.7	27.4



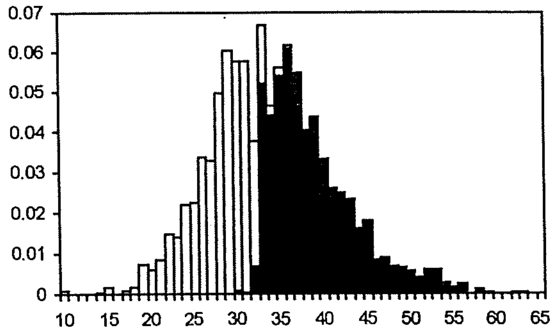
Rubberlip morwong

	Retained	Discarded	Total
Obs:	418 (31)	2647 (488)	
Co-op:	0 (0)		
Mean L:	32.8	15.9	16.6



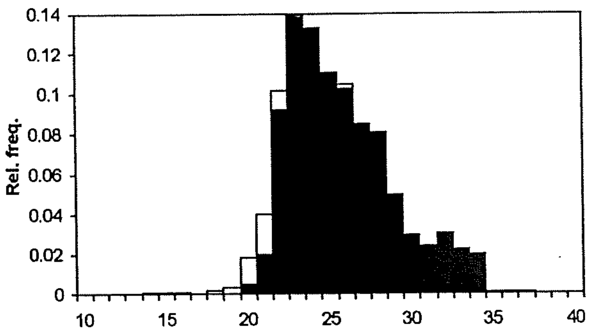
Eastern blue spot flathead

	Retained	Discarded	Total
Obs:	1188 (104)	1396 (162)	
Co-op:	0 (0)		
Mean L:	39.5	28.3	34.5



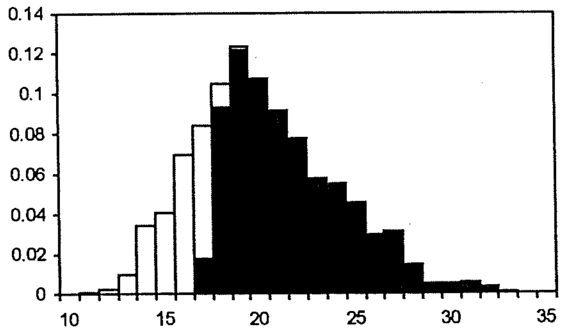
Yellowfin bream

	Retained	Discarded	Total
Obs:	2562 (73)	180 (55)	
Co-op:	0 (0)		
Mean L:	26.4	21.1	26.1



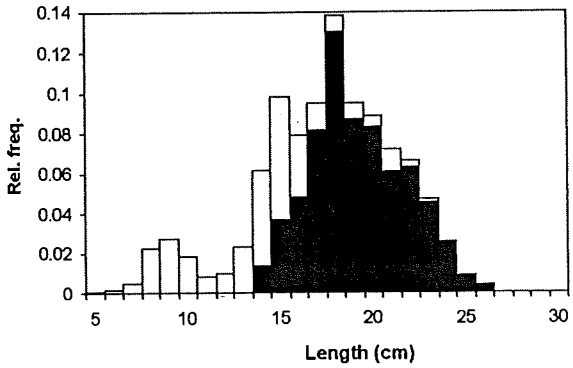
Tarwhine

	Retained	Discarded	Total
Obs:	2043 (55)	916 (75)	
Co-op:	0 (0)		
Mean L:	22.1	16.3	20.7



Red spot whiting (North only)

	Retained	Discarded	Total
Obs:	429 (22)	676 (98)	
Co-op:	0 (0)		
Mean L:	19.7	14.1	18.0



Snapper (North only)

	Retained	Discarded	Total
Obs:	143 (17)	2682 (229)	
Co-op:	0 (0)		
Mean L:	26.3	17.2	17.9

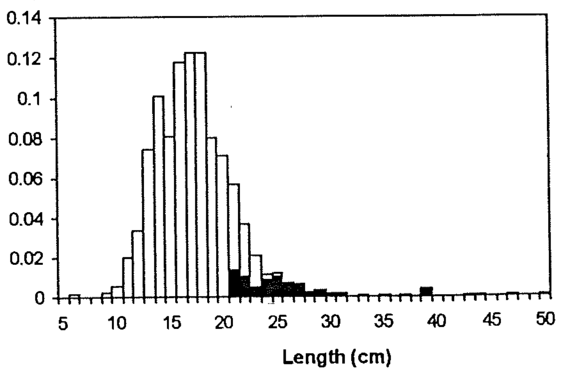


Table 1, page 1

Comparisons of catches (per fisher-day) across Regions, Years and Quarters: ANOVAs and SNK multiple comparisons

- fishing time and major partitions of catch

	ANOVA									SNK multiple comparisons		
	Model	**Transform**	**R**	**Y**	**Q**	**RxY**	**RxQ**	**YxQ**	**RxYxQ**	**Regions**	**Years**	**Quarters**
Fishing time	3-f	-	++	ns	ns	ns	ns	ns	ns	N = U < E		
Total catch	3-f	ln(x+1)	++	ns	++	ns	ns	ns	ns	N < U < E		Q1 = Q2 = Q4 < Q3
Retained catch	3-f	ln(x+1)	++	ns	+	ns	ns	ns	ns	N < U < E		Q1 Q2 Q4 Q3
Discarded catch	3-f	ln(x+1)	++	++	++	ns	ns	ns	ns	N < U < E	93 = 94 < 95	Q1 = Q2 = Q4 < Q3
Retained catch of non-quota species	3-f	ln(x+1)	++	+	ns	ns	+	ns	ns	Q1: N < U = E Q2: N < U < E Q3: N = U < E Q4: N < U < E	93 = 94 < 95	N: Q1 = Q2 = Q3 = Q4 U: Q3 < Q2 = Q4 < Q1 E: Q1 = Q2 = Q3 = Q4

Table 1, page 2

	ANOVA									SNK multiple comparisons		
	Model	Transform	R	Y	Q	RxY	RxQ	YxQ	RxYxQ	Regions	Years	Quarters
Discarded catch of quota species	3-f	ln(x+1)	++	++	++	ns	ns	ns	+	93,Q1: N < U = E	N,Q1: 93 = 94 = 95	N,93: Q1 = Q2 = Q4 < Q3
										93,Q2: N < U = E	N,Q2: 93 = 94 = 95	N,94: Q1 = Q2 = Q3 = Q4
										93,Q3: N < U < E	N,Q3: 93 = 94 = 95	N,95: Q4 Q1 Q2 Q3
										93,Q4: N < U = E	N,Q4: 93 = 94 = 95	U,93: Q1 Q2 Q3 Q4
										94,Q1: N < U = E	U,Q1: 93 = 94 < 95	U,94: Q1 = Q2 = Q3 = Q4
										94,Q2: N < U = E	U,Q2: 93 = 94 = 95	U,95: Q1 = Q2 = Q3 = Q4
										94,Q3: N < U < E	U,Q3: 93 94 95	E,93: Q1 = Q2 = Q4 < Q3
										94,Q4: N < U < E	U,Q4: 94 < 93 = 95	E,94: Q1 Q2 Q3 Q4
										95,Q1: N < U = E	E,Q1: 93 = 94 = 95	E,95: Q1 = Q2 = Q3 = Q4
										95,Q2: N < U < E	E,Q2: 93 94 95	
										95,Q3: N < U = E	E,Q3: 93 = 94 = 95	
										95,Q4: N < U = E	E,Q4: 93 < 94 = 95	
Discarded catch of non-quota commercial species	3-f	ln(x+1)	++	++	ns	ns	++	ns	ns	Q1: U < N < E	93 < 94 = 95	N: Q1 = Q2 = Q3 = Q4
										Q2: U < N < E		U: Q1 = Q2 = Q3 < Q4
										Q3: U < N < E		E: Q1 = Q2 = Q4 < Q3
										Q4: N = U < E		
Discarded catch of non-commercial species	3-f	ln(x+1)	++	ns	++	++	++	ns	ns	93: N < U < E	N: 93 = 94 < 95	N: Q1 = Q2 = Q4 < Q3
										94: N < U < E	U: 93 = 94 = 95	U: Q1 Q2 Q4 Q3
										95: N < U < E	E: 93 95 94	E: Q1 = Q2 = Q3 = Q4
										Q1: N < U < E		
										Q2: N < U < E		
										Q3: N < U < E		
										Q4: N < U < E		

Table 2, page 1

Comparison of catch rates (per fisher-day) across regions, Years and Quarters: ANOVAs and SNK multiple comparisons - discarded catches of 7 species of interest

	Model	Transform	R	Y	Q	RxY	RxQ	YxQ	RxYxQ	Regions	Years	Quarters
Redfish	3-f	ln(x+1)	++	++	++	++	++	++	++	93,Q1: N = U = E	N,Q1: 93 = 94 = 95	N,93: Q1 = Q2 = Q3 = Q4
										93,Q2: N = U = E	N,Q2: 93 = 94 = 95	N,94: Q1 = Q2 = Q3 = Q4
										93,Q3: N = U < E	N,Q3: 93 = 94 = 95	N,95: Q1 = Q2 = Q3 = Q4
										93,Q4: N < U = E	N,Q4: 93 = 94 = 95	U,93: Q1 = Q2 < Q3 = Q4
										94,Q1: N = U = E	U,Q1: 93 = 94 < 95	U,94: Q1 = Q2 = Q4 < Q3
										94,Q2: N = U < E	U,Q2: 93 = 94 < 95	U,95: Q4 Q2 Q1 Q3
										94,Q3: N < U = E	U,Q3: 93 < 94 = 95	E,93: Q1 < Q2 = Q4 < Q3
										94,Q4: N < U < E	U,Q4: 93 = 94 = 95	E,94: Q1 < Q2 Q4 Q3
										95,Q1: N < E < U	E,Q1: 93 94 95	E,95: Q1 Q3 Q4 Q2
										95,Q2: N < U = E	E,Q2: 93 < 94 = 95	
										95,Q3: N = E < U	E,Q3: 95 < 93 = 94	
										95,Q4: N < U = E	E,Q4: 93 95 94	
Tiger flathead	3-f	ln(x+1)	++	ns	ns	ns	++	ns	ns	Q1: N < U = E		N: Q1 = Q2 = Q4 < Q3
										Q2: N = U < E		U: Q2 Q3 Q4 Q1
										Q3: N = U = E		E: Q1 = Q2 = Q3 = Q4
										Q4: N < U < E		
Mirror dory	3-f	ln(x+1)	++	++	++	ns	+	ns	ns	Q1: U = E	93 = 94 < 95	U: Q2 Q3 Q4 Q1
(U and E)										Q2: U < E		E: Q4 Q2 Q3 Q1
										Q3: U < E		
										Q4: U = E		

Table 2, page 2

	Model	Transform	R	Y	Q	RxY	RxQ	YxQ	RxYxQ	Regions	Years	Quarters
"Offshore" Ocean perch (U and E)	3-f	ln(x+1)	++	ns	ns	++	ns	ns	ns	93: U = E 94: U < E 95: U < E	U: 94 = 95 < 93 E: 93 < 94 = 95	
"Inshore" Ocean perch (U and E)	3-f	ln(x+1)	++	++	++	+	++	ns	ns	Q1: U < E Q2: U < E Q3: U < E Q4: U < E 93: U < E 94: U < E 95: U < E	U: 94 < 93 = 95 E: 93 = 94 < 95	U: Q2 Q3 Q4 Q1 E: Q1 = Q2 < Q3 = Q4
Rubberlip morwong	3-f	ln(x+1)	++	ns	++	ns	+	ns	ns	Q1: N = U < E Q2: N = U < E Q3: N = U < E Q4: N = U = E		N: Q1 = Q2 = Q4 < Q3 U: Q2 Q1 Q3 Q4 E: Q1 = Q4 < Q2 = Q3
Snapper (N)	2-f	ln(x+1)		ns	++			ns				Q3 Q4 Q2 Q1

Table 3

Annual total,retained and discarded catches (tonnes, +/- 1 se) - all species combined

		Total catch			Retained			Discarded			% discarded
North	1993	905	+/-	74	590	+/-	53	316	+/-	47	*35*
	1994	961		106	556		64	405		51	*42*
	1995	1,171		91	657		52	513		55	*44*
	Mean 1993-95	1,012		53	601		33	411		29	*41*
Ulladulla	1993	2,902		176	1,987		26	915		174	*32*
	1994	2,741		290	1,605		42	1,136		287	*41*
	1995	2,316		103	1,380		30	936		98	*40*
	Mean 1993-95	2,653		118	1,657		19	996		117	*38*
Eden	1993	8,965		616	3,842		110	5,123		606	*57*
	1994	8,595		453	3,781		140	4,814		431	*56*
	1995	8,453		407	3,942		162	4,511		373	*53*
	Mean 1993-95	8,671		289	3,855		80	4,816		277	*56*
N+U+E	1993	12,772		645	6,419		125	6,353		633	*50*
	1994	12,297		548	5,942		160	6,355		520	*52*
	1995	11,939		429	5,979		173	5,961		390	*50*
	Mean 1993-95	12,336		316	6,113		89	6,223		302	*50*

Table 4

Annual retained and discarded catches (tonnes, +/- 1 se) - categories of species

		SEF quota species					Non-quota commercial species					Non-commercial species	
		Retained		Discarded		% discarded	Retained		Discarded		% discarded	Discarded	
North	1993	313 +/-	38	13 +/-	3	*4*	277 +/-	39	22 +/-	3	*7*	281 +/-	44
	1994	245	37	39	13	*14*	311	45	48	11	*13*	318	40
	1995	231	28	44	9	*16*	426	42	44	6	*9*	424	49
	Mean 1993-95	263	20	32	5	*11*	338	24	38	4	*10*	341	26
Ulladulla	1993	1,646	0	378	160	*19*	341	26	12	3	*4*	524	51
	1994	1,231	0	569	199	*32*	374	42	50	21	*12*	518	101
	1995	1,054	0	451	82	*30*	326	30	31	9	*9*	454	37
	Mean 1993-95	1,310	0	466	89	*26*	347	19	31	8	*8*	498	40
Eden	1993	2,536	0	1,653	428	*39*	1,306	110	858	190	*40*	2,612	345
	1994	2,679	0	1,102	169	*29*	1,102	140	894	105	*45*	2,818	276
	1995	2,634	0	1,197	199	*31*	1,308	162	1,067	154	*45*	2,248	193
	Mean 1993-95	2,616	0	1,317	167	*33*	1,239	80	939	89	*43*	2,559	161
N+U+E	1993	4,495	38	2,044	457	*31*	1,924	120	892	190	*32*	3,417	351
	1994	4,154	37	1,710	261	*29*	1,788	153	992	107	*36*	3,654	297
	1995	3,919	28	1,692	216	*30*	2,060	170	1,142	154	*36*	3,127	202
	Mean 1993-95	4,189	20	1,815	190	*30*	1,924	86	1,009	89	*34*	3,399	167

Table 5

Estimates of annual retained, discarded and total catches (estimates +/- 1 se) of commercial species
Combined catches of North, Ulladulla and Eden

	Total catch (t)			Retained catch (t)			Discarded catch (t)			% Discarded	Relative catch magnitude		
											Total	Retained	Discarded
Redfish	2,303	+/-	174	1,116	+/-	5	1,187	+/-	173	*52*	1	1	1
Spotted trevalla	788		11	745		0	43		11	*5*	2	2	13
Tiger flathead	671		12	582		4	89		11	*13*	3	3	9
Barracouta	463		70	261		47	202		47	*44*	4	7	2
Silver trevally	388		19	386		19	2		1	*1*	5	4	28
Pink ling	359		0	357		0	2		0	*1*	6	5	30
Southern frostfish	333		69	135		28	198		56	*59*	7	12	3
Piked dogfish	313		31	140		18	174		23	*55*	8	10	4
Blue warehou	294		14	249		0	45		14	*15*	9	9	12
Arrow squid	280		30	274		30	6		1	*2*	10	8	20
Jackass morwong	270		2	260		0	10		2	*4*	11	8	17
Velvet leatherjacket	216		22	92		9	124		18	*57*	12	17	7
Gemfish	203		71	58		0	146		71	*72*	13	20	6
Jack mackerel	195		28	39		7	156		25	*80*	14	24	5
Mirror dory	177		28	99		0	78		28	*44*	15	15	10
Offshore ocean perch	176		17	105		11	71		11	*40*	16	14	11
Inshore ocean perch	145		17	22		3	123		16	*85*	17	30	8
John dory	143		3	138		3	5		1	*3*	18	11	21
Deania spp. dogfish	123		40	123		40	0		0	*0*	19	13	52
Angel shark	93		7	93		7	0		0	*1*	20	16	46
Blue grenadier	78		1	75		0	4		1	*4*	21	18	23
Cuttlefish	75		4	57		4	18		2	*24*	22	21	16
Silver dory	74		6	33		2	42		4	*56*	23	26	14
Octopus	62		5	62		5	0		0	*0*	24	19	57
Common sawshark	49		4	48		4	1		0	*1*	25	22	45
Rubberlip morwong	48		4	18		1	30		4	*63*	26	32	15
Red gurnard	47		4	44		4	3		0	*7*	27	23	24
Shovelnose ray	38		7	36		7	1		0	*3*	28	25	37
Sharp-beaked gurnard	29		4	29		4	1		0	*2*	29	27	44
Eagle ray	27		3	25		3	2		1	*8*	30	28	29
Gummy shark	25		2	24		2	1		1	*4*	31	29	41
Centrophorus spp. dogfish	20		3	20		3	0		0	*0*	32	31	64
Long-nosed whaler	18		10	18		10	0		0	*0*	33	33	69
Banjo shark	17		2	15		2	2		0	*11*	34	34	32
Splendid perch	15		6	14		5	0		0	*2*	35	35	49
Spiky oreo	14		6	14		6	0		0	*0*	36	38	68
Eastern blue-spot flathead	14		1	11		1	3		0	*19*	37	39	25
Yellowfin bream	13		3	13		2	0		0	*3*	38	37	47
Whaler shark	13		4	6		2	6		3	*50*	39	45	19
Southern calamary	12		2	12		1	0		0	*3*	40	38	46
Tarwhine	12		2	11		2	2		0	*12*	41	40	36
Red spot whiting	11		2	10		1	2		1	*14*	42	42	35
Ribaldo	11		4	10		4	0		0	*2*	43	41	55
Snapper	9		1	4		1	5		1	*51*	44	51	22
Ogilby's ghost shark	9		2	6		1	3		1	*29*	45	46	27
Thintail thresher	8		5	1		1	7		5	*86*	46	77	18
Orange roughy	8		1	6		0	2		1	*21*	47	48	34
Smooth hammerhead	8		1	8		1	0		0	*0*	48	43	70
Mosaic leatherjacket	8		2	7		1	0		0	*5*	49	44	51
Green-eyed dogfish	7		5	6		4	1		1	*15*	50	47	39
Tailor	7		1	4		1	3		1	*38*	51	52	26
Blue-eye trevalla	6		0	6		0	0		0	*0*	52	49	71
Rudderfish	5		2	5		2	0		0	*0*	53	50	72
Mulloway	4		2	3		1	2		1	*39*	54	59	33
Blue swimmer crab	4		1	3		1	1		0	*24*	55	57	40
Spotted wobbegong	4		1	4		1	0		0	*2*	56	53	60
Pink tilefish	3		1	3		1	0		0	*0*	57	54	73
Hapuku	3		1	3		1	0		0	*0*	58	55	74
Spotted gurnard	3		1	1		1	2		1	*60*	59	75	31
Giant boarfish	3		0	3		0	0		0	*1*	60	56	65
Herbst's nurse shark	3		2	2		1	1		1	*29*	61	63	42
Deepwater bug	3		1	3		1	0		0	*3*	62	58	59
School shark	2		1	2		1	0		0	*0*	63	60	75
Australian salmon	2		2	2		2	0		0	*0*	64	61	76
Bastard trumpeter	2		0	2		0	0		0	*0*	65	62	77
Chinaman leatherjacket	2		0	2		0	0		0	*10*	66	65	53
White shark	2		1	1		1	1		1	*38*	67	76	43
Large-toothed flounder	2		0	2		0	0		0	*5*	68	66	58
Broadbill swordfish	2		1	2		1	0		0	*0*	69	64	78
Dusky flathead	2		0	2		0	0		0	*1*	70	67	66
Red mullet	2		0	1		0	0		0	*13*	71	71	54
Seal shark	2		1	2		1	0		0	*3*	72	69	63
Goblin shark	2		2	2		2	0		0	*0*	73	68	79
Balmain bug	2		0	1		0	0		0	*4*	74	70	62
Slender squid	1		0	1		0	0		0	*12*	75	74	56
Yellowfin leatherjacket	1		0	1		0	0		0	*1*	76	72	67
Tasmanian trumpeter	1		0	1		0	0		0	*0*	77	73	80
Red cod	1		1	0		0	1		1	*82*	78	80	38
King dory	1		0	1		0	0		0	*29*	79	79	50
Smooth small-toothed flounder	1		0	1		0	0		0	*5*	80	78	61

Table 6

Estimates of annual retained, discarded and total catches (estimates +/- 1 se) of commercial species North

	Total catch (t)		Retained catch (t)		Discarded catch (t)		% Discarded	Relative catch magnitude		
								Total	Retained	Discarded
Silver trevally	174	19	173	19	2	1	1	1	1	15
Tiger flathead	46	5	39	4	7	1	15	2	2	2
Redfish	44	10	25	5	19	5	44	3	5	1
Shovelnose ray	36	7	35	7	1	0	3	4	3	18
Piked dogfish	36	14	32	12	4	2	11	5	4	4
Eagle ray	23	3	21	3	2	1	9	6	7	10
John dory	22	3	22	3	0	0	2	7	6	25
Angel shark	18	4	18	4	0	0	1	8	8	26
Sawsharks	18	3	18	3	0	0	1	9	9	27
Long-nosed whaler	18	10	18	10	0	0	0	10	10	43
Cuttlefish	14	2	13	2	1	0	7	11	11	19
Red gurnard	14	2	12	1	2	0	12	12	13	12
Banjo shark	13	2	12	2	2	0	13	13	14	11
Yellowfin bream	13	3	13	2	0	0	3	14	12	23
Eastern blue-spot flathead	13	1	10	1	3	0	20	15	16	5
Tarwhine	12	2	11	2	2	0	12	16	15	16
Smooth hammerhead	7	1	7	1	0	0	0	17	17	44
Southern calamary	7	1	7	1	0	0	1	18	18	33
Whaler shark	7	3	4	1	2	2	36	19	21	7
Tailor	7	1	4	1	3	1	38	20	22	6
Snapper	6	1	1	0	5	1	76	21	36	3
Rubberlip morwong	5	1	3	1	2	0	39	22	23	8
Velvet leatherjacket	5	1	5	1	0	0	8	23	19	24
Sharp-beaked gurnard	5	1	5	1	0	0	3	24	20	30
Red spot whiting	4	2	3	1	1	1	32	25	28	17
Mulloway	4	2	3	1	2	1	39	26	29	13
Blue swimmer crab	4	1	3	1	1	0	24	27	27	20
Tilefish	3	1	3	1	0	0	0	28	24	45
Gummy shark	3	1	3	1	0	0	3	29	25	34
Inshore ocean perch	3	1	1	0	2	1	65	30	44	9
Spotted wobbegong	3	1	3	1	0	0	2	31	26	35
Arrow squid	2	0	2	0	0	0	7	32	31	28
Australian salmon	2	2	2	2	0	0	0	33	30	46
White shark	2	1	1	1	1	1	38	34	42	22
Large-toothed flounder	2	0	2	0	0	0	5	35	33	31
Giant boarfish	2	0	2	0	0	0	1	36	32	40
Spotted gurnard	2	1	0	0	2	1	93	37	47	14
Dusky flathead	2	0	2	0	0	0	1	38	34	39
Balmain bug	2	0	1	0	0	0	4	39	35	37
Slender squid	1	0	1	0	0	0	12	40	41	29
Chinaman leatherjacket	1	0	1	0	0	0	7	41	39	32
Red mullet	1	0	1	0	0	0	3	42	38	38
Yellowfin leatherjacket	1	0	1	0	0	0	1	43	37	41
Herbst's nurse shark	1	1	1	1	0	0	0	44	40	47
Centrophorus dogfish	1	1	1	1	0	0	0	45	43	42
Smooth small-toothed flounder	1	0	1	0	0	0	6	46	45	36
Ogilby's ghost shark	1	0	0	0	1	0	88	47	46	21

Table 7

Estimates of annual retained, discarded and total catches (estimates +/- 1 se) of commercial species
Ulladulla

	Total catch (t)		Retained catch (t)		Discarded catch (t)		% Discarded	Relative catch magnitude		
								Total	Retained	Discarded
Redfish	1,150	+/- 74	782	+/- 0	368	+/- 74	*32*	1	1	1
Tiger flathead	170	3	152	0	17	3	*10*	2	2	3
Pink ling	96	0	96	0	0	0	*0*	3	3	26
Gemfish	84	51	20	0	65	51	*77*	4	13	2
Mirror dory	70	2	63	0	7	2	*10*	5	6	6
Piked dogfish	67	12	67	12	0	0	*1*	6	4	14
Silver trevally	66	0	66	0	0	0	*0*	7	5	34
Angel shark	56	5	56	5	0	0	*0*	8	7	24
Offshore ocean perch	56	8	52	8	4	1	*7*	9	8	7
John dory	50	0	50	0	0	0	*1*	10	9	20
Arrow squid	37	4	37	4	0	0	*1*	11	10	19
Southern frostfish	32	11	17	6	15	7	*47*	12	15	4
Sharp-beaked gurnard	23	4	23	4	0	0	*2*	13	11	16
Common saw shark	21	2	21	2	0	0	*1*	14	12	23
Cuttlefish	20	2	19	2	0	0	*2*	15	14	17
Jackass morwong	15	0	15	0	0	0	*0*	16	16	31
Splendid perch	15	6	14	5	0	0	*2*	17	17	18
Centrophorus spp. dogfish	12	3	12	3	0	0	*0*	18	18	28
Inshore ocean perch	12	2	5	1	7	1	*58*	19	25	5
Rubberlip morwong	10	1	8	1	2	0	*18*	20	19	9
Blue grenadier	7	0	6	0	1	0	*8*	21	22	13
Red gurnard	7	2	7	2	0	0	*4*	22	20	21
Velvet leatherjacket	7	1	6	1	0	0	*6*	23	21	15
Jack mackerel	6	1	5	1	1	0	*13*	24	24	12
Octopus	5	2	5	2	0	0	*1*	25	23	27
Silver dory	5	1	3	0	2	0	*39*	26	30	8
Blue warehou	5	0	5	0	0	0	*0*	27	26	35
Gummy shark	5	1	5	1	0	0	*0*	28	27	36
Rudderfish	4	1	4	1	0	0	*0*	29	28	37
Banjo shark	3	1	3	1	0	0	*5*	30	29	22
Eagle ray	3	1	3	1	0	0	*3*	31	31	25
Deania spp. dogfish	2	1	2	1	0	0	*0*	32	32	32
Barracouta	2	1	1	0	1	1	*72*	33	39	10
Deepwater bug	2	0	2	0	0	0	*1*	34	33	30
Herbst's nurse shark	2	1	1	1	1	1	*51*	35	38	11
Shovelnose ray	1	0	1	0	0	0	*2*	36	34	29
Whaler shark	1	1	1	1	0	0	*0*	37	35	38
Spotted trevalla	1	0	1	0	0	0	*0*	38	36	33
Broadbill swordfish	1	0	1	0	0	0	*0*	39	37	39

Table 8

Estimates of annual retained, discarded and total catches (estimates +/- 1 se) of commercial species
Eden

	Total catch (t)		Retained catch (t)		Discarded catch (t)		% Discarded	Relative catch magnitude		
								Total	Retained	Discarded
Redfish	1108 +/-	157	308 +/-	0	800 +/-	157	*72*	1	3	1
Spotted trevalla	787	11	744	0	43	11	*6*	2	1	13
Barracouta	461	70	261	47	201	47	*44*	3	5	2
Tiger flathead	455	10	390	0	64	10	*14*	4	2	11
Southern frostfish	302	68	118	26	183	56	*61*	5	11	3
Blue warehou	289	14	245	0	45	14	*16*	6	7	12
Pink ling	263	0	261	0	2	0	*1*	7	4	23
Jackass morwong	255	2	245	0	10	2	*4*	8	6	17
Arrow squid	240	30	235	30	6	1	*2*	9	8	19
Piked dogfish	210	25	41	7	169	23	*80*	10	17	4
Velvet leatherjacket	204	22	81	9	123	18	*60*	11	12	6
Jack mackerel	188	28	33	7	155	25	*82*	12	20	5
Silver trevally	147	0	146	0	1	0	*1*	13	9	29
Inshore ocean perch	130	17	16	2	114	16	*88*	14	26	7
Deania spp. dogfish	121	40	121	40	0	0	*0*	15	10	32
Offshore ocean perch	120	15	53	7	67	11	*56*	16	16	10
Gemfish	119	50	38	0	81	50	*68*	17	18	8
Mirror dory	107	28	36	0	71	28	*66*	18	19	9
Blue grenadier	71	1	68	0	3	1	*4*	19	13	22
John dory	70	1	66	0	4	1	*6*	20	14	20
Silver dory	69	6	30	2	40	4	*57*	21	21	14
Octopus	55	4	55	4	0	0	*0*	22	15	40
Cuttlefish	41	3	25	2	17	2	*40*	23	23	16
Rubberlip morwong	32	4	6	1	26	4	*82*	24	35	15
Red gurnard	27	3	25	3	1	0	*5*	25	22	26
Angel shark	18	2	18	2	0	0	*1*	26	24	37
Gummy shark	17	2	16	2	1	1	*5*	27	25	30
Spiky oreo	14	6	14	6	0	0	*0*	28	27	43
Ribaldo	11	4	10	4	0	0	*2*	29	28	35
Sawsharks	10	2	10	1	0	0	*2*	30	29	36
Thintail thresher	8	5	0	0	7	5	*94*	31	52	18
Orange roughy	8	1	6	0	2	1	*21*	32	33	24
Ogilby's ghost shark	8	2	6	1	1	1	*20*	33	32	25
Red spot whiting	7	0	6	0	0	0	*2*	34	31	38
Centrophorus spp. dogfish	7	2	7	2	0	0	*0*	35	30	44
Mosaic leatherjacket	6	2	6	1	0	0	*5*	36	34	31
Green-eyed dogfish	6	5	5	4	1	1	*17*	37	36	28
Whaler shark	5	3	1	0	4	2	*82*	38	50	21
Blue-eye trevalla	5	0	5	0	0	0	*0*	39	37	45
Southern calamary	5	1	4	1	0	0	*6*	40	38	33
Hapuku	3	1	3	1	0	0	*0*	41	39	46
Snapper	2	1	2	1	0	0	*0*	42	40	47
Bastard trumpeter	2	0	2	0	0	0	*0*	43	41	48
School shark	2	1	2	1	0	0	*0*	44	42	49
Sharp-beaked gurnard	2	0	1	0	0	0	*6*	45	44	39
Goblin shark	2	2	2	2	0	0	*0*	46	43	50
Seal shark	1	1	1	1	0	0	*3*	47	45	42
Tasmanian trumpeter	1	0	1	0	0	0	*0*	48	46	51
Red cod	1	1	0	0	1	1	*82*	49	53	27
Spotted gurnard	1	1	1	1	0	0	*6*	50	48	41
Eagle ray	1	1	1	1	0	0	*0*	51	47	52
King dory	1	0	1	0	0	0	*25*	52	51	34
Rudderfish	1	1	1	1	0	0	*0*	53	49	53

Table 9

Contribution of Ulladulla and Eden fleets to mean annual landings (1993-95) by all trawlers operating in the SEF in NSW

includes catches declared as being taken in SEF waters (outside 3 nm) and NSW waters (inside 3 nm)
excludes trips targeting Royal red prawns (catches of prawns > 50 kg) and trips > 3 days duration

	Landings (t) into Ulladulla and Eden	**Landings (t) into Ulladulla and Eden as % of landings into all NSW ports**
Redfish	1,091	*70*
Spotted trevalla	745	*96*
Tiger flathead	543	*69*
Ling	357	*73*
Jackass morwong	260	*90*
Blue warehou	249	*84*
Silver trevally	213	*55*
John dory	116	*55*
Mirror dory	99	*60*
Blue grenadier	75	*85*
Gemfish	58	*54*
All quota species	3,926	*68*

Appendix A

Species summaries (Observer survey)

A.1	Redfish	*Centroberyx affinis*
A.2	Spotted trevalla	*Seriolella punctata*
A.3	Tiger flathead	*Neoplatycephalus richardsoni*
A.4	Barracouta	*Thyrsites atun*
A.5	Silver trevally	*Pseudocaranx dentex*
A.6	Pink ling	*Genypterus blacodes*
A.7	Southern frostfish	*Lepidopus caudatus*
A.8	Piked dogfish	*Squalus megalops*
A.9	Blue warehou	*Seriolella brama*
A.10	Arrow squid	*Nototodarus gouldi*
A.11	Jackass morwong	*Nemadactylus macropterus*
A.12	Velvet leatherjacket	*Meuschenia scaber*
A.13	Gemfish	*Rexea solandri*
A.14	Jack mackerel	*Trachurus declivis*
A.15	Mirror dory	*Zenopsis nebulosis*
A.16	Ocean perch (Offshore)	*Helicolenus percoides* (offshore form)
A.17	Ocean perch (Inshore)	*Helicolenus percoides* (inshore form)
A.18	John dory	*Zeus faber*
A.19	Brier shark + Long-snouted dogfish	*Deania* spp.
A.20	Angel sharks	*Squatina* spp.
A.21	Blue grenadier	*Macruronus novaezelandiae*
A.22	Cuttlefish	*Sepia* spp.
A.23	Silver dory	*Cyttus australis*
A.24	Octopus	Order Octopoda
A.25	Sawsharks	*Pristiophorus* spp.
A.26	Rubberlip morwong	*Nemadactylus douglasi*
A.27	Red gurnard	*Chelidonichthys kumu*
A.28	Shovelnose ray	*Aptychotrema rostrata*
A.29	Sharp-beaked gurnard	*Pterygotrigla polyommata*
A.30	Eagle ray	*Myliobatis australis*
A.31	Gummy shark	*Mustelus antarcticus*
A.32	*Centrophorus* dogfishes	*Centrophorus* spp.
A.33	Eastern blue-spot flathead	*Platycephalus caeruleopunctatus*
A.34	Yellowfin bream	*Acanthopagrus australis*
A.35	Snapper	*Pagrus auratus*

Appendix A

Species summaries (Observer survey)

Appendix to

The interaction between fish trawling (in NSW) and other commercial and recreational fisheries

Final report to

The Fisheries Research & Development Corporation

Project No: 92/79

August, 1996

Geoffrey W. Liggins
(Principal investigator)

NSW Fisheries Research Institute
PO Box 21, Cronulla, NSW, 2230

ISBN 0 7310 9402 6

Appendix A.1

Redfish

Centroberyx affinis

Figure 1.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 1.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 1.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 1.1
Annual retained and discarded catches (t)

Table 1.2
Annual retained and discarded catches (number of fish)

Figure 1.4
Size distributions of retained and discarded catches

Figure 1.1

Retained and discarded catches (kg per fisher-day) - Redfish
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

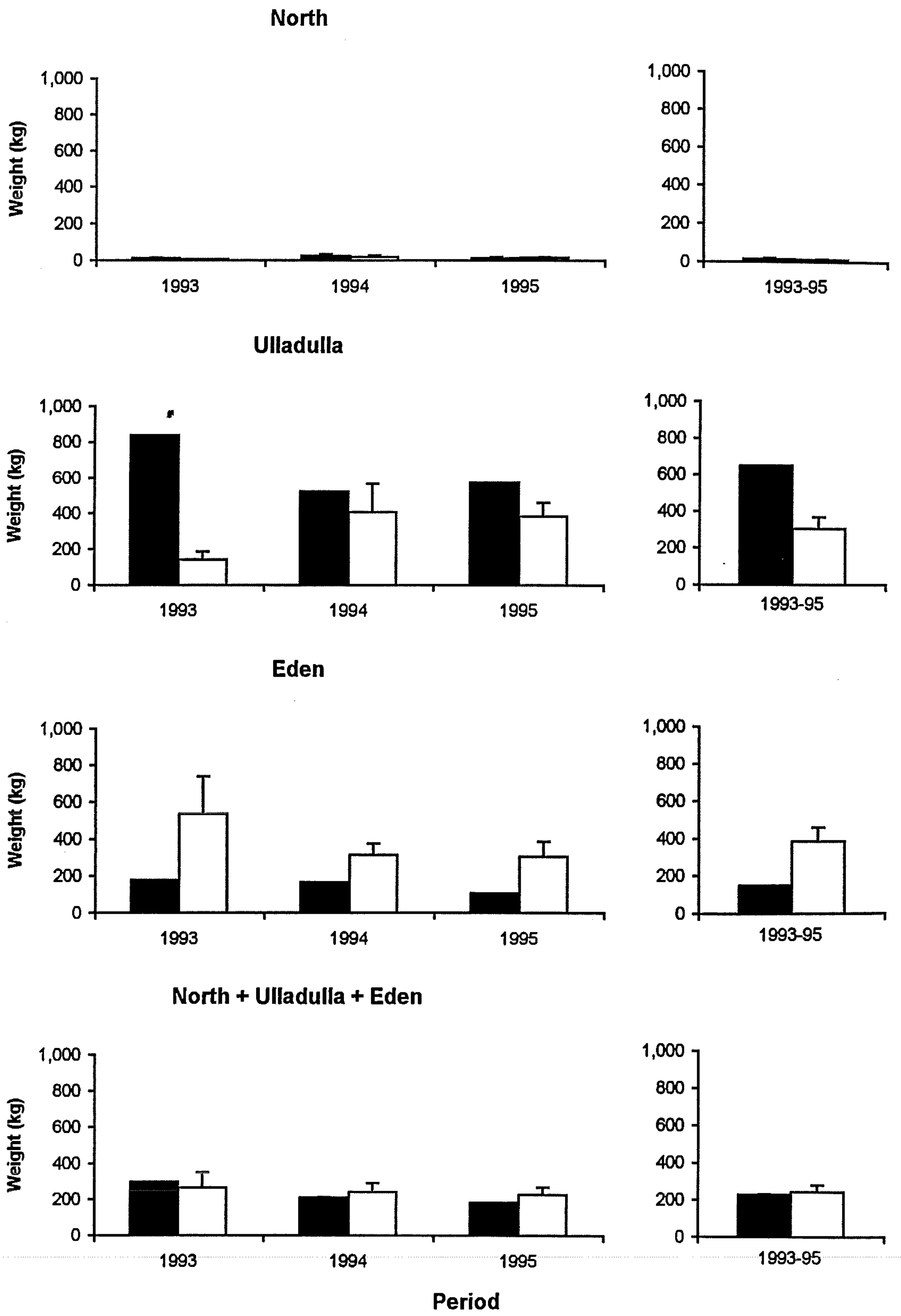


Figure 1.2

Retained and discarded catches (number of fish per fisher-day) - Redfish
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

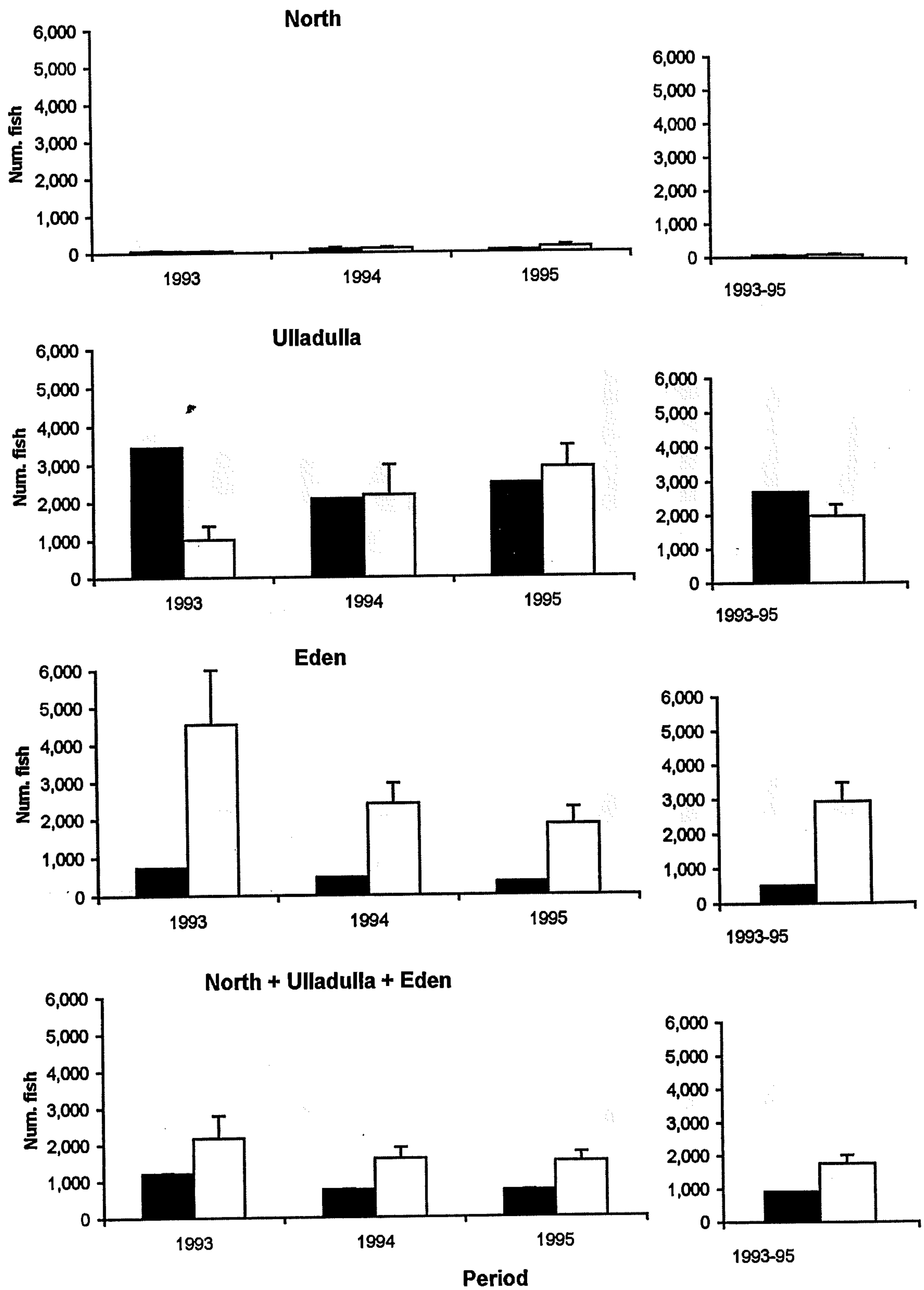


Figure 1.3

Retained and discarded catches (per fisher-day) - Redfish
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

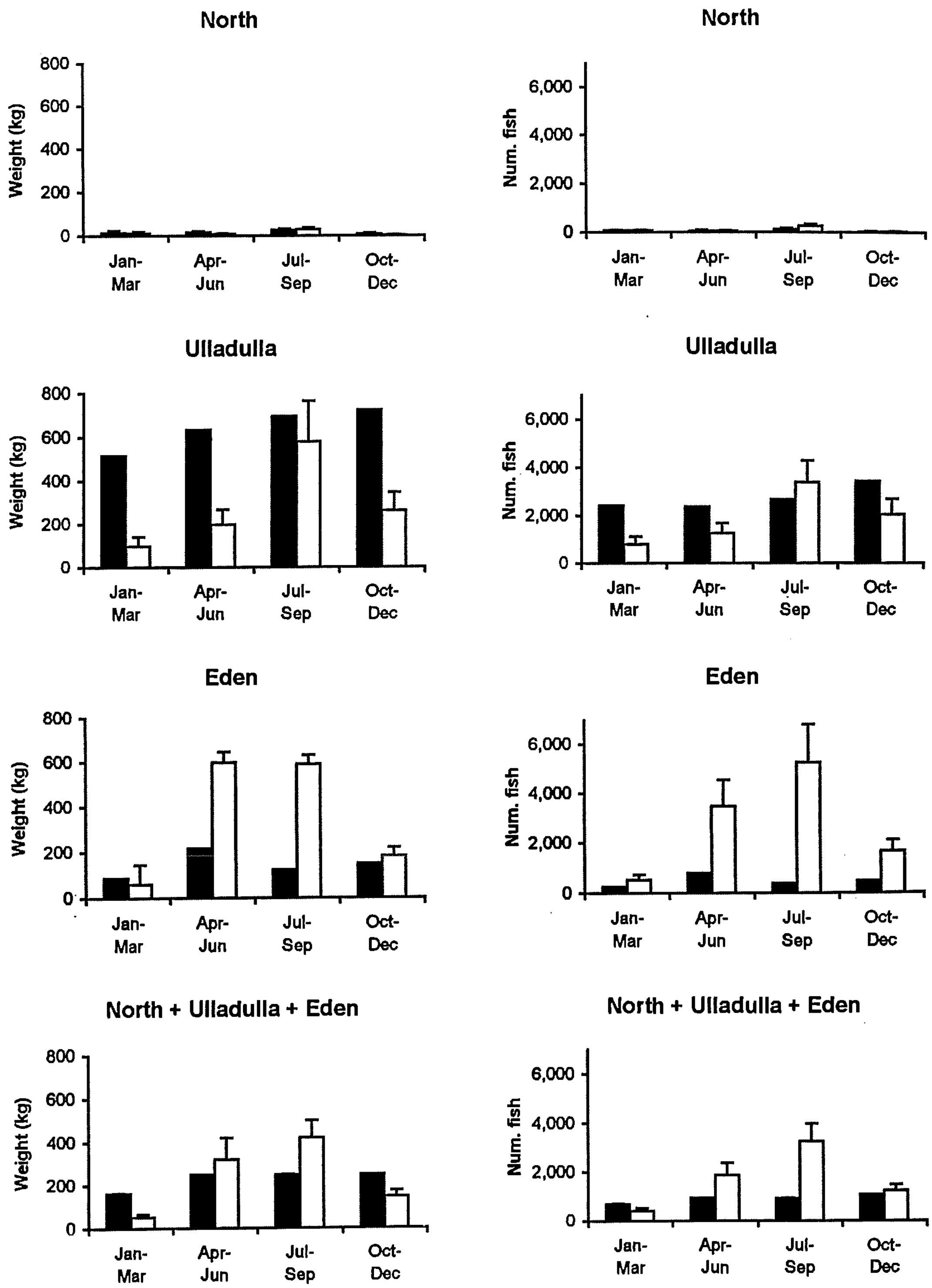


Table 1.1

Annual retained and discarded catches - Redfish (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	24	6	17	5	7	3	30
	1994	66	26	37	14	28	12	43
	1995	43	11	20	6	23	7	53
	Mean 1993-95	44	10	25	5	19	5	44
Ulladulla	1993	1,260	59	1,078	0	181	59	14
	1994	1,147	198	644	0	503	198	44
	1995	1,044	82	625	0	419	82	40
	Mean 1993-95	1,150	74	782	0	368	74	32
Eden	1993	1,477	418	365	0	1,112	418	75
	1994	984	126	338	0	645	126	66
	1995	864	175	222	0	643	175	74
	Mean 1993-95	1,108	157	308	0	800	157	72
N+U+E	1993	2,761	422	1,461	5	1,300	422	47
	1994	2,196	236	1,020	14	1,177	235	54
	1995	1,951	194	867	6	1,085	194	56
	Mean 1993-95	2,303	174	1,116	5	1,187	173	52

Table 1.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	157	38	89	28	68	27	43
	1994	326	116	158	57	168	64	52
	1995	317	88	86	24	231	79	73
	Mean 1993-95	267	51	111	23	156	35	58
Ulladulla	1993	5,730	455	4,429	0	1,302	455	23
	1994	5,259	975	2,570	0	2,689	975	51
	1995	5,887	602	2,719	0	3,168	602	54
	Mean 1993-95	5,625	411	3,239	0	2,386	411	42
Eden	1993	10,901	3,041	1,523	0	9,378	3,041	86
	1994	5,936	1,086	984	0	4,952	1,086	83
	1995	4,643	937	727	0	3,916	937	84
	Mean 1993-95	7,160	1,121	1,078	0	6,082	1,121	85
N+U+E	1993	16,788	3,075	6,040	28	10,748	3,075	64
	1994	11,520	1,464	3,711	57	7,809	1,461	68
	1995	10,847	1,117	3,532	24	7,315	1,116	67
	Mean 1993-95	13,052	1,195	4,428	23	8,624	1,194	66

Figure 1.4, page 1

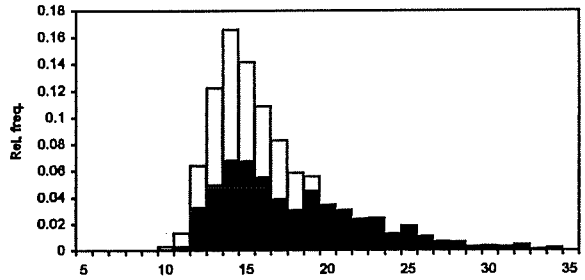
Size distributions of retained and discarded catches of Redfish

Retained catch: black bars Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

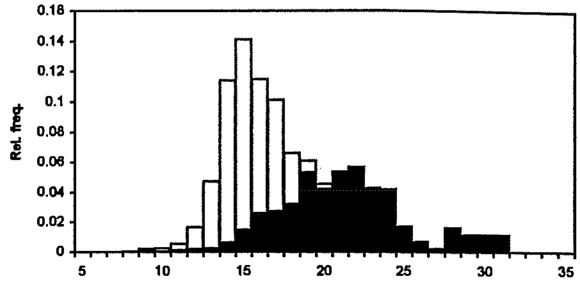
North, 1993

	Retained	Discarded	Total
Obs:	919 (18)	689 (48)	
Co-op:	0 (0)		
Mean L:	18.5	15.2	17.1



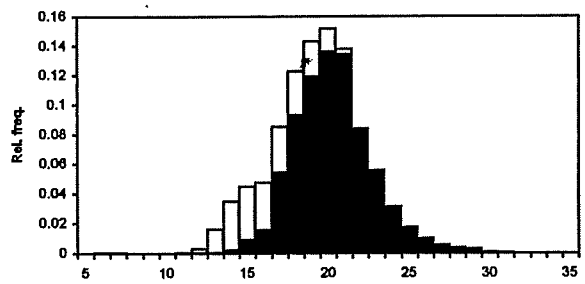
North, 1994

	Retained	Discarded	Total
Obs:	822 (13)	1766 (53)	
Co-op:	0 (0)		
Mean L:	22.2	15.7	18.8



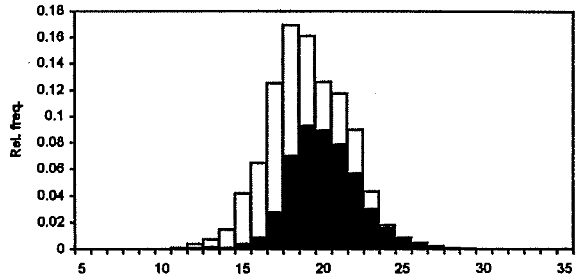
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	6473 (41)	3392 (80)	
Co-op:	0 (0)		
Mean L:	20.9	16.8	19.9



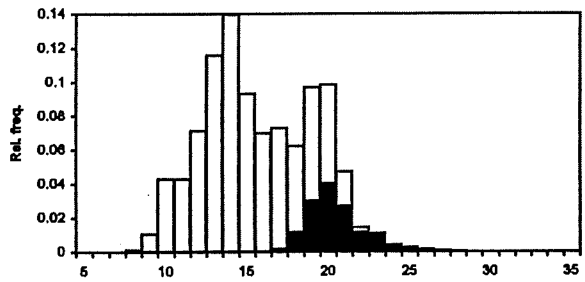
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	4194 (25)	4781 (84)	
Co-op:	5826 (35)		
Mean L:	20.6	18.6	19.6



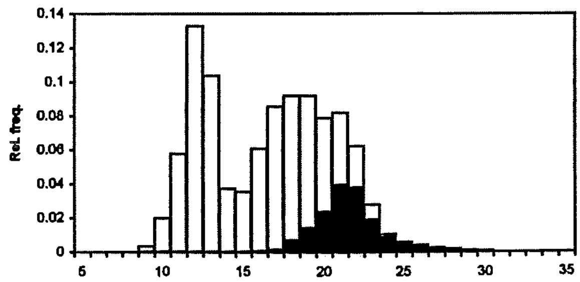
Eden, 1993

	Retained	Discarded	Total
Obs:	2074 (22)	4133 (91)	
Co-op:	0 (0)		
Mean L:	21.0	15.5	16.3



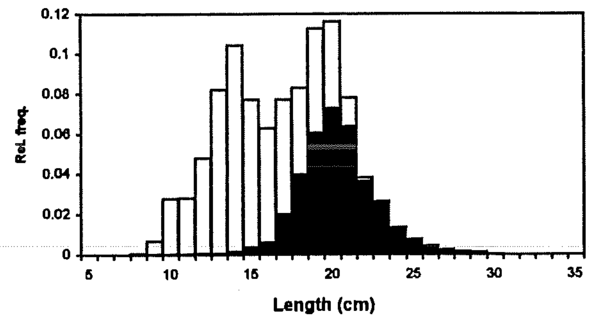
Eden, 1994

	Retained	Discarded	Total
Obs:	2559 (22)	5905 (141)	
Co-op:	3327 (20)		
Mean L:	22.2	16.2	17.2



N + U + E, 1993

	Retained	Discarded	Total
Obs:	9465 (81)	8214 (219)	
Co-op:	0 (0)		
Mean L:	20.9	15.7	17.6



N + U + E, 1994

	Retained	Discarded	Total
Obs:	7575 (60)	12452 (278)	
Co-op:	9152 (55)		
Mean L:	21.1	17.0	18.3

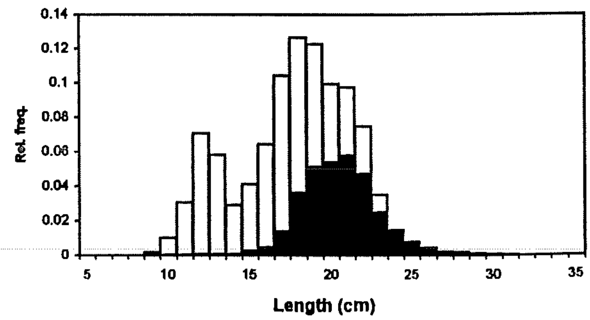
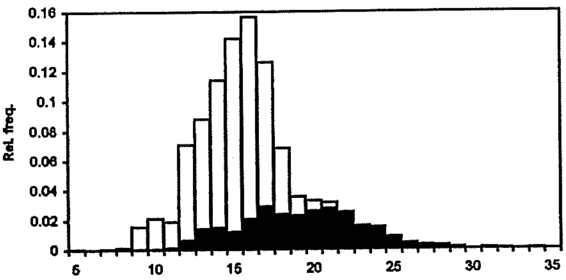


Figure 1.4, page 2

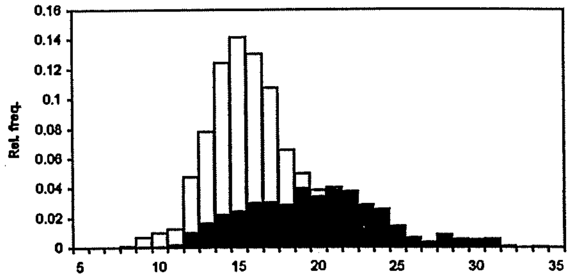
North, 1995

	Retained	Discarded	Total
Obs:	1276 (18)	1927 (81)	
Co-op:	0 (0)		
Mean L:	19.7	15.3	16.5



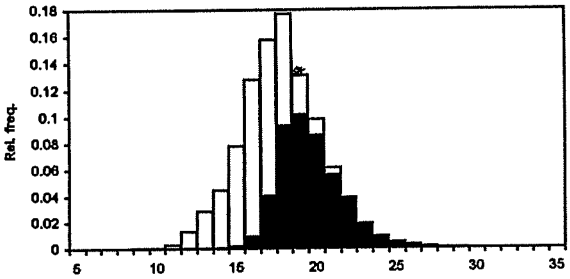
North, 1993-95

	Retained	Discarded	Total
Obs:	3017 (49)	4382 (182)	
Co-op:	0 (0)		
Mean L:	20.5	15.4	17.6



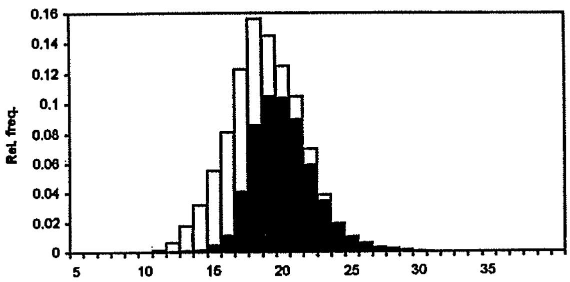
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	11129 (70)	11530 (153)	
Co-op:	6989 (37)		
Mean L:	20.1	16.8	18.3



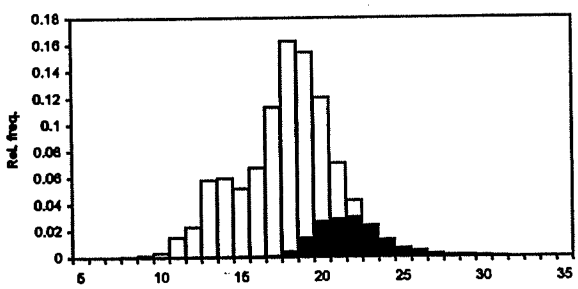
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	21796 (136)	19703 (317)	
Co-op:	12814 (72)		
Mean L:	20.6	17.5	19.3



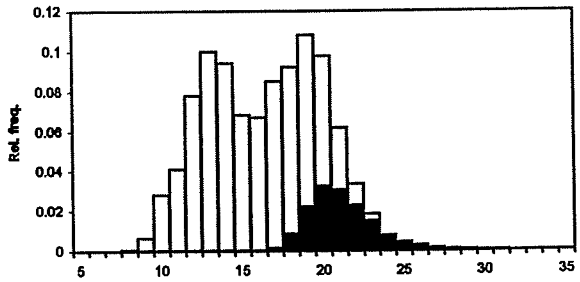
Eden, 1995

	Retained	Discarded	Total
Obs:	2903 (21)	4638 (119)	
Co-op:	2775 (16)		
Mean L:	22.4	17.7	18.4



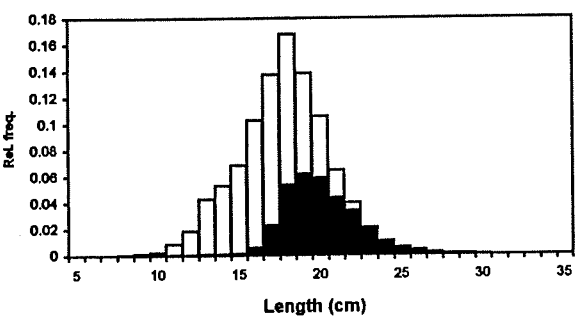
Eden, 1993-95

	Retained	Discarded	Total
Obs:	7536 (65)	14676 (351)	
Co-op:	6102 (36)		
Mean L:	21.7	16.2	17.0



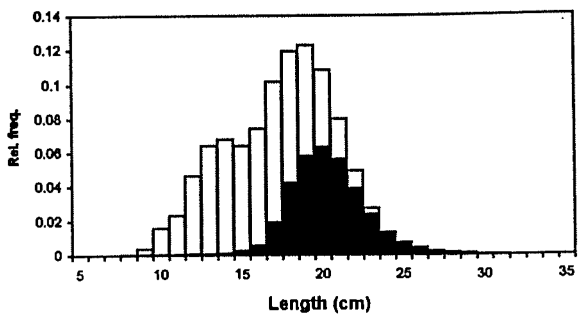
N + U + E, 1995

	Retained	Discarded	Total
Obs:	15309 (109)	18095 (353)	
Co-op:	9764 (53)		
Mean L:	20.6	17.2	18.3



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	32349 (250)	38761 (850)	
Co-op:	18916 (108)		
Mean L:	20.9	16.6	18.0



Appendix A.2

Spotted trevalla

Seriolella punctata

Figure 2.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 2.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 2.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 2.1
Annual retained and discarded catches (t)

Table 2.2
Annual retained and discarded catches (number of fish)

Figure 2.4
Size distributions of retained and discarded catches

Figure 2.1

Retained and discarded catches (kg per fisher-day) - Spotted trevalla
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

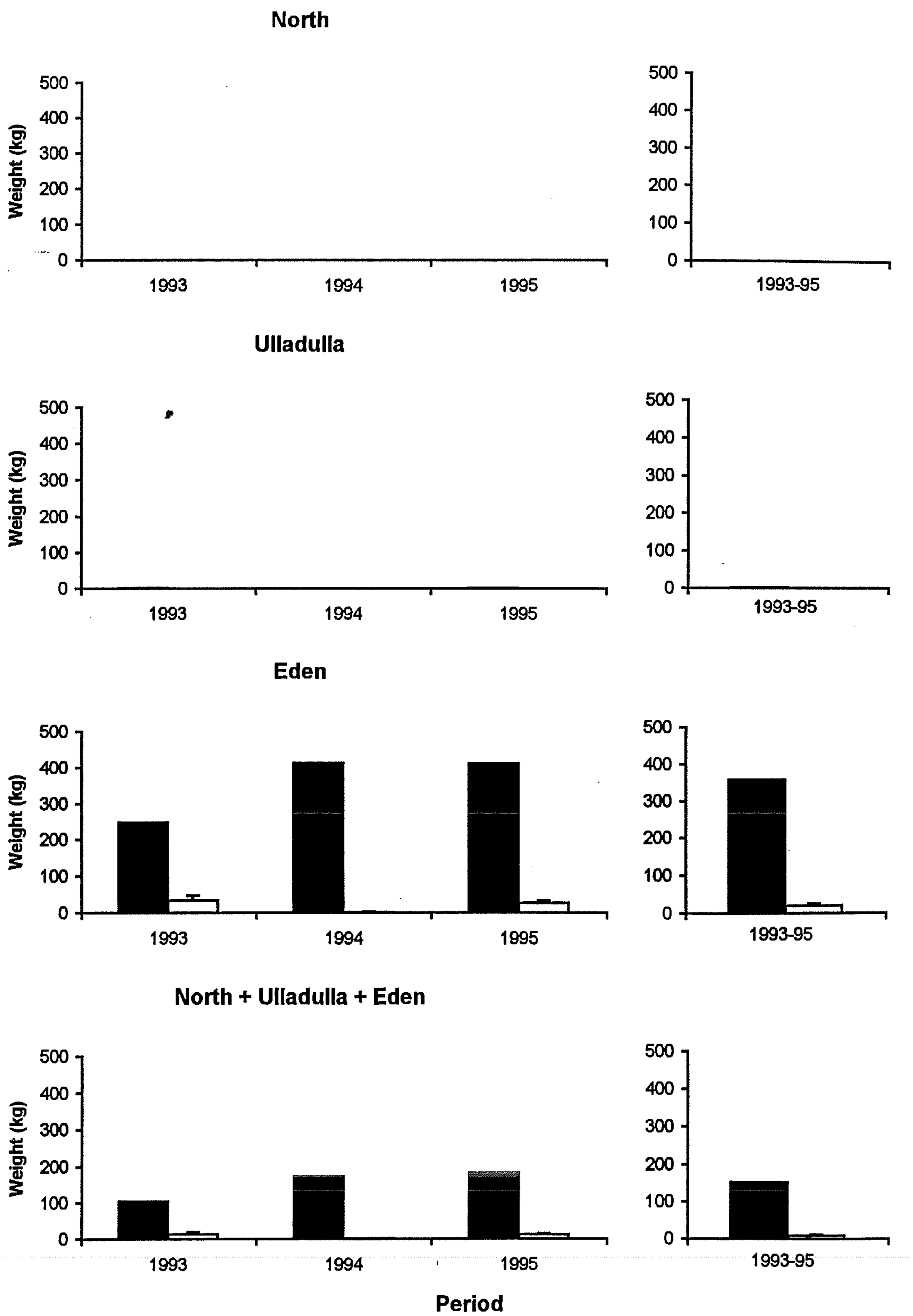


Figure 2.2

Retained and discarded catches (number of fish per fisher-day) - Spotted trevalla
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

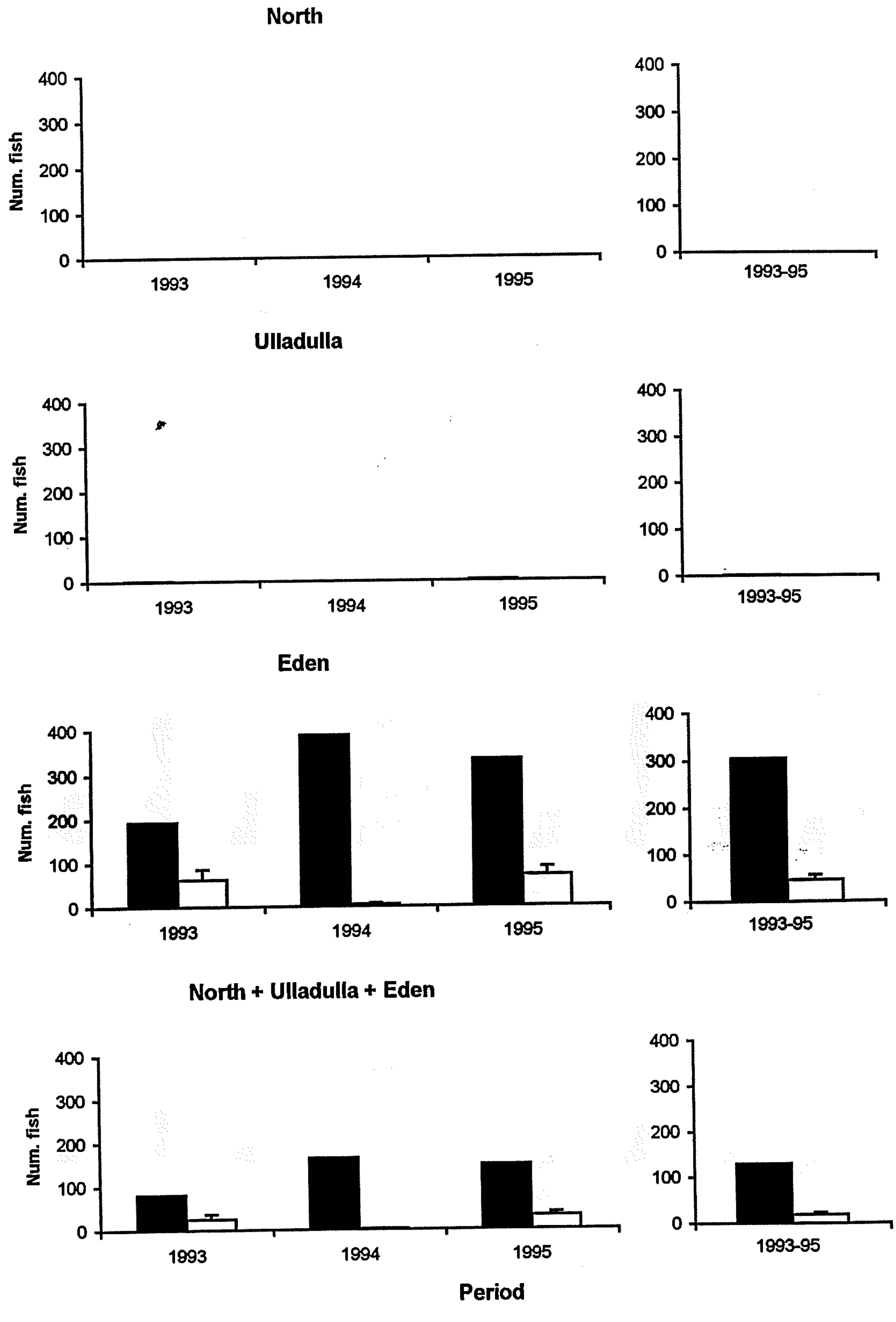


Figure 2.3

Retained and discarded catches (per fisher-day) - Spotted trevalla

by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

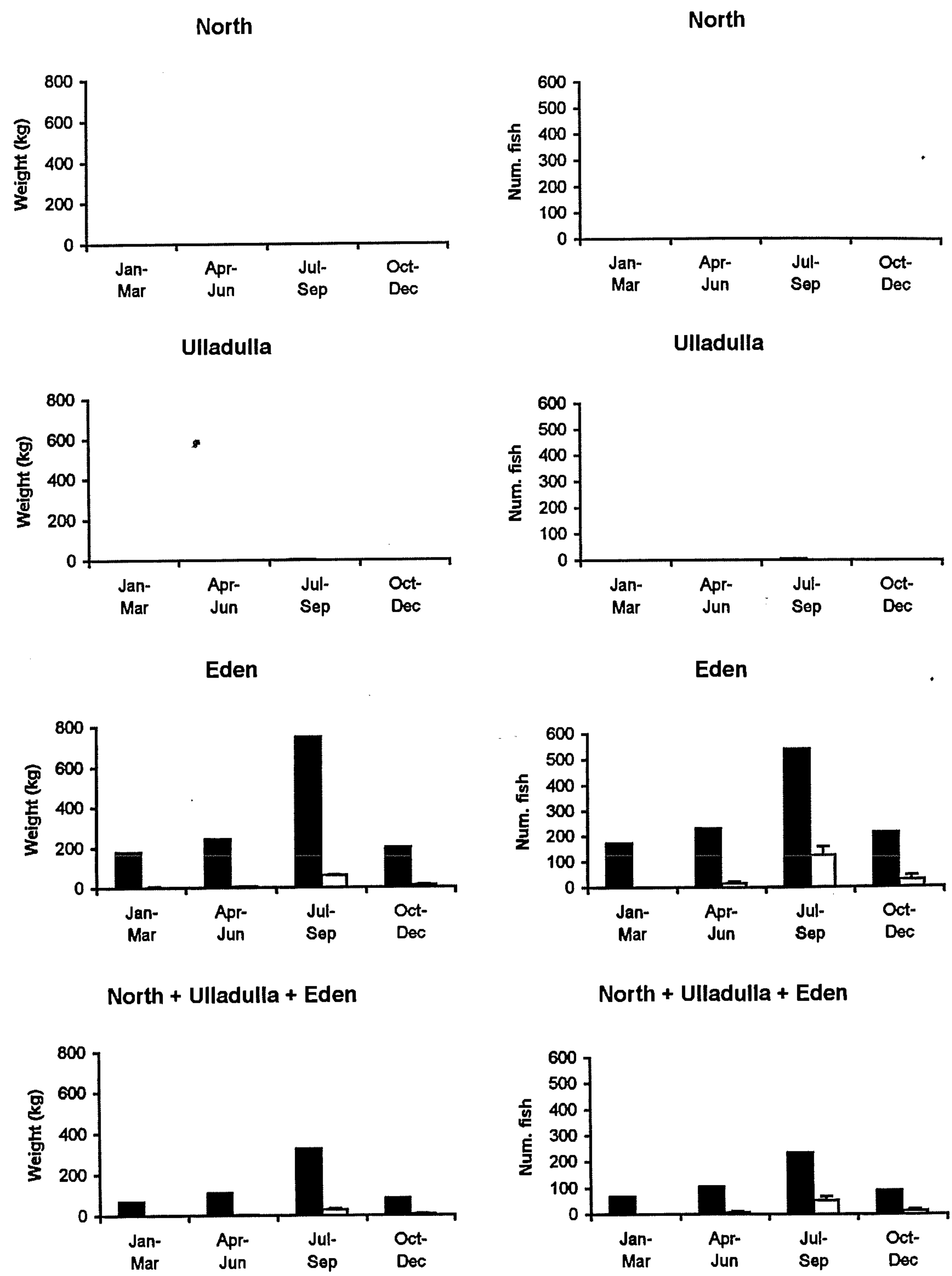


Table 2.1

Annual retained and discarded catches - Spotted trevalla (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	1	0	1	0	0	0	0
	1994	0	0	0	0	0	0	0
	1995	2	0	2	0	0	0	0
	Mean 1993-95	1	0	1	0	0	0	0
Eden	1993	583	29	514	0	69	29	12
	1994	852	2	848	0	4	2	1
	1995	925	15	870	0	55	15	6
	Mean 1993-95	787	11	744	0	43	11	5
N+U+E	1993	584	29	515	0	69	29	12
	1994	852	2	848	0	4	2	1
	1995	927	15	872	0	55	15	6
	Mean 1993-95	788	11	745	0	43	11	5

Table 2.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	2	0	2	0	0	0	1
	1994	0	0	0	0	0	0	0
	1995	3	0	3	0	0	0	0
	Mean 1993-95	2	0	2	0	0	0	0
Eden	1993	525	50	400	0	126	50	24
	1994	808	4	798	0	10	4	1
	1995	853	38	704	0	149	38	17
	Mean 1993-95	729	21	634	0	95	21	13
N+U+E	1993	528	50	402	0	126	50	24
	1994	808	4	798	0	10	4	1
	1995	856	38	707	0	149	38	17
	Mean 1993-95	731	21	636	0	95	21	13

Figure 2.4, page 1

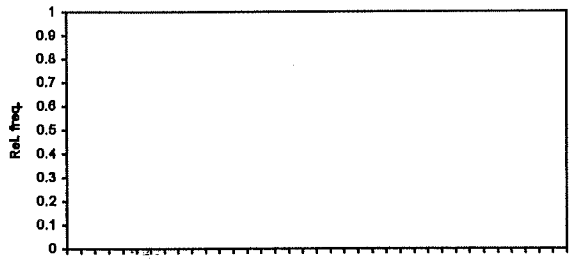
Size distributions of retained and discarded catches of Spotted trevalla

Retained catch: black bars Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

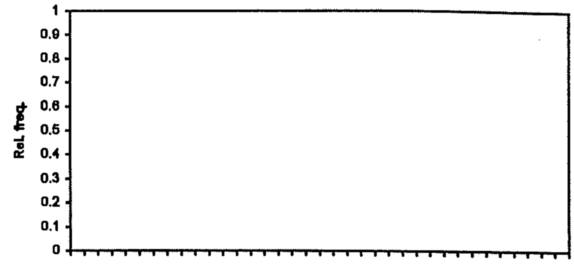
North, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



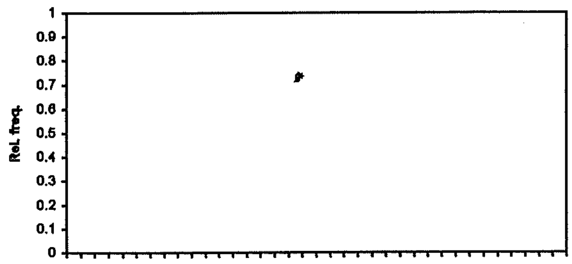
North, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



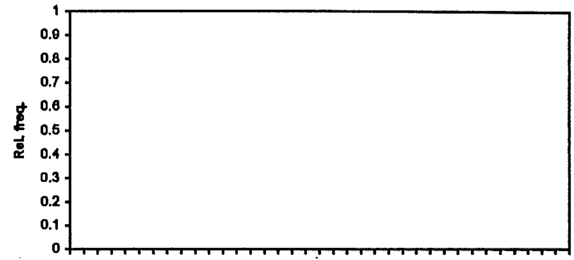
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



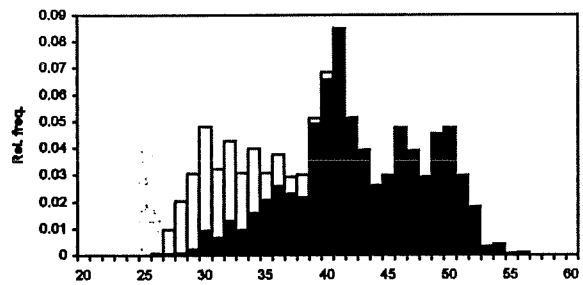
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



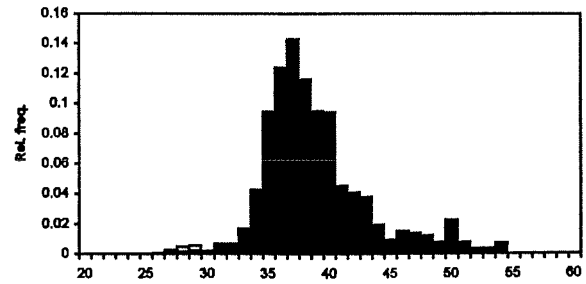
Eden, 1993

	Retained	Discarded	Total
Obs:	1806 (23)	232 (23)	
Co-op:	0 (0)		
Mean L:	43.2	32.3	40.6



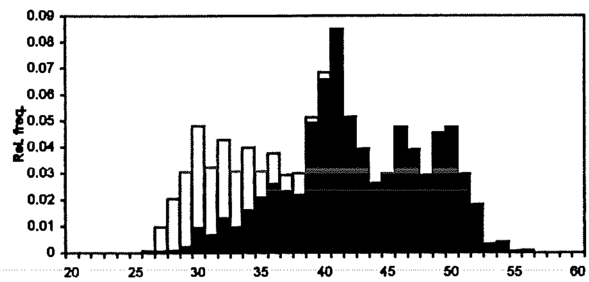
Eden, 1994

	Retained	Discarded	Total
Obs:	1344 (17)	40 (15)	
Co-op:	1679 (12)		
Mean L:	39.4	29.3	39.3



N + U + E, 1993

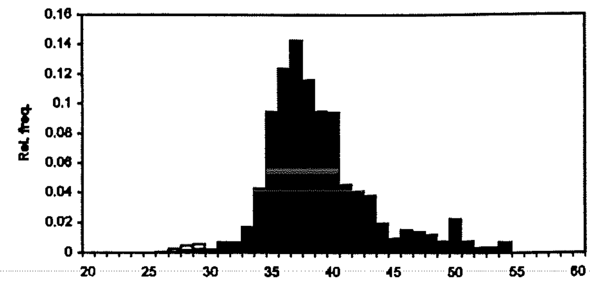
	Retained	Discarded	Total
Obs:	1806 (23)	232 (23)	
Co-op:	0 (0)		
Mean L:	43.2	32.3	40.6



Length (cm)

N + U + E, 1994

	Retained	Discarded	Total
Obs:	1344 (17)	40 (15)	
Co-op:	1679 (12)		
Mean L:	39.4	29.3	39.3

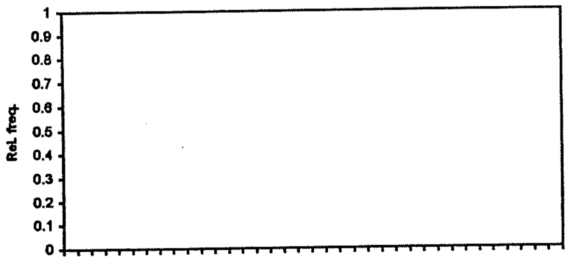


Length (cm)

Figure 2.4, page 2

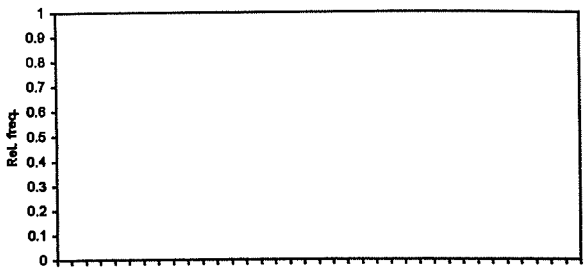
North, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



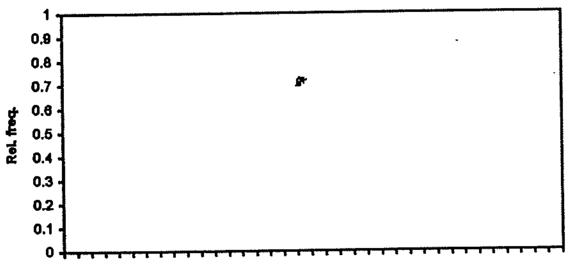
North, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



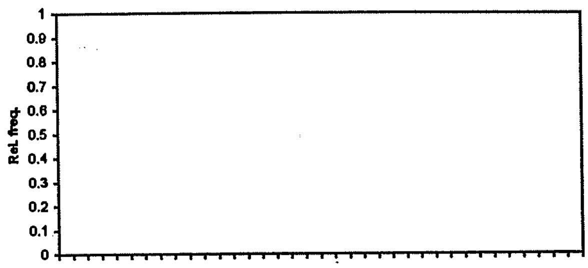
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



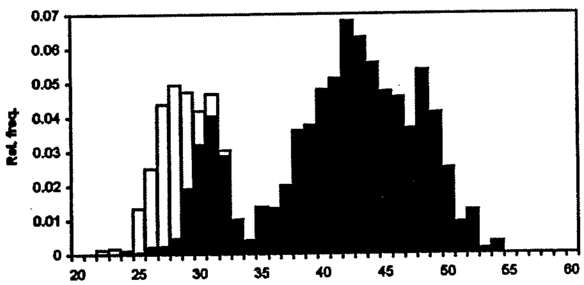
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



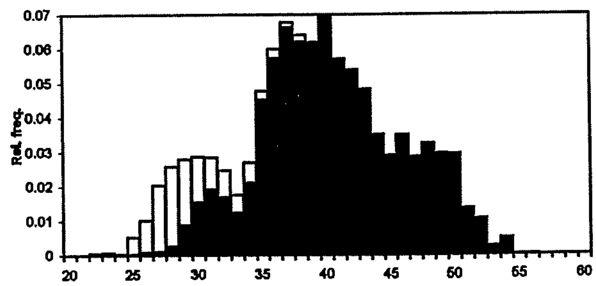
Eden, 1995

	Retained	Discarded	Total
Obs:	936 (13)	383 (48)	
Co-op:	981 (11)		
Mean L:	41.8	28.1	39.5



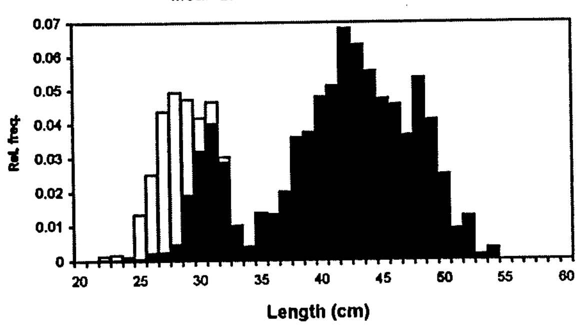
Eden, 1993-95

	Retained	Discarded	Total
Obs:	4086 (53)	655 (86)	
Co-op:	2660 (23)		
Mean L:	41.1	30.0	39.7



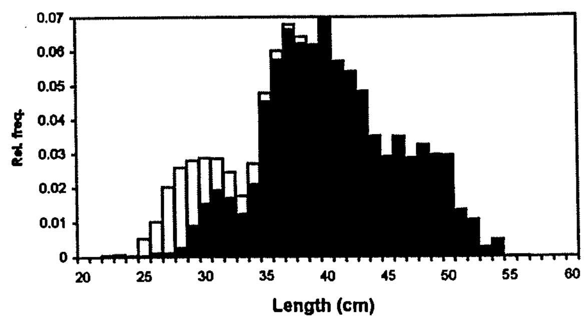
N + U + E, 1995

	Retained	Discarded	Total
Obs:	936 (13)	383 (48)	
Co-op:	981 (11)		
Mean L:	41.8	28.1	39.5



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	4086 (53)	655 (86)	
Co-op:	2660 (23)		
Mean L:	41.1	30.0	39.7



Appendix A.3

Tiger flathead

Neoplatycephalus richardsoni

Figure 3.1

Retained and discarded catches (kg per fisher-day) - Tiger flathead
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

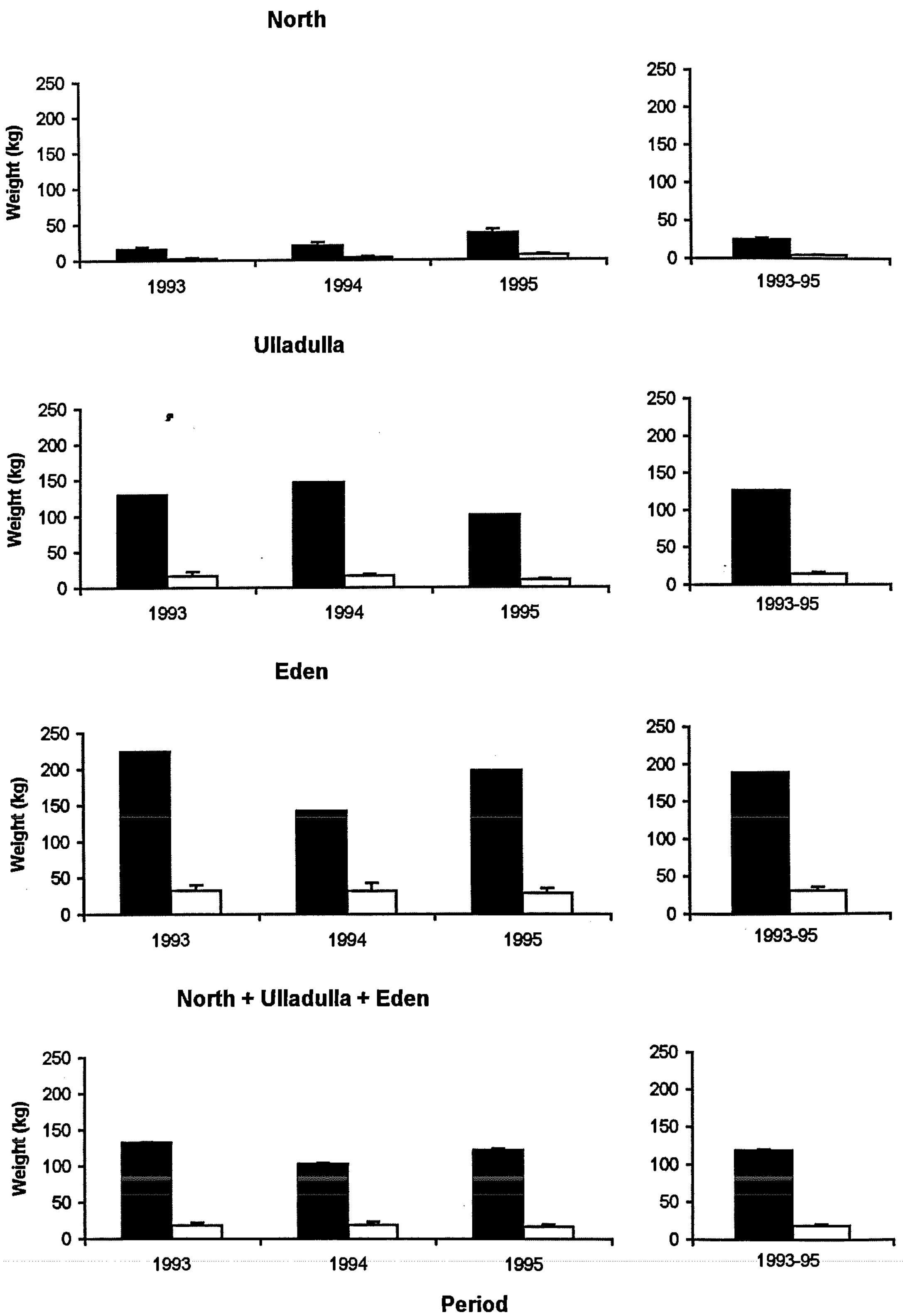


Figure 3.2

Retained and discarded catches (number of fish per fisher-day) - Tiger flathead
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

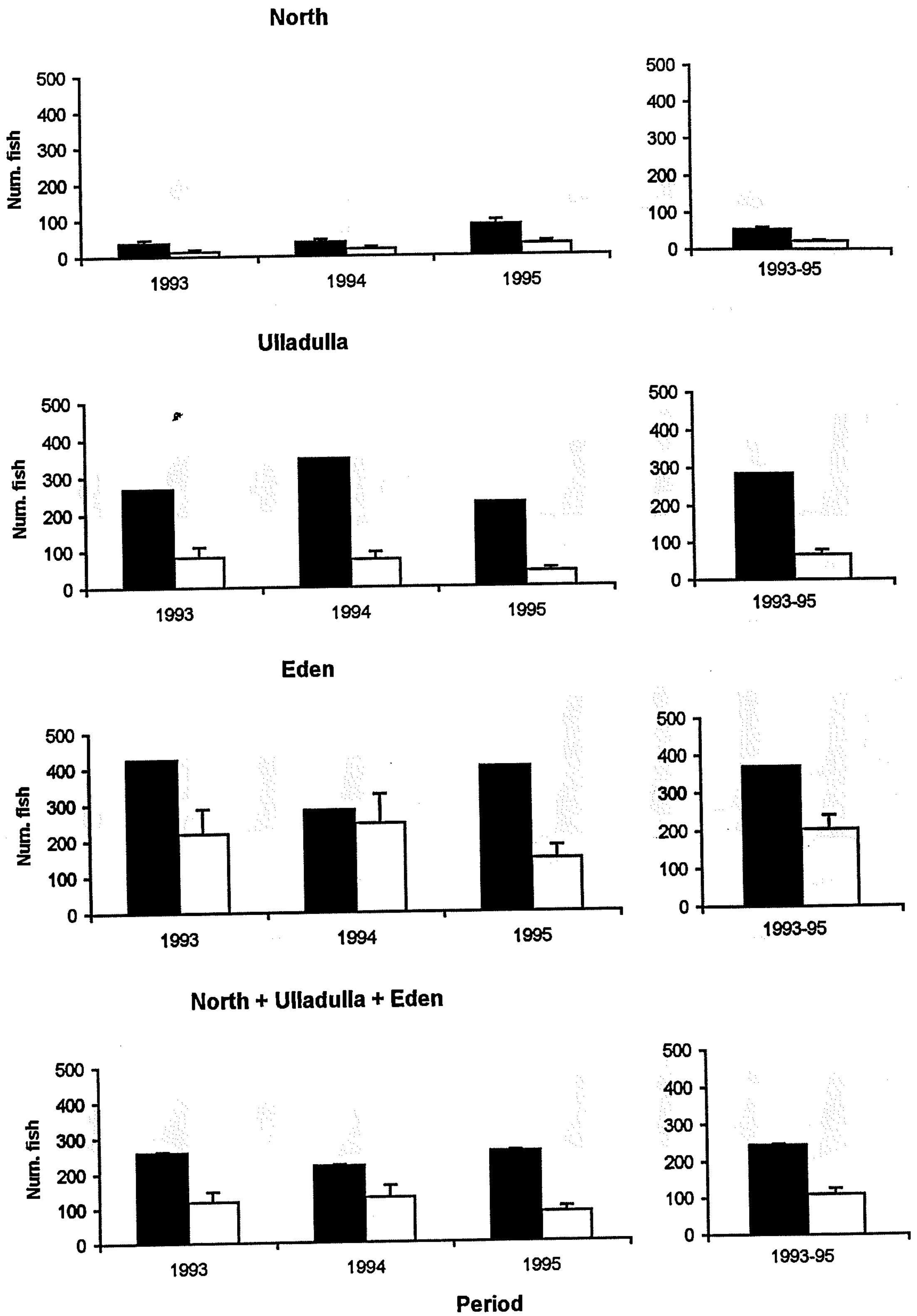


Figure 3.3

Retained and discarded catches (per fisher-day) - Tiger flathead
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

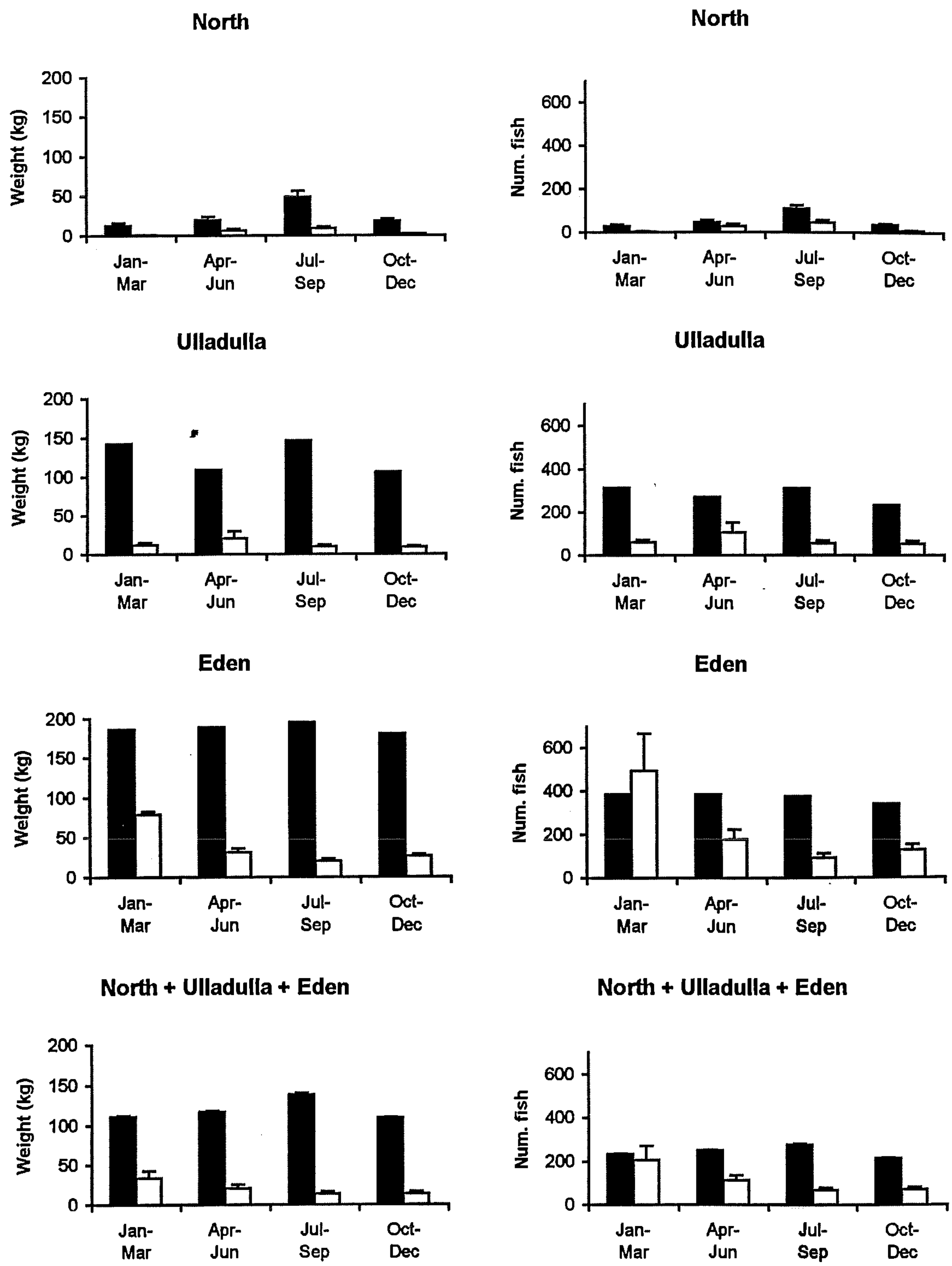


Table 3.1

Annual retained and discarded catches - Tiger flathead (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	29	6	25	5	4	1	*14*
	1994	39	7	32	7	6	2	*16*
	1995	71	10	60	8	11	2	*15*
	Mean 1993-95	46	5	39	4	7	1	*15*
Ulladulla	1993	187	8	167	0	21	6	*11*
	1994	201	2	181	0	21	2	*10*
	1995	120	2	109	0	11	2	*9*
	Mean 1993-95	170	3	152	0	17	3	*10*
Eden	1993	530	16	463	0	67	16	*13*
	1994	357	23	291	0	66	23	*18*
	1995	478	14	417	0	61	14	*13*
	Mean 1993-95	455	10	390	0	64	10	*14*
N+U+E	1993	746	19	654	5	91	18	*12*
	1994	596	24	504	7	92	23	*16*
	1995	670	17	587	8	83	14	*12*
	Mean 1993-95	671	12	582	4	89	11	*13*

Table 3.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	82	20	60	14	22	8	27
	1994	93	16	63	11	30	9	33
	1995	186	26	136	19	50	10	27
	Mean 1993-95	120	12	86	9	34	5	28
Ulladulla	1993	451	36	345	0	106	36	23
	1994	524	24	429	0	94	24	18
	1995	294	10	250	0	45	10	15
	Mean 1993-95	423	15	342	0	82	15	19
Eden	1993	1,334	143	880	0	454	143	34
	1994	1,085	166	581	0	504	166	46
	1995	1,158	75	848	0	310	75	27
	Mean 1993-95	1,192	77	770	0	422	77	35
N+U+E	1993	1,867	149	1,285	14	582	148	31
	1994	1,702	169	1,073	11	629	168	37
	1995	1,639	80	1,234	19	404	76	25
	Mean 1993-95	1,736	80	1,197	9	538	79	31

Figure 3.4, page 1

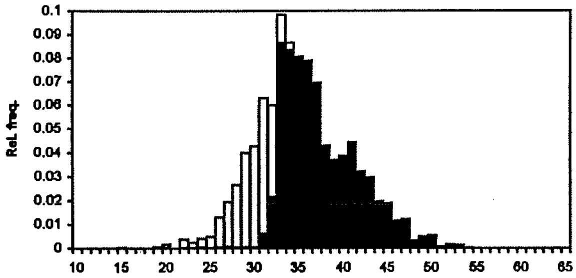
Size distributions of retained and discarded catches of Tiger flathead

Retained catch: black bars Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

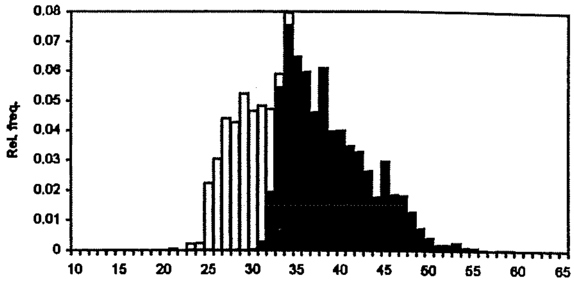
North, 1993

	Retained	Discarded	Total
Obs:	1440 (36)	587 (46)	
Co-op:	0 (0)		
Mean L:	38.2	30.0	36.0



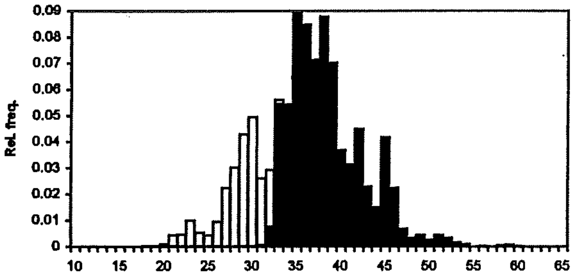
North, 1994

	Retained	Discarded	Total
Obs:	2220 (56)	674 (52)	
Co-op:	0 (0)		
Mean L:	39.2	29.3	35.9



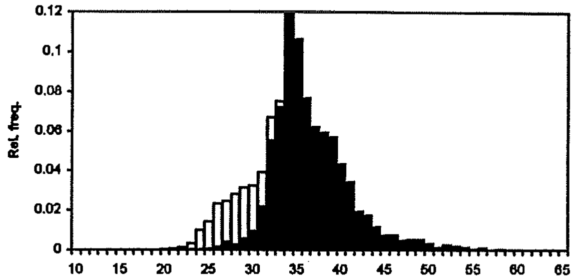
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	1575 (27)	1826 (90)	
Co-op:	0 (0)		
Mean L:	39.0	29.0	36.7



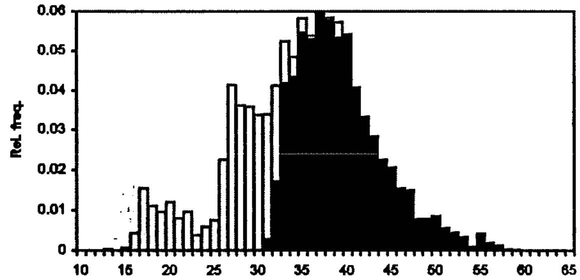
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	682 (10)	1533 (92)	
Co-op:	1012 (10)		
Mean L:	37.1	28.6	35.6



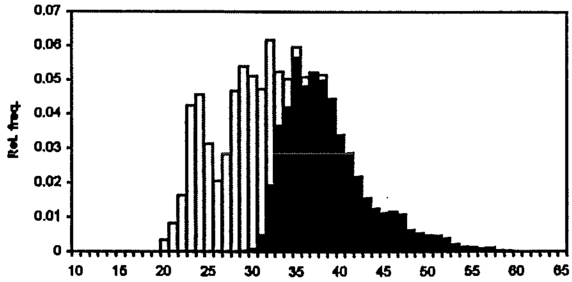
Eden, 1993

	Retained	Discarded	Total
Obs:	3867 (57)	1261 (105)	
Co-op:	0 (0)		
Mean L:	39.8	27.6	35.7



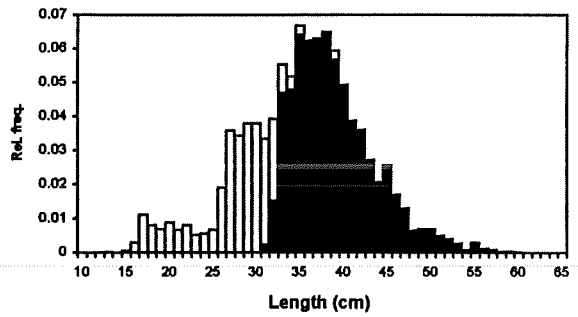
Eden, 1994

	Retained	Discarded	Total
Obs:	1818 (21)	695 (108)	
Co-op:	3176 (26)		
Mean L:	39.1	28.3	34.1



N + U + E, 1993

	Retained	Discarded	Total
Obs:	6882 (120)	3674 (241)	
Co-op:	0 (0)		
Mean L:	39.6	27.9	35.9



N + U + E, 1994

	Retained	Discarded	Total
Obs:	4720 (87)	2902 (252)	
Co-op:	4188 (36)		
Mean L:	38.3	28.4	34.6

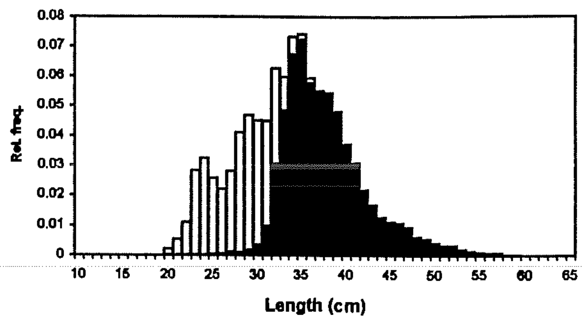
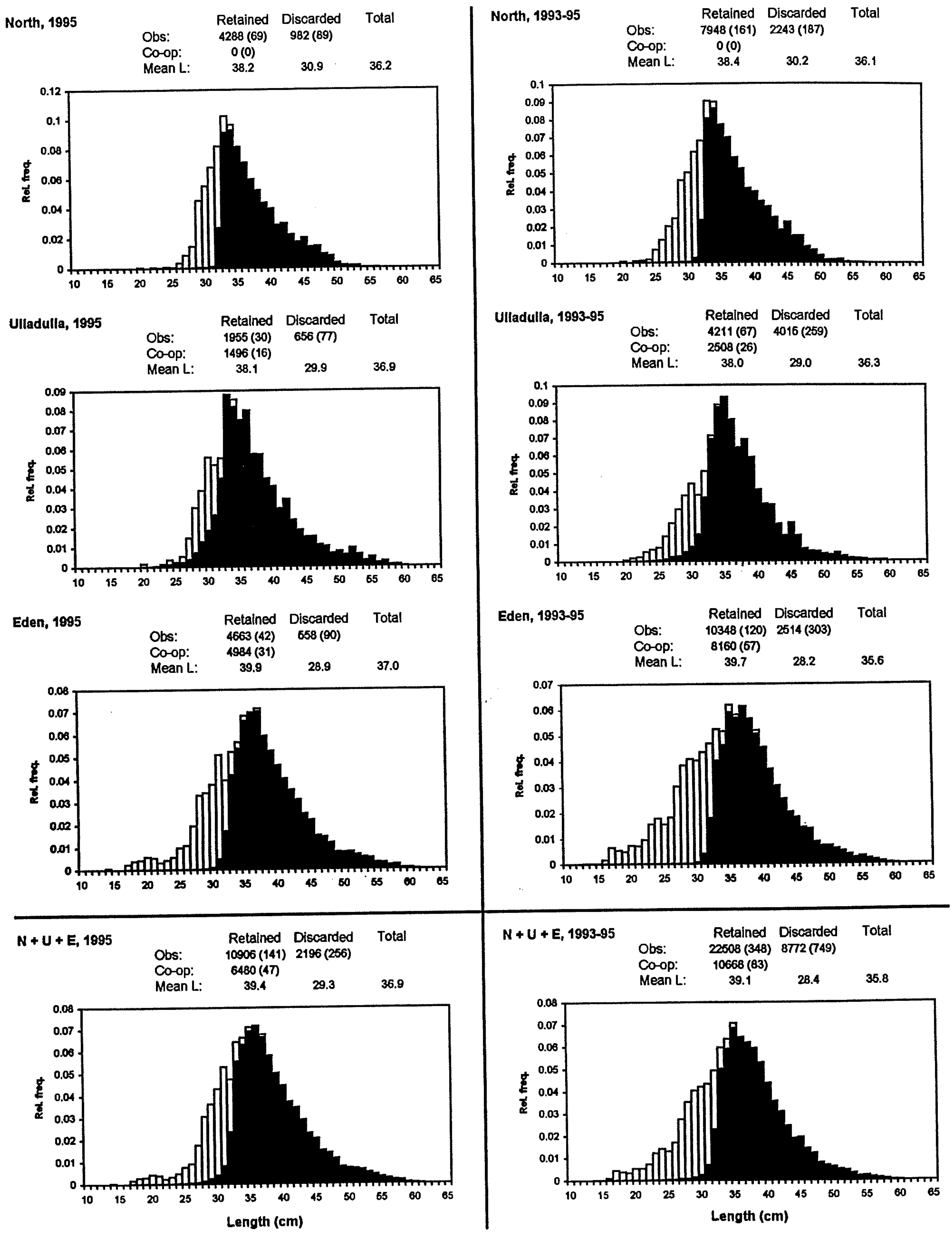


Figure 3.4, page 2



Appendix A.4

Barracouta

Thyrsites atun

Figure 4.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 4.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 4.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 4.1
Annual retained and discarded catches (t)

Table 4.2
Annual retained and discarded catches (number of fish)

Figure 4.1

Retained and discarded catches (kg per fisher-day) - Barracouta
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

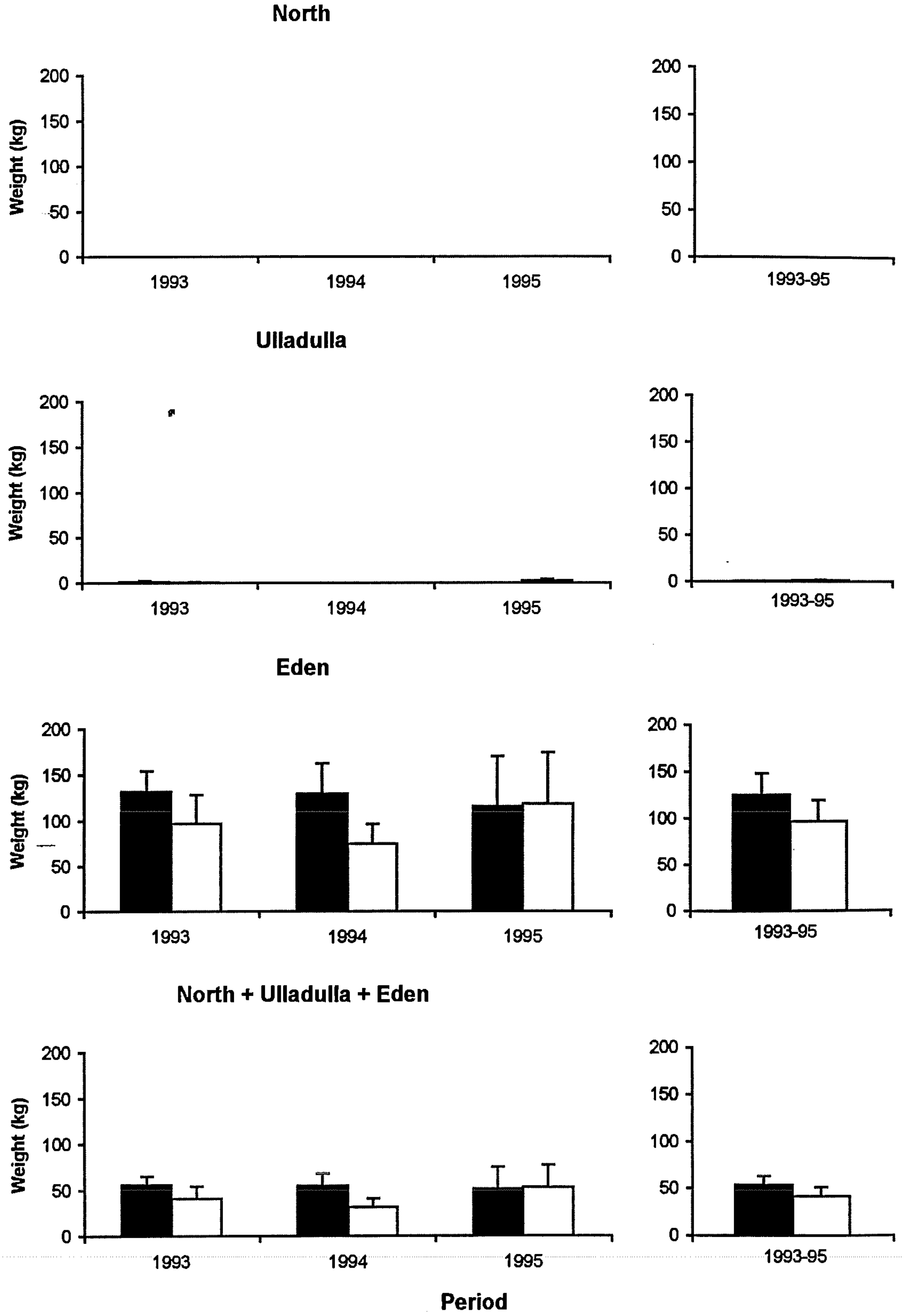


Figure 4.3

Retained and discarded catches (per fisher-day) - Barracouta
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

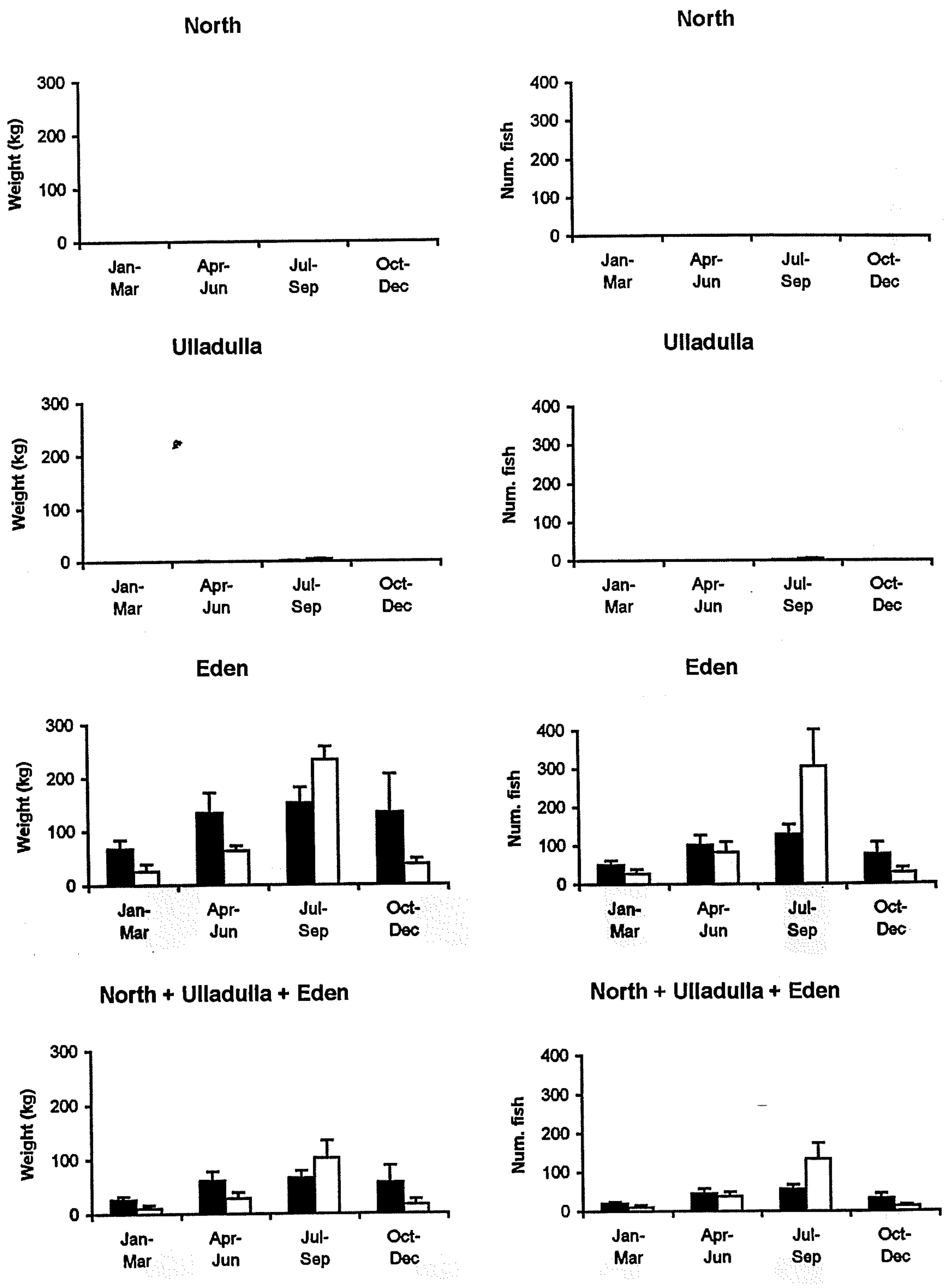


Figure 4.2

Retained and discarded catches (number of fish per fisher-day) - Barracouta
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

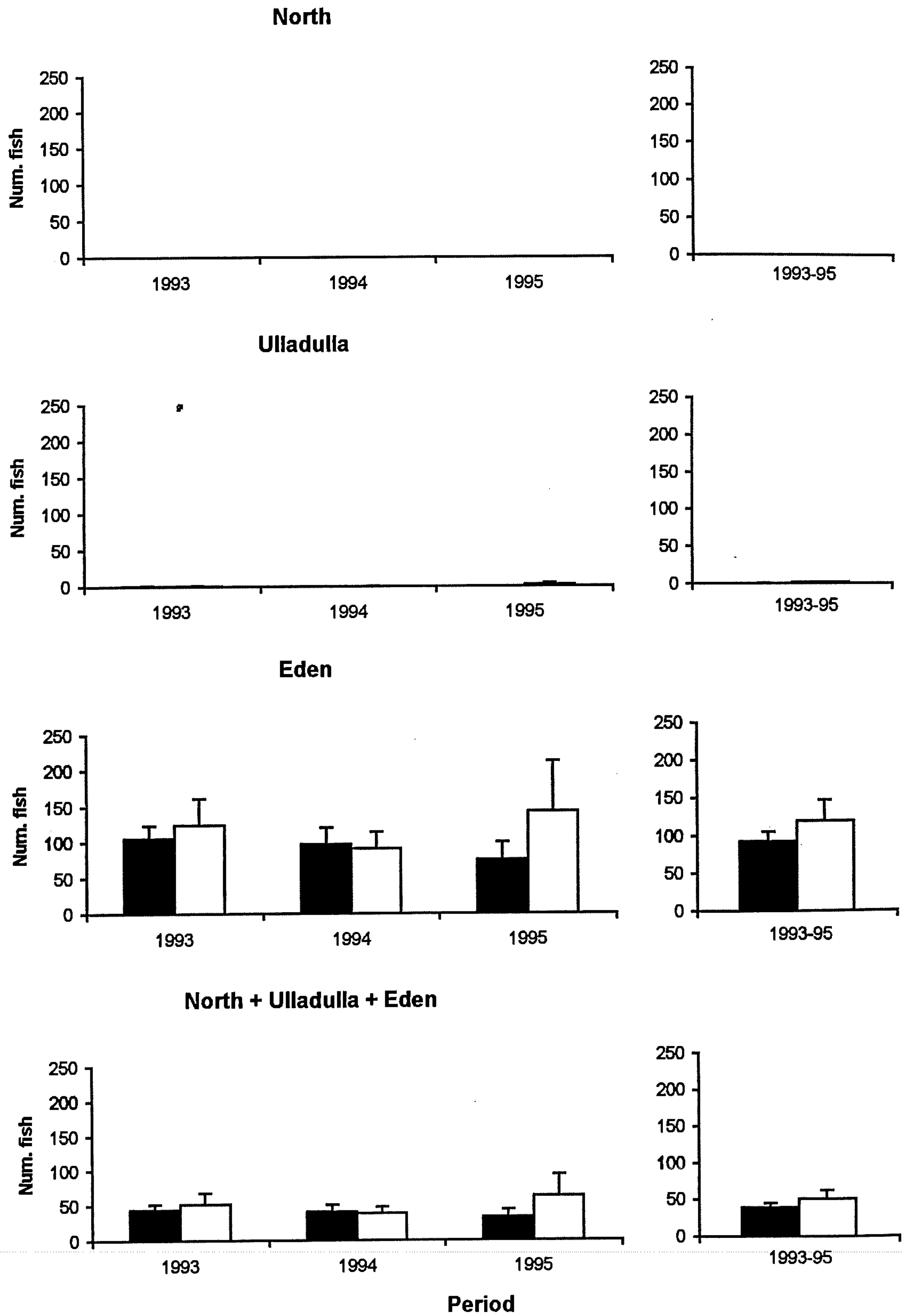


Table 4.1

Annual retained and discarded catches - Barracouta (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	2	1	1	1	1	1	*36*
	1994	0	0	0	0	0	0	*100*
	1995	3	2	0	0	3	2	*99*
	Mean 1993-95	2	1	1	0	1	1	*72*
Eden	1993	473	78	273	47	200	65	*42*
	1994	418	104	265	67	152	45	*36*
	1995	494	166	244	115	250	118	*51*
	Mean 1993-95	461	70	261	47	201	47	*44*
N+U+E	1993	475	78	274	47	201	65	*42*
	1994	418	104	265	67	152	45	*36*
	1995	497	166	244	115	252	118	*51*
	Mean 1993-95	463	70	261	47	202	47	*44*

Table 4.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	2	1	1	1	1	1	*48*
	1994	0	0	0	0	0	0	*100*
	1995	3	2	0	0	3	2	*98*
	Mean 1993-95	2	1	0	0	1	1	*79*
Eden	1993	474	88	217	38	257	77	*54*
	1994	386	84	199	48	186	49	*48*
	1995	461	159	159	53	303	147	*66*
	Mean 1993-95	440	67	192	27	249	58	*56*
N+U+E	1993	476	88	218	38	258	77	54
	1994	386	84	199	48	187	49	48
	1995	464	159	159	53	306	147	66
	Mean 1993-95	442	67	192	27	250	58	57

Appendix A.5

Silver trevally

Pseudocaranx dentex

Figure 5.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 5.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 5.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 5.1
Annual retained and discarded catches (t)

Table 5.2
Annual retained and discarded catches (number of fish)

Figure 5.4
Size distributions of retained and discarded catches

Figure 5.1

Retained and discarded catches (kg per fisher-day) - Silver trevally
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

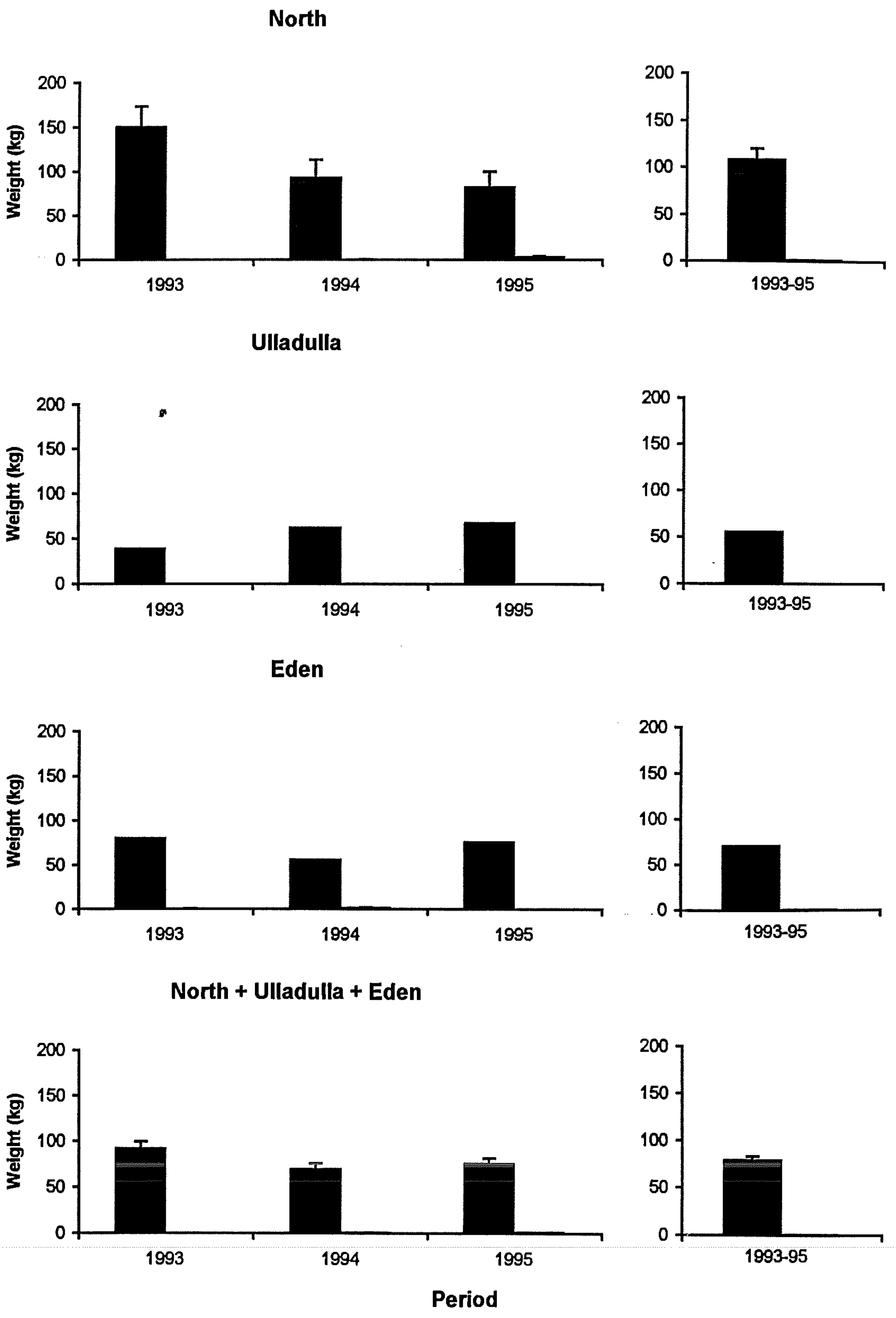


Figure 5.2

Retained and discarded catches (number of fish per fisher-day) - Silver trevally
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

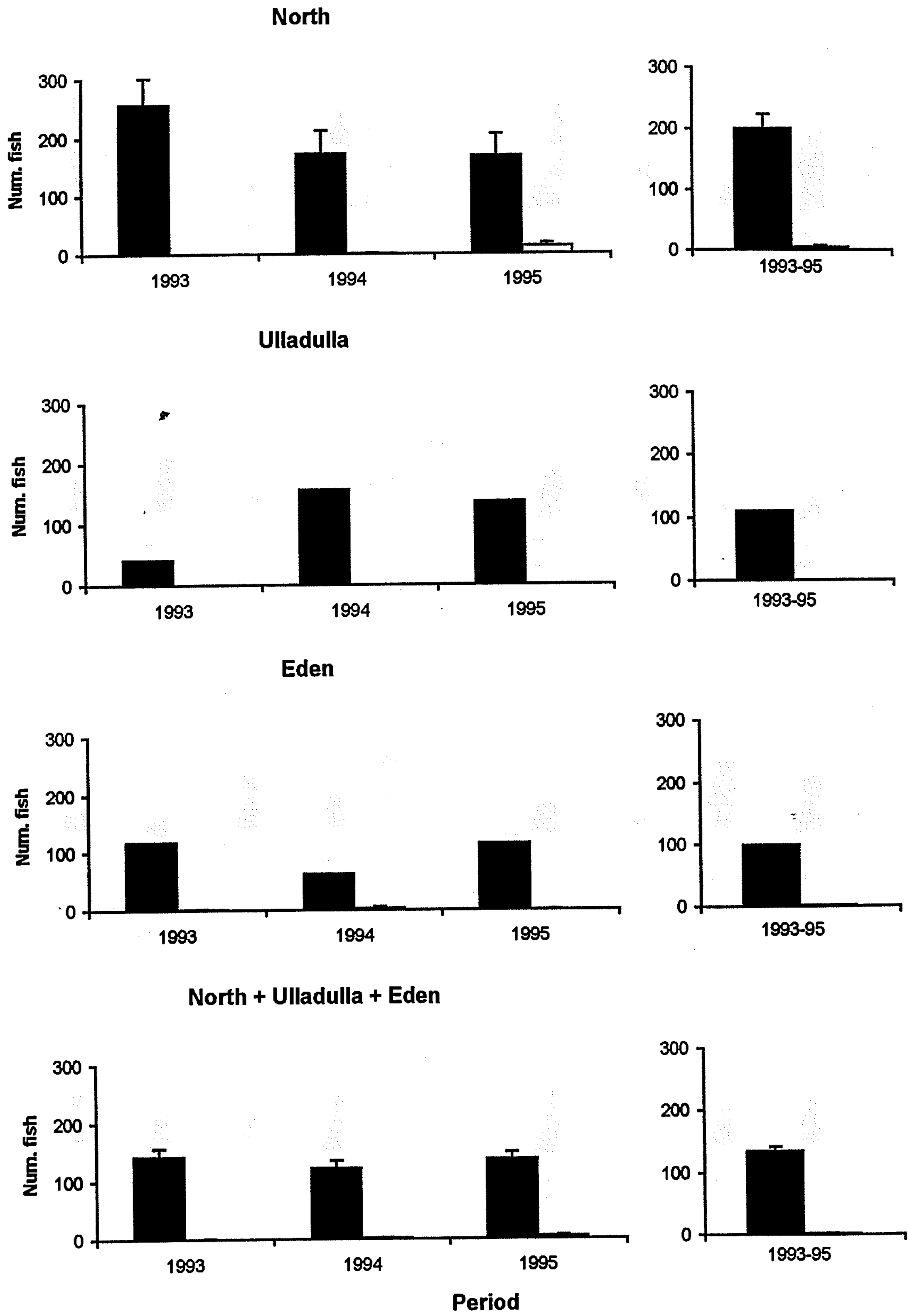


Figure 5.3

Retained and discarded catches (per fisher-day) - Silver trevally
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

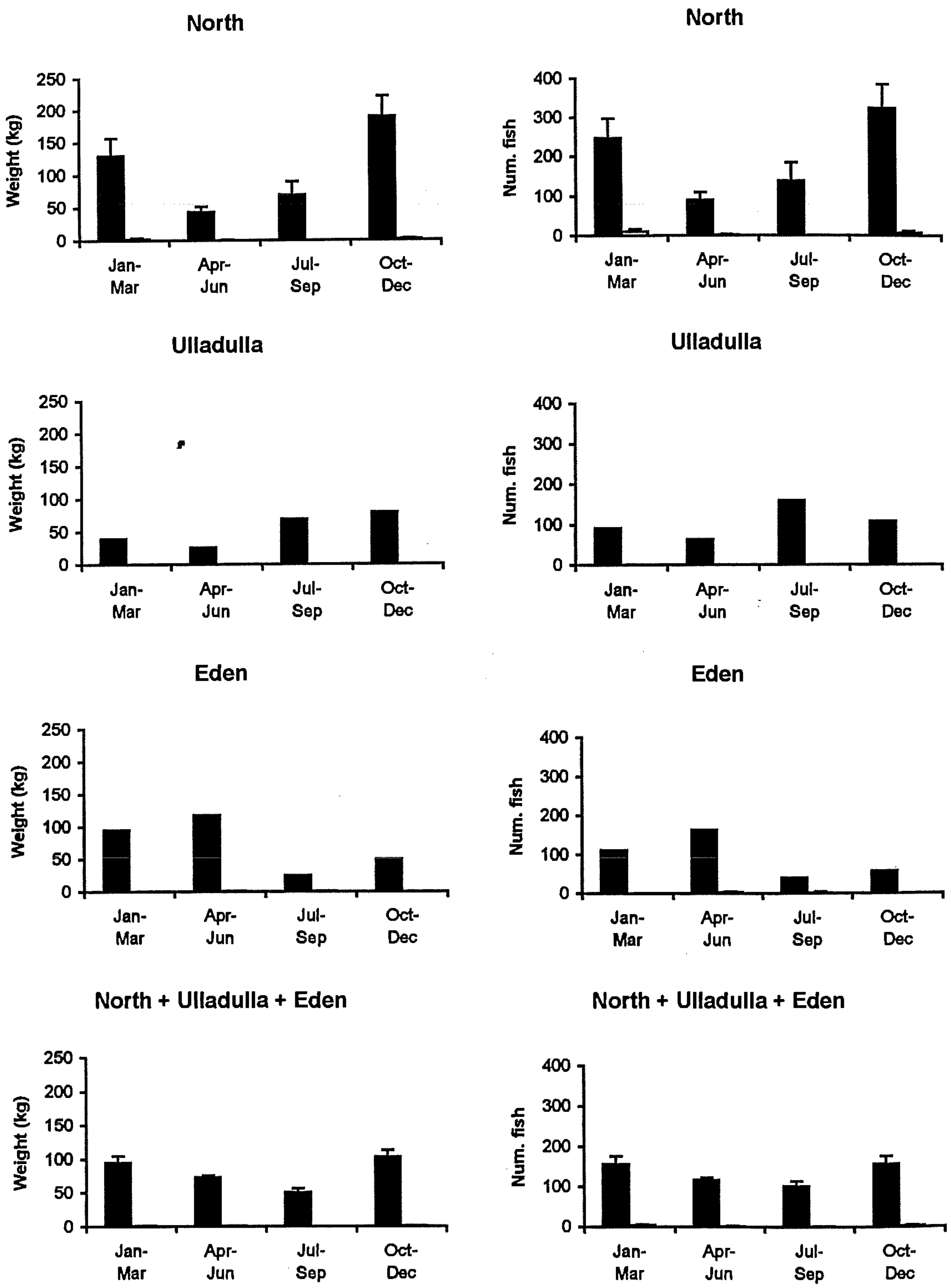


Table 5.1

Annual retained and discarded catches - Silver trevally (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	240 +/-	37	240 +/-	37	0 +/-	0	*0*
	1994	148	33	148	33	0	0	*0*
	1995	136	29	131	28	4	2	*3*
	Mean 1993-95	174	19	173	19	2	1	*1*
Ulladulla	1993	50	0	50	0	0	0	*0*
	1994	76	0	76	0	0	0	*0*
	1995	73	0	73	0	0	0	*0*
	Mean 1993-95	66	0	66	0	0	0	*0*
Eden	1993	166	0	165	0	0	0	*0*
	1994	116	1	114	0	2	1	*2*
	1995	160	0	160	0	0	0	*0*
	Mean 1993-95	147	0	146	0	1	0	*1*
N+U+E	1993	455	37	454	37	0	0	*0*
	1994	340	33	338	33	2	1	*1*
	1995	369	29	365	28	4	2	*1*
	Mean 1993-95	388	19	386	19	2	1	*1*

Table 5.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	410 +/-	71	410 +/-	71	0 +/-	0	*0*
	1994	278	63	276	63	2	1	*1*
	1995	289	63	269	61	20	9	*7*
	Mean 1993-95	326	38	318	37	7	3	2
Ulladulla	1993	53	0	53	0	0	0	*0*
	1994	194	0	194	0	0	0	*0*
	1995	150	0	150	0	0	0	*0*
	Mean 1993-95	132	0	132	0	0	0	*0*
Eden	1993	245	2	243	0	2	2	*1*
	1994	135	4	129	0	6	4	*5*
	1995	244	1	243	0	1	1	*0*
	Mean 1993-95	208	2	205	0	3	2	*1*
N+U+E	1993	708	71	706	71	2	2	0
	1994	607	63	599	63	8	4	1
	1995	682	63	662	61	21	9	3
	Mean 1993-95	666	38	656	37	10	3	2

Figure 5.4, page 1

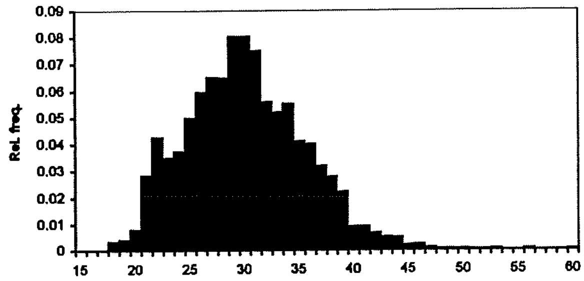
Size distributions of retained and discarded catches of Silver trevally

Retained catch: black bars Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

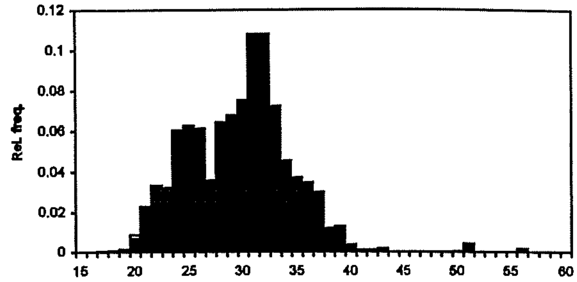
North, 1993

	Retained	Discarded	Total
Obs:	4507 (70)	3 (2)	
Co-op:	0 (0)		
Mean L:	30.6	21.5	30.6



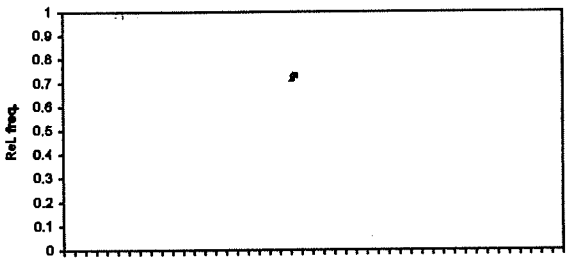
North, 1994

	Retained	Discarded	Total
Obs:	1071 (29)	96 (8)	
Co-op:	0 (0)		
Mean L:	30.3	20.6	30.2



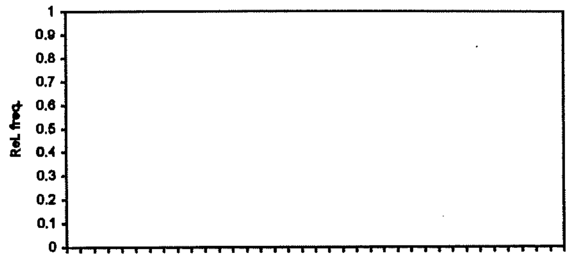
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	280 (6)	0 (0)	
Co-op:	0 (0)		
Mean L:			



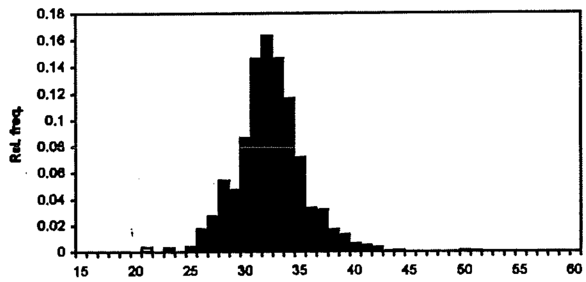
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	30 (1)	0 (0)	
Co-op:	345 (2)		
Mean L:			



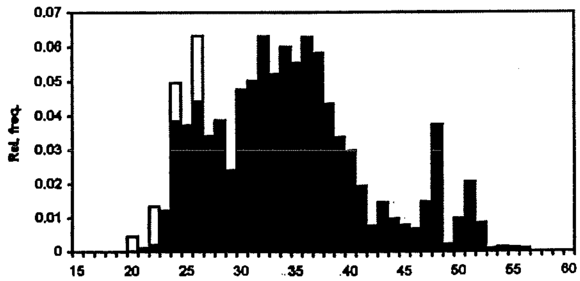
Eden, 1993

	Retained	Discarded	Total
Obs:	711 (15)	4 (1)	
Co-op:	0 (0)		
Mean L:	32.8	23.8	32.7



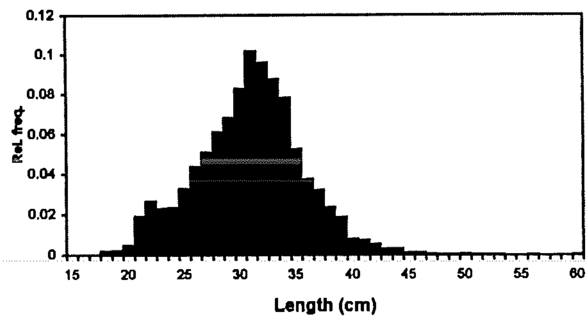
Eden, 1994

	Retained	Discarded	Total
Obs:	89 (2)	4 (3)	
Co-op:	1240 (7)		
Mean L:	35.1	24.4	34.6



N + U + E, 1993

	Retained	Discarded	Total
Obs:	5498 (90)	7 (3)	
Co-op:	0 (0)		
Mean L:	31.4	23.7	31.4



N + U + E, 1994

	Retained	Discarded	Total
Obs:	1190 (32)	100 (11)	
Co-op:	1584 (9)		
Mean L:	31.8	23.6	31.7

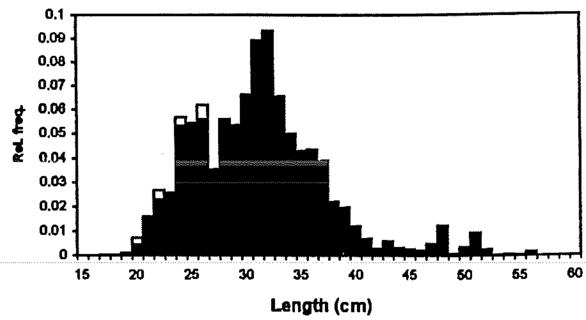
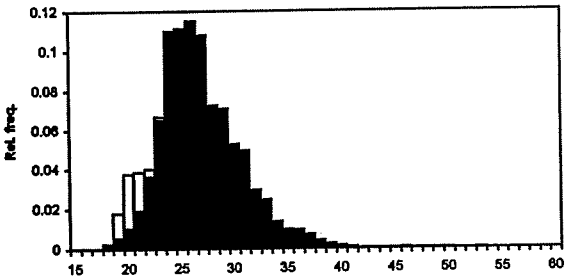


Figure 5.4, page 2

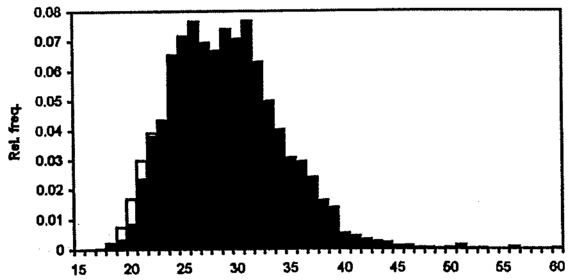
North, 1995

	Retained	Discarded	Total
Obs:	2702 (61)	224 (28)	
Co-op:	0 (0)		
Mean L:	27.5	20.8	27.1



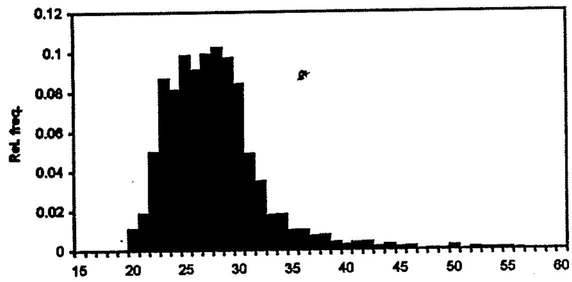
North, 1993-95

	Retained	Discarded	Total
Obs:	8281 (150)	323 (38)	
Co-op:	0 (0)		
Mean L:	29.6	20.8	29.4



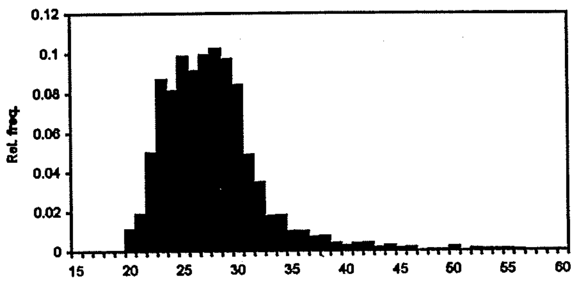
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	745 (11)	0 (0)	
Co-op:	530 (6)		
Mean L:	28.1		



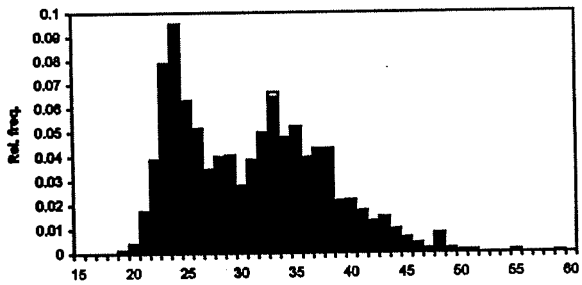
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	1055 (17)	0 (0)	
Co-op:	876 (8)		
Mean L:	28.1		28.1



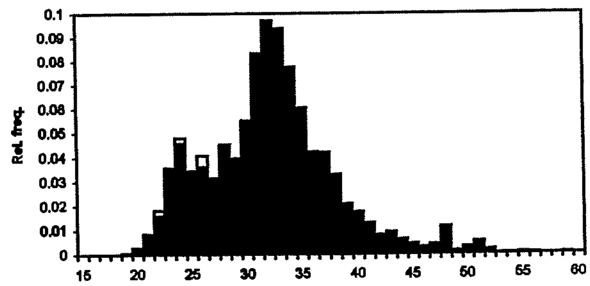
Eden, 1995

	Retained	Discarded	Total
Obs:	896 (13)	1 (1)	
Co-op:	635 (6)		
Mean L:	31.3	23.6	31.3



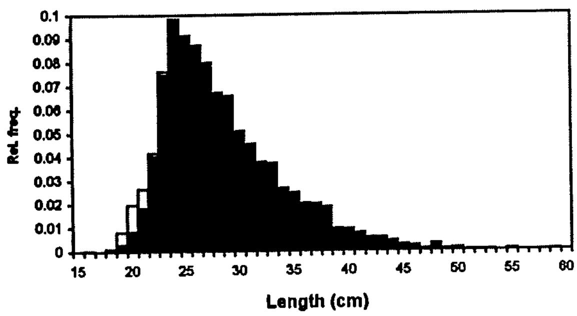
Eden, 1993-95

	Retained	Discarded	Total
Obs:	1696 (30)	9 (6)	
Co-op:	1774 (12)		
Mean L:	32.7	24.2	32.6



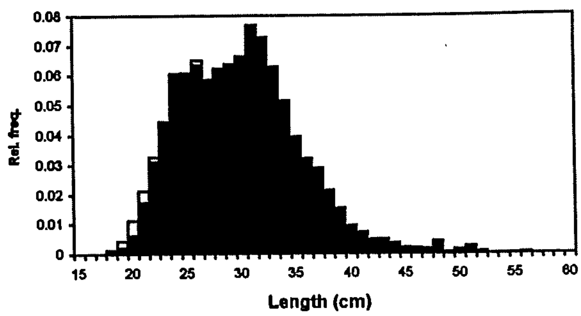
N + U + E, 1995

	Retained	Discarded	Total
Obs:	4343 (76)	225 (29)	
Co-op:	1065 (11)		
Mean L:	29.1	20.9	28.8



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	11031 (197)	332 (43)	
Co-op:	2649 (20)		
Mean L:	30.6	21.8	30.5



Appendix A.6

Ling

Genypterus blacodes

Figure 6.1

Retained and discarded catches (kg per fisher-day) - Ling
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

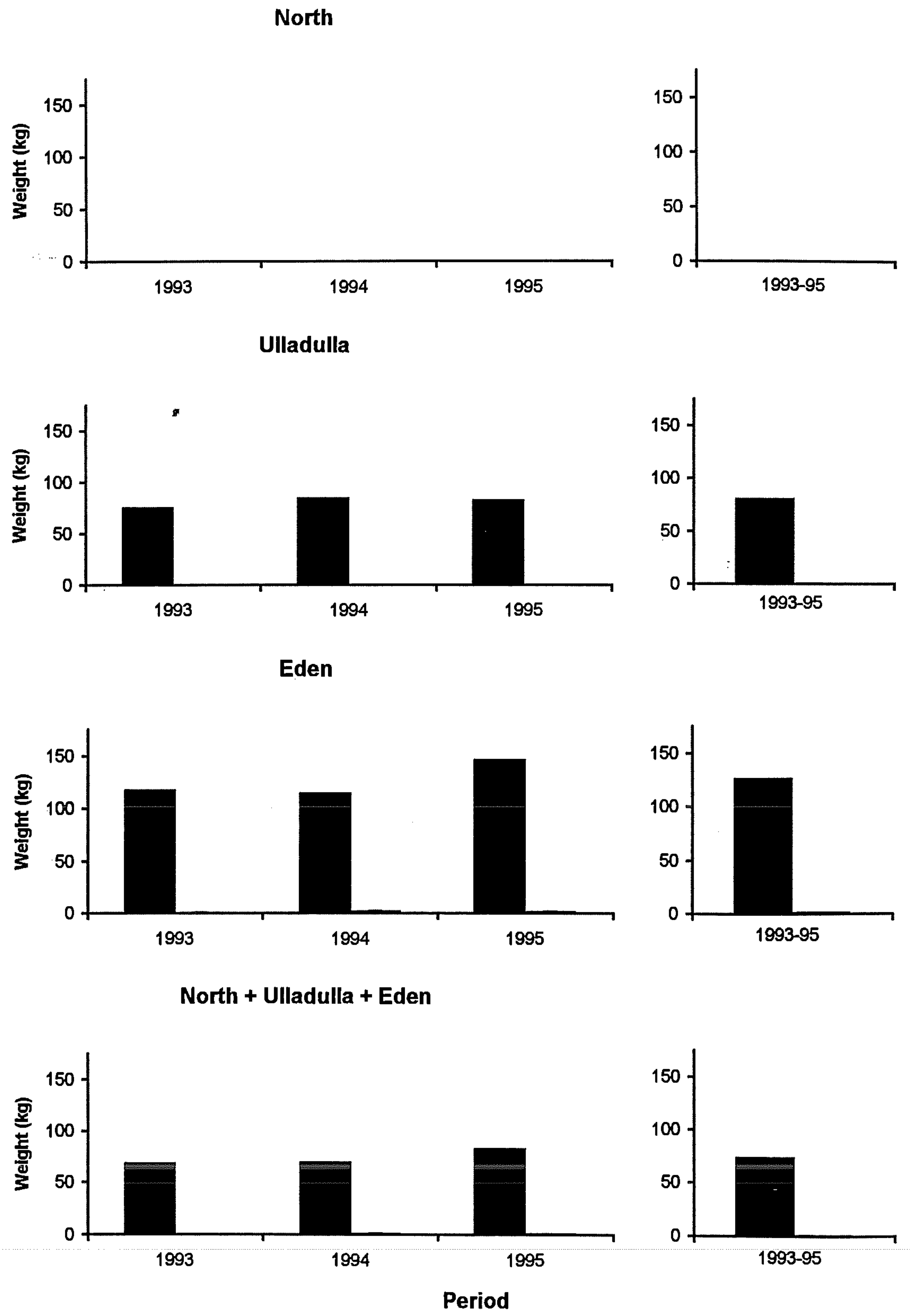


Figure 6.2

Retained and discarded catches (number of fish per fisher-day) - Ling
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

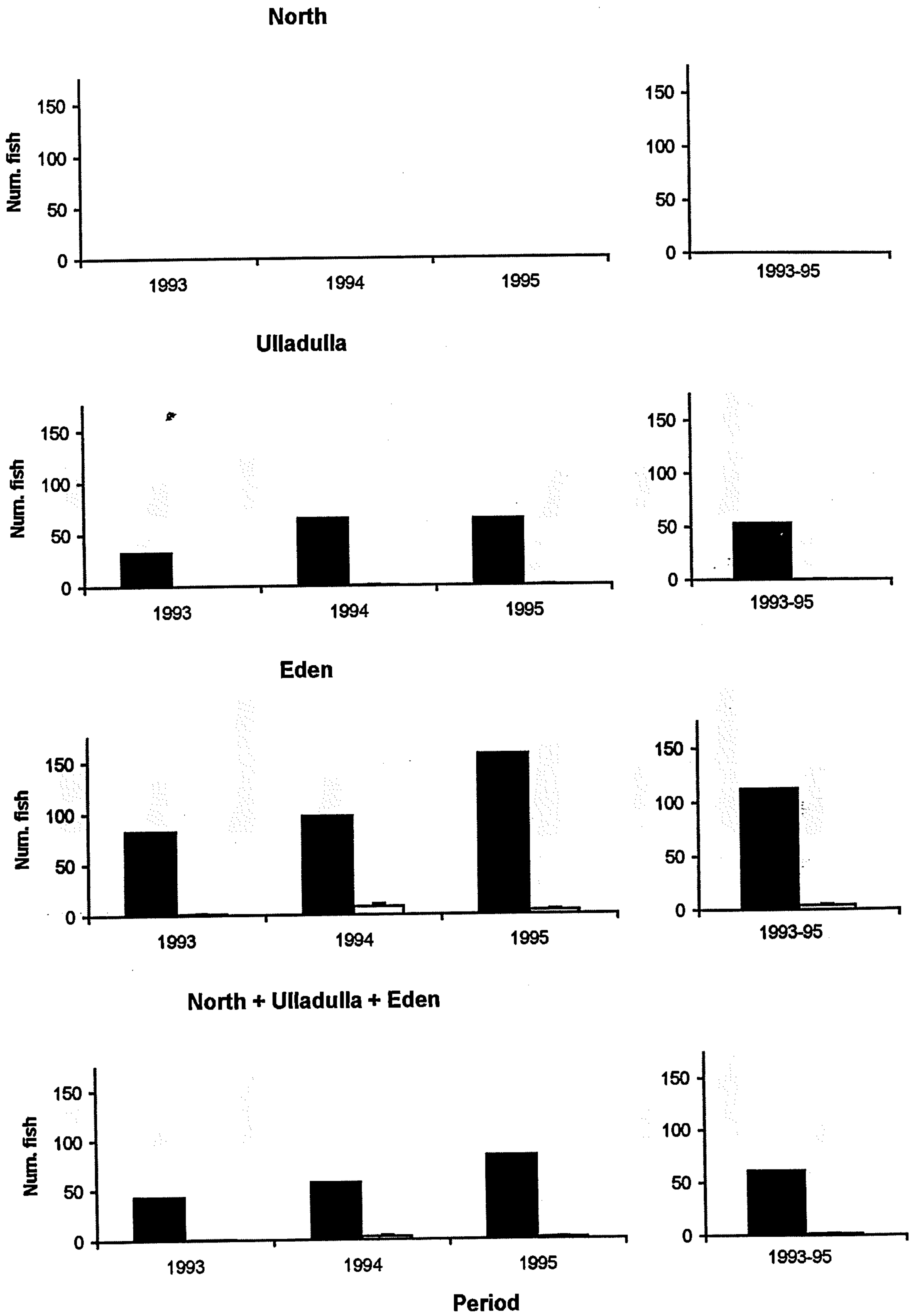


Figure 6.3

Retained and discarded catches (per fisher-day) - Ling
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

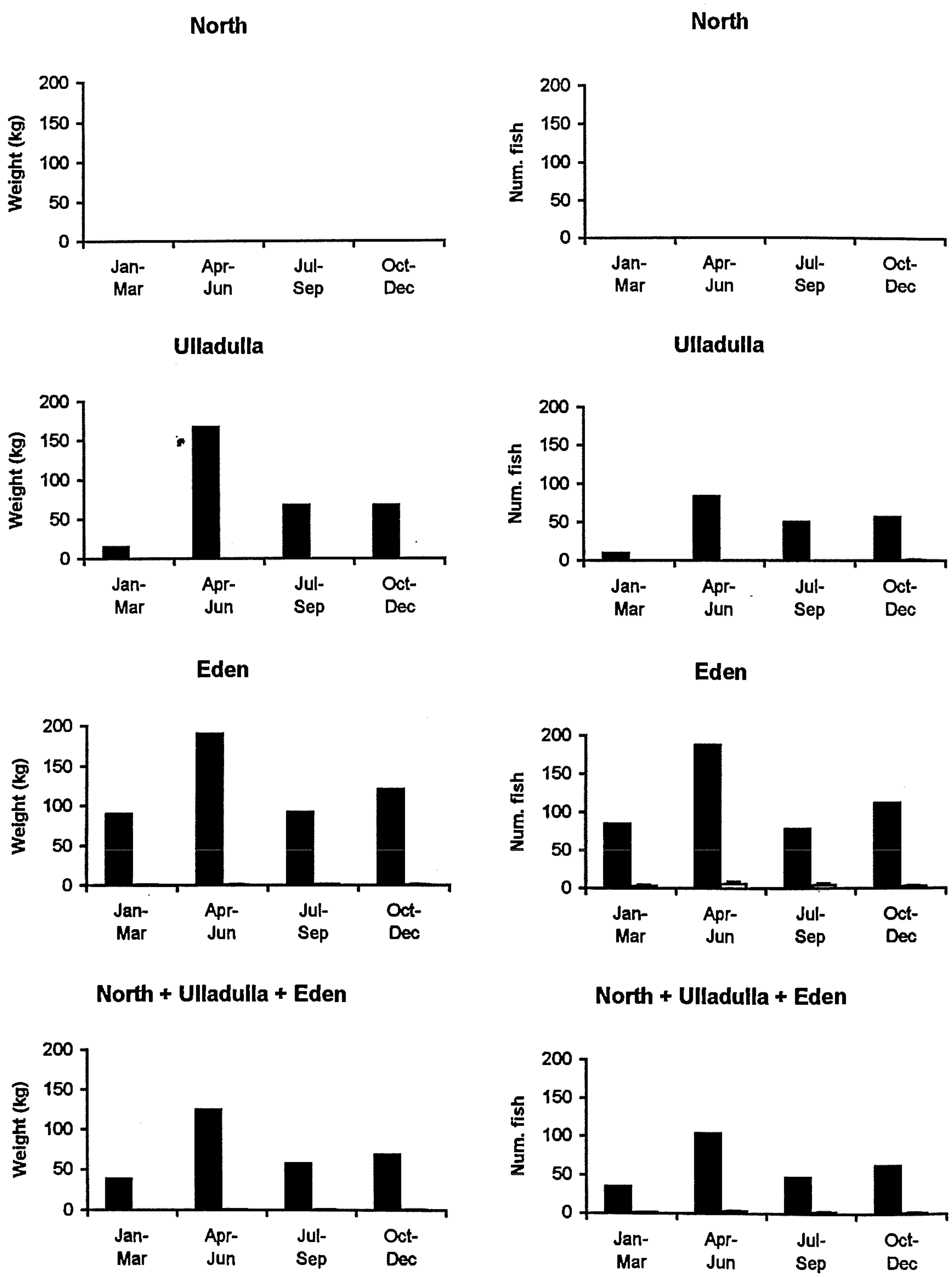


Table 6.1

Annual retained and discarded catches - Ling (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	0	+/- 0	0	+/- 0	0	+/- 0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	96	0	96	0	0	0	*0*
	1994	104	0	104	0	0	0	*0*
	1995	89	0	89	0	0	0	*0*
	Mean 1993-95	96	0	96	0	0	0	*0*
Eden	1993	243	0	242	0	0	0	*0*
	1994	237	1	234	0	3	1	*1*
	1995	309	1	307	0	2	1	*1*
	Mean 1993-95	263	0	261	0	2	0	*1*
N+U+E	1993	339	0	338	0	0	0	*0*
	1994	341	1	337	0	3	1	*1*
	1995	399	1	397	0	2	1	*1*
	Mean 1993-95	359	0	357	0	2	0	*1*

Table 6.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	0	+/- 0	0	+/- 0	0	+/- 0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	42	0	42	0	0	0	*0*
	1994	81	1	80	0	1	1	*1*
	1995	70	0	70	0	0	0	*0*
	Mean 1993-95	64	0	64	0	0	0	*0*
Eden	1993	174	1	172	0	2	1	*1*
	1994	216	5	200	0	16	5	7
	1995	339	2	332	0	7	2	2
	Mean 1993-95	243	2	234	0	8	2	3
N+U+E	1993	216	1	214	0	2	1	1
	1994	296	5	280	0	16	5	6
	1995	409	2	402	0	7	2	2
	Mean 1993-95	307	2	298	0	9	2	3

Figure 6.4, page 1

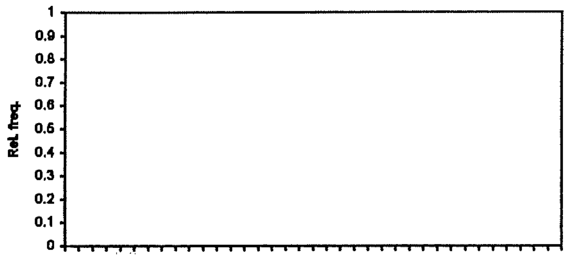
Size distributions of retained and discarded catches of Ling

Retained catch: black bars   Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

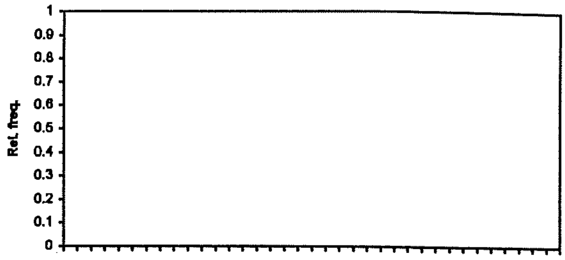
North, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



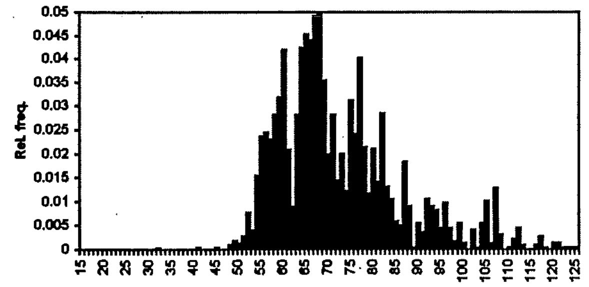
North, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



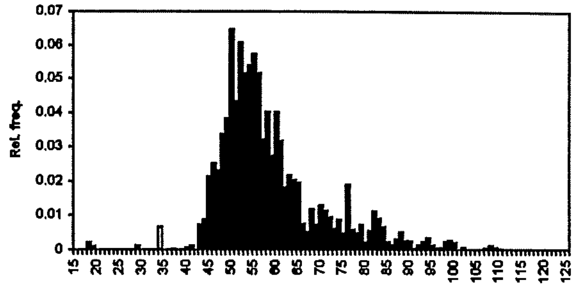
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	567 (13)	2 (2)	
Co-op:	0 (0)		
Mean L:	72.8	40.8	72.7



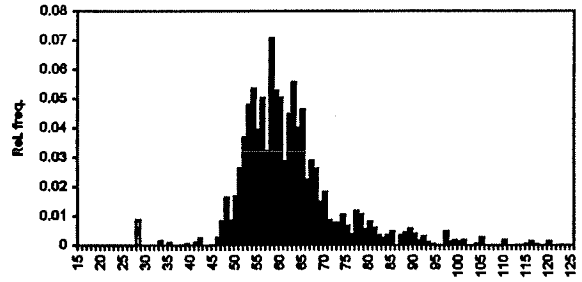
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	460 (9)	1 (1)	
Co-op:	811 (16)		
Mean L:	59.2	34.5	59.0



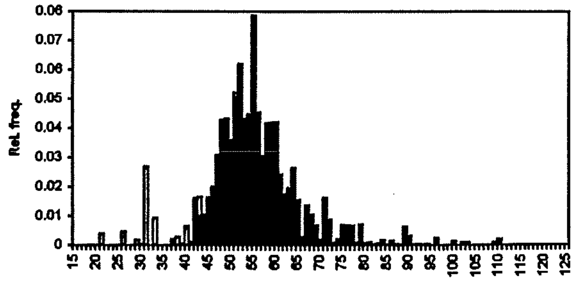
Eden, 1993

	Retained	Discarded	Total
Obs:	816 (22)	6 (5)	
Co-op:	0 (0)		
Mean L:	62.8	31.7	62.4



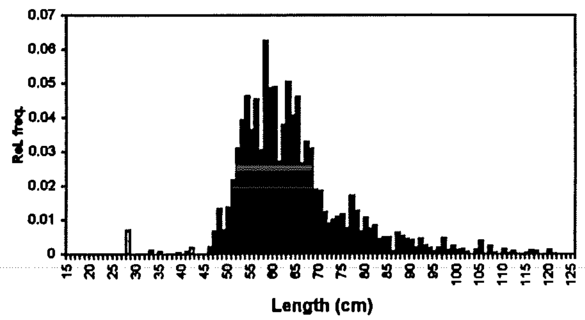
Eden, 1994

	Retained	Discarded	Total
Obs:	330 (8)	17 (14)	
Co-op:	640 (8)		
Mean L:	57.4	34.7	55.7



N + U + E, 1993

	Retained	Discarded	Total
Obs:	1382 (35)	7 (7)	
Co-op:	0 (0)		
Mean L:	64.7	31.8	64.4



N + U + E, 1994

	Retained	Discarded	Total
Obs:	790 (17)	18 (15)	
Co-op:	1452 (24)		
Mean L:	57.9	34.7	56.6

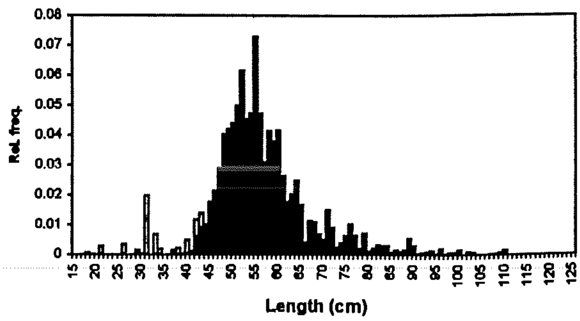
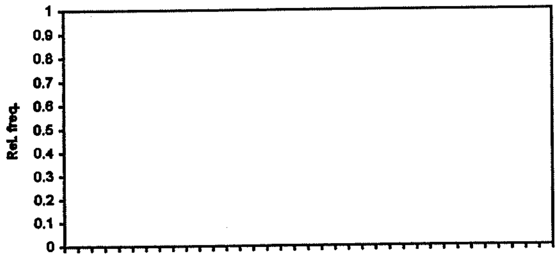


Figure 6.4, page 2

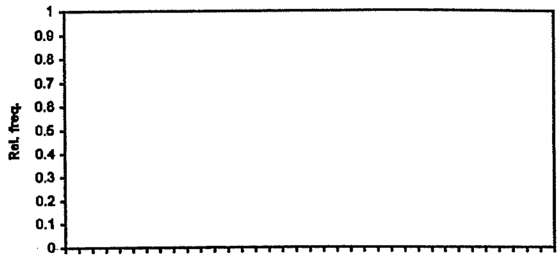
North, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



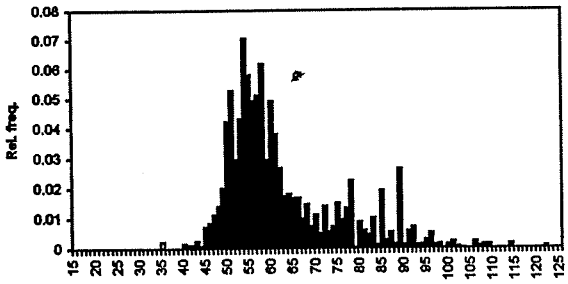
North, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



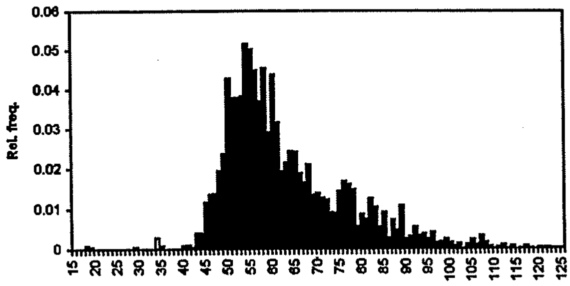
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	363 (9)	1 (1)	
Co-op:	432 (10)		
Mean L:	62.8	35.5	62.8



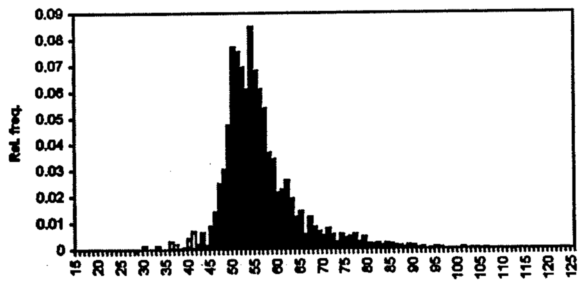
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	1391 (31)	4 (4)	
Co-op:	1243 (26)		
Mean L:	63.5	34.9	63.4



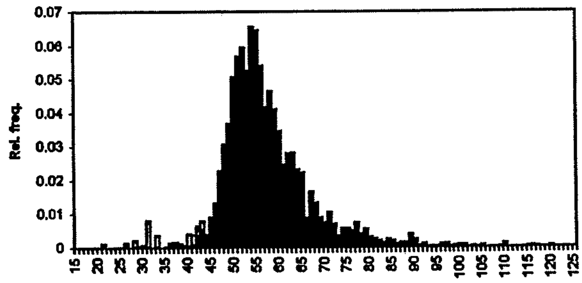
Eden, 1995

	Retained	Discarded	Total
Obs:	1014 (13)	14 (12)	
Co-op:	1405 (19)		
Mean L:	56.7	39.7	56.4



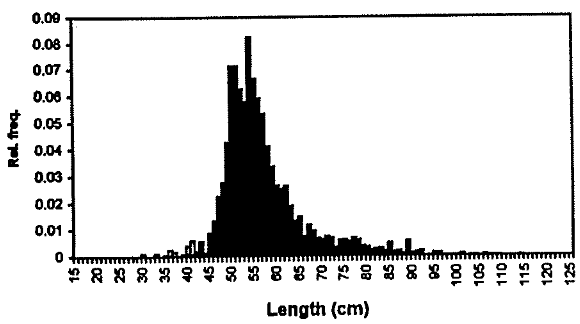
Eden, 1993-95

	Retained	Discarded	Total
Obs:	2158 (43)	36 (31)	
Co-op:	2045 (27)		
Mean L:	58.4	35.9	57.6



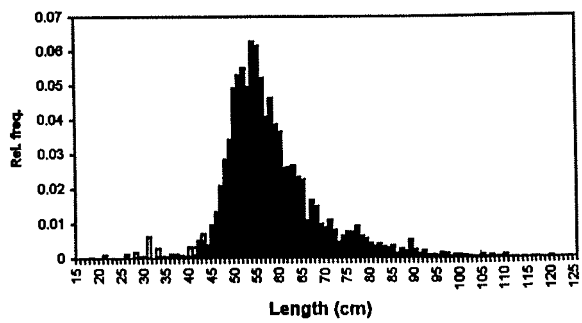
N + U + E, 1995

	Retained	Discarded	Total
Obs:	1377 (22)	15 (13)	
Co-op:	1837 (29)		
Mean L:	57.8	39.6	57.5



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	3549 (74)	40 (35)	
Co-op:	3288 (53)		
Mean L:	59.5	35.9	58.8



Appendix A.7

Southern frostfish

Lepidopus caudatus

Figure 7.1

Retained and discarded catches (kg per fisher-day) - Southern frostfish
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

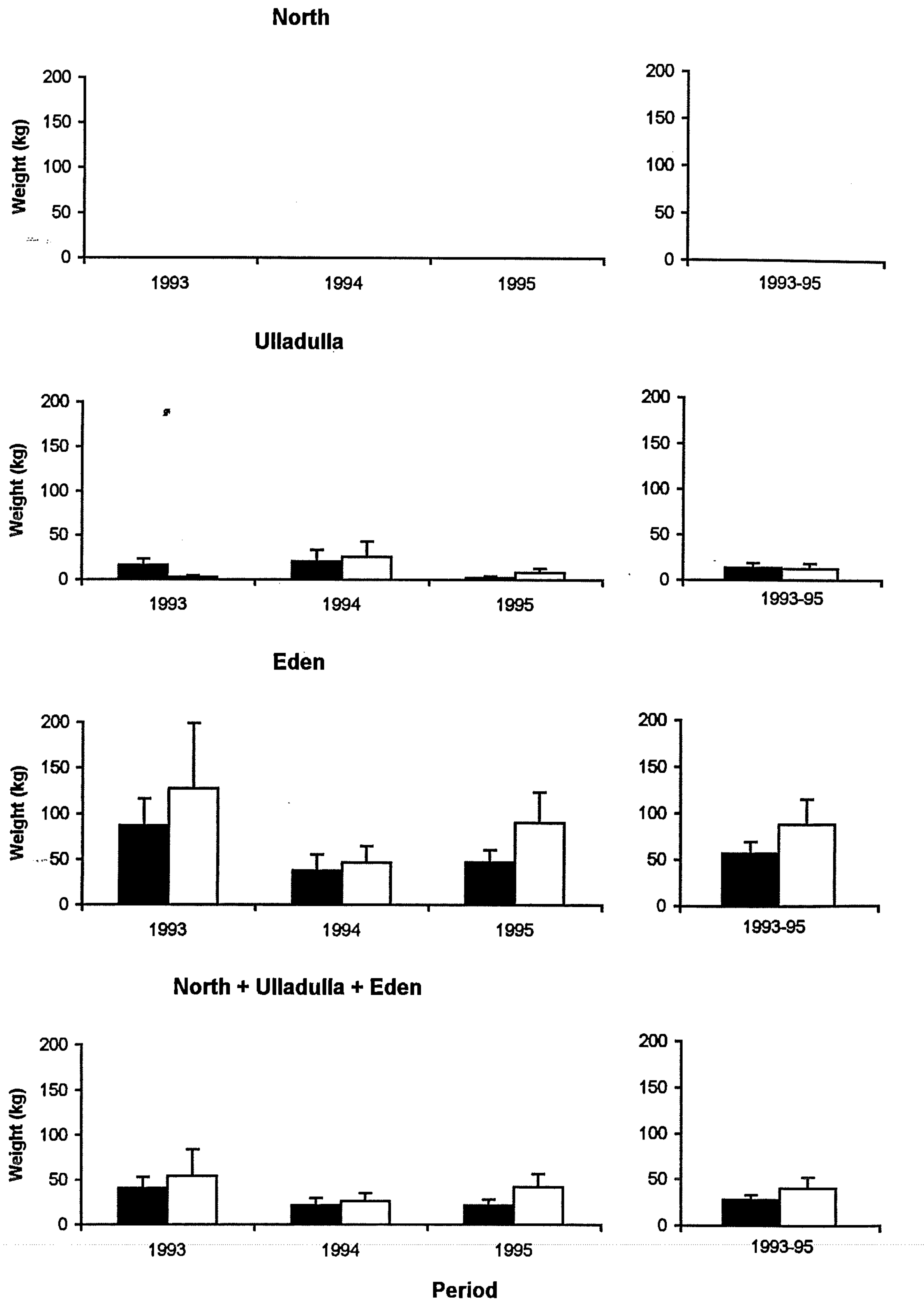


Figure 7.2

Retained and discarded catches (number of fish per fisher-day) - Southern frostfish

by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

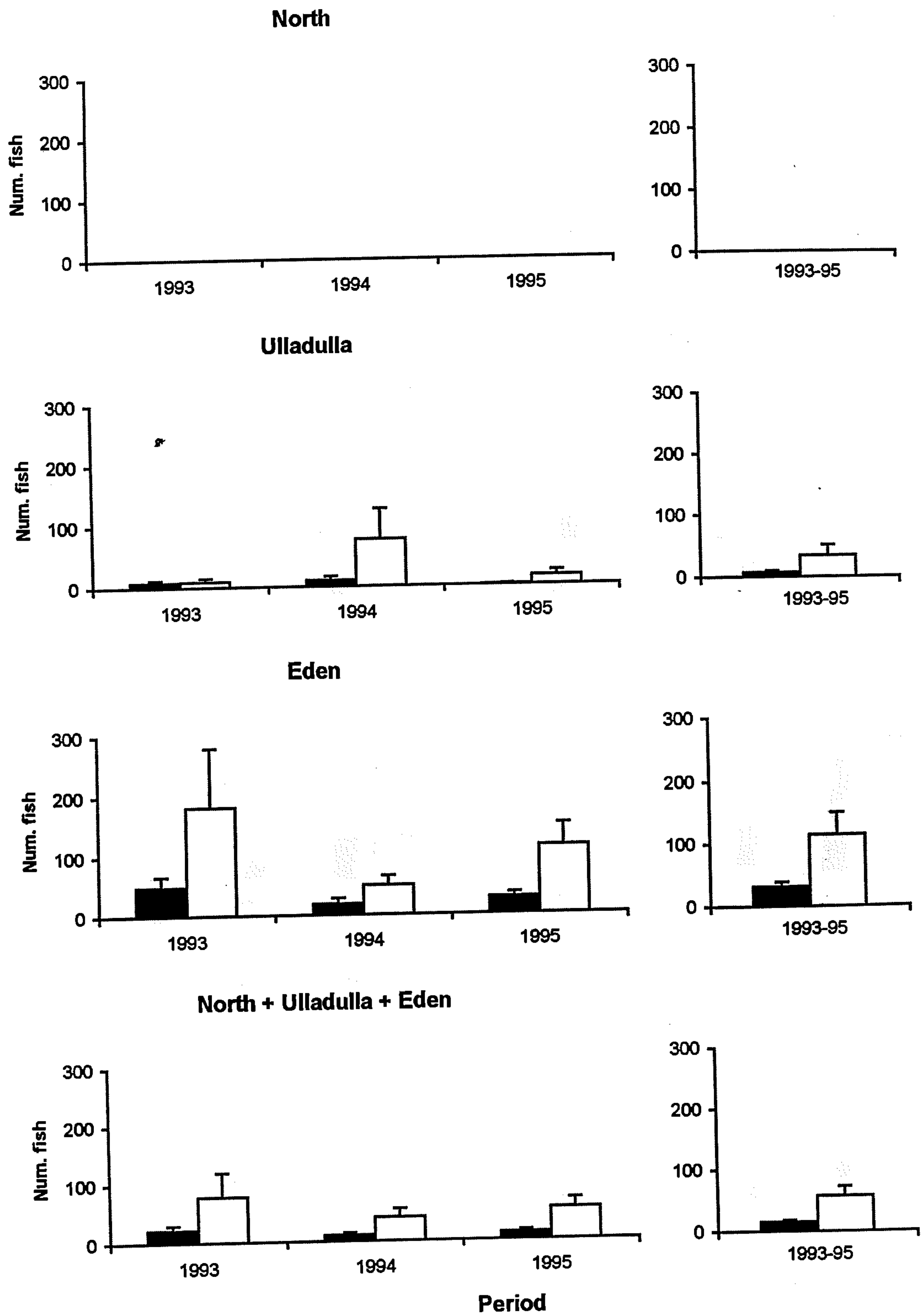


Figure 7.3

Retained and discarded catches (per fisher-day) - Southern frostfish
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

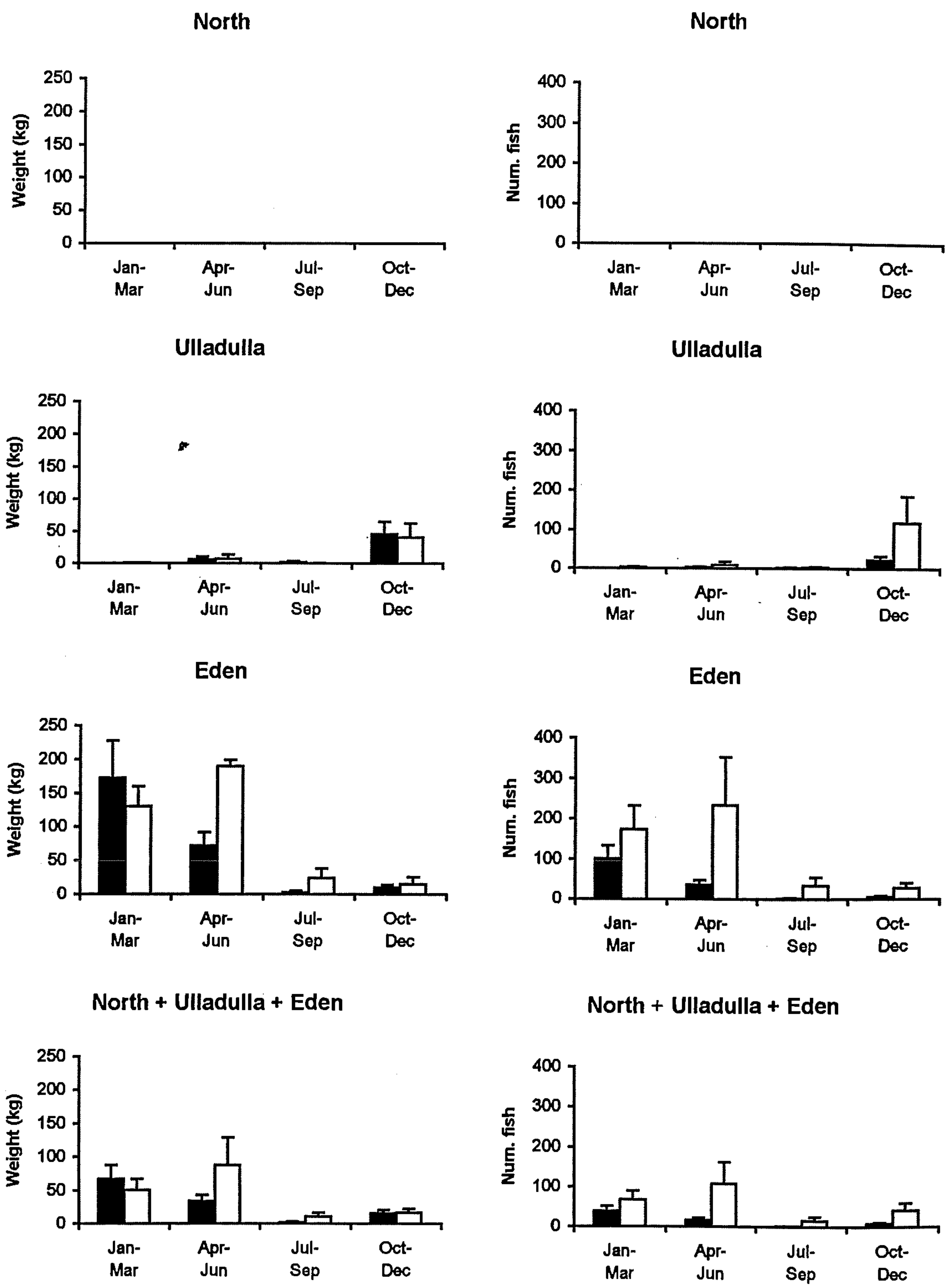


Table 7.1

Annual retained and discarded catches - Southern frostfish (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	0 +/-	0	0 +/-	0	0 +/-	0	
	1994	0	0	0	0	0	0	*0*
	1995	0	0	0	0	0	0	*0*
Mean 1993-95		0	0	0	0	0	0	*0*
Ulladulla	1993	25	11	21	9	4	2	*15*
	1994	58	30	26	16	32	21	*56*
	1995	12	6	3	2	9	6	*76*
Mean 1993-95		32	11	17	6	15	7	*47*
Eden	1993	443	175	179	61	264	148	*60*
	1994	172	65	77	37	95	37	*55*
	1995	290	84	99	29	191	70	*66*
Mean 1993-95		302	68	118	26	183	56	*61*
N+U+E	1993	468	176	200	62	267	148	*57*
	1994	230	71	103	40	127	43	*55*
	1995	302	85	102	29	200	71	*66*
Mean 1993-95		333	69	135	26	198	56	*59*

Table 7.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	0 +/-	0	0 +/-	0	0 +/-	0	
	1994	0	0	0	0	0	0	*0*
	1995	0	0	0	0	0	0	*0*
Mean 1993-95		0	0	0	0	0	0	*0*
Ulladulla	1993	22	10	11	5	11	7	*51*
	1994	107	65	13	8	94	62	*88*
	1995	17	9	1	1	16	8	*92*
Mean 1993-95		49	22	8	3	40	21	*83*
Eden	1993	476	214	101	36	375	203	*79*
	1994	140	45	39	18	101	33	*72*
	1995	298	87	58	17	240	79	*80*
Mean 1993-95		305	78	66	15	239	74	*78*
N+U+E	1993	498	214	111	37	386	203	*78*
	1994	247	79	52	20	195	70	*79*
	1995	316	88	60	17	256	79	*81*
Mean 1993-95		353	81	74	15	279	76	*79*

Appendix A.8

Piked dogshark

Squalus megalops

Figure 8.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 8.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 8.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 8.1
Annual retained and discarded catches (t)

Table 8.2
Annual retained and discarded catches (number of fish)

Figure 8.1

Retained and discarded catches (kg per fisher-day) - Piked dogshark
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

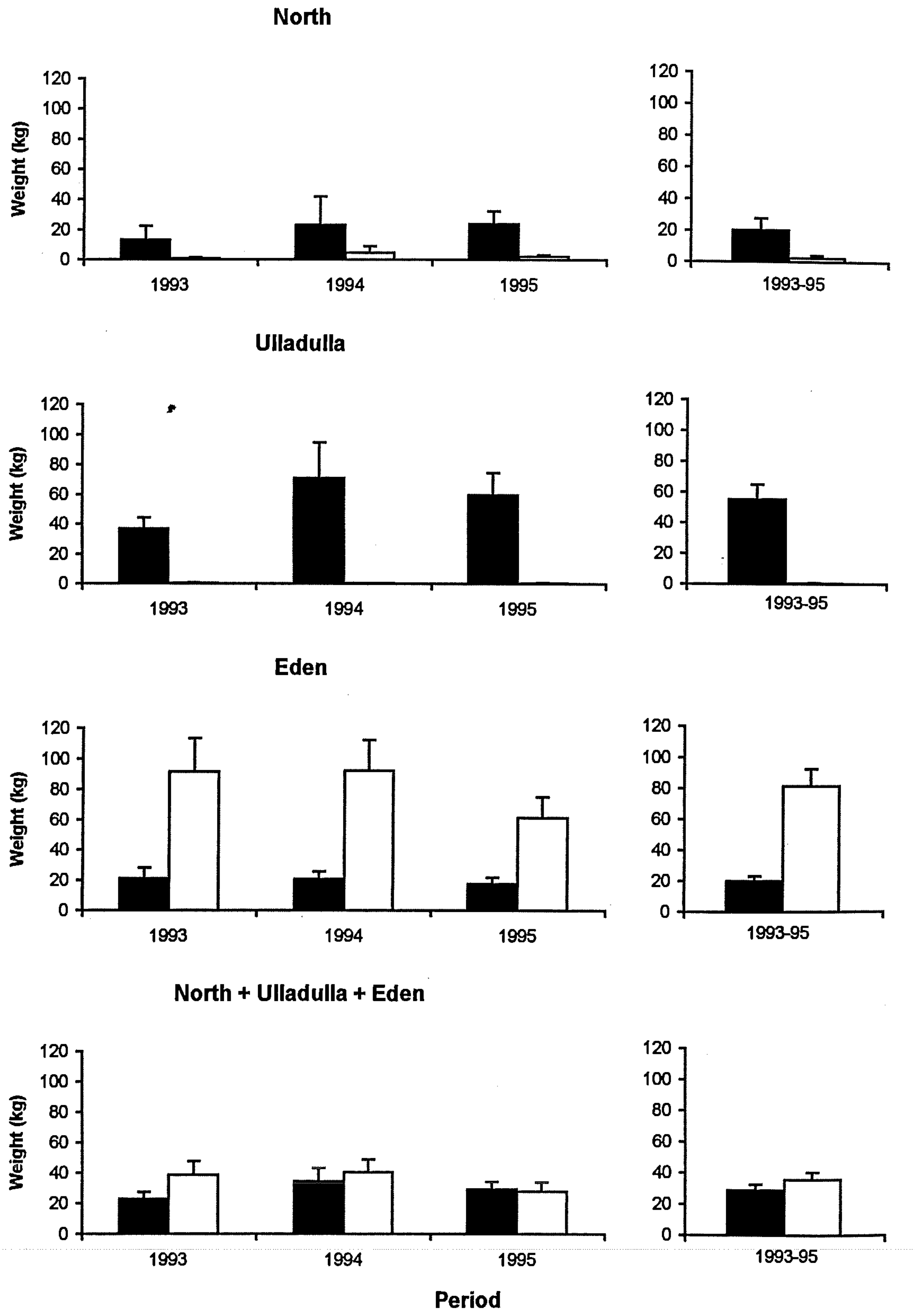


Figure 8.2

Retained and discarded catches (number of fish per fisher-day) - Piked dogshark
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

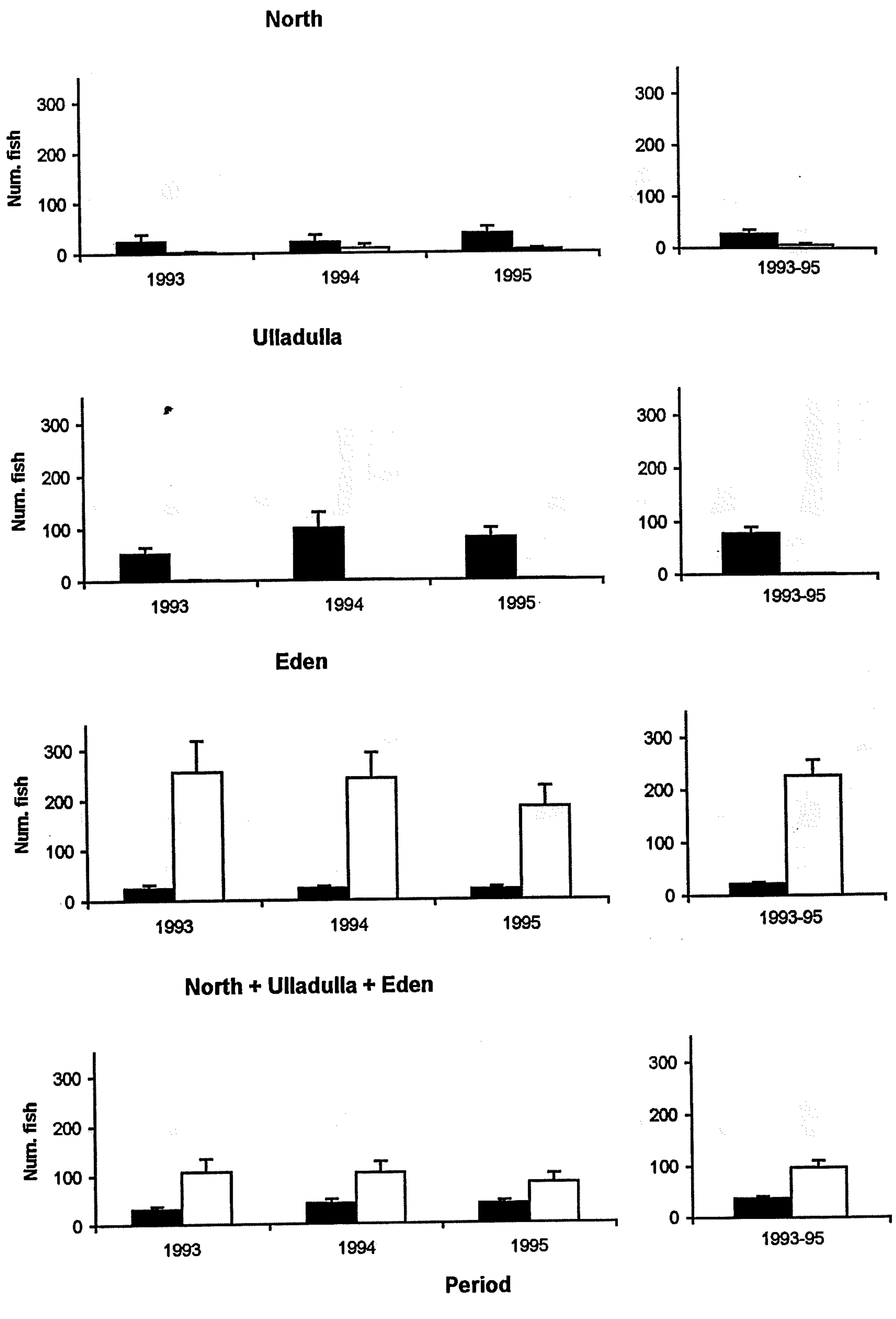


Figure 8.3

Retained and discarded catches (per fisher-day) - Piked dogshark
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

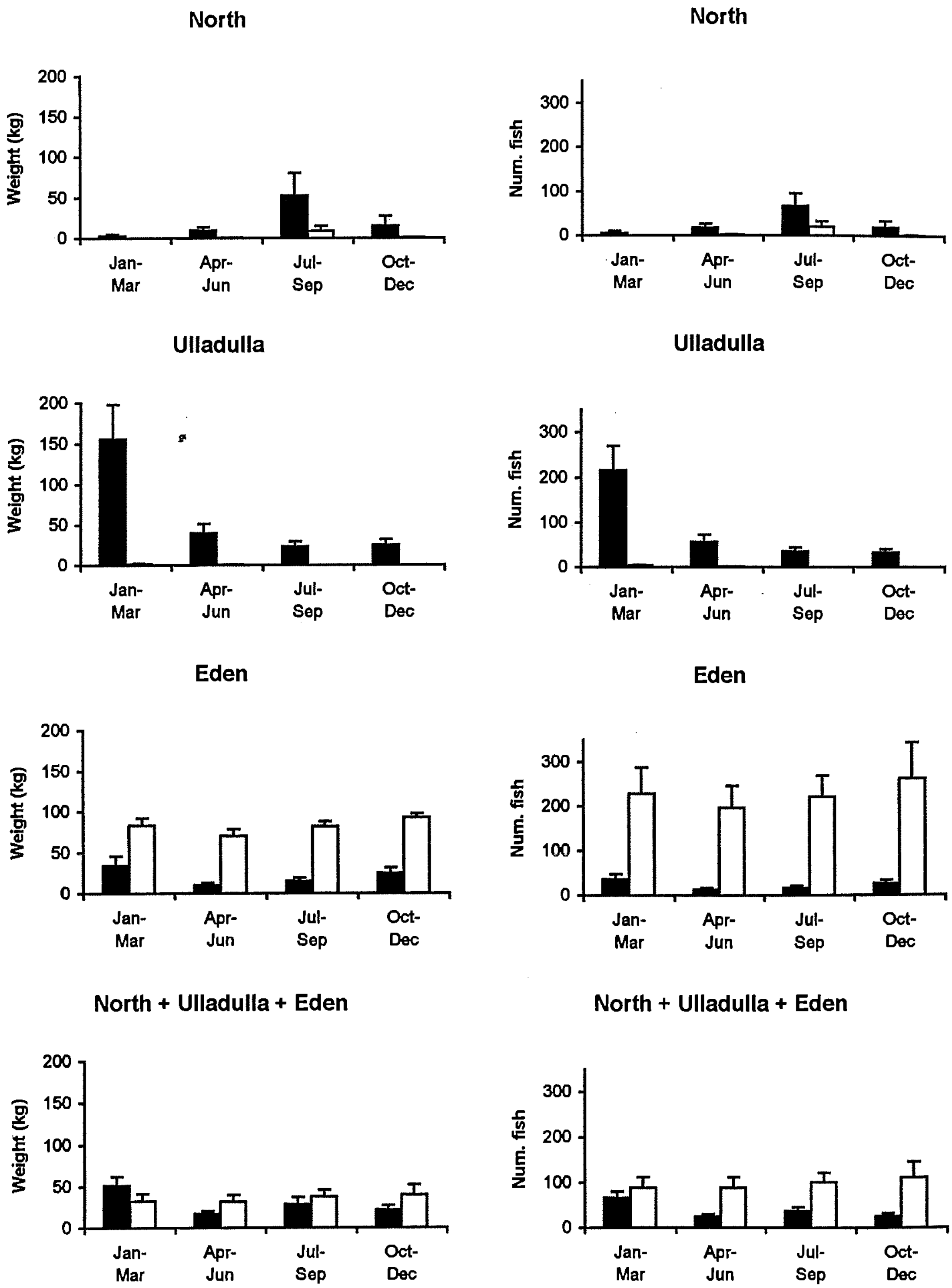


Table 8.1

Annual retained and discarded catches - Piked dogshark (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	23 +/-	16	21 +/-	15	1 +/-	1	*6*
	1994	44	37	37	30	7	7	*16*
	1995	41	15	38	14	3	2	*8*
	Mean 1993-95	36	14	32	12	4	2	*11*
Ulladulla	1993	48	9	47	9	1	0	*1*
	1994	88	29	87	29	0	0	*0*
	1995	65	16	65	16	0	0	*1*
	Mean 1993-95	67	12	67	12	0	0	*1*
Eden	1993	233	49	44	14	189	45	*81*
	1994	232	44	43	10	189	41	*81*
	1995	166	36	37	9	129	29	*78*
	Mean 1993-95	210	25	41	7	169	23	*80*
N+U+E	1993	304	52	112	23	192	45	*63*
	1994	364	64	167	43	196	42	*54*
	1995	272	42	140	23	133	29	*49*
	Mean 1993-95	313	31	140	18	174	23	*55*

Table 8.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	42 +/-	26	38 +/-	24	4 +/-	3	*10*
	1994	48	37	34	24	14	14	*29*
	1995	68	25	59	21	9	5	*13*
	Mean 1993-95	53	17	44	13	9	5	*17*
Ulladulla	1993	69	15	67	15	2	1	*2*
	1994	124	38	123	38	1	1	*1*
	1995	89	20	88	20	1	1	*1*
	Mean 1993-95	94	15	93	15	1	0	*1*
Eden	1993	576	134	49	16	527	131	*91*
	1994	540	108	46	11	494	106	*91*
	1995	430	92	42	10	388	86	*90*
	Mean 1993-95	515	65	46	7	470	63	*91*
N+U+E	1993	687	138	154	32	533	131	*78*
	1994	713	120	203	46	510	107	*71*
	1995	587	98	189	31	397	86	*68*
	Mean 1993-95	662	69	182	21	480	63	*72*

Appendix A.9

Blue warehou

Seriolella brama

Figure 9.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 9.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 9.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 9.1
Annual retained and discarded catches (t)

Table 9.2
Annual retained and discarded catches (number of fish)

Figure 9.4
Size distributions of retained and discarded catches

Figure 9.1

Retained and discarded catches (kg per fisher-day) - Blue warehou
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

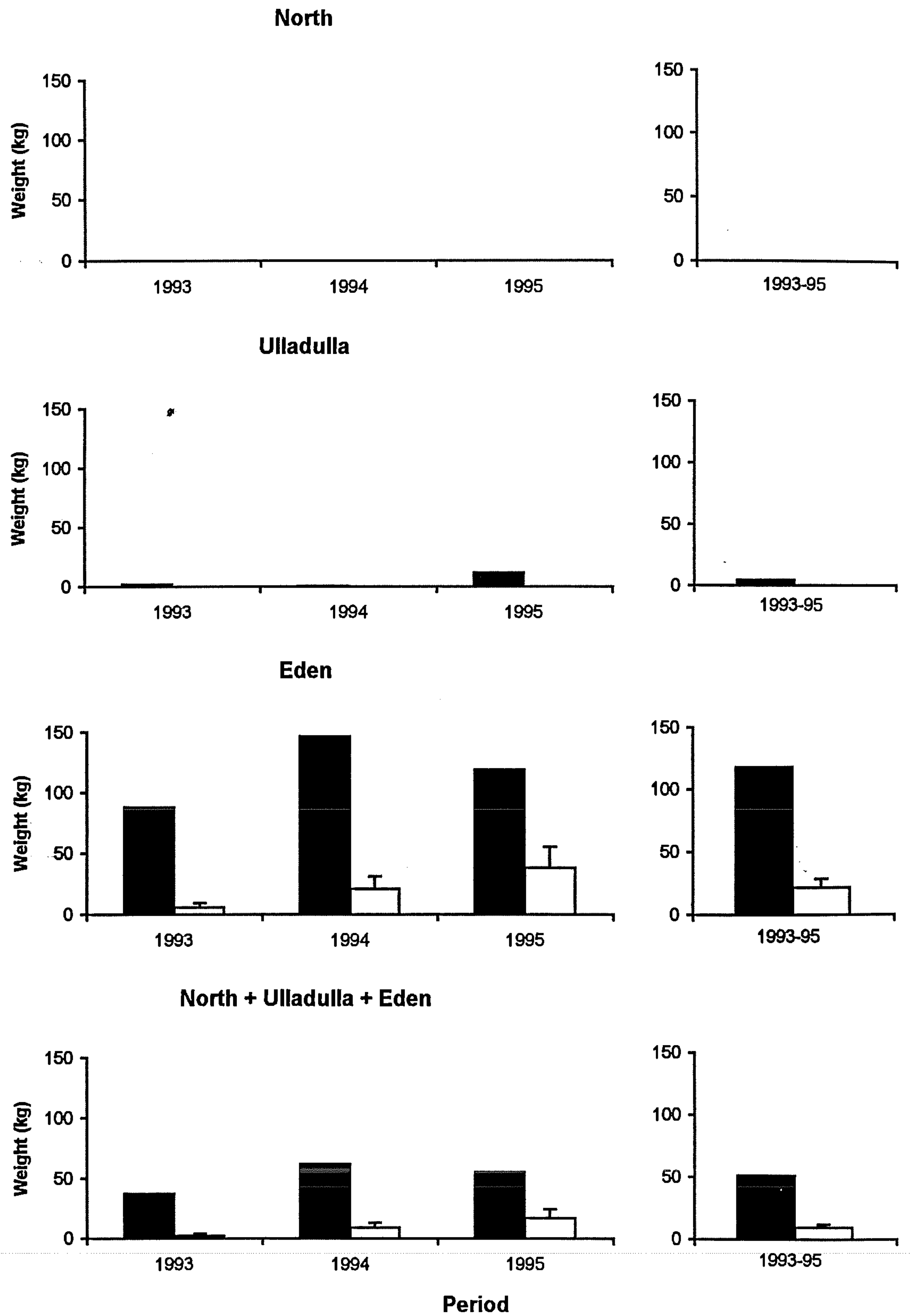


Figure 9.2

Retained and discarded catches (number of fish per fisher-day) - Blue warehou
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

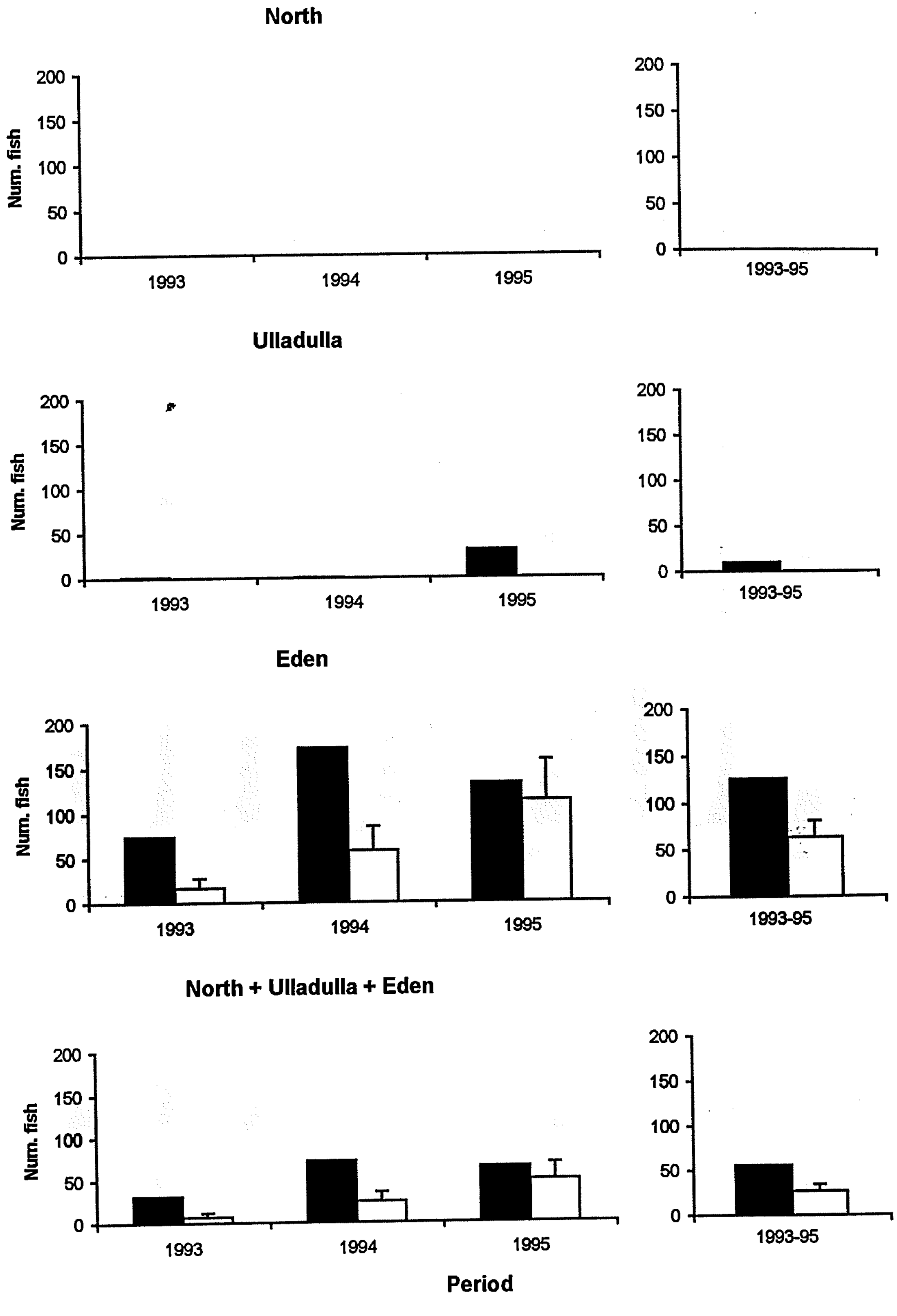


Figure 9.3

Retained and discarded catches (per fisher-day) - Blue warehou
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

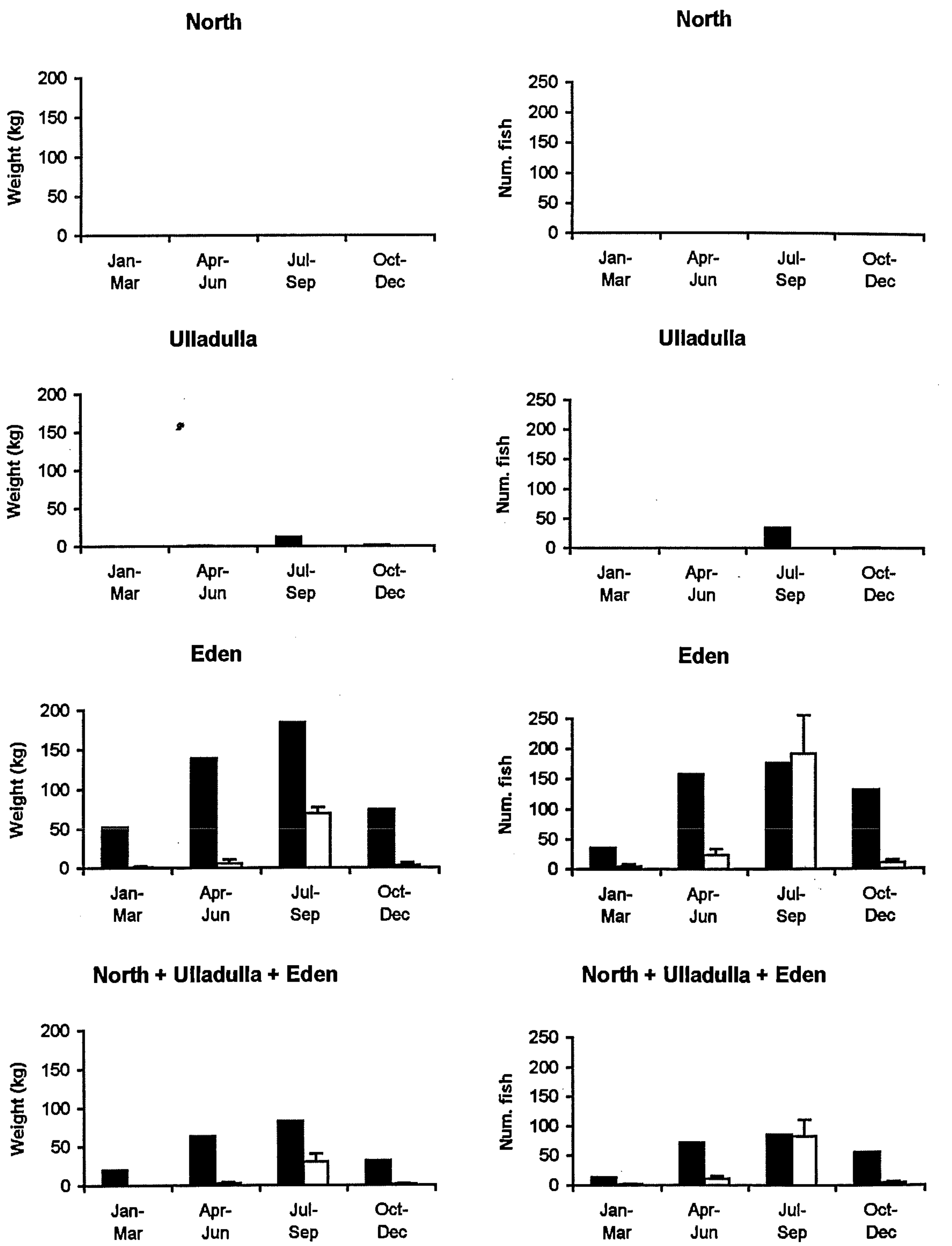


Table 9.1

Annual retained and discarded catches - Blue warehou (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	0 +/-	0	0 +/-	0	0 +/-	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	2	0	2	0	0	0	*0*
	1994	0	0	0	0	0	0	*0*
	1995	12	0	12	0	0	0	*0*
	Mean 1993-95	5	0	5	0	0	0	*0*
Eden	1993	193	8	181	0	12	8	*6*
	1994	343	21	301	0	42	21	*12*
	1995	332	37	252	0	81	37	*24*
	Mean 1993-95	289	14	245	0	45	14	*16*
N+U+E	1993	195	8	184	0	12	8	*6*
	1994	343	21	301	0	42	21	*12*
	1995	345	37	264	0	81	37	*23*
	Mean 1993-95	294	14	249	0	45	14	*15*

Table 9.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	0 +/-	0	0 +/-	0	0 +/-	0	
	1994	0	0	0	0	0	0	*100*
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	*100*
Ulladulla	1993	1	0	1	0	0	0	*0*
	1994	0	0	0	0	0	0	*0*
	1995	34	0	34	0	0	0	*0*
	Mean 1993-95	12	0	12	0	0	0	*0*
Eden	1993	187	23	153	0	35	23	*18*
	1994	471	56	353	0	118	56	*25*
	1995	519	94	280	0	239	94	*46*
	Mean 1993-95	393	37	262	0	131	37	*33*
N+U+E	1993	189	23	154	0	35	23	*18*
	1994	472	56	353	0	118	56	*25*
	1995	553	94	313	0	239	94	*43*
	Mean 1993-95	404	37	274	0	131	37	*32*

Figure 9.4, page 1

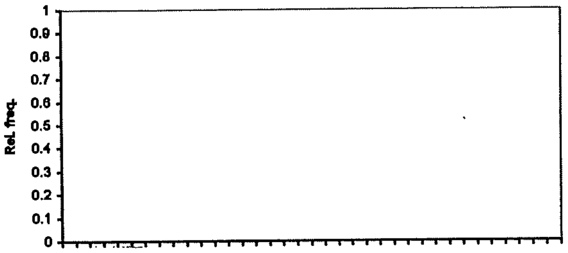
Size distributions of retained and discarded catches of Blue warehou

Retained catch: black bars   Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

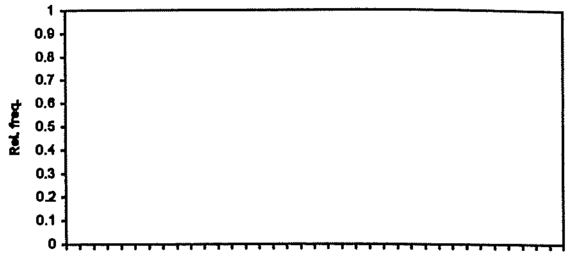
North, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



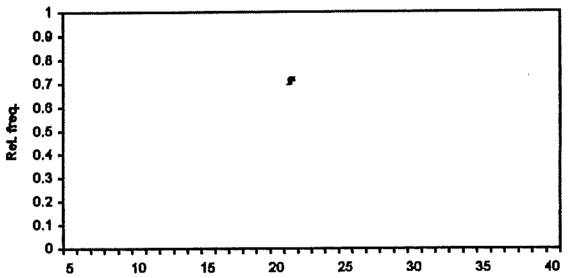
North, 1994

	Retained	Discarded	Total
Obs:	0 (0)	1 (1)	
Co-op:	0 (0)		
Mean L:			



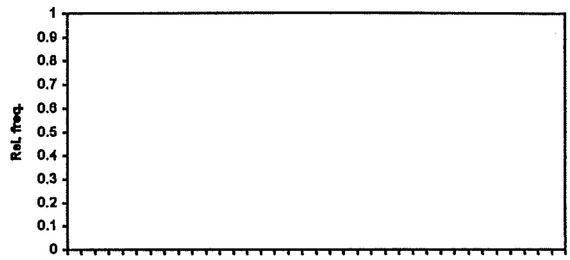
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	15 (1)	0 (0)	
Co-op:	0 (0)		
Mean L:			



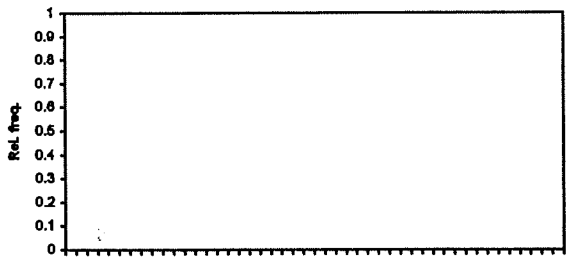
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



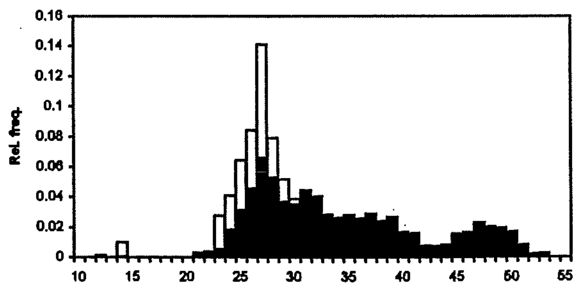
Eden, 1993

	Retained	Discarded	Total
Obs:	432 (8)	26 (9)	
Co-op:	0 (0)		
Mean L:			



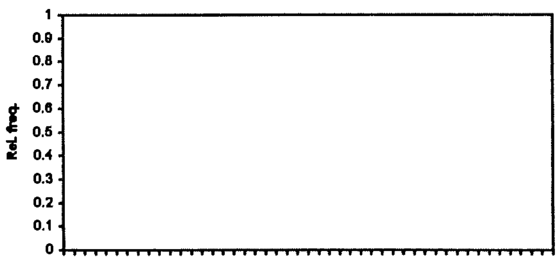
Eden, 1994

	Retained	Discarded	Total
Obs:	1123 (11)	102 (21)	
Co-op:	1766 (14)		
Mean L:	34.9	26.1	32.7



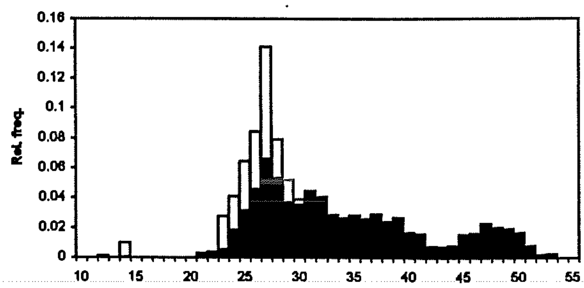
N + U + E, 1993

	Retained	Discarded	Total
Obs:	447 (9)	26 (9)	
Co-op:	0 (0)		
Mean L:			



N + U + E, 1994

	Retained	Discarded	Total
Obs:	1123 (11)	103 (22)	
Co-op:	1766 (14)		
Mean L:	34.9	26.1	32.7

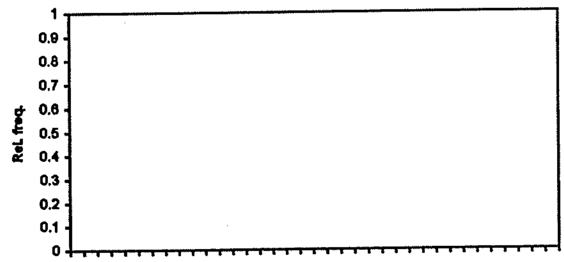


Length (cm)   Length (cm)

Figure 9.5, page 2

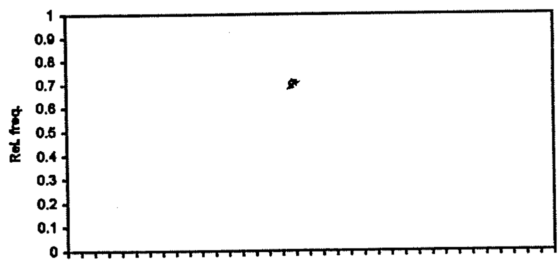
North, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



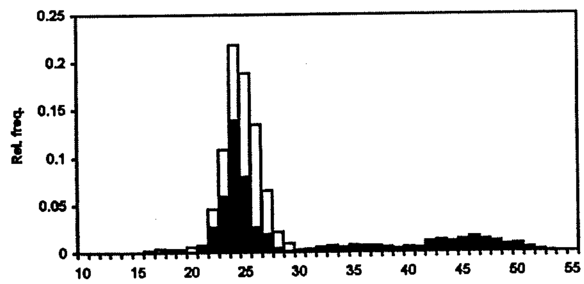
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



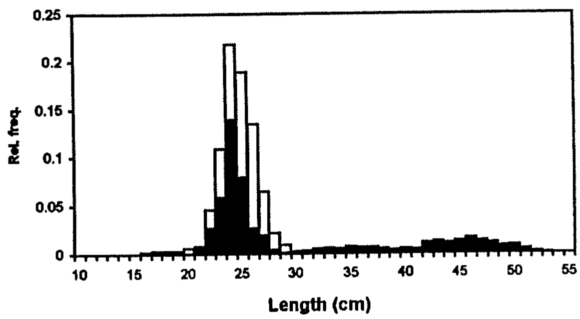
Eden, 1995

	Retained	Discarded	Total
Obs:	1016 (10)	418 (43)	
Co-op:	1244 (12)		
Mean L:	30.9	25.3	28.3



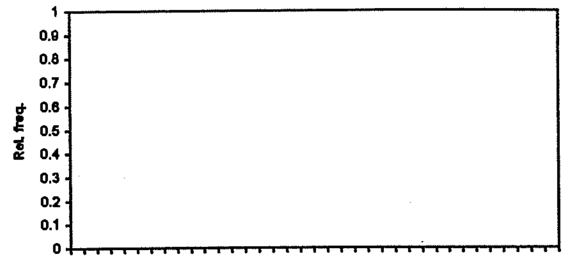
N + U + E, 1995

	Retained	Discarded	Total
Obs:	1016 (10)	418 (43)	
Co-op:	1244 (12)		
Mean L:	30.9	25.3	28.3



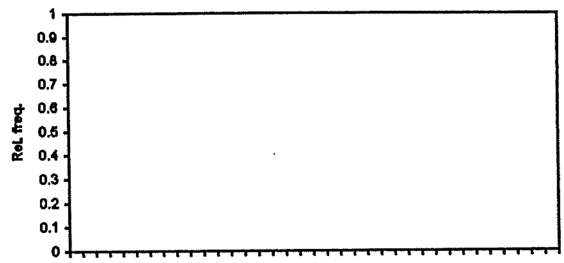
North, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	1 (1)	
Co-op:	0 (0)		
Mean L:			



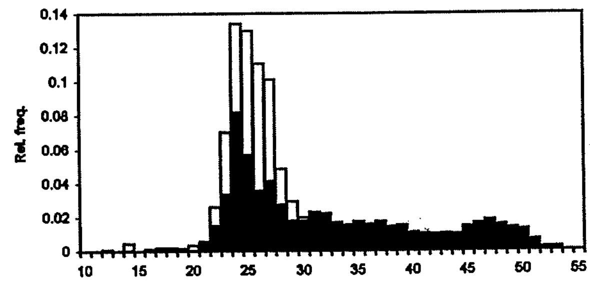
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	15 (1)	0 (0)	
Co-op:	0 (0)		
Mean L:			



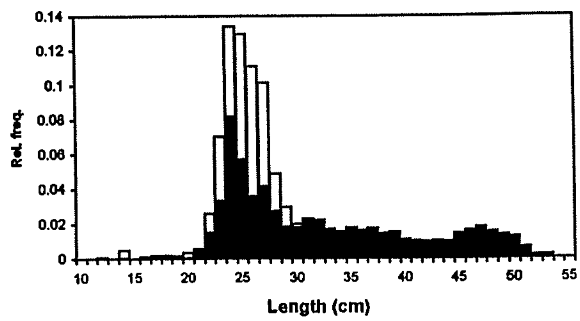
Eden, 1993-95

	Retained	Discarded	Total
Obs:	2572 (29)	546 (73)	
Co-op:	3010 (26)		
Mean L:	33.1	25.6	30.4



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	2587 (30)	547 (74)	
Co-op:	3010 (26)		
Mean L:	33.1	25.6	30.4



Appendix A.10

Arrow squid

Nototodarus gouldi

Figure 10.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 10.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 10.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 10.1
Annual retained and discarded catches (t)

Table 10.2
Annual retained and discarded catches (number of fish)

Figure 10.3

Retained and discarded catches (per fisher-day) - Arrow squid
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

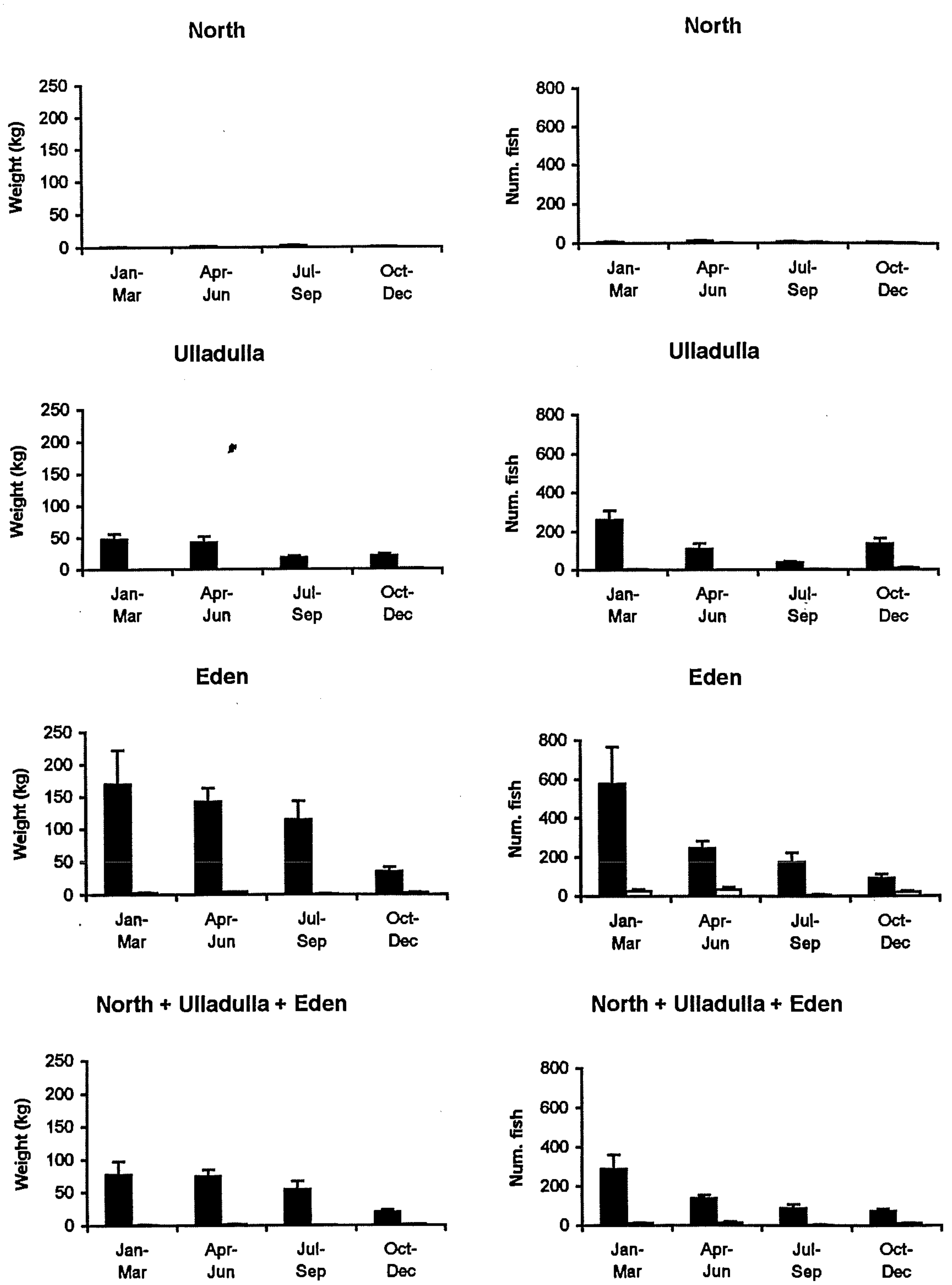


Table 10.1

Annual retained and discarded catches - Arrow squid (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	2	0	2	0	0	0	*2*
	1994	2	1	1	1	0	0	*21*
	1995	4	1	3	1	0	0	*4*
	Mean 1993-95	2	0	2	0	0	0	*7*
Ulladulla	1993	39	5	39	5	0	0	*0*
	1994	36	8	35	8	0	0	*1*
	1995	37	6	36	6	1	0	*2*
	Mean 1993-95	37	4	37	4	0	0	*1*
Eden	1993	260	45	256	45	4	1	*2*
	1994	129	17	122	16	7	2	*6*
	1995	332	76	326	78	6	1	*2*
	Mean 1993-95	240	30	235	30	6	1	*2*
N+U+E	1993	301	45	297	45	4	1	*1*
	1994	166	18	158	18	8	2	*5*
	1995	373	76	366	76	7	1	*2*
	Mean 1993-95	280	30	274	30	6	1	*2*

Table 10.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	13	4	13	4	1	0	*5*
	1994	9	3	3	1	6	3	*62*
	1995	19	4	17	4	2	1	*9*
	Mean 1993-95	14	2	11	2	3	1	*20*
Ulladulla	1993	135	23	135	23	0	0	*0*
	1994	184	44	180	43	3	2	*2*
	1995	141	19	134	19	8	3	*5*
	Mean 1993-95	153	18	150	17	4	1	*2*
Eden	1993	523	99	494	99	28	8	*5*
	1994	307	42	267	38	41	12	*13*
	1995	867	235	808	234	59	19	*7*
	Mean 1993-95	566	86	523	86	43	8	*8*
N+U+E	1993	671	102	642	101	29	8	*4*
	1994	500	60	450	57	50	13	*10*
	1995	1,027	235	959	235	68	19	*7*
	Mean 1993-95	733	86	684	87	49	8	*7*

Appendix A.11

Jackass morwong

Nemadactylus macropterus

Figure 11.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 11.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 11.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 11.1
Annual retained and discarded catches (t)

Table 11.2
Annual retained and discarded catches (number of fish)

Figure 11.4
Size distributions of retained and discarded catches

Figure 11.1

Retained and discarded catches (kg per fisher-day) - Jackass morwong
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

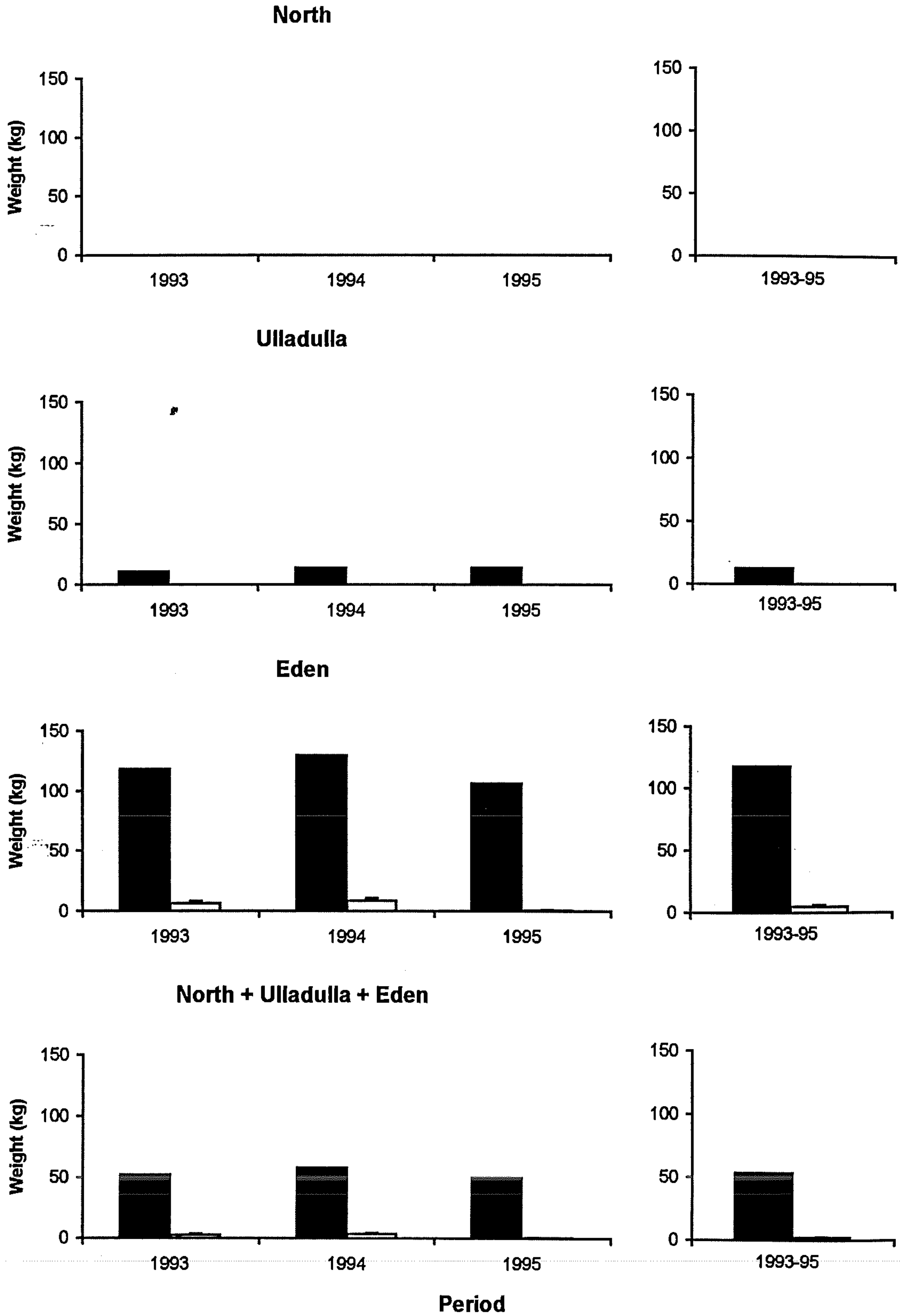


Figure 11.2

Retained and discarded catches (number of fish per fisher-day) - Jackass morwong
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

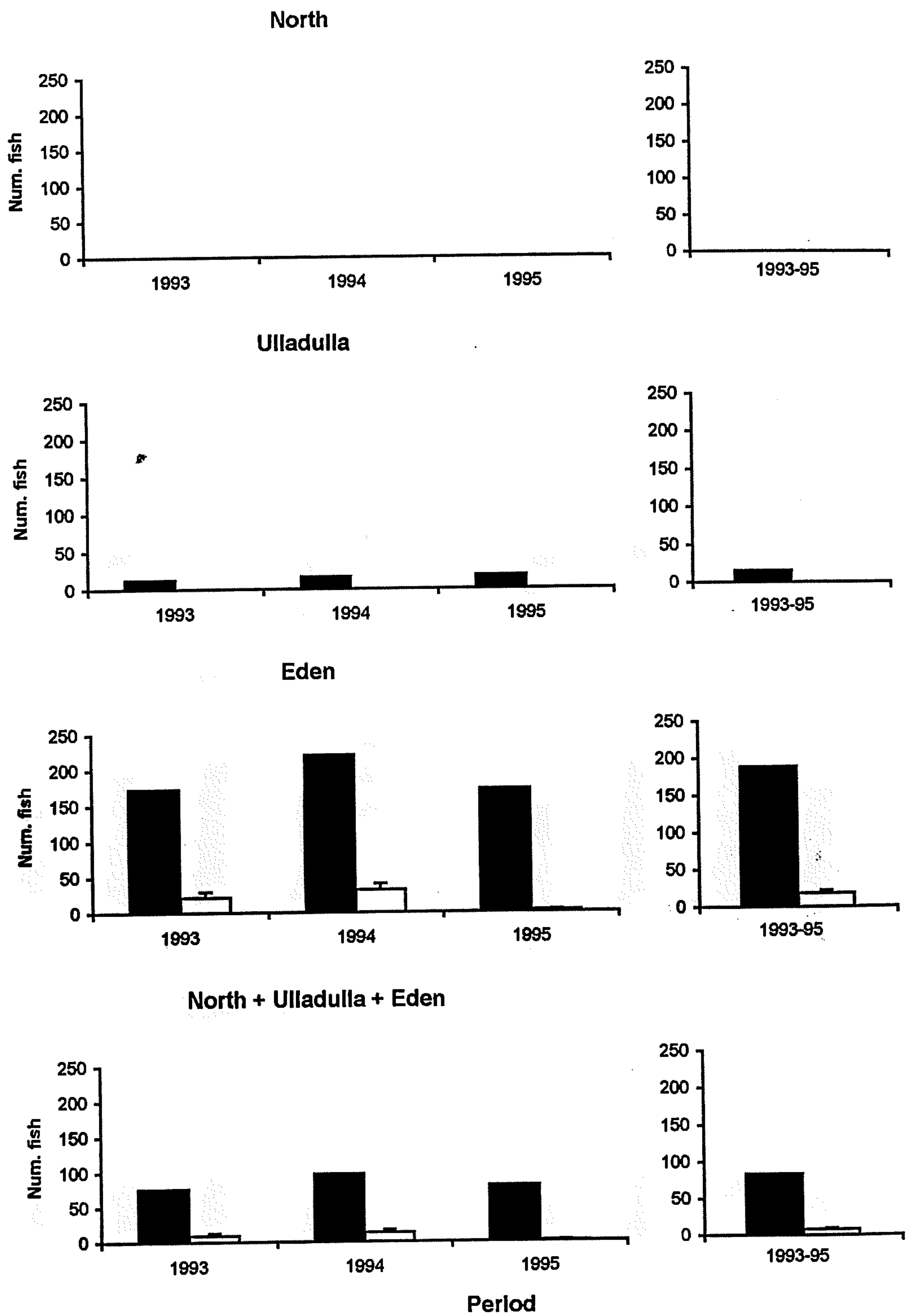


Figure 11.3

Retained and discarded catches (per fisher-day) - Jackass morwong

by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

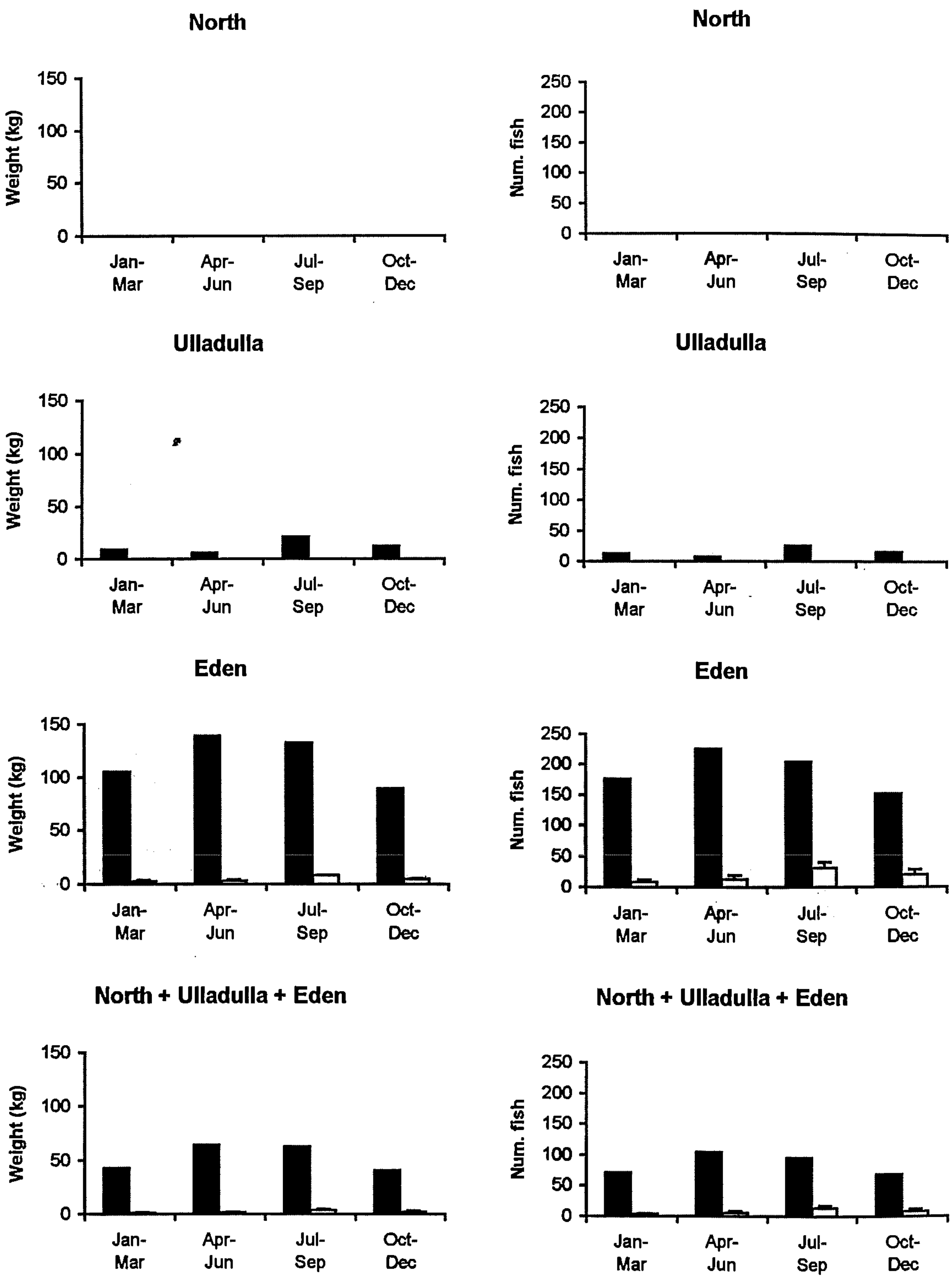


Table 11.1

Annual retained and discarded catches - Jackass morwong (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	0 +/-	0	0 +/-	0	0 +/-	0	
	1994	0	0	0	0	0	0	*0*
	1995	0	0	0	0	0	0	*0*
	Mean 1993-95	0	0	0	0	0	0	*0*
Ulladulla	1993	14	0	14	0	0	0	*0*
	1994	17	0	17	0	0	0	*0*
	1995	15	0	15	0	0	0	*0*
	Mean 1993-95	15	0	15	0	0	0	*0*
Eden	1993	257	4	244	0	12	4	*5*
	1994	283	5	266	0	17	5	*6*
	1995	226	0	224	0	1	0	*1*
	Mean 1993-95	255	2	245	0	10	2	*4*
N+U+E	1993	270	4	258	0	12	4	*5*
	1994	300	5	283	0	17	5	*6*
	1995	240	0	239	0	1	0	*1*
	Mean 1993-95	270	2	260	0	10	2	*4*

Table 11.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	0 +/-	0	0 +/-	0	0 +/-	0	
	1994	0	0	0	0	0	0	*0*
	1995	0	0	0	0	0	0	*0*
	Mean 1993-95	0	0	0	0	0	0	*0*
Ulladulla	1993	16	0	16	0	0	0	*0*
	1994	20	0	20	0	0	0	*0*
	1995	19	0	19	0	0	0	*0*
	Mean 1993-95	19	0	19	0	0	0	*0*
Eden	1993	404	15	359	0	45	15	*11*
	1994	517	18	452	0	64	18	*12*
	1995	369	1	364	0	5	1	*1*
	Mean 1993-95	430	8	392	0	38	8	*9*
N+U+E	1993	420	15	375	0	45	15	*11*
	1994	537	18	473	0	64	18	*12*
	1995	389	1	364	0	5	1	*1*
	Mean 1993-95	449	8	411	0	38	8	*8*

Figure 11.4, page 1

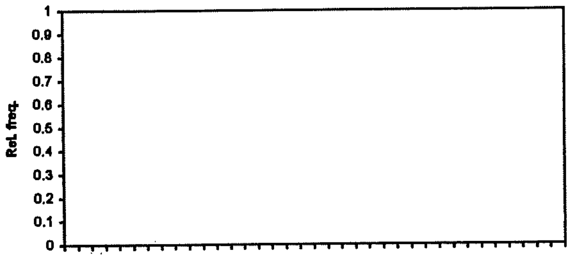
Size distributions of retained and discarded catches of Jackass morwong

Retained catch: black bars   Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

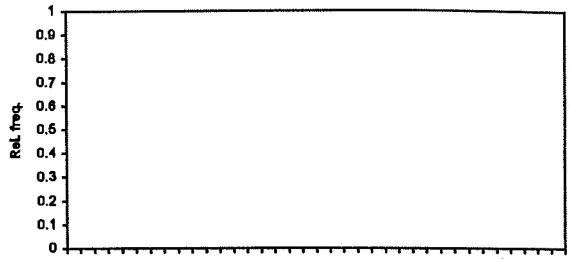
North, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



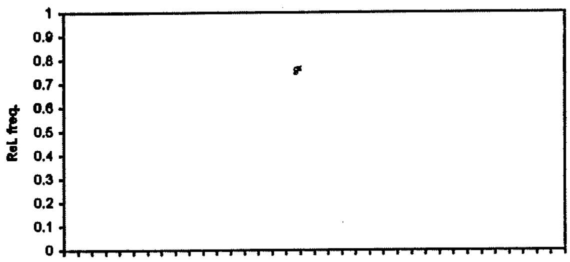
North, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



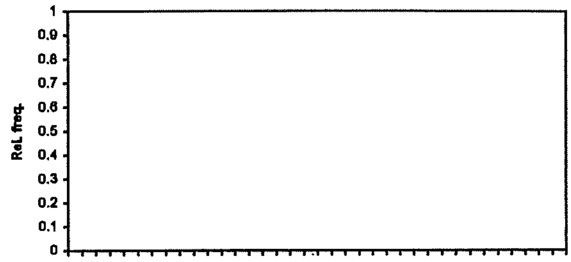
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	15 (5)	1 (1)	
Co-op:	0 (0)		
Mean L:			



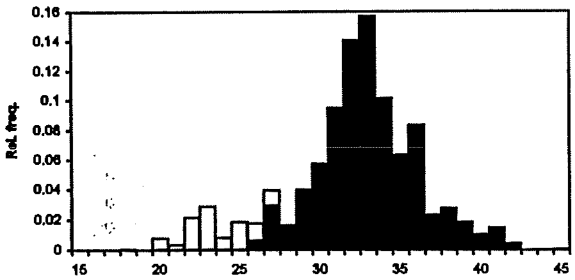
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	0 (0)	1 (1)	
Co-op:	120 (4)		
Mean L:			



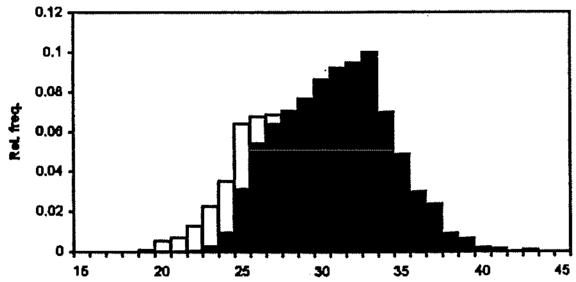
Eden, 1993

	Retained	Discarded	Total
Obs:	728 (26)	114 (27)	
Co-op:	0 (0)		
Mean L:	33.6	24.1	32.5



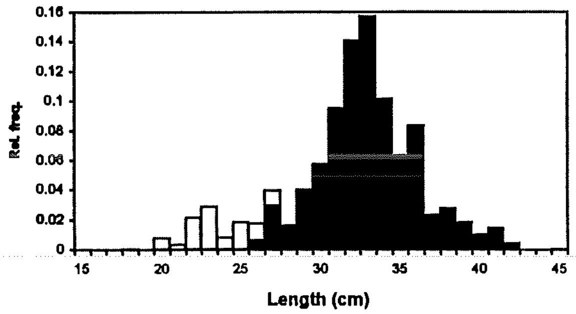
Eden, 1994

	Retained	Discarded	Total
Obs:	1282 (22)	288 (49)	
Co-op:	2651 (20)		
Mean L:	31.4	24.4	30.5



N + U + E, 1993

	Retained	Discarded	Total
Obs:	743 (31)	115 (28)	
Co-op:	0 (0)		
Mean L:	33.6	24.1	32.5



N + U + E, 1994

	Retained	Discarded	Total
Obs:	1282 (22)	289 (50)	
Co-op:	2771 (24)		
Mean L:	31.4	24.4	30.5

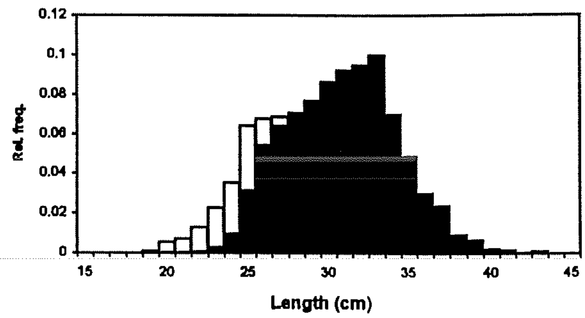
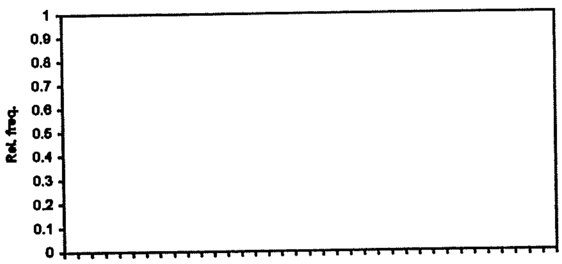


Figure 11.4, page 2

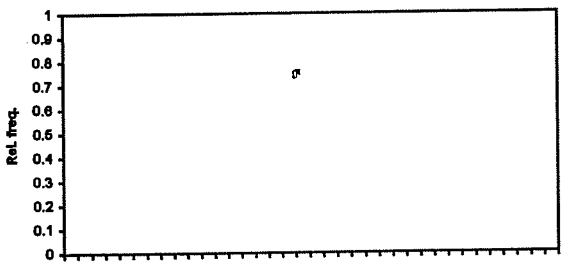
North, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



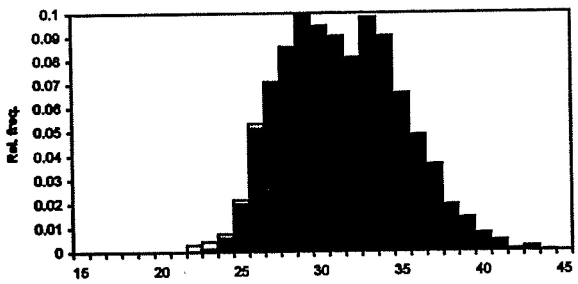
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	115 (3)	0 (0)	
Co-op:	0 (0)		
Mean L:			



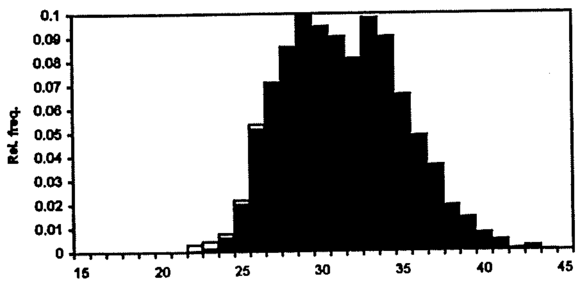
Eden, 1995

	Retained	Discarded	Total
Obs:	1622 (18)	29 (16)	
Co-op:	4853 (29)		
Mean L:	31.9	24.7	31.8



N + U + E, 1995

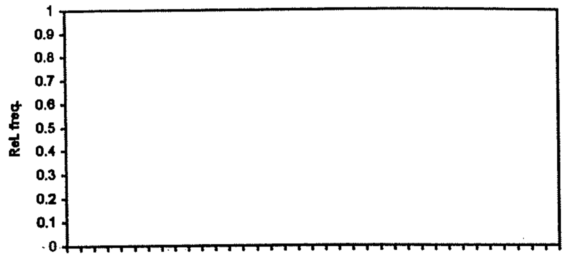
	Retained	Discarded	Total
Obs:	1737 (21)	29 (16)	
Co-op:	4853 (29)		
Mean L:	31.9	24.7	31.8



Length (cm)

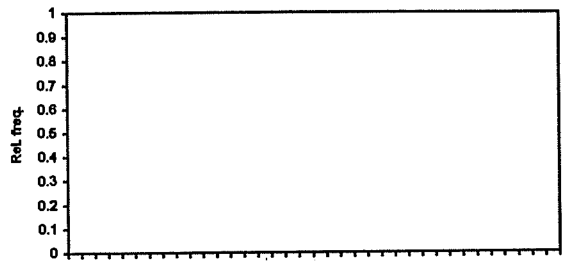
North, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



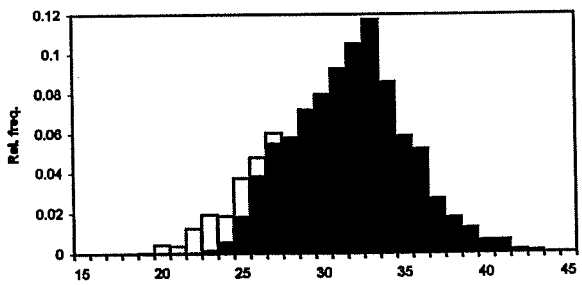
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	130 (8)	2 (2)	
Co-op:	120 (4)		
Mean L:			



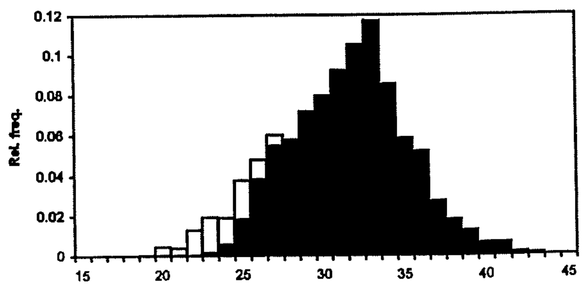
Eden, 1993-95

	Retained	Discarded	Total
Obs:	3632 (66)	431 (92)	
Co-op:	7503 (49)		
Mean L:	32.2	24.3	31.5



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	3762 (74)	433 (94)	
Co-op:	7623 (53)		
Mean L:	32.2	24.3	31.5



Length (cm)

Appendix A.12

Velvet leatherjacket

Meuschenia scaber

Figure 12.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 12.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 12.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 12.1
Annual retained and discarded catches (t)

Table 12.2
Annual retained and discarded catches (number of fish)

Figure 12.1

Retained and discarded catches (kg per fisher-day) - Velvet leatherjacket
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

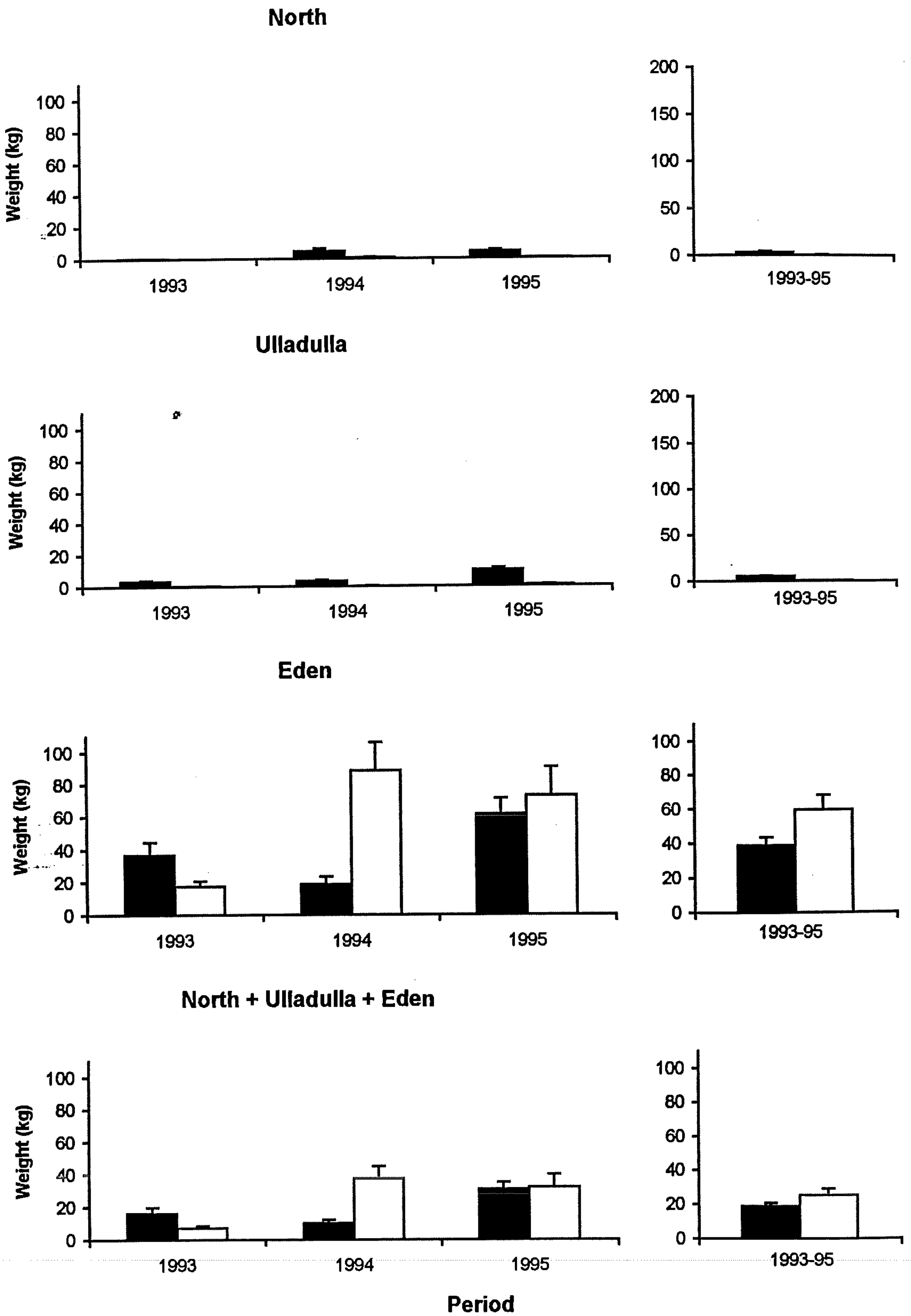


Figure 12.2

Retained and discarded catches (number of fish per fisher-day) - Velvet leatherjacket
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

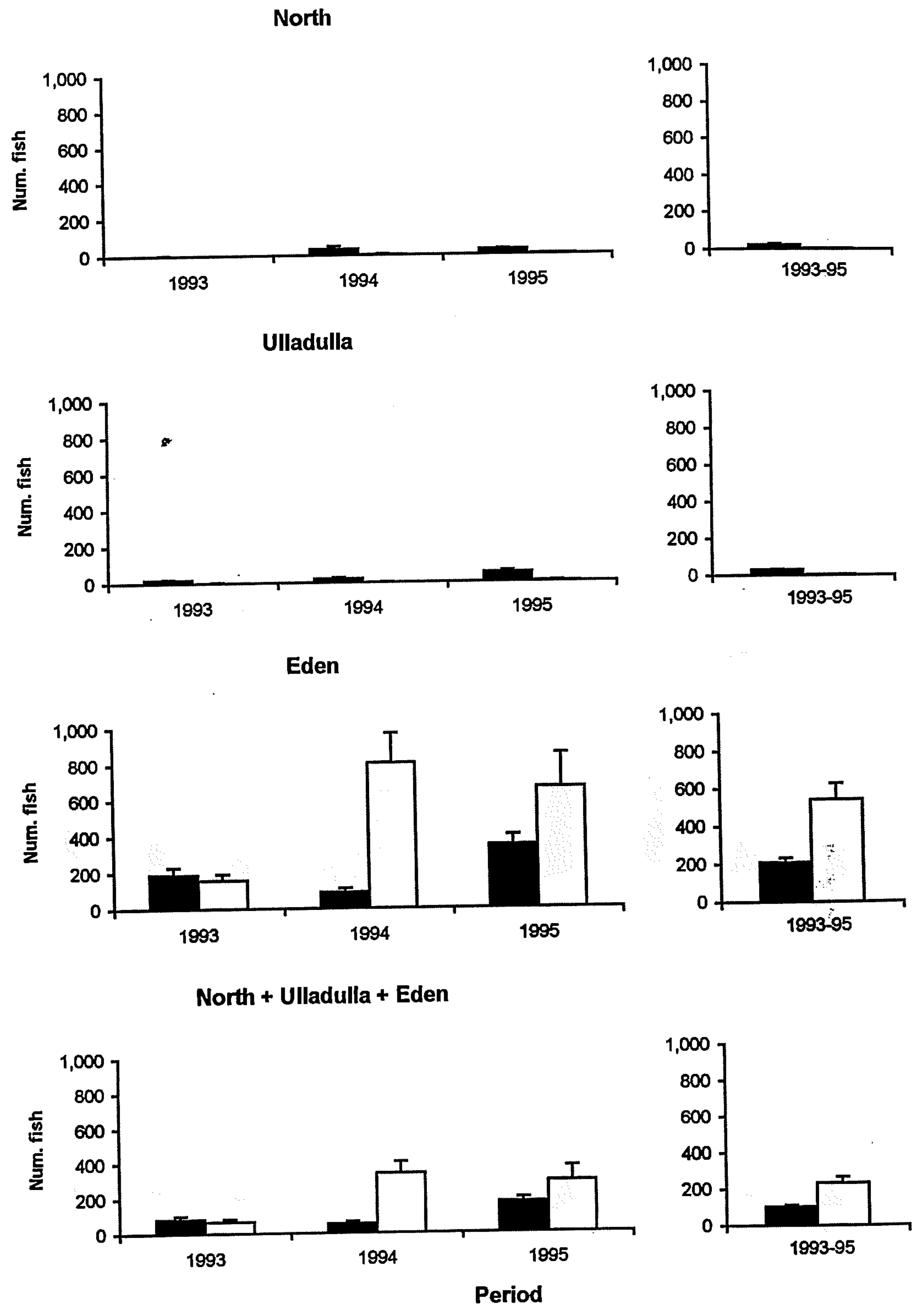


Figure 12.3

Retained and discarded catches (per fisher-day) - Velvet leatherjacket
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

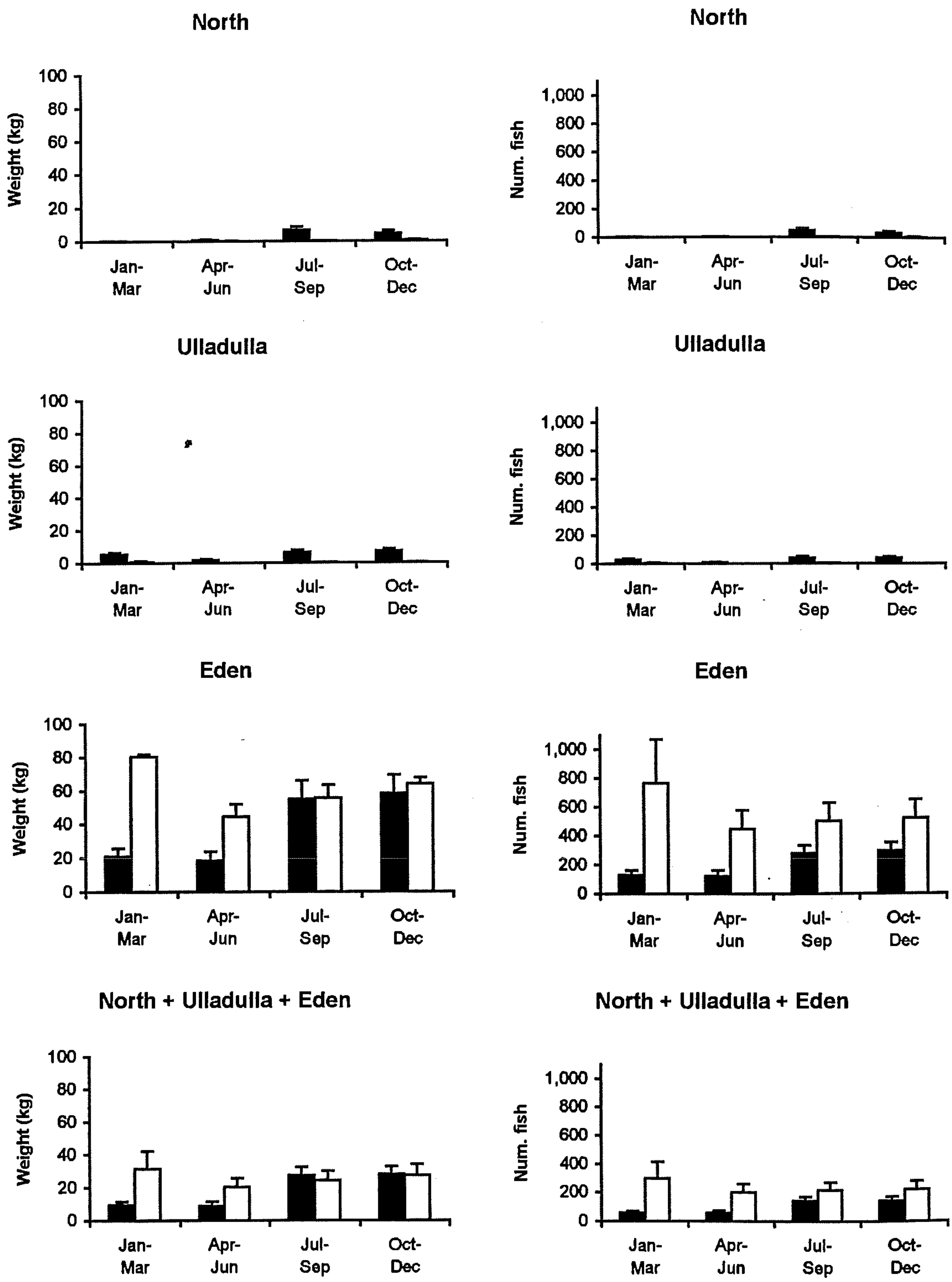


Table 12.1

Annual retained and discarded catches - Velvet leatherjacket (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	0	0	0	0	0	0	*19*
	1994	8	3	7	3	1	1	*11*
	1995	7	1	7	1	0	0	*4*
	Mean 1993-95	5	1	5	1	0	0	*8*
Ulladulla	1993	5	1	4	1	0	0	*7*
	1994	4	1	4	1	0	0	*4*
	1995	12	2	11	2	1	0	*7*
	Mean 1993-95	7	1	6	1	0	0	*6*
Eden	1993	111	20	75	17	36	7	*32*
	1994	219	41	38	9	181	36	*83*
	1995	283	48	130	20	153	38	*54*
	Mean 1993-95	204	22	81	9	123	18	*60*
N+U+E	1993	116	20	80	17	36	7	*31*
	1994	232	41	49	10	182	36	*79*
	1995	302	48	147	20	154	38	*51*
	Mean 1993-95	216	22	92	9	124	18	*57*

Table 12.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	2	1	2	1	1	0	*24*
	1994	63	24	55	22	7	5	*12*
	1995	46	9	43	9	3	1	*7*
	Mean 1993-95	37	8	33	8	4	2	*10*
Ulladulla	1993	24	7	22	7	2	1	*8*
	1994	27	9	26	9	1	1	*5*
	1995	62	11	57	9	5	3	*8*
	Mean 1993-95	38	5	35	5	3	1	*7*
Eden	1993	713	130	389	85	323	75	*45*
	1994	1,831	360	182	48	1,648	337	*90*
	1995	2,137	446	732	117	1,405	401	*66*
	Mean 1993-95	1,560	196	435	51	1,126	176	72
N+U+E	1993	739	130	413	85	326	75	44
	1994	1,921	361	263	53	1,657	337	86
	1995	2,245	446	832	117	1,412	401	63
	Mean 1993-95	1,635	196	503	52	1,132	176	69

Appendix A.13

Gemfish

Rexea solandri

Figure 13.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 13.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 13.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 13.1
Annual retained and discarded catches (t)

Table 13.2
Annual retained and discarded catches (number of fish)

Figure 13.4
Size distributions of retained and discarded catches

Figure 13.1

Retained and discarded catches (kg per fisher-day) - Gemfish
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

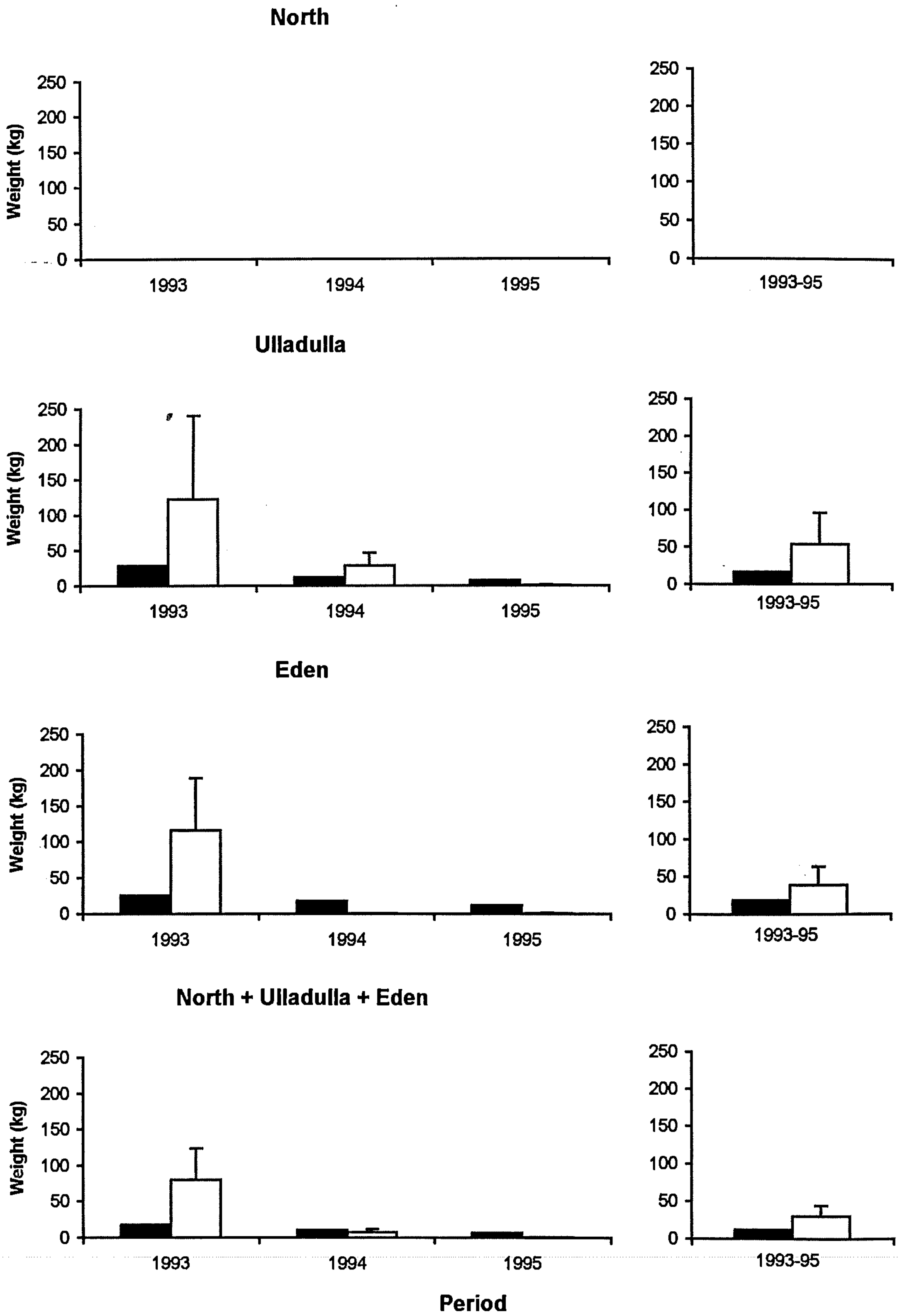


Figure 13.2

Retained and discarded catches (number of fish per fisher-day) - Gemfish
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

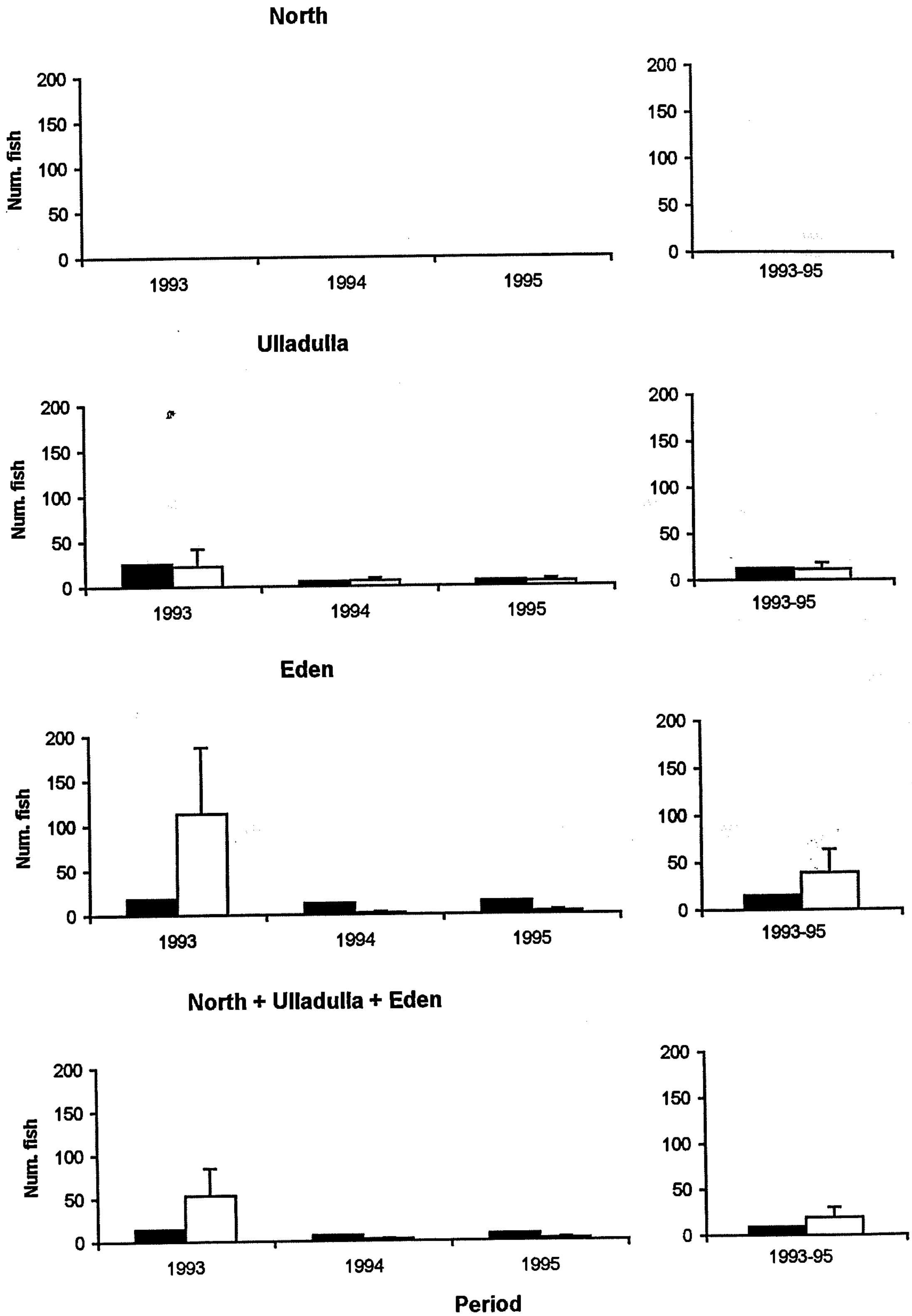


Figure 13.3

Retained and discarded catches (per fisher-day) - Gemfish
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

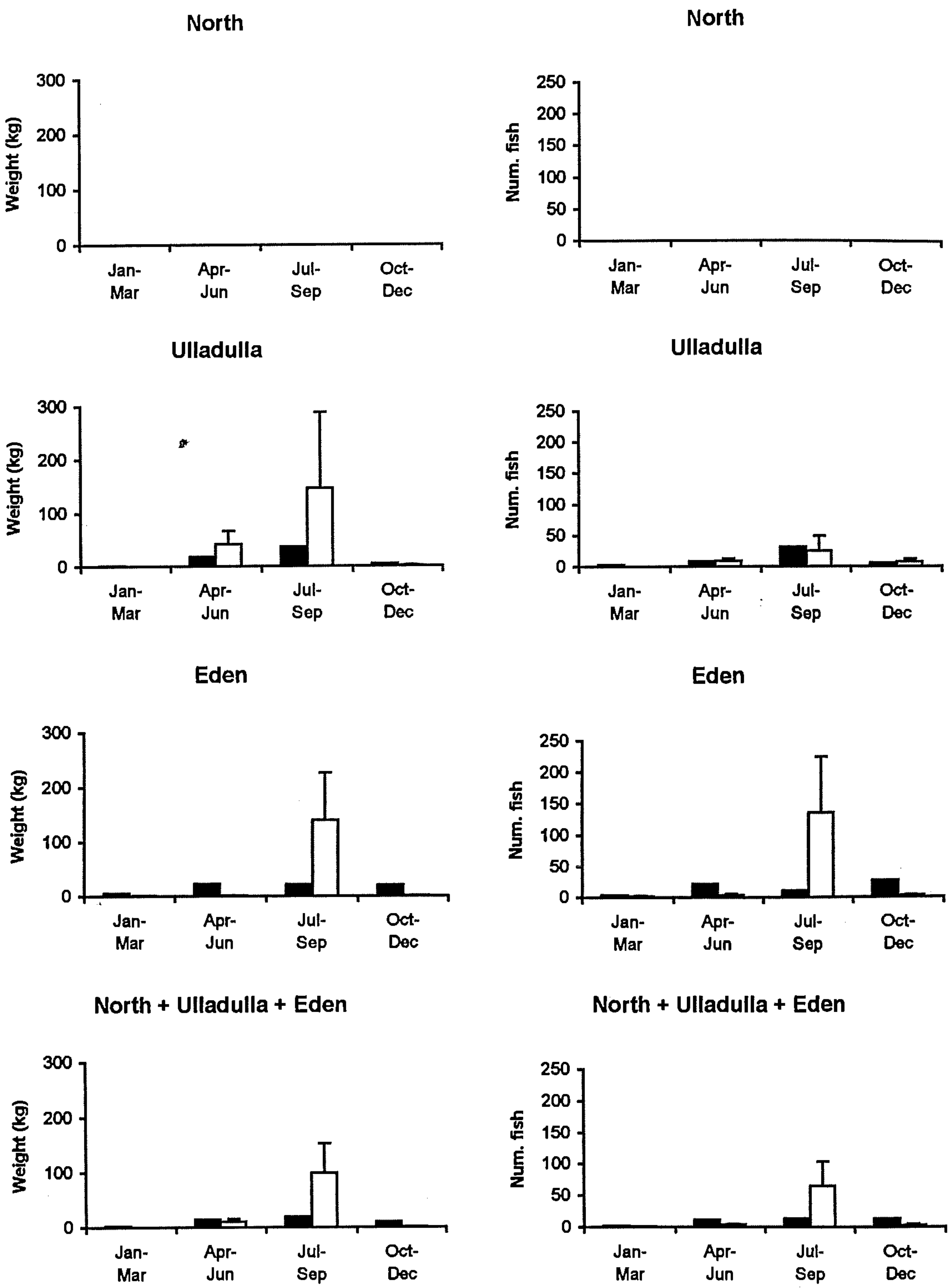


Table 13.1

Annual retained and discarded catches - Gemfish (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	0	+/- 0	0	+/- 0	0	+/- 0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	*100*
	Mean 1993-95	0	0	0	0	0	0	*100*
Ulladulla	1993	193	152	36	0	157	152	*81*
	1994	51	22	15	0	36	22	*71*
	1995	9	1	8	0	1	1	*10*
	Mean 1993-95	84	51	20	0	65	51	*77*
Eden	1993	294	149	53	0	240	149	*82*
	1994	37	1	36	0	1	1	*3*
	1995	26	1	25	0	2	1	*7*
	Mean 1993-95	119	50	38	0	81	50	*68*
N+U+E	1993	487	213	90	0	397	213	*82*
	1994	88	22	51	0	37	22	*42*
	1995	35	1	33	0	3	1	*8*
	Mean 1993-95	203	71	58	0	146	71	*72*

Table 13.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	0	+/- 0	0	+/- 0	0	+/- 0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	*100*
	Mean 1993-95	0	0	0	0	0	0	*100*
Ulladulla	1993	61	25	32	0	29	25	*47*
	1994	14	4	6	0	7	4	*53*
	1995	12	4	7	0	5	4	*42*
	Mean 1993-95	29	9	15	0	14	9	*47*
Eden	1993	272	153	38	0	234	153	*86*
	1994	30	2	27	0	4	2	*12*
	1995	38	3	31	0	7	3	*18*
	Mean 1993-95	113	51	32	0	82	51	*72*
N+U+E	1993	333	155	70	0	263	155	*79*
	1994	44	4	33	0	11	4	*25*
	1995	50	5	38	0	12	5	*24*
	Mean 1993-95	142	52	47	0	95	52	*67*

Figure 13.4, page 1

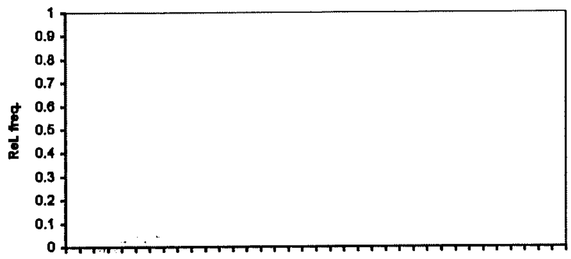
Size distributions of retained and discarded catches of Gemfish

Retained catch: black bars Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

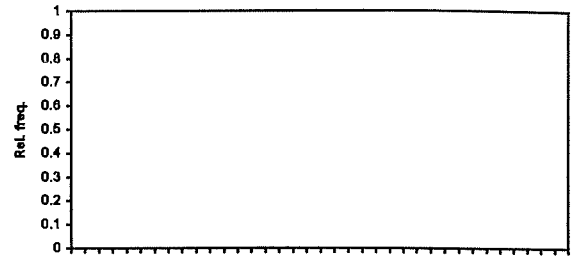
North, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



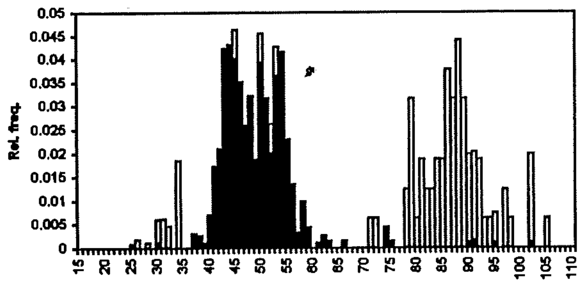
North, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



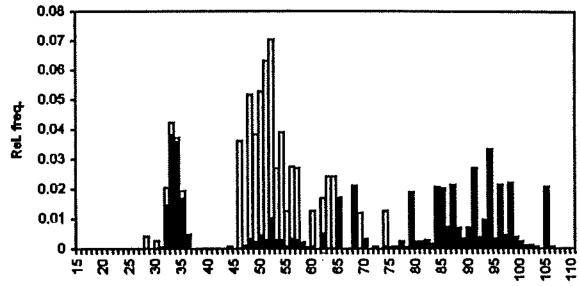
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	380 (9)	85 (9)	
Co-op:	0 (0)		
Mean L:	49.7	81.4	64.6



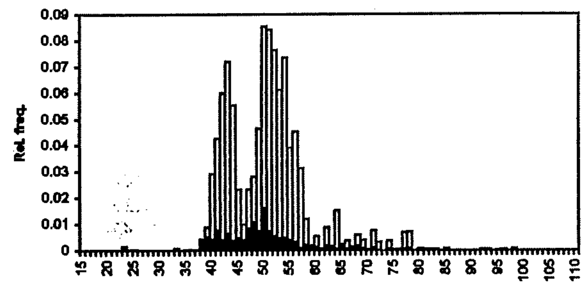
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	232 (5)	63 (5)	
Co-op:	37 (3)		
Mean L:	72.4	53.4	62.4



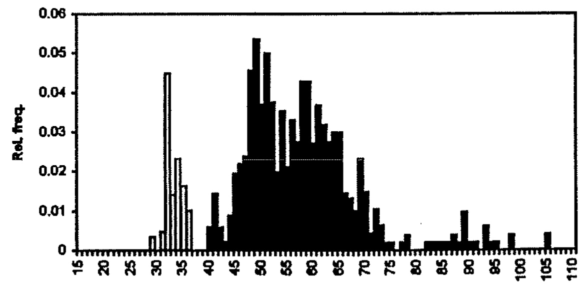
Eden, 1993

	Retained	Discarded	Total
Obs:	450 (24)	396 (25)	
Co-op:	0 (0)		
Mean L:	51.6	51.0	51.1



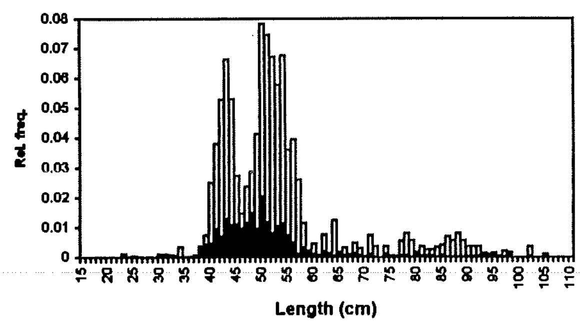
Eden, 1994

	Retained	Discarded	Total
Obs:	369 (13)	25 (4)	
Co-op:	0 (0)		
Mean L:	58.6	33.7	55.6



N + U + E, 1993

	Retained	Discarded	Total
Obs:	830 (33)	481 (34)	
Co-op:	0 (0)		
Mean L:	50.7	54.3	53.5



N + U + E, 1994

	Retained	Discarded	Total
Obs:	601 (18)	88 (9)	
Co-op:	37 (3)		
Mean L:	61.3	46.9	57.8

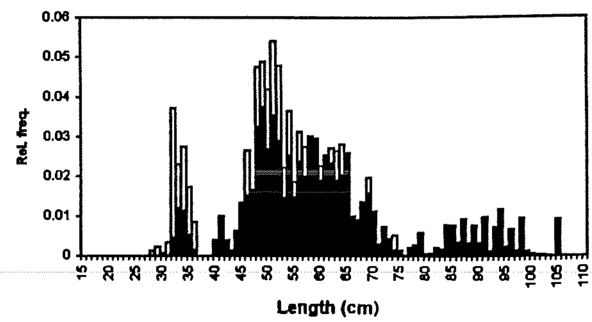
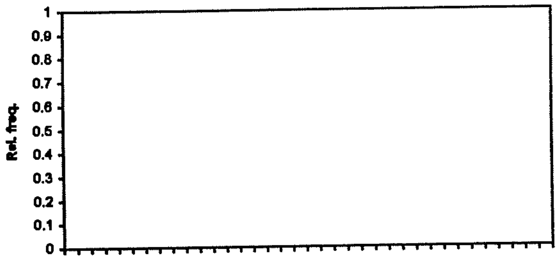


Figure 13.4, page 2

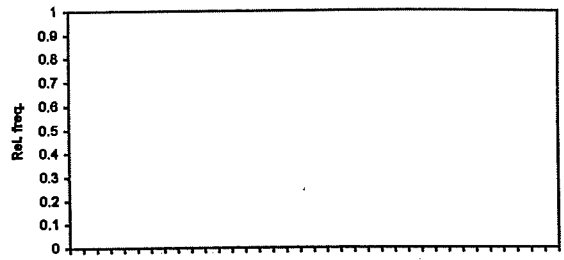
North, 1995

	Retained	Discarded	Total
Obs:	0 (0)	2 (2)	
Co-op:	0 (0)		
Mean L:			



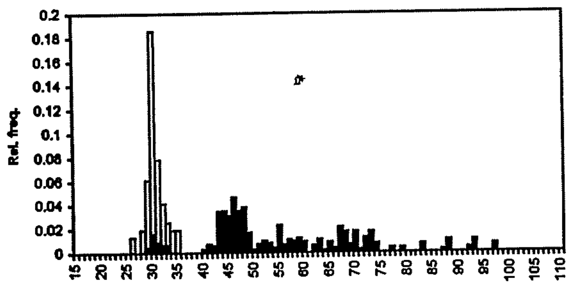
North, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	2 (2)	
Co-op:	0 (0)		
Mean L:			



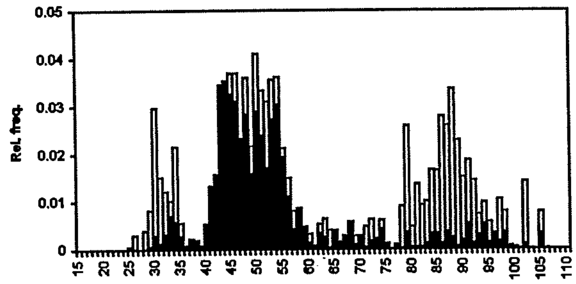
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	97 (6)	26 (7)	
Co-op:	41 (2)		
Mean L:	55.7	31.0	45.4



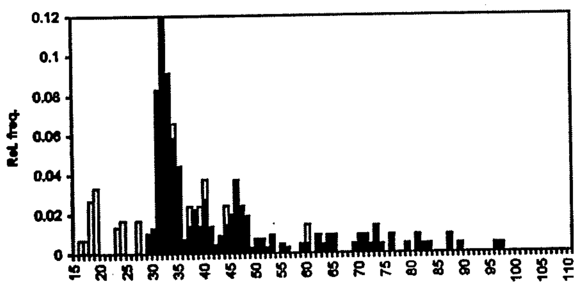
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	709 (20)	174 (21)	
Co-op:	78 (5)		
Mean L:	53.8	70.4	61.6



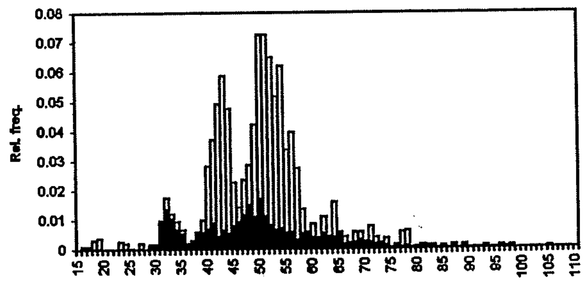
Eden, 1995

	Retained	Discarded	Total
Obs:	286 (6)	16 (7)	
Co-op:	0 (0)		
Mean L:	43.8	28.4	41.0



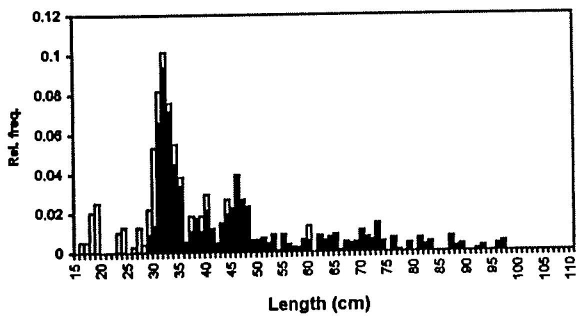
Eden, 1993-95

	Retained	Discarded	Total
Obs:	1105 (43)	437 (36)	
Co-op:	0 (0)		
Mean L:	51.0	50.1	50.4



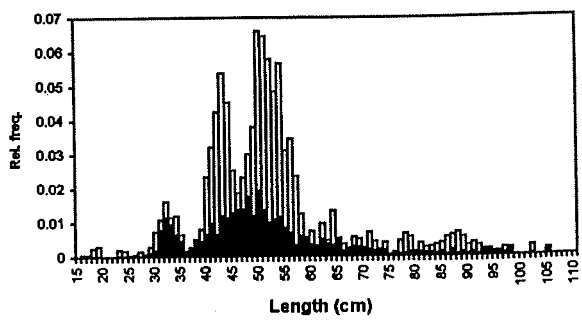
N + U + E, 1995

	Retained	Discarded	Total
Obs:	383 (12)	44 (16)	
Co-op:	41 (2)		
Mean L:	45.9	29.5	42.0



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	1814 (63)	613 (59)	
Co-op:	78 (5)		
Mean L:	51.9	53.0	52.6



Appendix A.14

Jack mackerel

Trachurus declivis

Figure 14.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 14.2
Retained and discarded catches (per fisher-day), by quarter, by region

Table 14.1
Annual retained and discarded catches (t)

Figure 14.1

Retained and discarded catches (kg per fisher-day) - Jack mackerel
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

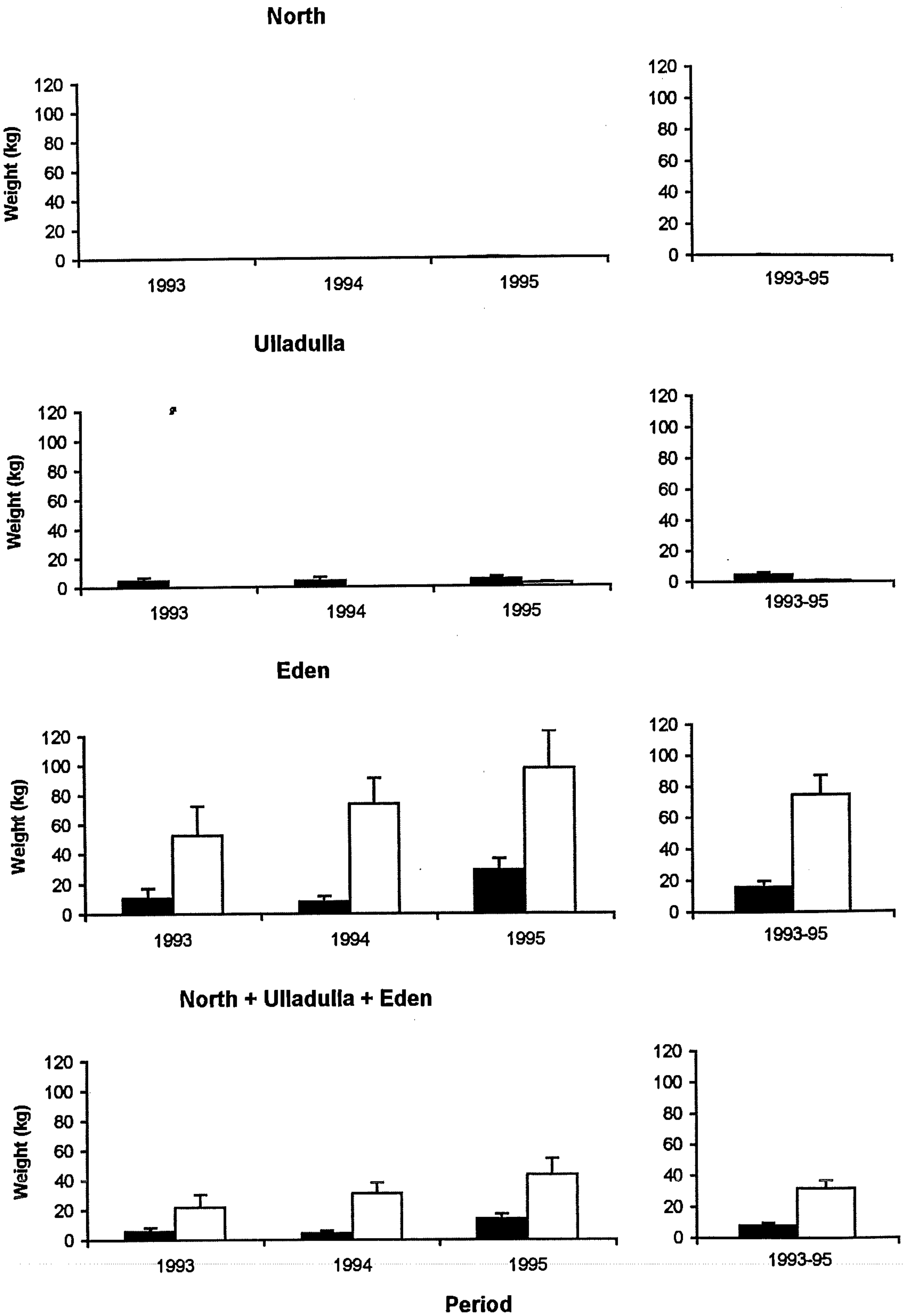


Figure 14.2

Retained and discarded catches (per fisher-day) - Jack mackerel
by Quarter, by Region

(mean weight per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

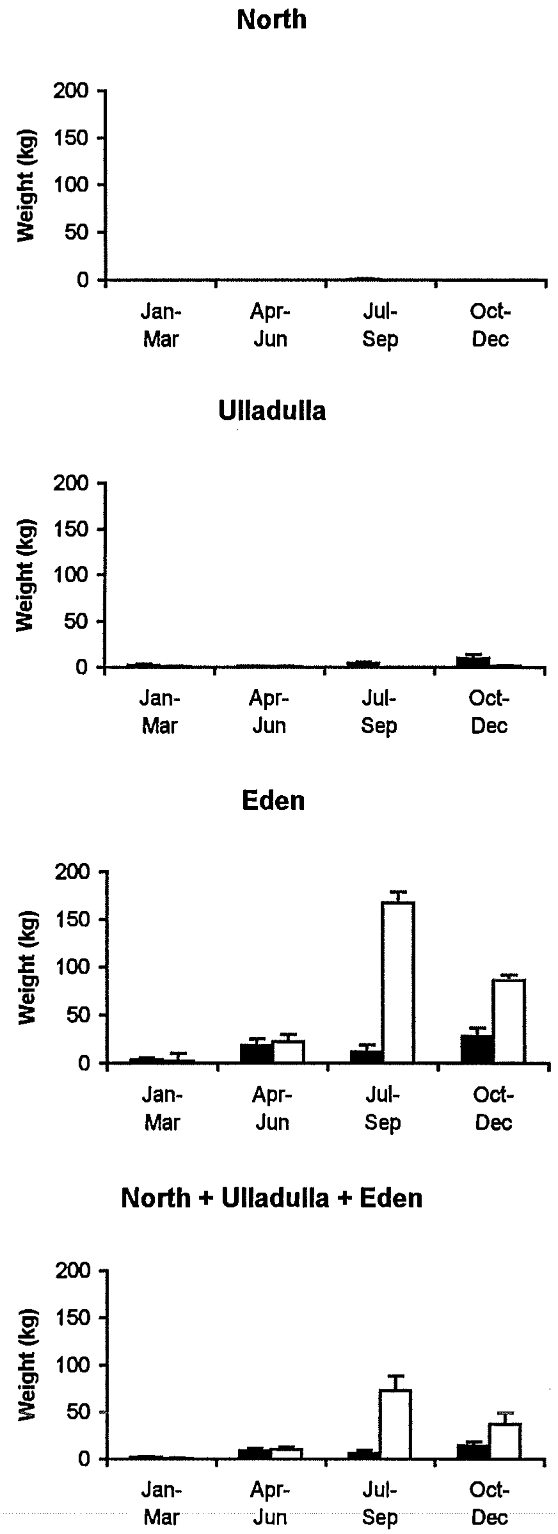


Table 14.1

Annual retained and discarded catches - Jack mackerel (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	1	1	1	1	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	6	3	6	3	0	0	*0*
	1994	5	3	5	3	0	0	*0*
	1995	8	2	5	2	2	1	*32*
	Mean 1993-95	6	1	5	1	1	0	*13*
Eden	1993	130	42	22	13	108	41	*83*
	1994	168	37	17	7	151	36	*90*
	1995	267	62	61	16	206	52	*77*
	Mean 1993-95	188	28	33	7	155	25	*82*
N+U+E	1993	136	42	28	13	108	41	*80*
	1994	173	37	22	8	151	36	*87*
	1995	275	62	67	16	209	52	*76*
	Mean 1993-95	195	28	39	7	156	25	*80*

Appendix A.15

Mirror dory

Zenopsis nebulosis

Figure 15.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 15.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 15.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 15.1
Annual retained and discarded catches (t)

Table 15.2
Annual retained and discarded catches (number of fish)

Figure 15.4
Size distributions of retained and discarded catches

Figure 15.1

Retained and discarded catches (kg per fisher-day) - Mirror dory
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

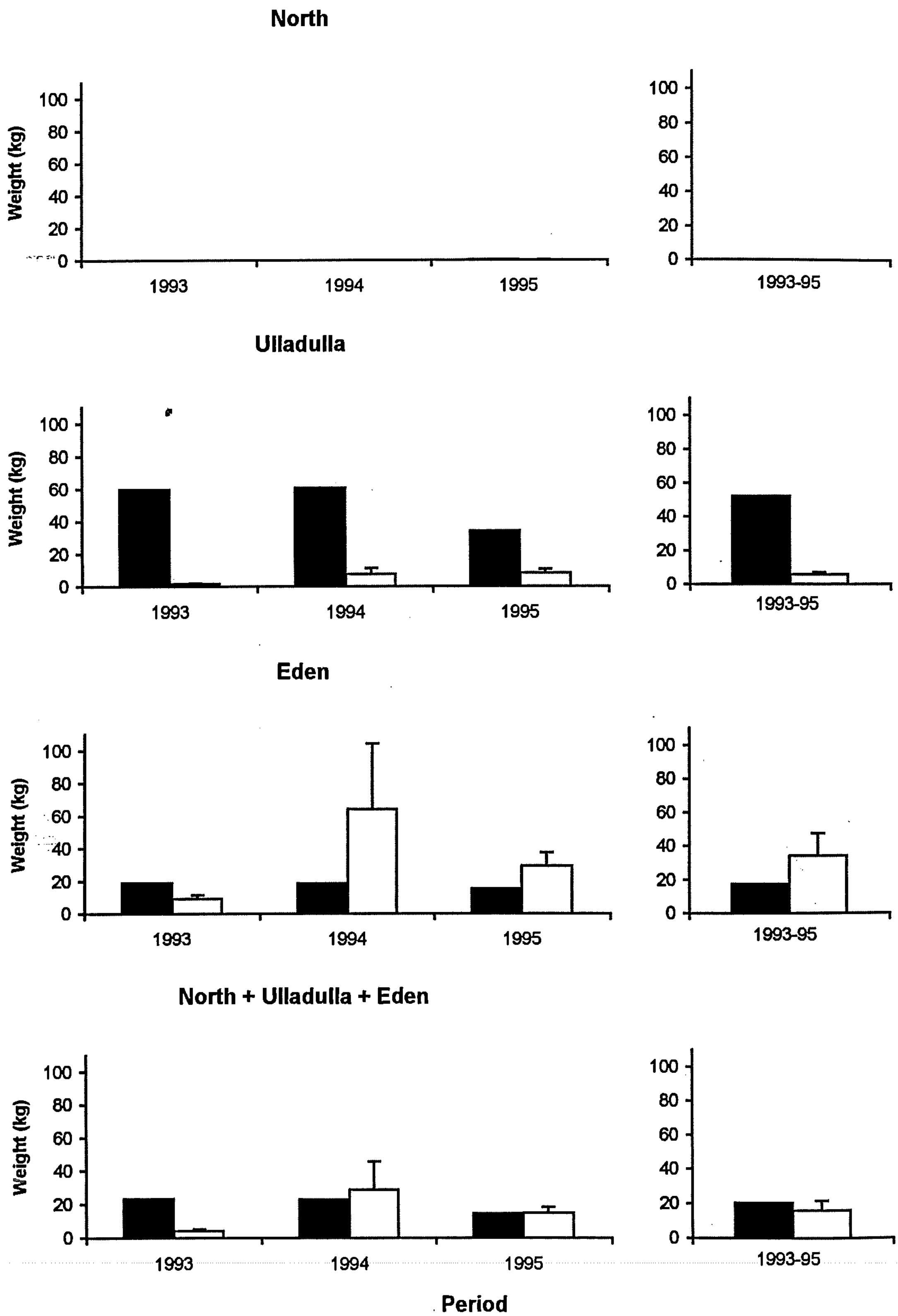


Figure 15.2

Retained and discarded catches (number of fish per fisher-day) - Mirror dory
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

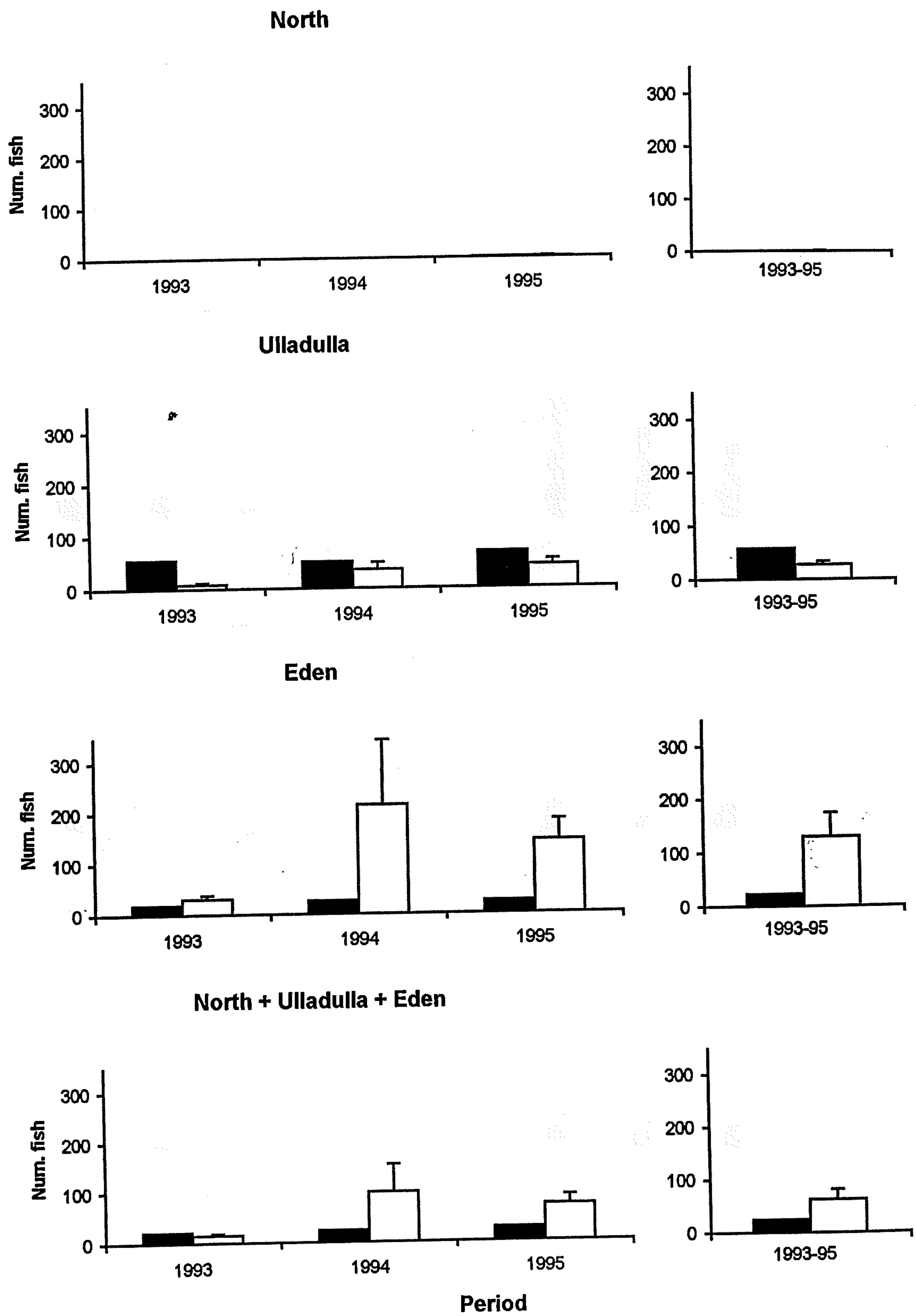


Figure 15.3

Retained and discarded catches (per fisher-day) - Mirror dory
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

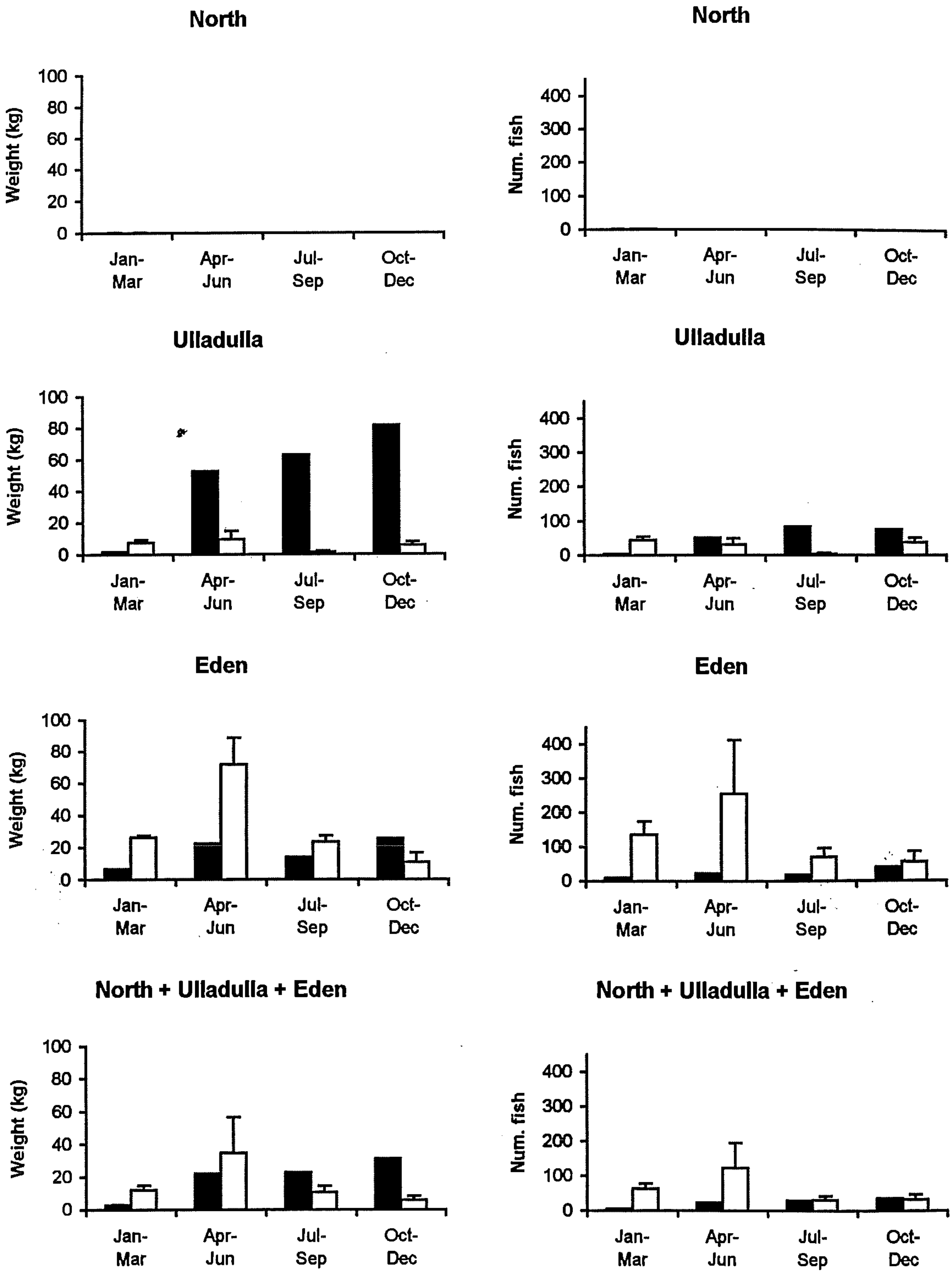


Table 15.1

Annual retained and discarded catches - Mirror dory (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	70
	1995	1	0	0	0	0	0	32
	Mean 1993-95	0	0	0	0	0	0	40
Ulladulla	1993	79	1	77	0	2	1	3
	1994	84	4	75	0	9	4	11
	1995	46	3	37	0	9	3	20
	Mean 1993-95	70	2	63	0	7	2	10
Eden	1993	58	5	39	0	19	5	32
	1994	169	82	38	0	131	82	78
	1995	94	17	32	0	62	17	66
	Mean 1993-95	107	28	36	0	71	28	66
N+U+E	1993	136	5	116	0	21	5	15
	1994	254	82	113	0	141	82	56
	1995	141	18	70	0	71	18	50
	Mean 1993-95	177	28	99	0	78	28	44

Table 15.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	81
	1995	3	2	1	1	2	1	53
	Mean 1993-95	1	1	0	0	1	0	57
Ulladulla	1993	81	4	70	0	11	4	13
	1994	106	17	62	0	43	17	41
	1995	119	12	74	0	46	12	38
	Mean 1993-95	102	7	69	0	33	7	33
Eden	1993	102	15	39	0	63	15	62
	1994	493	268	53	0	440	268	89
	1995	355	87	52	0	303	87	85
	Mean 1993-95	317	94	48	0	269	94	85
N+U+E	1993	183	15	109	0	74	15	40
	1994	599	268	115	0	484	268	81
	1995	477	88	127	1	350	88	73
	Mean 1993-95	420	94	117	0	303	94	72

Figure 15.4, page 1

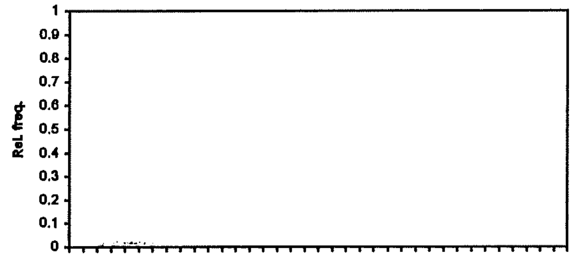
Size distributions of retained and discarded catches of Mirror dory

Retained catch: black bars Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

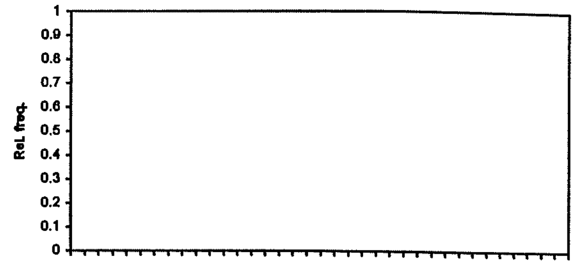
North, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



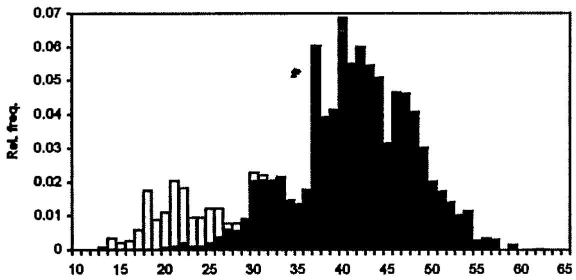
North, 1994

	Retained	Discarded	Total
Obs:	0 (0)	3 (3)	
Co-op:	0 (0)		
Mean L:			



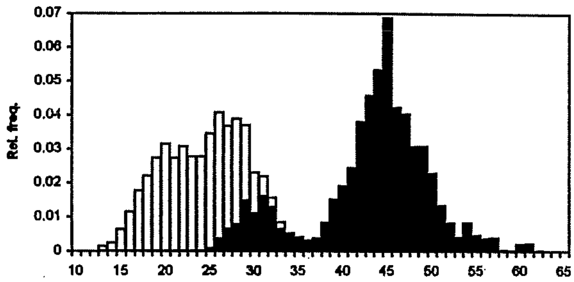
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	866 (22)	266 (48)	
Co-op:	0 (0)		
Mean L:	42.0	21.9	39.3



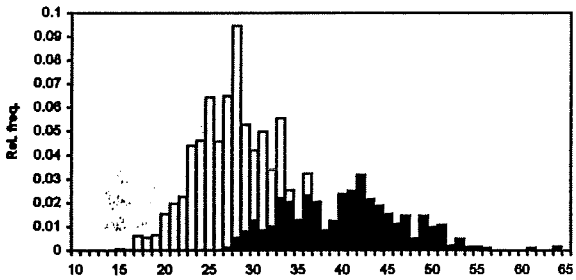
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	554 (12)	946 (45)	
Co-op:	446 (10)		
Mean L:	43.8	23.8	35.6



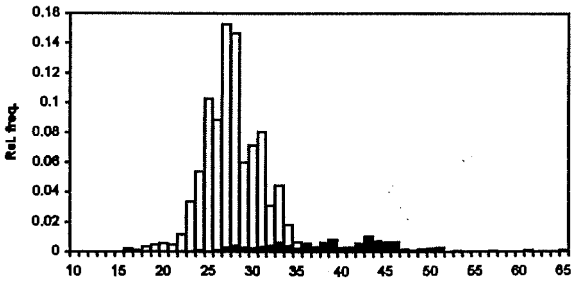
Eden, 1993

	Retained	Discarded	Total
Obs:	274 (15)	575 (61)	
Co-op:	0 (0)		
Mean L:	40.8	27.3	32.5



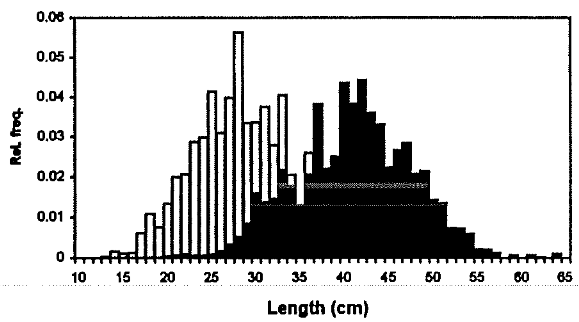
Eden, 1994

	Retained	Discarded	Total
Obs:	94 (3)	621 (67)	
Co-op:	55 (1)		
Mean L:	39.9	28.0	29.3



N + U + E, 1993

	Retained	Discarded	Total
Obs:	1140 (37)	841 (109)	
Co-op:	0 (0)		
Mean L:	41.6	26.5	35.5



N + U + E, 1994

	Retained	Discarded	Total
Obs:	648 (15)	1570 (115)	
Co-op:	501 (11)		
Mean L:	42.0	27.6	30.4

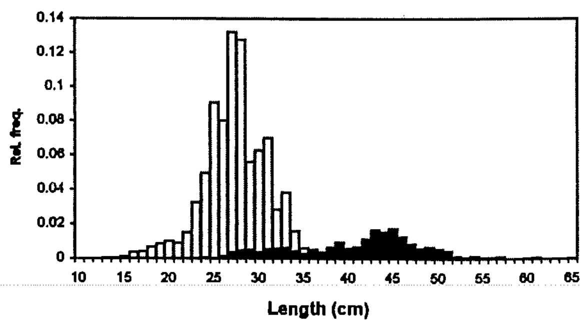
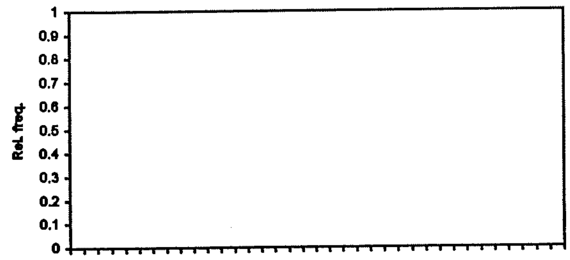


Figure 15.4, page 2

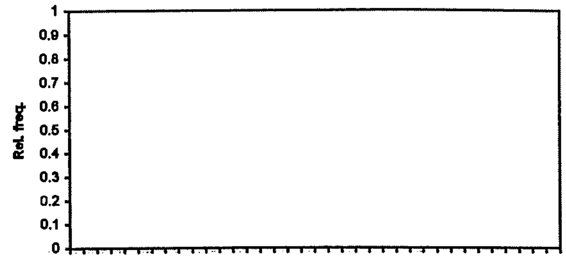
North, 1995

	Retained	Discarded	Total
Obs:	12 (1)	42 (5)	
Co-op:	0 (0)		
Mean L:			



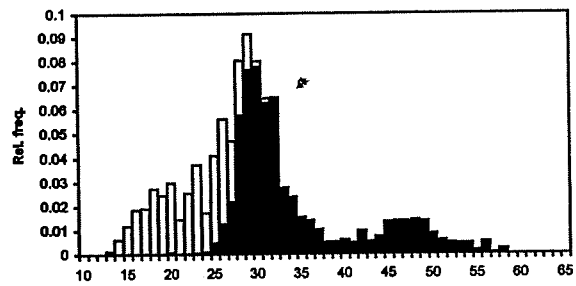
North, 1993-95

	Retained	Discarded	Total
Obs:	12 (1)	45 (8)	
Co-op:	0 (0)		
Mean L:			



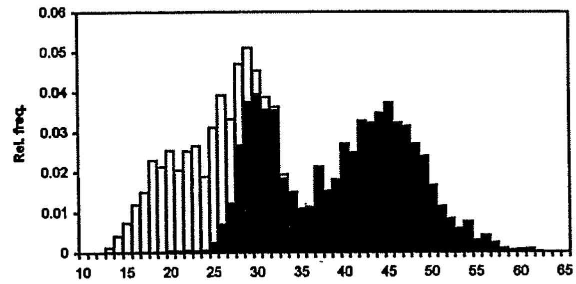
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	388 (7)	396 (54)	
Co-op:	891 (15)		
Mean L:	35.0	23.0	30.4



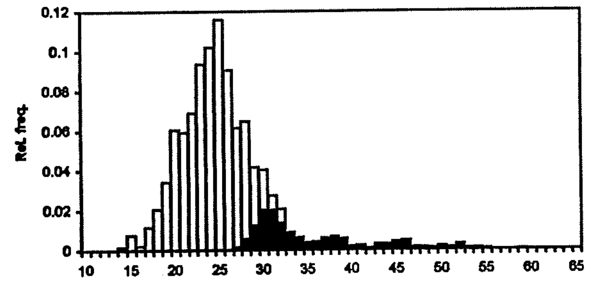
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	1808 (41)	1608 (147)	
Co-op:	1337 (25)		
Mean L:	40.0	23.2	34.5



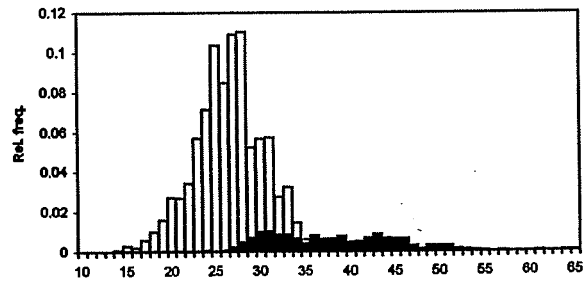
Eden, 1995

	Retained	Discarded	Total
Obs:	292 (4)	558 (70)	
Co-op:	271 (4)		
Mean L:	36.0	24.5	26.2



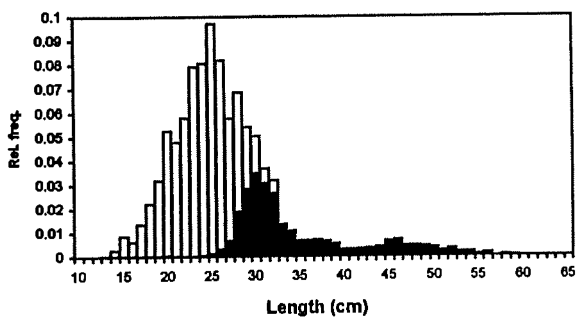
Eden, 1993-95

	Retained	Discarded	Total
Obs:	660 (22)	1754 (198)	
Co-op:	326 (5)		
Mean L:	38.8	26.6	28.5



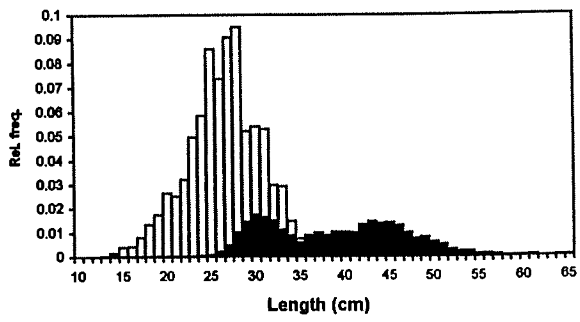
N + U + E, 1995

	Retained	Discarded	Total
Obs:	692 (12)	996 (129)	
Co-op:	1162 (19)		
Mean L:	35.4	24.3	27.2



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	2480 (64)	3407 (353)	
Co-op:	1663 (30)		
Mean L:	39.5	26.3	29.9



Appendix A.16

Ocean perch (offshore form)

Helicolenus percoides (offshore form)

Figure 16.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 16.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 16.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 16.1
Annual retained and discarded catches (t)

Table 16.2
Annual retained and discarded catches (number of fish)

Figure 16.4
Size distributions of retained and discarded catches

Figure 16.1

Retained and discarded catches (kg per fisher-day) - Ocean perch (off.)
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

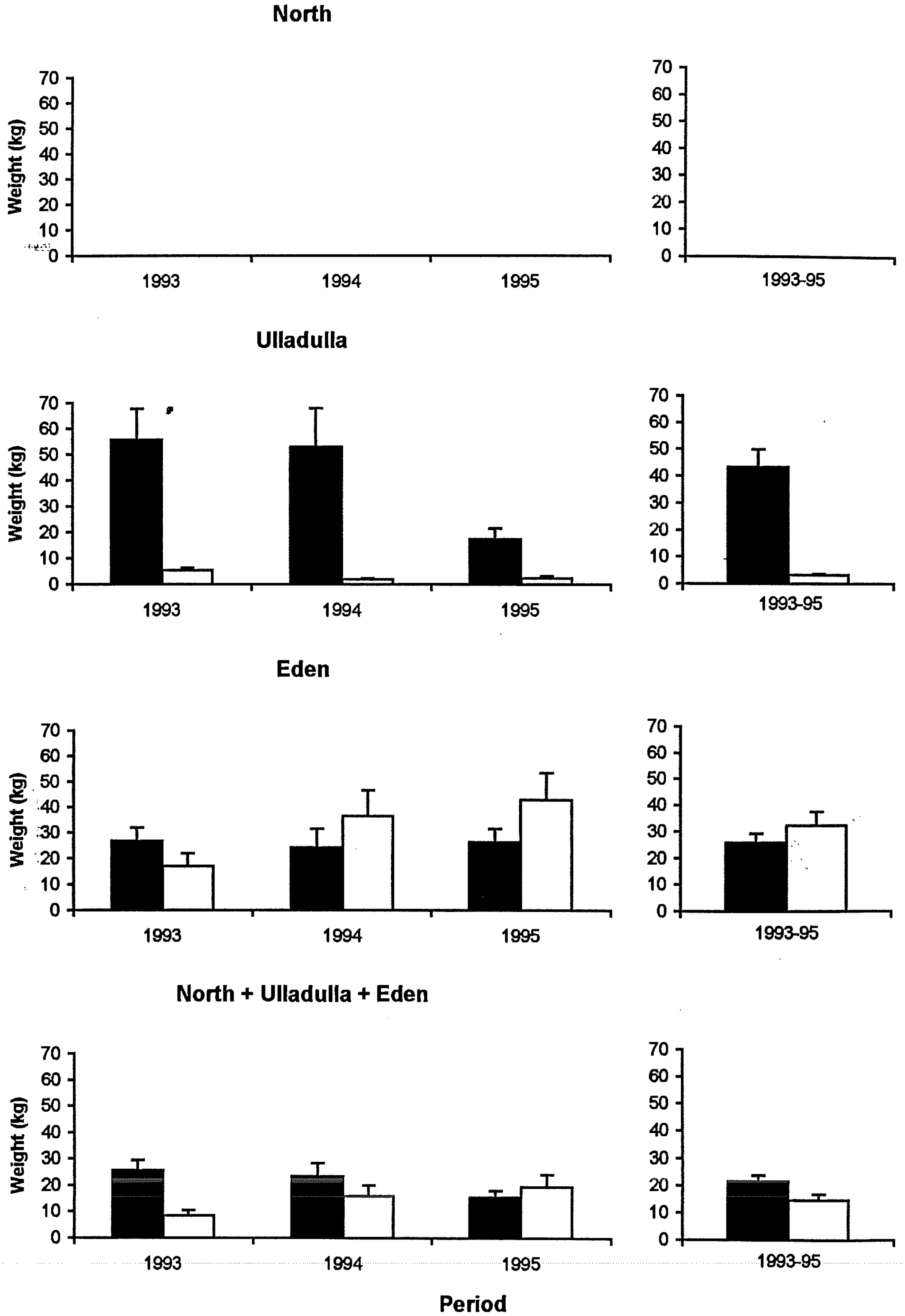


Figure 16.2

Retained and discarded catches (number of fish per fisher-day) - Ocean perch (off.)
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

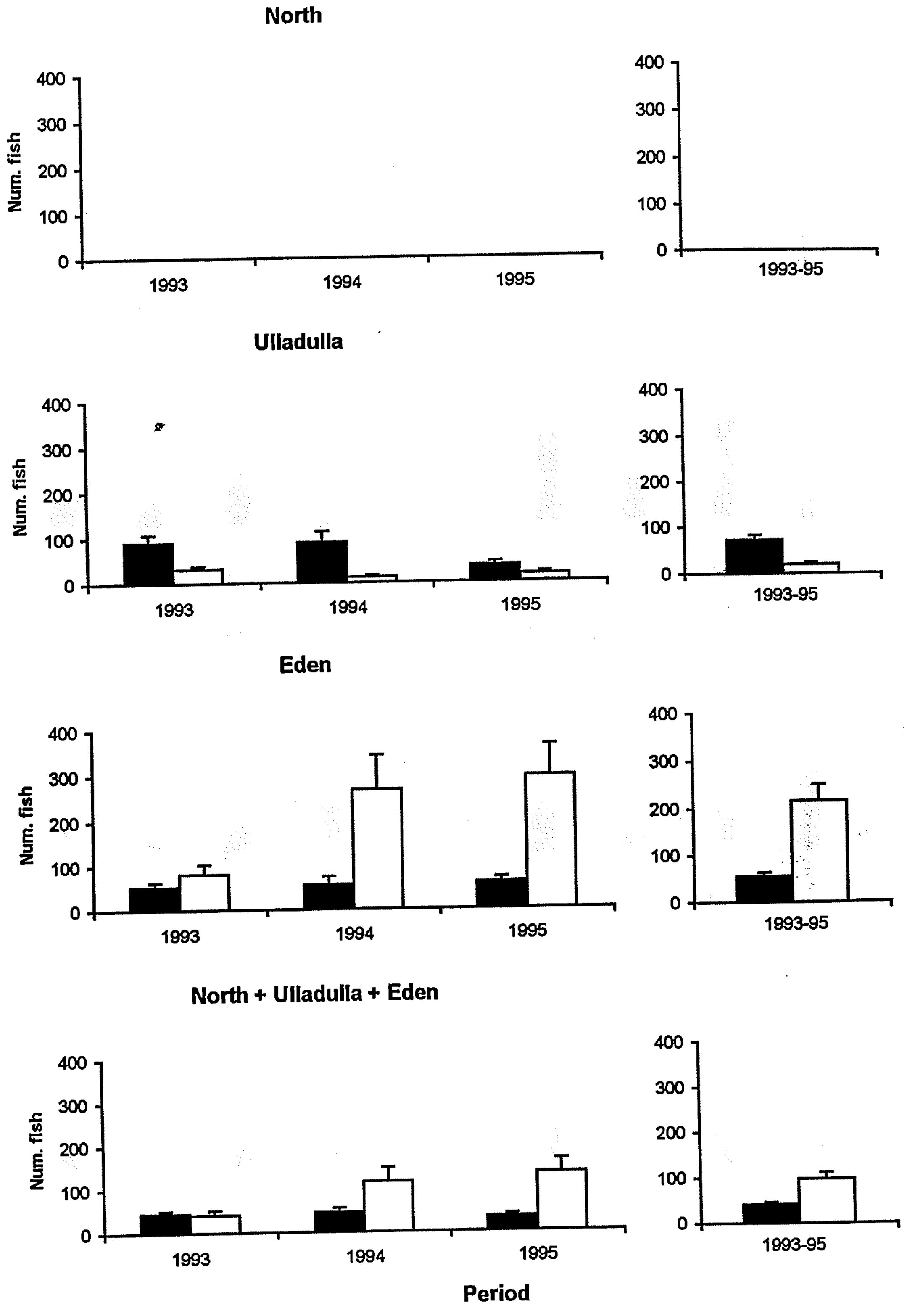


Figure 16.3

Retained and discarded catches (per fisher-day) - Ocean perch (off.)
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

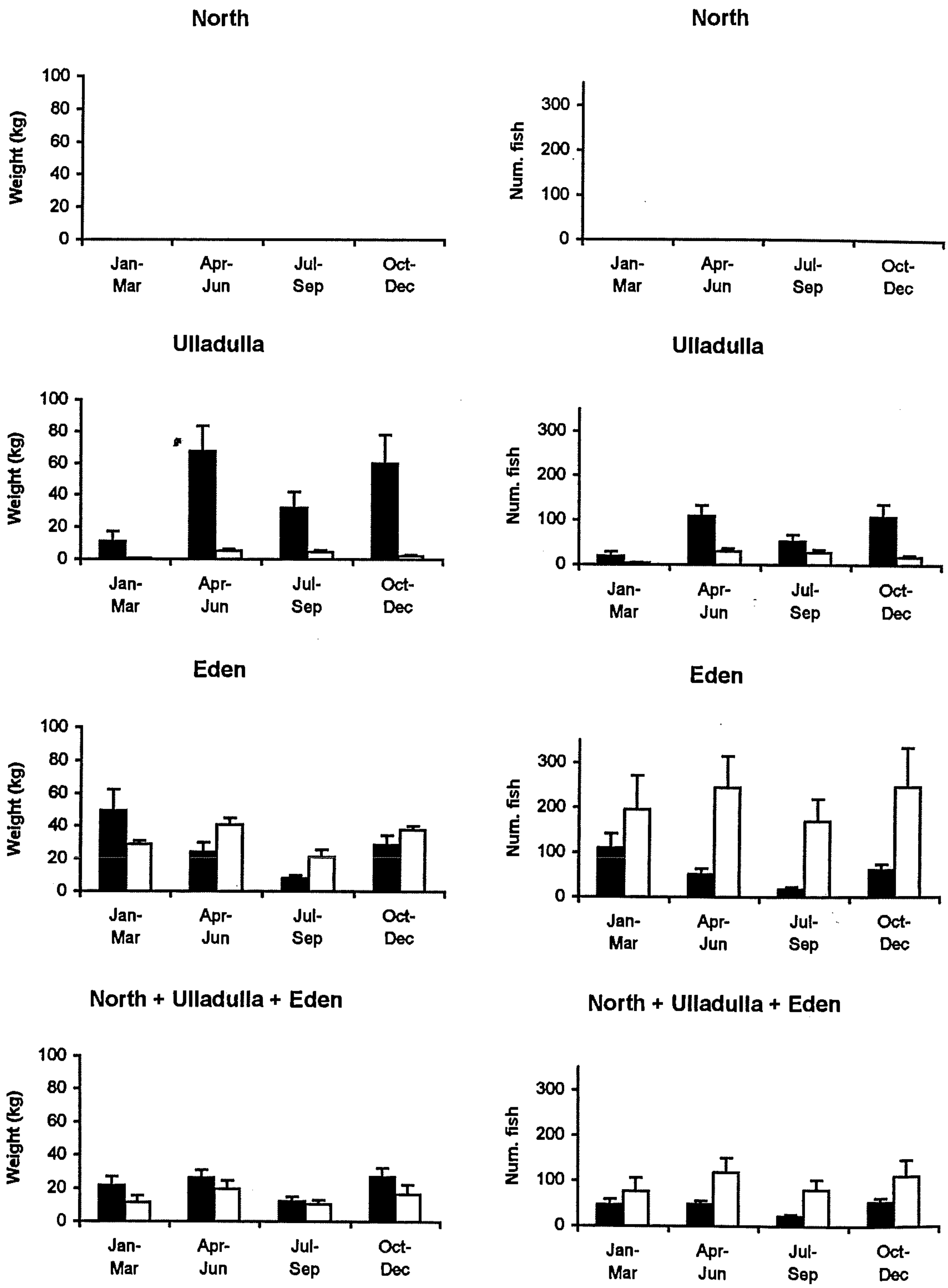


Table 16.1

Annual retained and discarded catches - Ocean perch (off.) (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	0	+/- 0	0	+/- 0	0	+/- 0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	78	16	71	16	7	1	9
	1994	68	19	65	18	2	1	3
	1995	21	5	19	4	3	1	12
	Mean 1993-95	56	8	52	8	4	1	7
Eden	1993	90	19	55	11	35	10	39
	1994	124	29	50	15	75	20	60
	1995	146	30	55	11	91	22	62
	Mean 1993-95	120	15	53	7	67	11	56
N+U+E	1993	169	25	127	19	42	10	25
	1994	192	35	115	24	77	20	40
	1995	168	30	74	12	93	22	56
	Mean 1993-95	176	17	105	11	71	11	40

Table 16.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	0	+/- 0	0	+/- 0	0	+/- 0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	153	28	113	23	40	7	26
	1994	125	30	110	28	15	4	12
	1995	56	12	38	9	18	6	31
	Mean 1993-95	112	14	87	13	24	3	22
Eden	1993	273	61	107	22	166	45	61
	1994	665	172	116	37	549	157	83
	1995	750	165	125	25	625	148	83
	Mean 1993-95	563	82	116	17	447	74	79
N+U+E	1993	426	67	221	32	205	46	48
	1994	790	174	226	47	565	157	71
	1995	806	165	163	26	643	146	80
	Mean 1993-95	674	83	203	21	471	74	70

Figure 16.4, page 1

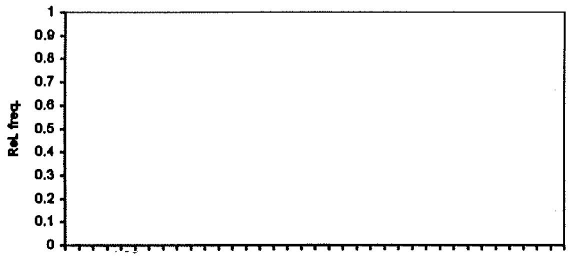
Size distributions of retained and discarded catches of Ocean perch (off.)

Retained catch: black bars   Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

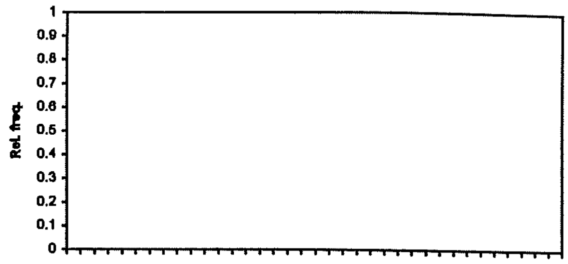
North, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



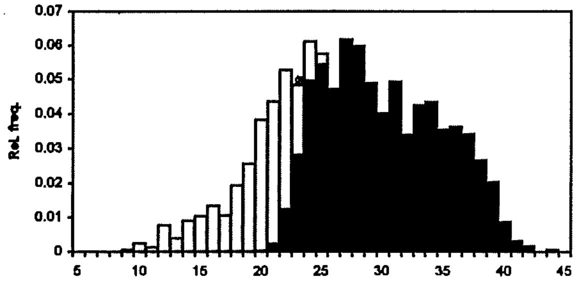
North, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



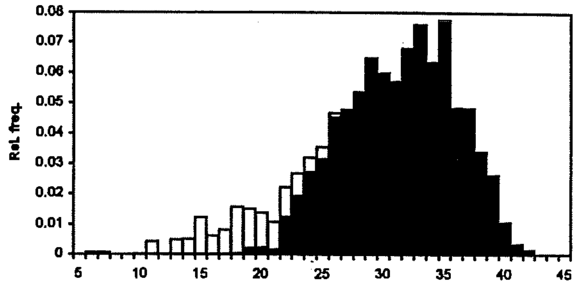
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	1142 (12)	767 (61)	
Co-op:	0 (0)		
Mean L:	30.7	20.0	27.9



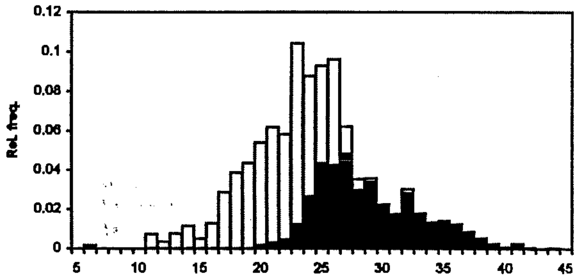
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	747 (10)	338 (38)	
Co-op:	706 (9)		
Mean L:	31.9	19.1	30.4



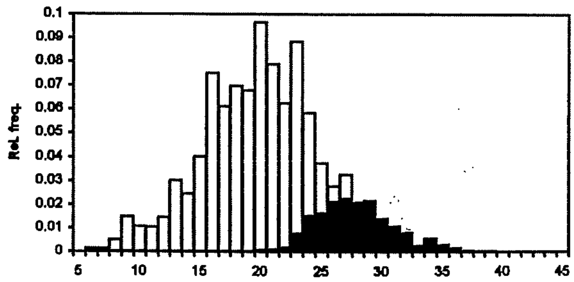
Eden, 1993

	Retained	Discarded	Total
Obs:	1213 (21)	696 (76)	
Co-op:	0 (0)		
Mean L:	29.4	22.0	24.9



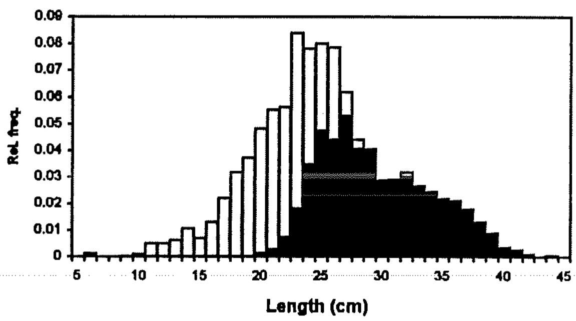
Eden, 1994

	Retained	Discarded	Total
Obs:	488 (9)	1145 (80)	
Co-op:	242 (2)		
Mean L:	28.4	19.3	20.9



N + U + E, 1993

	Retained	Discarded	Total
Obs:	2355 (33)	1463 (137)	
Co-op:	0 (0)		
Mean L:	30.1	21.6	26.0



N + U + E, 1994

	Retained	Discarded	Total
Obs:	1235 (19)	1483 (118)	
Co-op:	948 (11)		
Mean L:	30.1	19.3	22.4

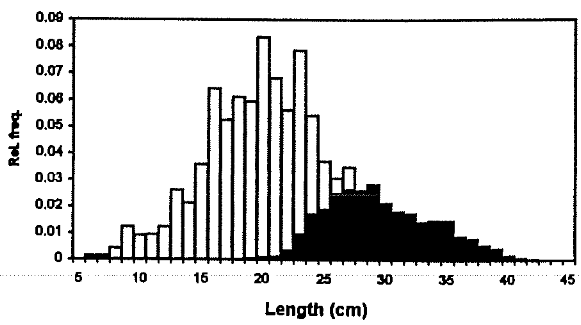
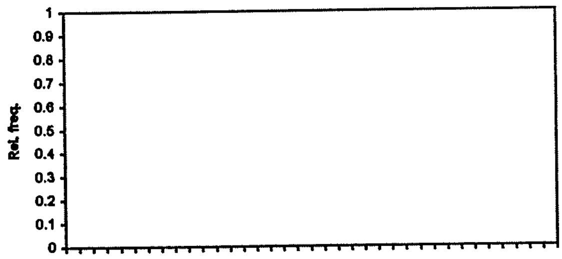


Figure 16.4, page 2

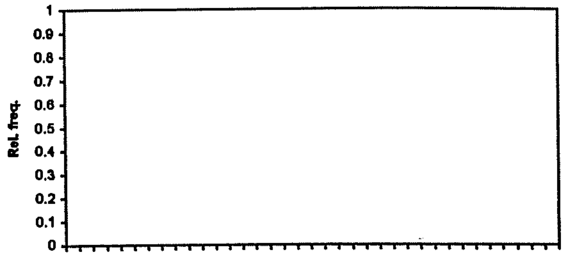
North, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (2)	
Co-op:	0 (0)		
Mean L:			



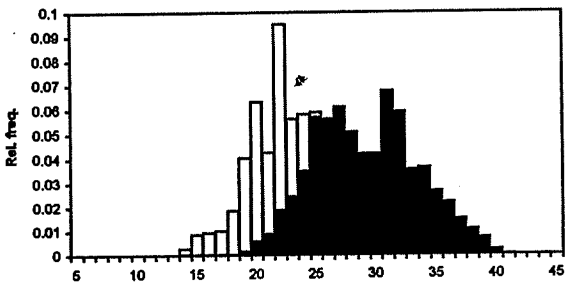
North, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	0 (2)	
Co-op:	0 (0)		
Mean L:			



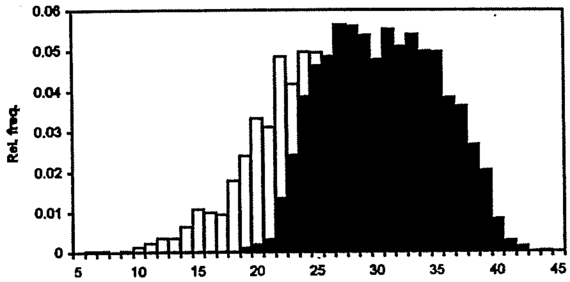
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	479 (6)	193 (31)	
Co-op:	597 (6)		
Mean L:	29.7	21.1	27.0



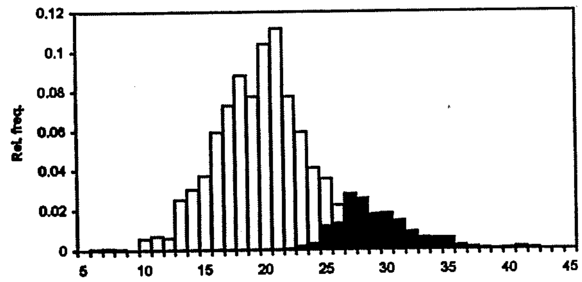
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	2368 (27)	1298 (130)	
Co-op:	1304 (16)		
Mean L:	31.1	20.1	28.7



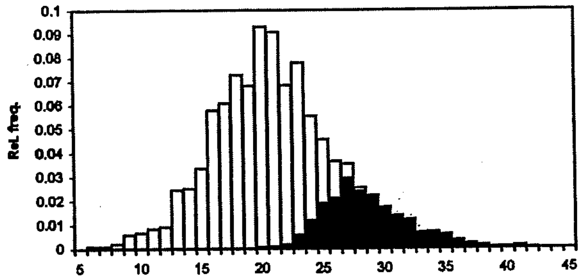
Eden, 1995

	Retained	Discarded	Total
Obs:	1263 (12)	1379 (78)	
Co-op:	107 (1)		
Mean L:	29.7	19.7	21.4



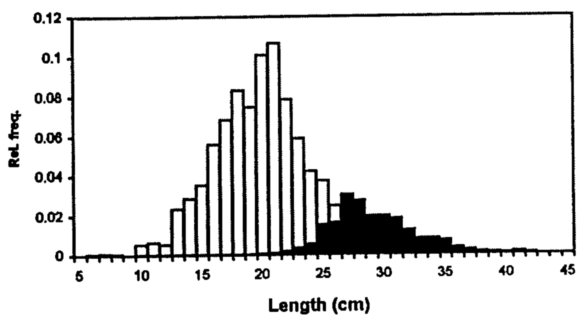
Eden, 1993-95

	Retained	Discarded	Total
Obs:	2964 (42)	3220 (234)	
Co-op:	349 (3)		
Mean L:	29.2	19.8	21.7



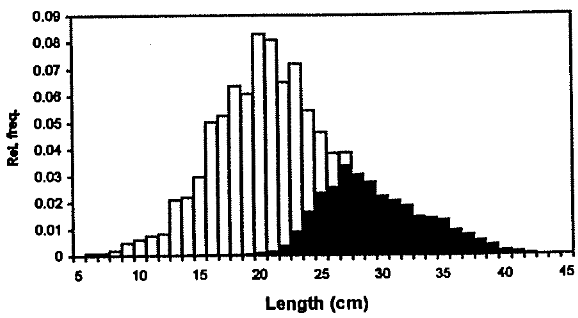
N + U + E, 1995

	Retained	Discarded	Total
Obs:	1742 (17)	1672 (111)	
Co-op:	704 (7)		
Mean L:	29.7	19.7	21.8



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	5332 (69)	4518 (366)	
Co-op:	1652 (18)		
Mean L:	30.0	19.8	22.9



Appendix A.17

Ocean perch (inshore form)

Helicolenus percoides (inshore form)

Figure 17.1

Retained and discarded catches (kg per fisher-day) - Ocean perch (Ins.)
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

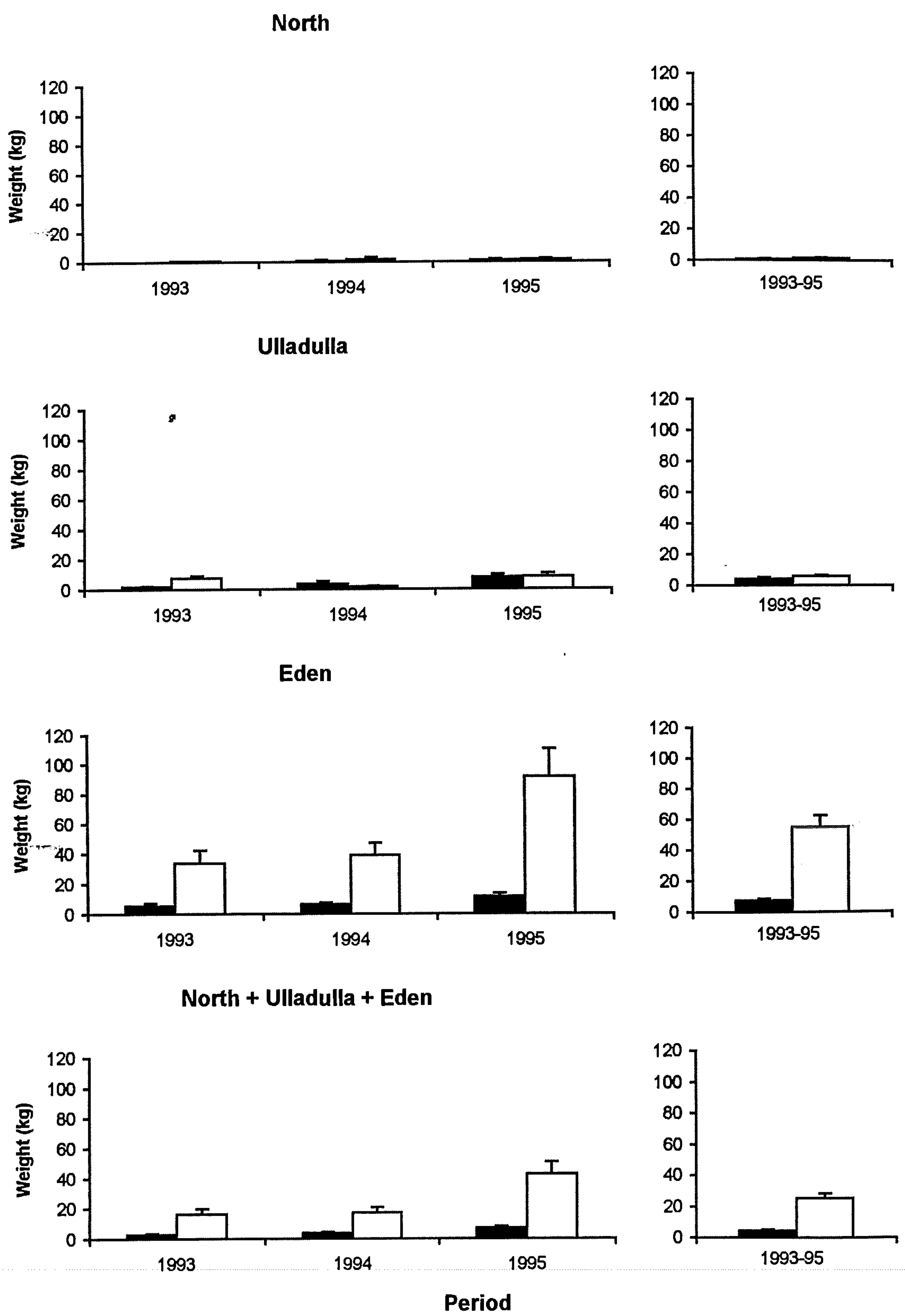


Figure 17.2

Retained and discarded catches (number of fish per fisher-day) - Ocean perch (Ins.)
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

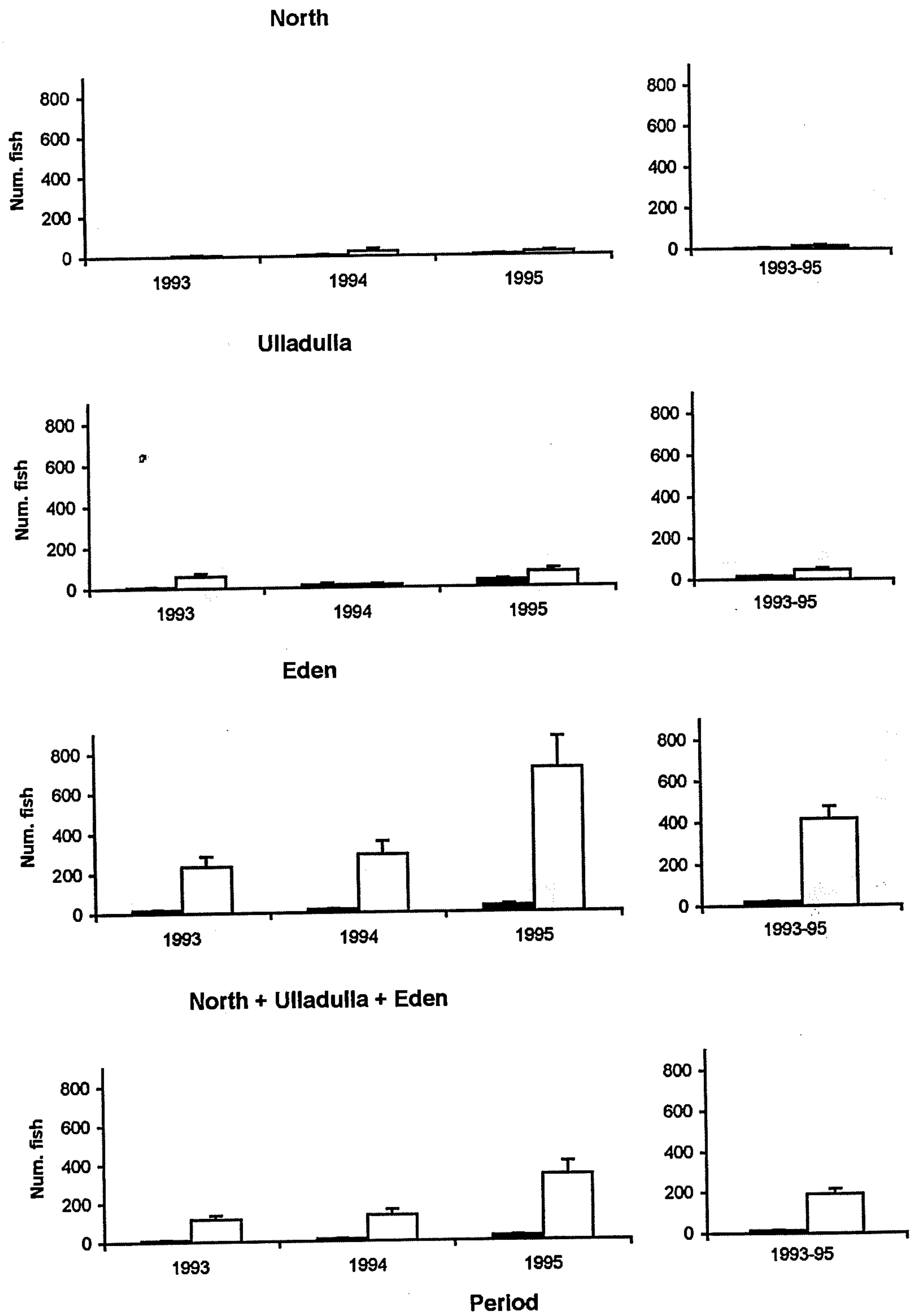


Figure 17.3

Retained and discarded catches (per fisher-day) - Ocean perch (Ins.)
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

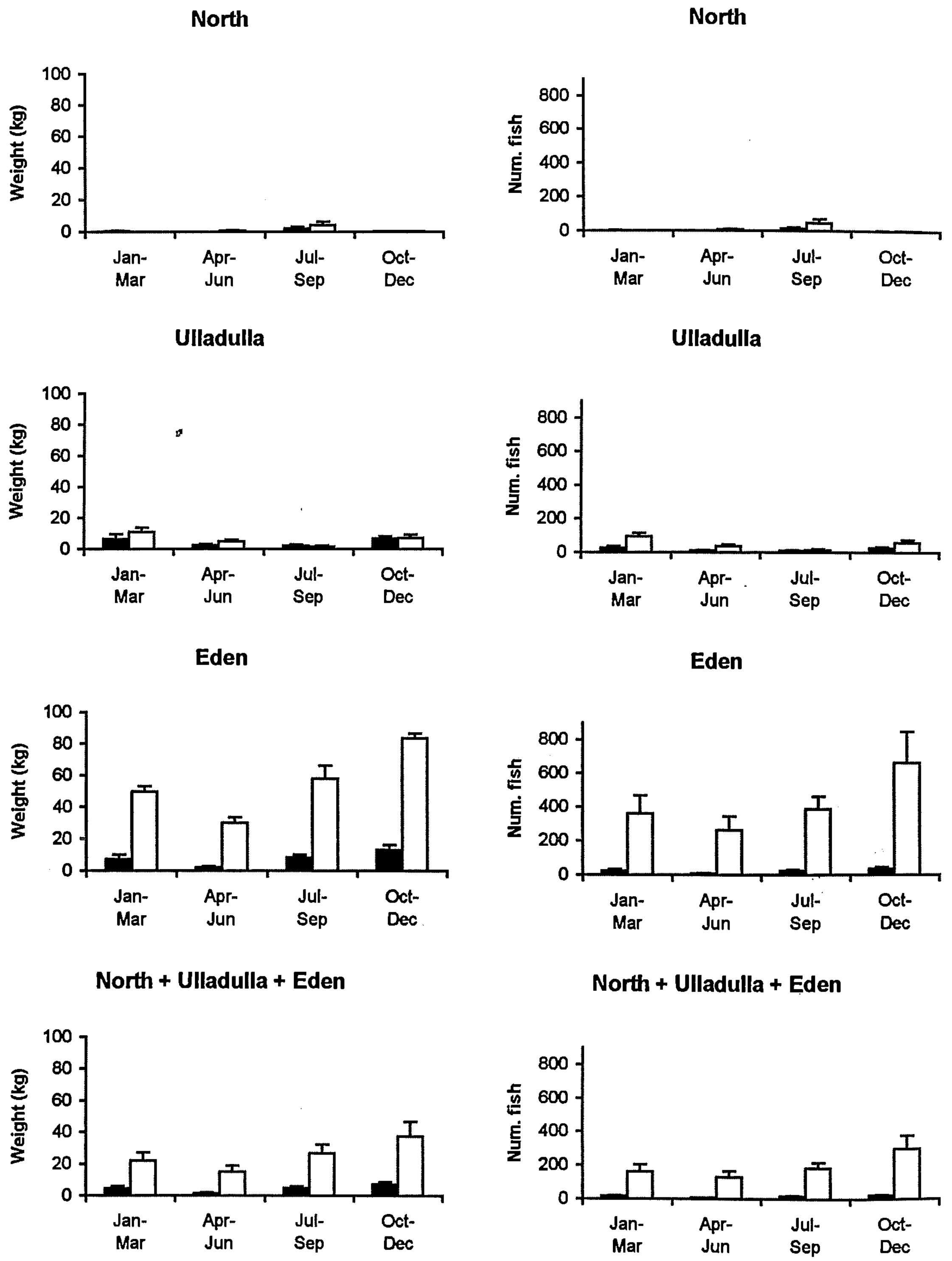


Table 17.1

Annual retained and discarded catches - Ocean perch (Ins.) (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	1 +/-	0	0 +/-	0	1 +/-	0	*88*
	1994	4	2	1	1	3	2	*67*
	1995	4	2	2	1	2	1	*56*
	Mean 1993-95	3	1	1	0	2	1	*65*
Ulladulla	1993	12	2	2	1	10	2	*82*
	1994	6	2	4	2	2	1	*31*
	1995	18	3	9	2	9	2	*51*
	Mean 1993-95	12	2	5	1	7	1	*58*
Eden	1993	81	19	11	4	70	18	*86*
	1994	93	18	13	2	80	17	*86*
	1995	217	42	24	5	193	40	*89*
	Mean 1993-95	130	17	16	2	114	16	*88*
N+U+E	1993	93	19	13	4	80	18	*86*
	1994	104	18	19	3	85	17	*82*
	1995	239	43	34	5	205	40	*86*
	Mean 1993-95	145	17	22	3	123	16	*85*

Table 17.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	9 +/-	3	1 +/-	0	8 +/-	3	*91*
	1994	41	26	7	5	34	24	*83*
	1995	36	14	10	6	26	10	*72*
	Mean 1993-95	29	10	6	3	23	9	*79*
Ulladulla	1993	83	17	8	2	75	16	*90*
	1994	34	11	18	9	16	6	*48*
	1995	115	21	37	7	78	17	*68*
	Mean 1993-95	78	10	21	4	57	8	*73*
Eden	1993	515	108	33	11	482	106	*94*
	1994	631	138	36	6	595	138	*94*
	1995	1,589	333	68	14	1,521	328	*96*
	Mean 1993-95	912	126	46	6	866	124	*95*
N+U+E	1993	608	110	42	11	566	107	*93*
	1994	707	141	61	12	645	138	*91*
	1995	1,740	334	115	16	1,625	329	*93*
	Mean 1993-95	1,018	126	73	8	945	124	*93*

Figure 17.4, page 1

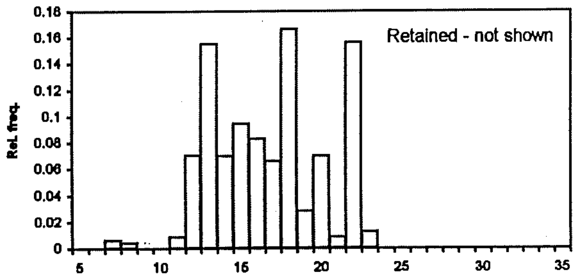
Size distributions of retained and discarded catches of Ocean perch (Ins.)

Retained catch: black bars   Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

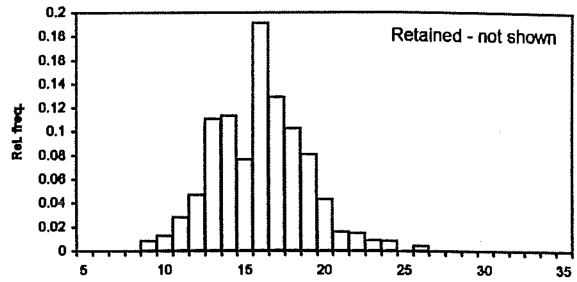
North, 1993

	Retained	Discarded	Total
Obs:	0 (0)	127 (17)	
Co-op:	0 (0)		
Mean L:		17.2	



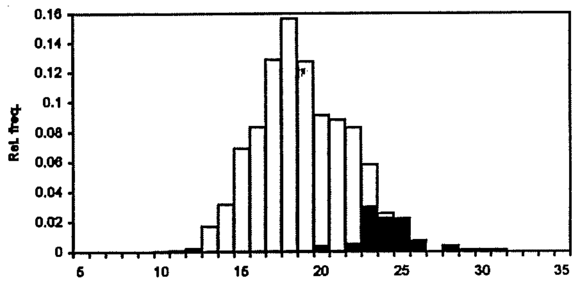
North, 1994

	Retained	Discarded	Total
Obs:	0 (0)	264 (18)	
Co-op:	0 (0)		
Mean L:		16.5	



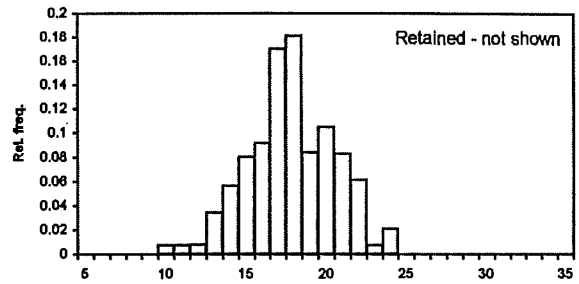
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	56 (5)	1613 (70)	
Co-op:	0 (0)		
Mean L:	24.7	18.8	19.4



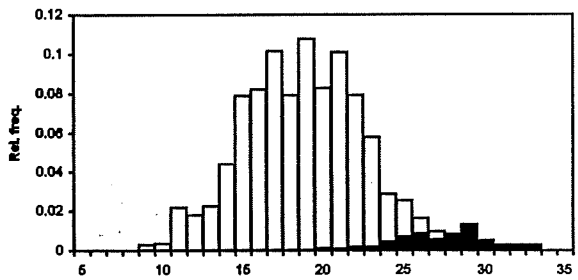
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	0 (0)	324 (24)	
Co-op:	22 (1)		
Mean L:		18.3	



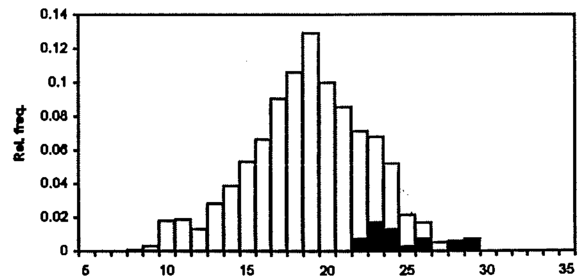
Eden, 1993

	Retained	Discarded	Total
Obs:	72 (4)	1803 (111)	
Co-op:	0 (0)		
Mean L:	28.1	19.0	19.6



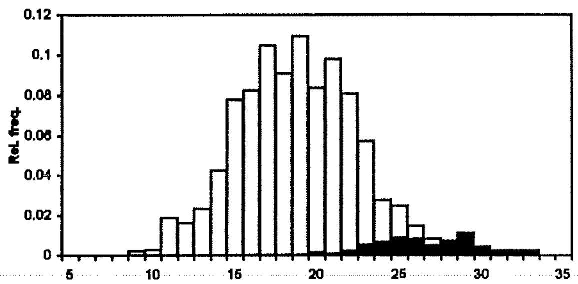
Eden, 1994

	Retained	Discarded	Total
Obs:	26 (1)	1136 (116)	
Co-op:	0 (0)		
Mean L:	25.2	19.1	19.4



N + U + E, 1993

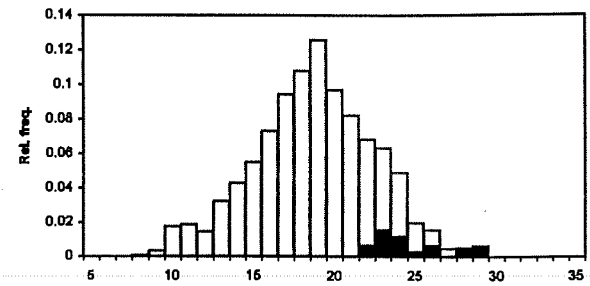
	Retained	Discarded	Total
Obs:	128 (9)	3543 (198)	
Co-op:	0 (0)		
Mean L:	27.4	18.9	19.5



Length (cm)

N + U + E, 1994

	Retained	Discarded	Total
Obs:	26 (1)	1724 (158)	
Co-op:	22 (1)		
Mean L:	25.2	18.9	19.2

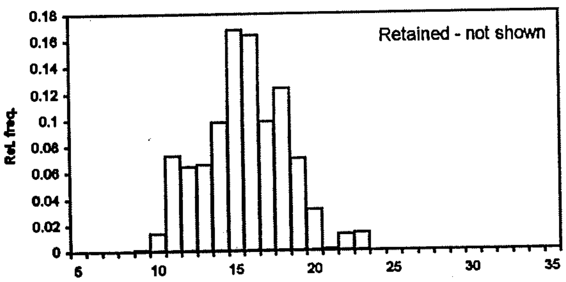


Length (cm)

Figure 17.4, page 2

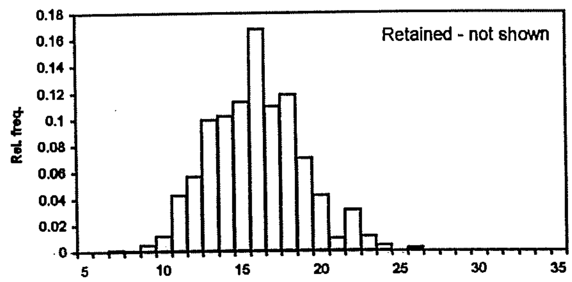
North, 1995

	Retained	Discarded	Total
Obs:	106 (3)	237 (32)	
Co-op:	0 (0)		
Mean L:		16.1	



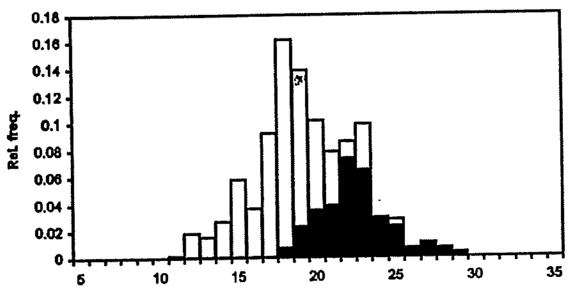
North, 1993-95

	Retained	Discarded	Total
Obs:	106 (3)	628 (67)	
Co-op:	0 (0)		
Mean L:		16.4	



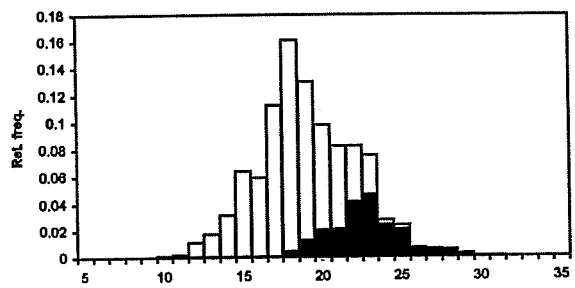
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	112 (2)	630 (71)	
Co-op:	0 (0)		
Mean L:	22.9	18.5	19.9



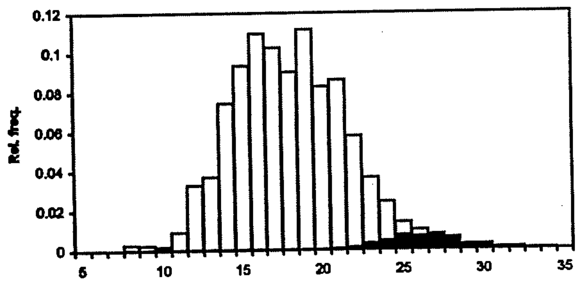
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	168 (7)	2567 (165)	
Co-op:	22 (1)		
Mean L:	23.2	18.6	19.6



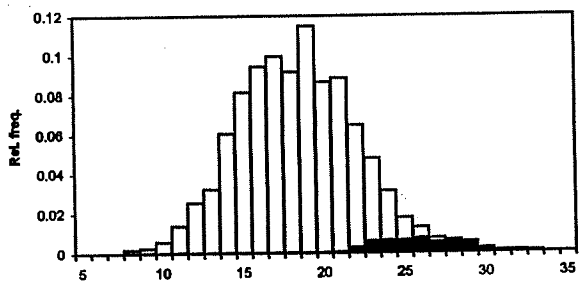
Eden, 1995

	Retained	Discarded	Total
Obs:	375 (4)	2908 (135)	
Co-op:	191 (2)		
Mean L:	27.0	18.2	18.6



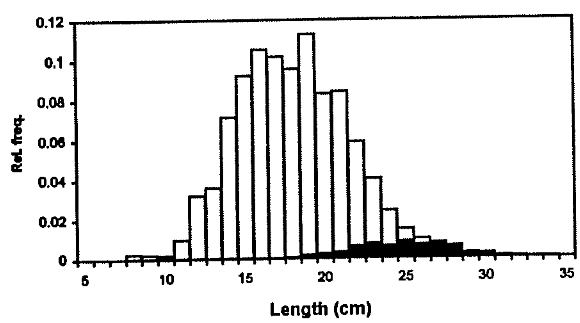
Eden, 1993-95

	Retained	Discarded	Total
Obs:	473 (9)	5847 (362)	
Co-op:	191 (2)		
Mean L:	26.8	18.5	19.0



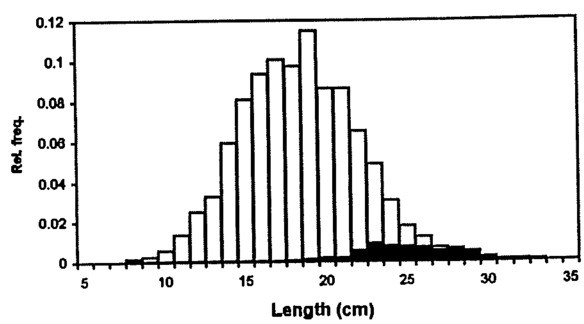
N + U + E, 1995

	Retained	Discarded	Total
Obs:	593 (9)	3775 (238)	
Co-op:	191 (2)		
Mean L:	25.5	18.2	18.6



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	747 (19)	9042 (694)	
Co-op:	213 (3)		
Mean L:	25.9	18.5	18.9



Appendix A.18

John dory

Zeus faber

Figure 18.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 18.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 18.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 18.1
Annual retained and discarded catches (t)

Table 18.2
Annual retained and discarded catches (number of fish)

Figure 18.4
Size distributions of retained and discarded catches

Figure 18.1

Retained and discarded catches (kg per fisher-day) - John dory
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

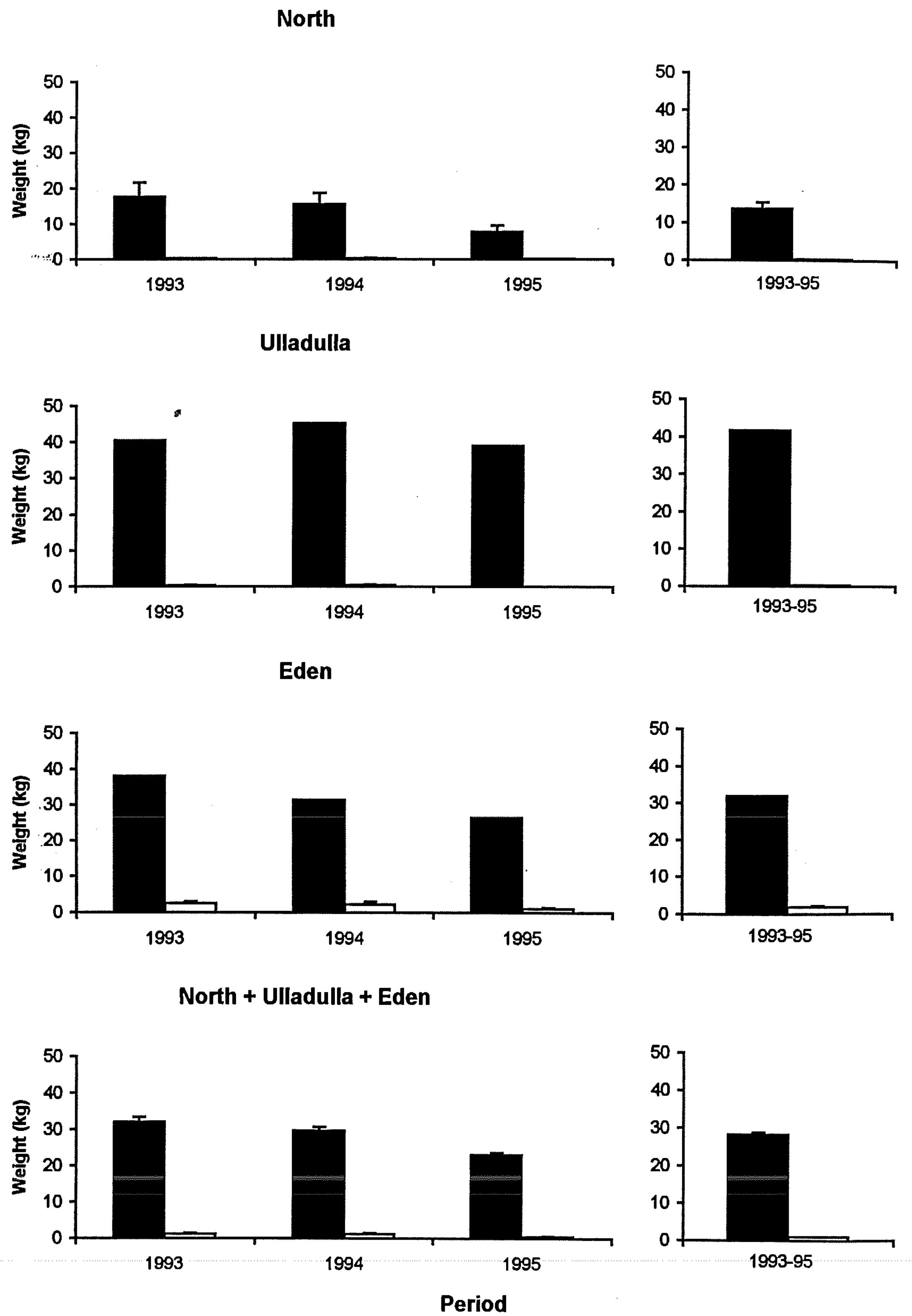


Figure 18.2

Retained and discarded catches (number of fish per fisher-day) - John dory

by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

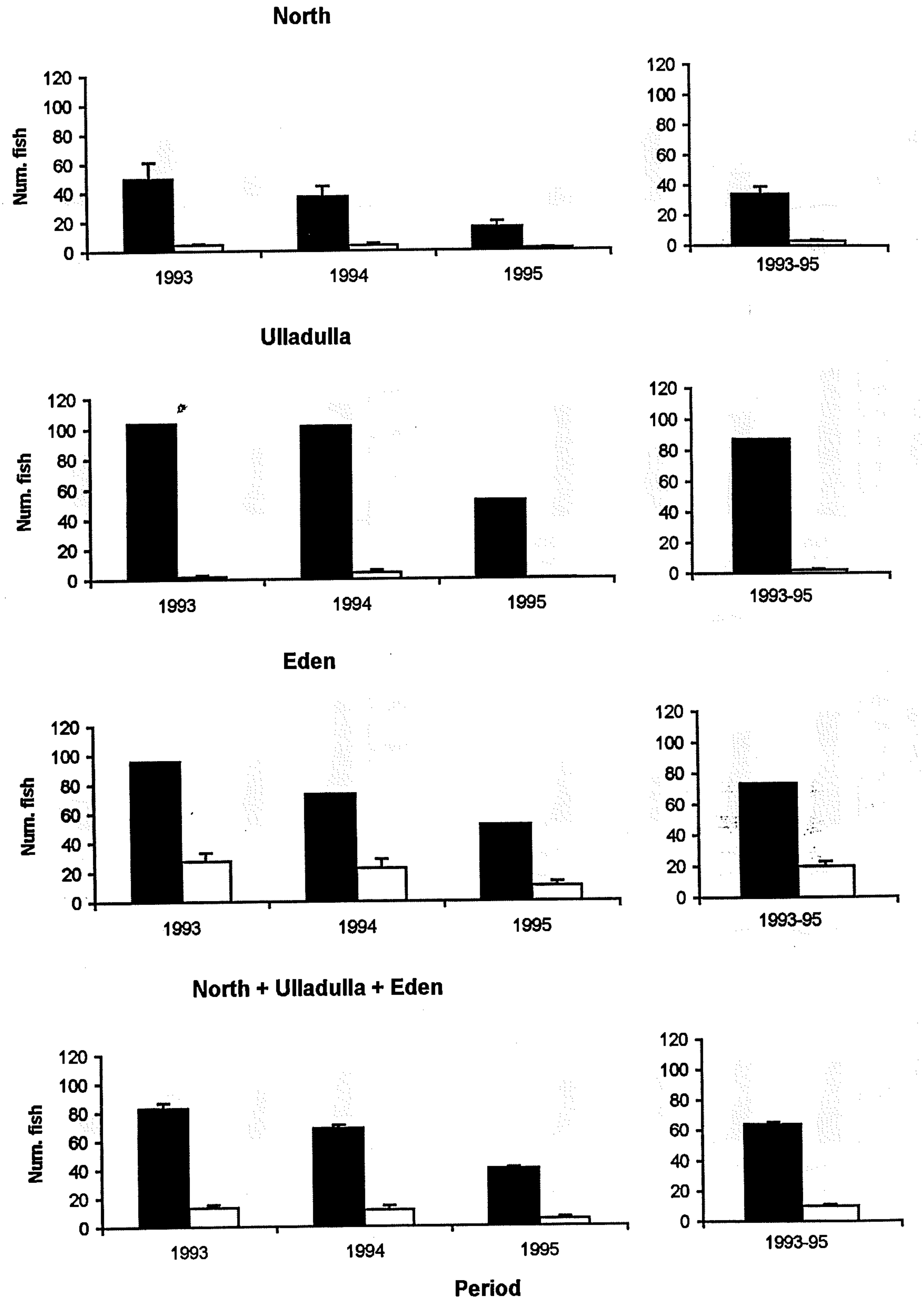


Figure 18.3

Retained and discarded catches (per fisher-day) - John dory

by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

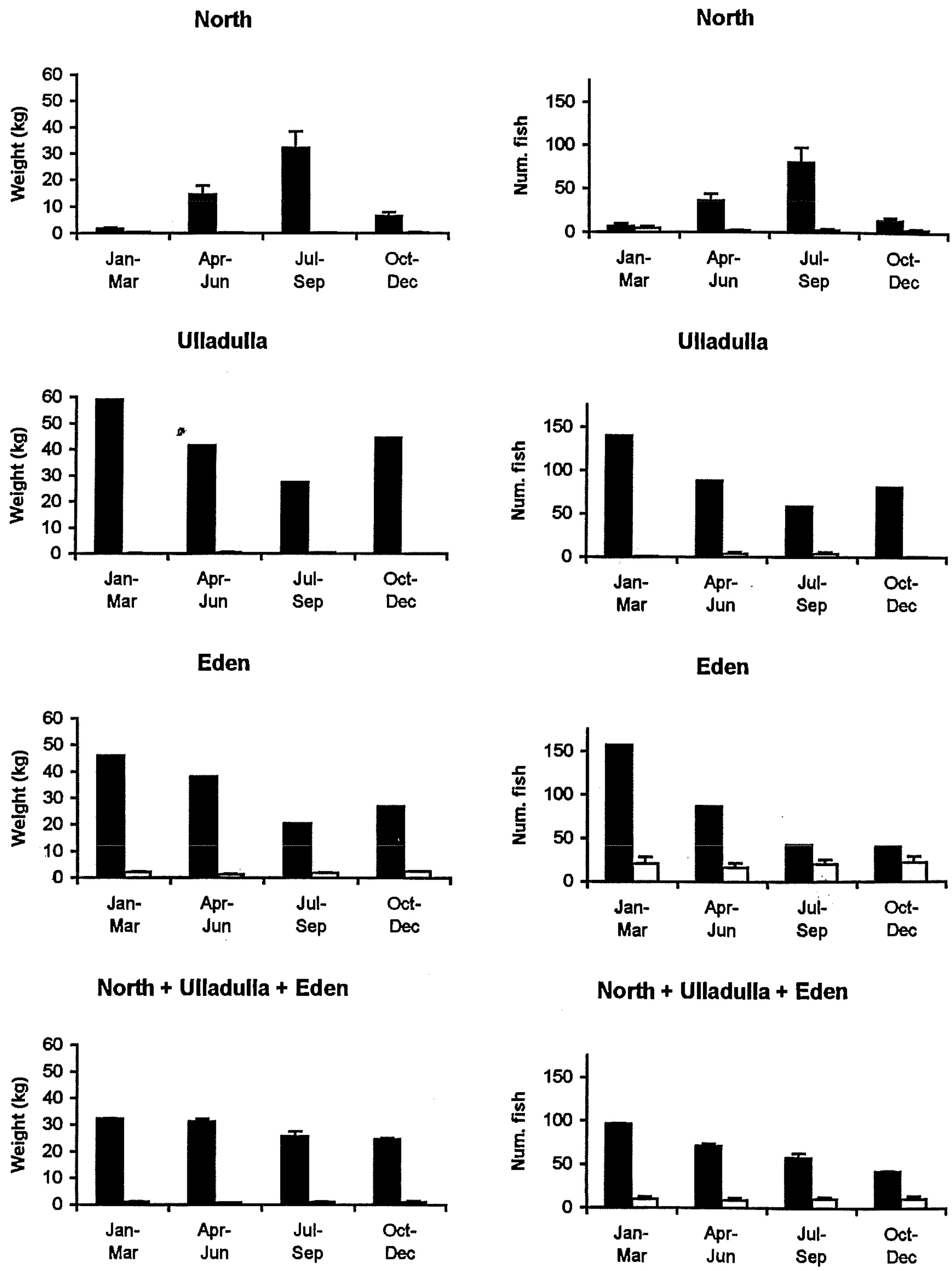


Table 18.1

Annual retained and discarded catches - John dory (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	29 +/-	6	28 +/-	6	0 +/-	0	*2*
	1994	25	5	25	5	0	0	*2*
	1995	13	3	12	3	0	0	*2*
	Mean 1993-95	22	3	22	3	0	0	*2*
Ulladulla	1993	52	0	52	0	0	0	*1*
	1994	56	0	56	0	1	0	*1*
	1995	43	0	43	0	0	0	*0*
	Mean 1993-95	50	0	50	0	0	0	*1*
Eden	1993	84	1	79	0	5	1	*6*
	1994	69	1	64	0	5	1	*7*
	1995	58	1	56	0	2	1	*4*
	Mean 1993-95	70	1	66	0	4	1	*6*
N+U+E	1993	165	7	159	6	6	1	*4*
	1994	151	5	145	5	6	1	*4*
	1995	113	3	111	3	2	1	*2*
	Mean 1993-95	143	3	138	3	5	1	*3*

Table 18.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	86 +/-	19	79 +/-	19	7 +/-	1	*8*
	1994	65	12	59	12	6	2	*9*
	1995	28	6	25	6	2	1	*9*
	Mean 1993-95	59	8	54	8	5	1	*8*
Ulladulla	1993	135	1	133	0	2	1	*2*
	1994	131	2	125	0	5	2	*4*
	1995	57	0	57	0	0	0	*0*
	Mean 1993-95	108	1	105	0	3	1	*2*
Eden	1993	255	12	198	0	57	12	*22*
	1994	196	13	150	0	46	13	*23*
	1995	130	7	109	0	21	7	*16*
	Mean 1993-95	194	6	153	0	41	6	*21*
N+U+E	1993	476	22	410	19	66	12	*14*
	1994	391	18	334	12	57	13	*15*
	1995	215	9	192	6	24	7	*11*
	Mean 1993-95	361	10	312	8	49	6	*14*

Figure 18.4, page 1

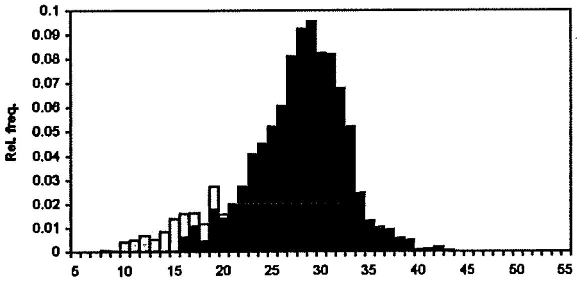
Size distributions of retained and discarded catches of John dory

Retained catch: black bars Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

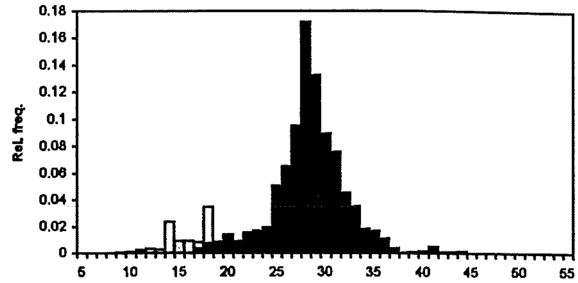
North, 1993

	Retained	Discarded	Total
Obs:	1767 (68)	259 (68)	
Co-op:	0 (0)		
Mean L:	28.6	15.7	27.6



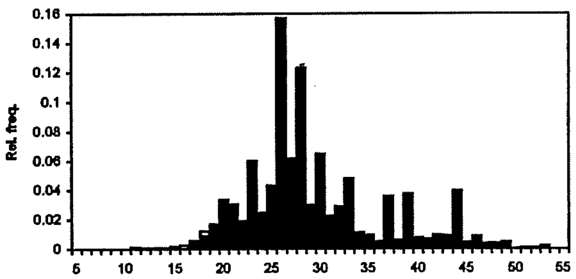
North, 1994

	Retained	Discarded	Total
Obs:	1223 (32)	76 (30)	
Co-op:	0 (0)		
Mean L:	29.0	16.4	27.9



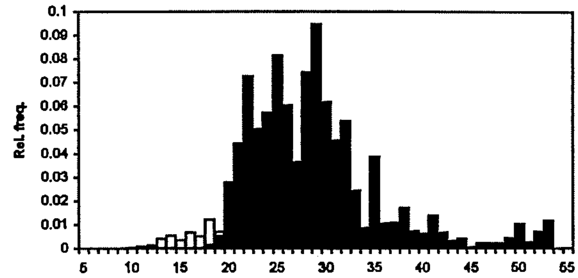
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	797 (18)	121 (24)	
Co-op:	0 (0)		
Mean L:	30.1	16.8	29.9



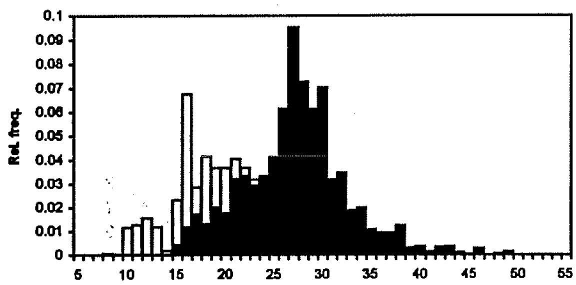
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	241 (7)	132 (26)	
Co-op:	162 (4)		
Mean L:	29.6	16.5	29.0



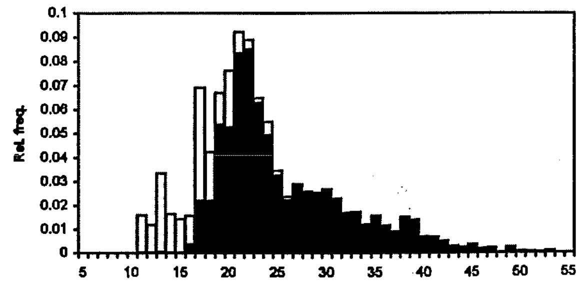
Eden, 1993

	Retained	Discarded	Total
Obs:	1076 (30)	176 (50)	
Co-op:	0 (0)		
Mean L:	27.8	16.7	25.3



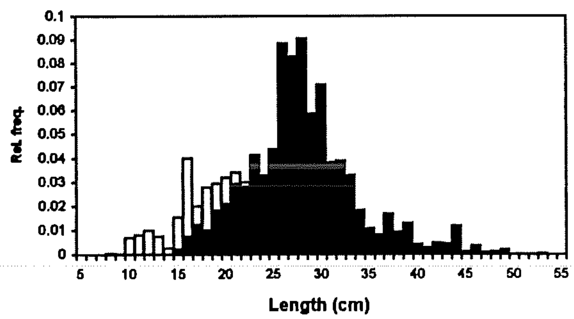
Eden, 1994

	Retained	Discarded	Total
Obs:	737 (15)	68 (26)	
Co-op:	202 (2)		
Mean L:	26.4	17.0	24.2



N + U + E, 1993

	Retained	Discarded	Total
Obs:	3640 (106)	555 (132)	
Co-op:	0 (0)		
Mean L:	28.7	16.6	27.0



N + U + E, 1994

	Retained	Discarded	Total
Obs:	2201 (64)	276 (81)	
Co-op:	354 (6)		
Mean L:	28.0	16.9	26.4

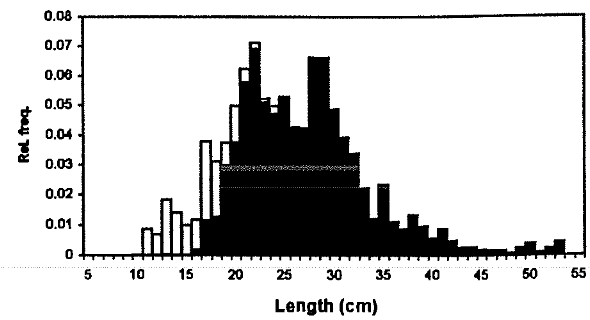
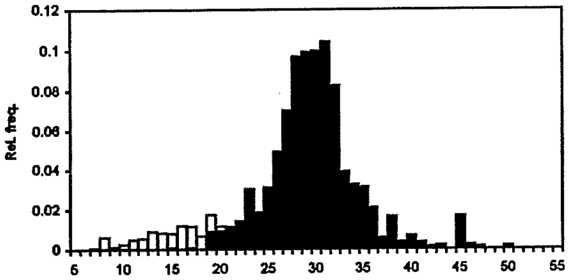


Figure 18.4, page 2

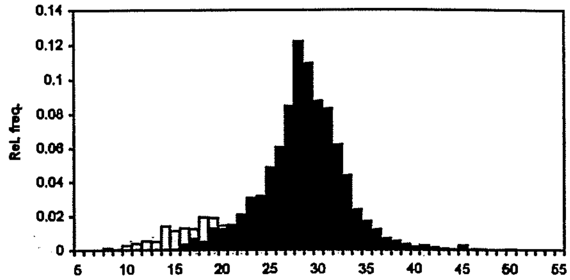
North, 1995

	Retained	Discarded	Total
Obs:	747 (21)	95 (34)	
Co-op:	0 (0)		
Mean L:	30.4	15.1	29.1



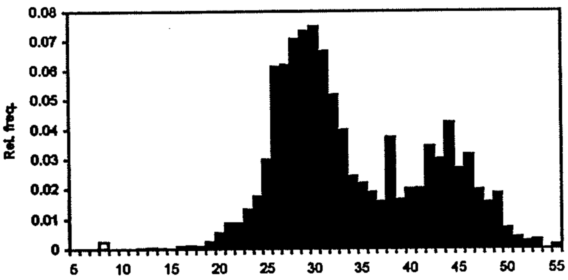
North, 1993-95

	Retained	Discarded	Total
Obs:	3737 (111)	430 (122)	
Co-op:	0 (0)		
Mean L:	29.0	15.9	27.9



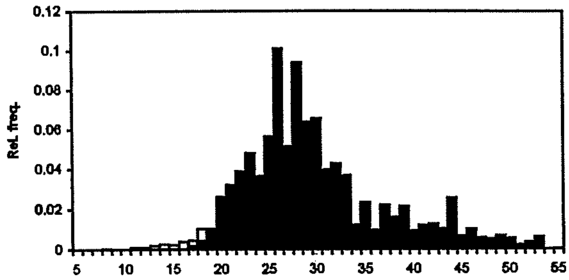
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	932 (24)	7 (4)	
Co-op:	126 (5)		
Mean L:	34.5	11.0	34.4



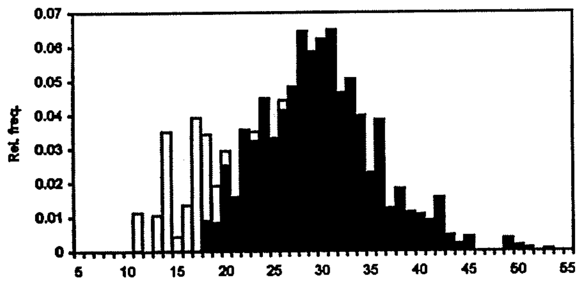
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	1970 (49)	260 (53)	
Co-op:	279 (9)		
Mean L:	30.7	16.5	30.3



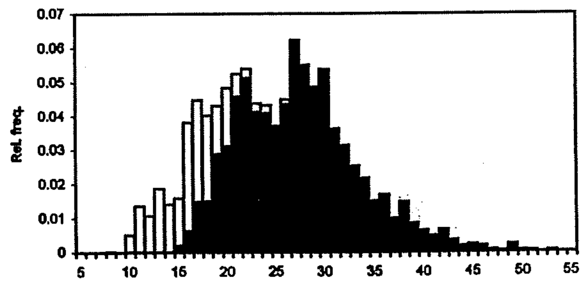
Eden, 1995

	Retained	Discarded	Total
Obs:	480 (11)	33 (19)	
Co-op:	405 (4)		
Mean L:	30.3	16.7	28.1



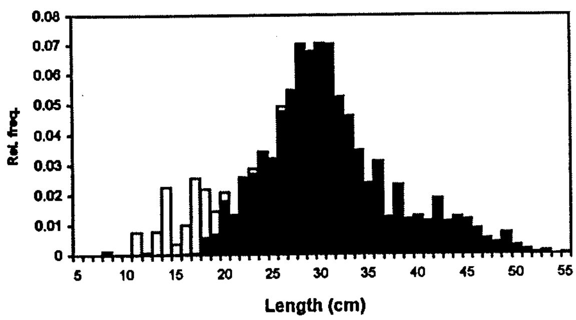
Eden, 1993-95

	Retained	Discarded	Total
Obs:	2293 (56)	276 (95)	
Co-op:	607 (6)		
Mean L:	27.9	16.8	25.6



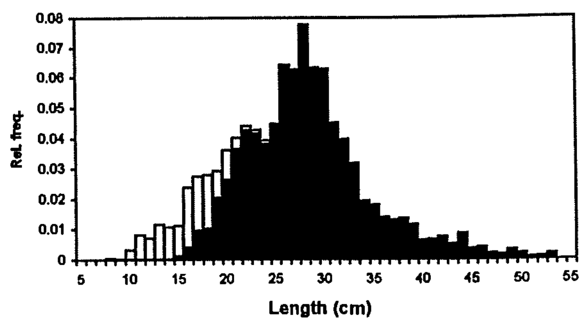
N + U + E, 1995

	Retained	Discarded	Total
Obs:	2169 (56)	135 (57)	
Co-op:	531 (9)		
Mean L:	31.5	16.5	29.9



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	8000 (216)	966 (270)	
Co-op:	885 (15)		
Mean L:	29.0	16.7	27.4



Appendix A.19

Deania spp.

Figure 19.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 19.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 19.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 19.1
Annual retained and discarded catches (t)

Table 19.2
Annual retained and discarded catches (number of fish)

Figure 19.1

Retained and discarded catches (kg per fisher-day) - Deania sp.

by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

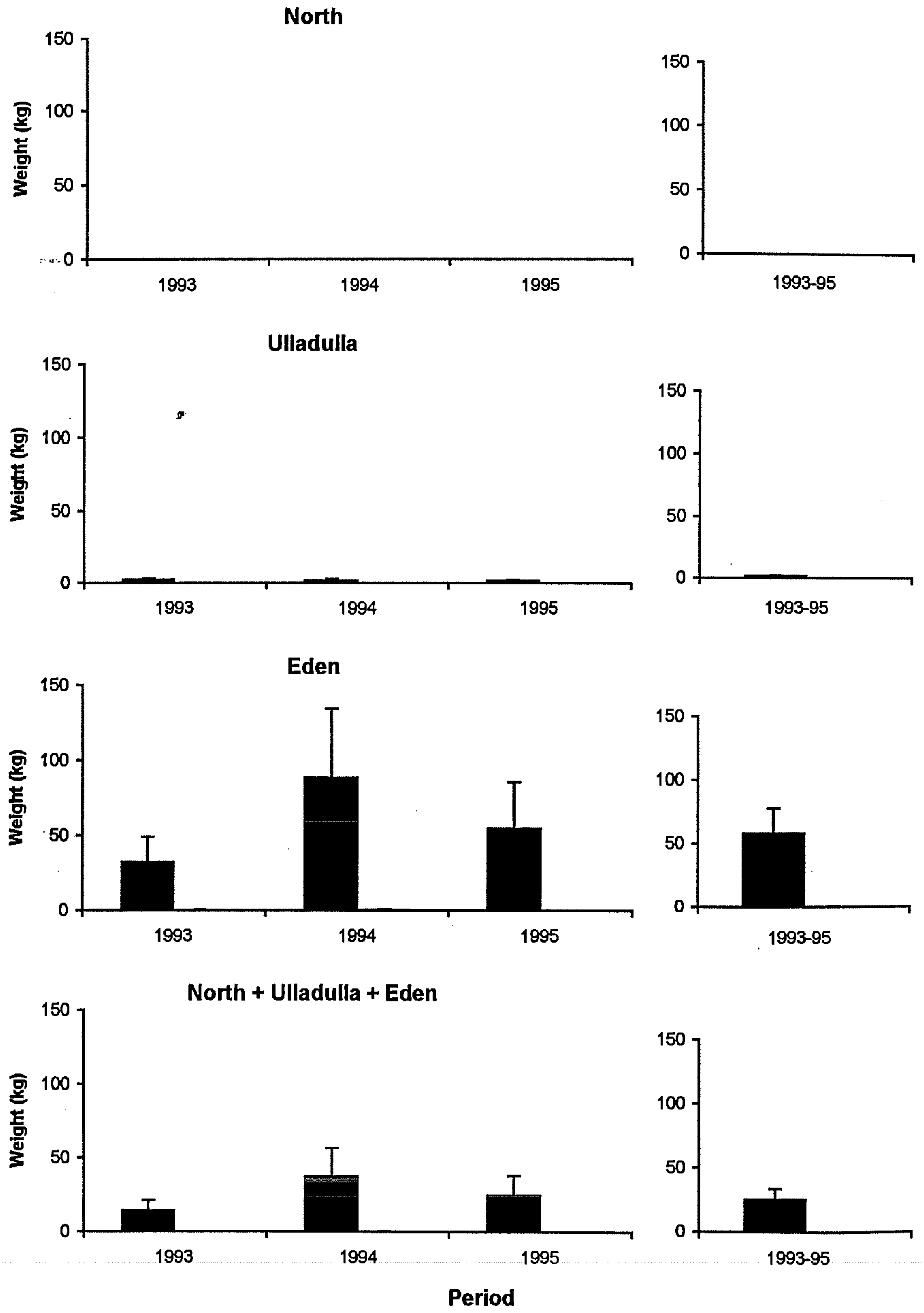


Figure 19.2

Retained and discarded catches (number of fish per fisher-day) - Deania sp.

by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

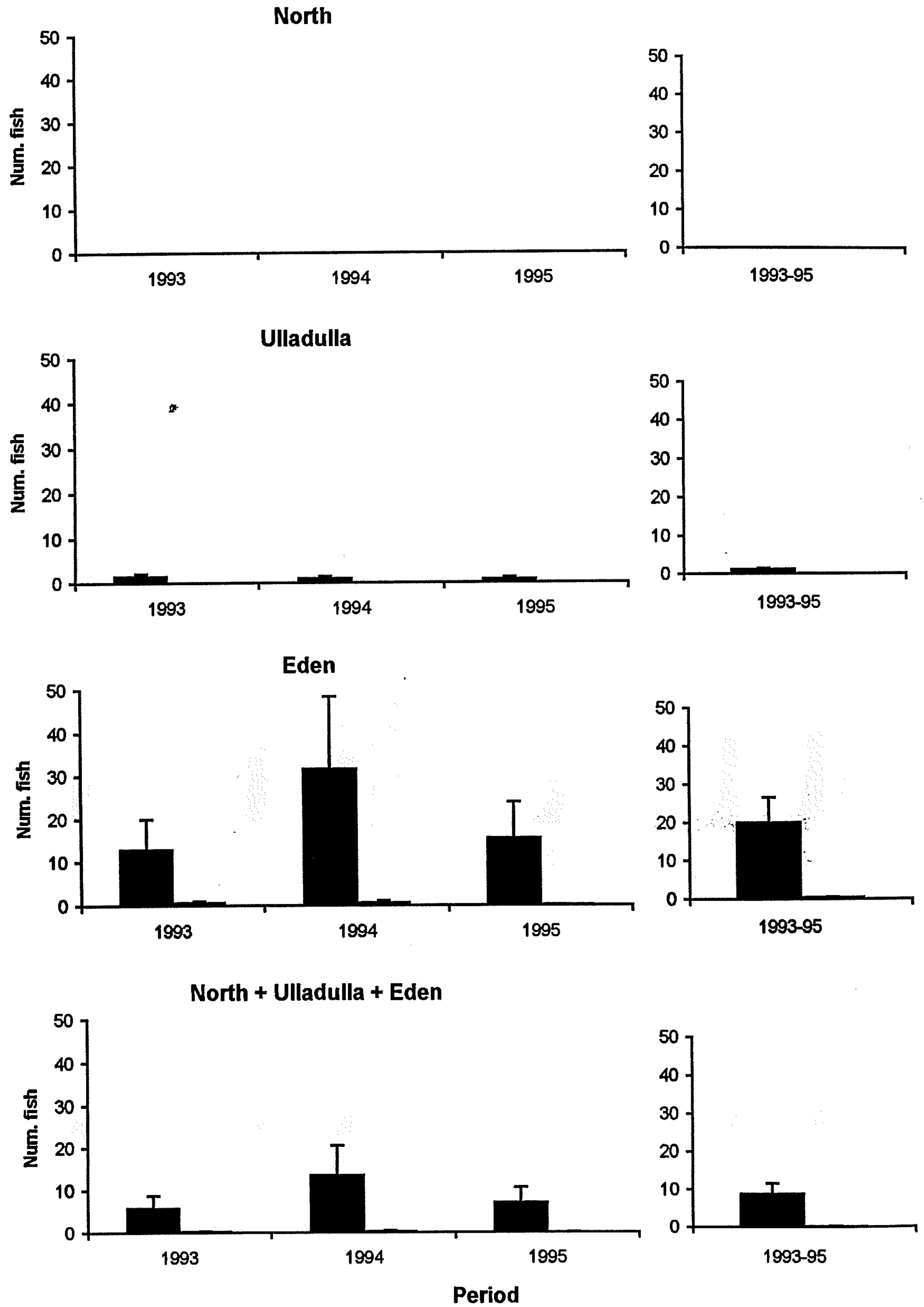


Figure 19.3

Retained and discarded catches (per fisher-day) - Deania sp.
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

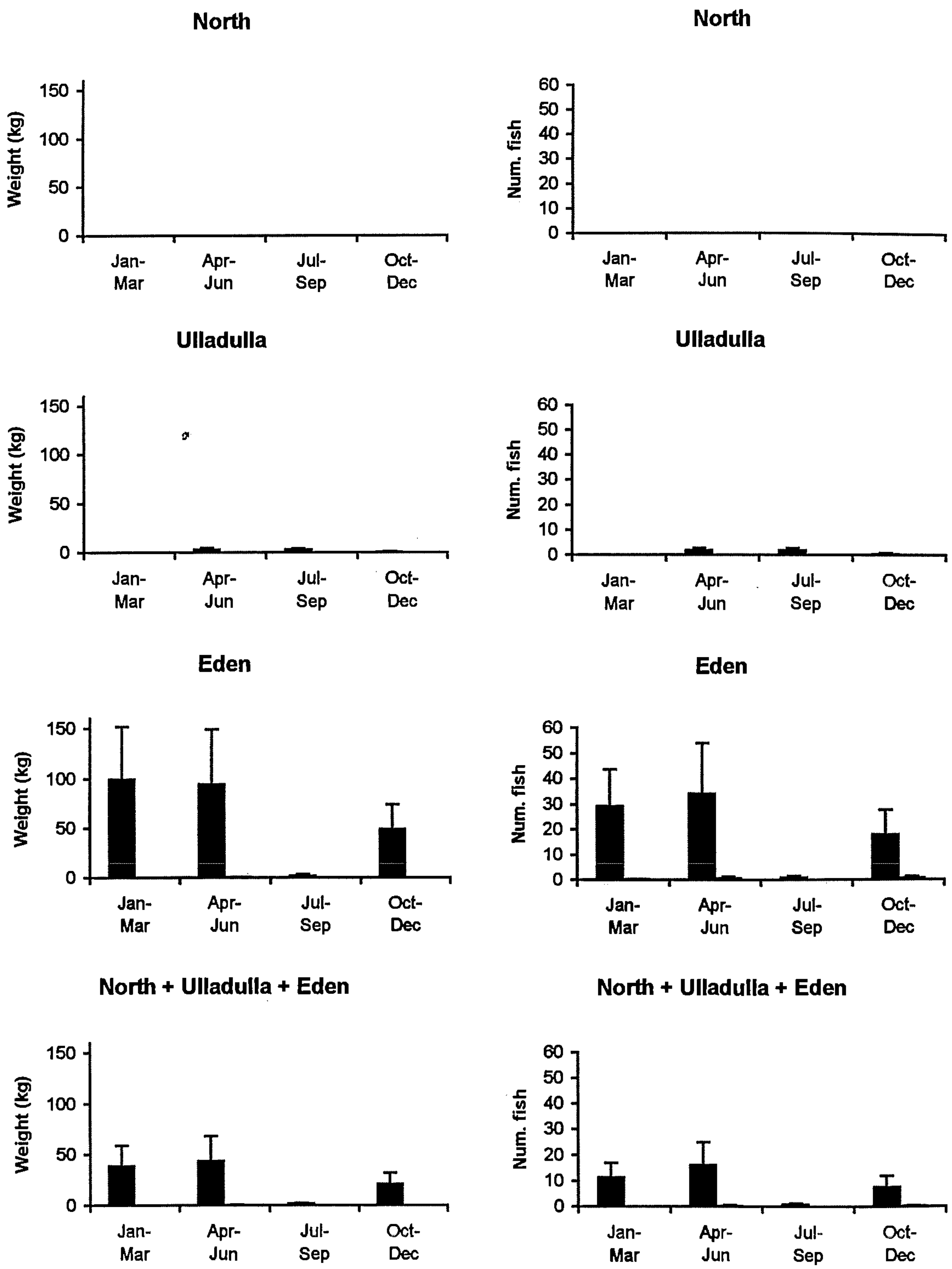


Table 19.1

Annual retained and discarded catches - Deania sp. (t)

		Total (t)			Retained (t)			Discarded (t)			% Discarded
North	1993	0	+/-	0	0	+/-	0	0	+/-	0	
	1994	0		0	0		0	0		0	
	1995	0		0	0		0	0		0	
	Mean 1993-95	0		0	0		0	0		0	
Ulladulla	1993	3		1	3		1	0		0	*0*
	1994	2		1	2		1	0		0	*0*
	1995	1		1	1		1	0		0	*0*
	Mean 1993-95	2		1	2		1	0		0	*0*
Eden	1993	67		35	67		35	0		0	*0*
	1994	181		95	180		95	1		1	*0*
	1995	116		65	116		65	0		0	*0*
	Mean 1993-95	121		40	121		40	0		0	*0*
N+U+E	1993	70		35	69		35	0		0	*0*
	1994	183		95	182		95	1		1	*0*
	1995	117		65	117		65	0		0	*0*
	Mean 1993-95	123		40	123		40	0		0	*0*

Table 19.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)			Retained (x1000)			Discarded (x1000.)			% Discarded
North	1993	0	+/-	0	0	+/-	0	0	+/-	0	
	1994	0		0	0		0	0		0	
	1995	0		0	0		0	0		0	
	Mean 1993-95	0		0	0		0	0		0	
Ulladulla	1993	2		1	2		1	0		0	*0*
	1994	1		1	1		1	0		0	*1*
	1995	1		1	1		1	0		0	*0*
	Mean 1993-95	1		0	1		0	0		0	*0*
Eden	1993	28		15	27		15	1		1	*4*
	1994	66		35	65		34	1		1	*2*
	1995	33		18	33		18	0		0	*0*
	Mean 1993-95	42		14	41		14	1		0	*2*
N+U+E	1993	30		15	28		15	1		1	*4*
	1994	67		35	66		34	1		1	*2*
	1995	34		18	33		18	0		0	*0*
	Mean 1993-95	43		14	43		14	1		0	*2*

Appendix A.20

Angel sharks

Squatina spp.

Figure 20.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 20.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 20.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 20.1
Annual retained and discarded catches (t)

Table 20.2
Annual retained and discarded catches (number of fish)

Figure 20.1

Retained and discarded catches (kg per fisher-day) - Angel sharks
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

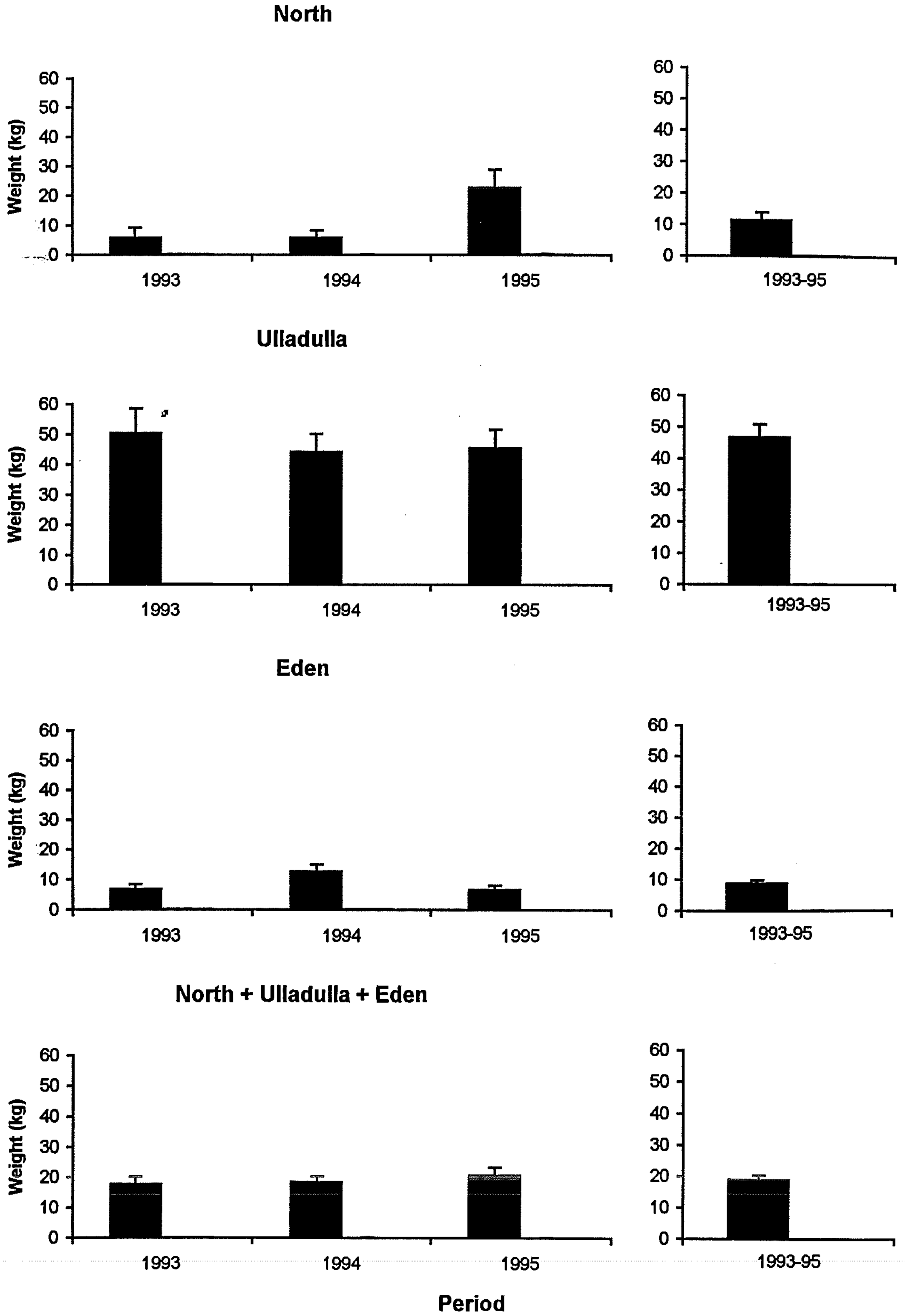


Figure 20.2

Retained and discarded catches (number of fish per fisher-day) - Angel sharks
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

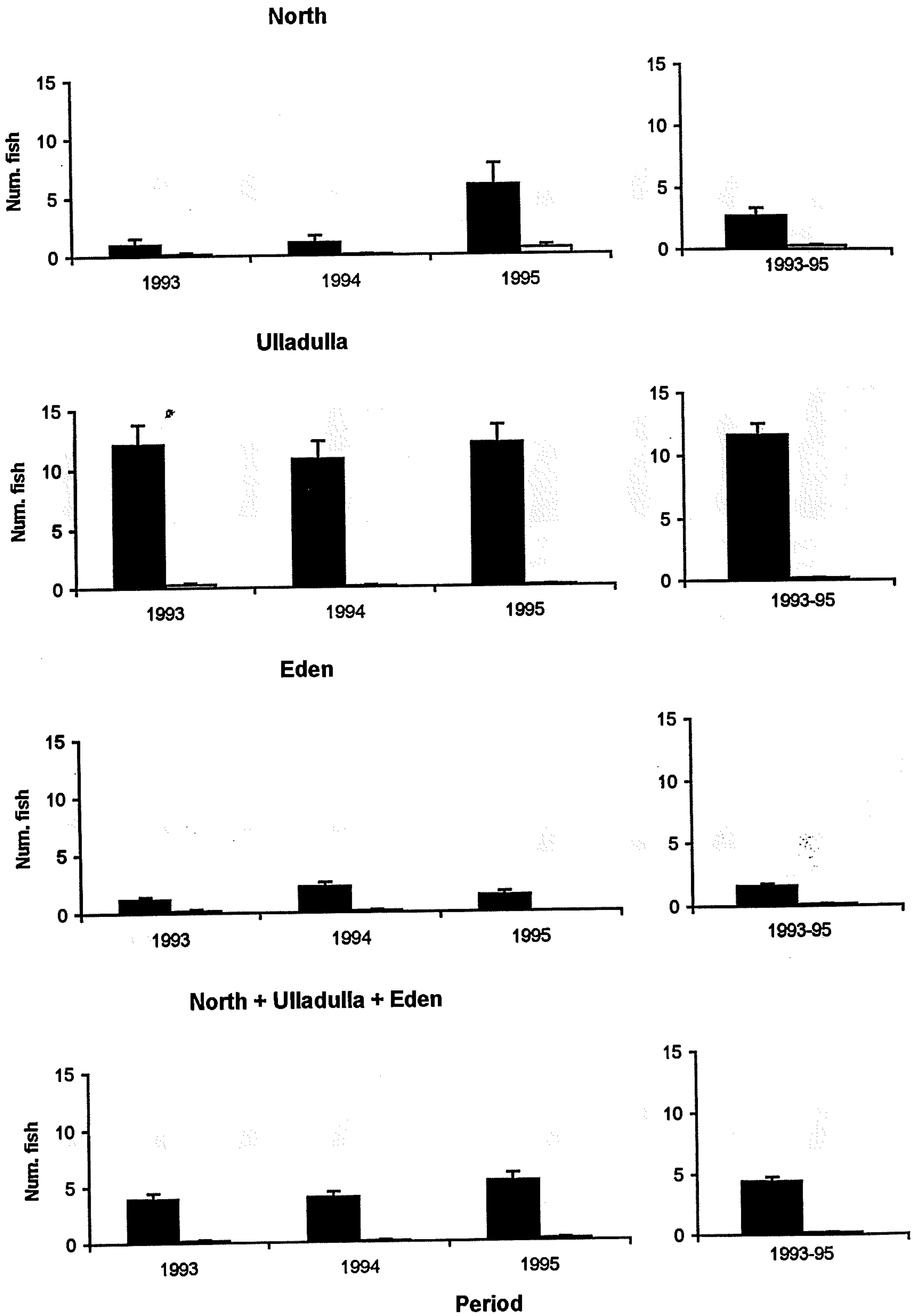


Figure 20.3

Retained and discarded catches (per fisher-day) - Angel sharks

by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

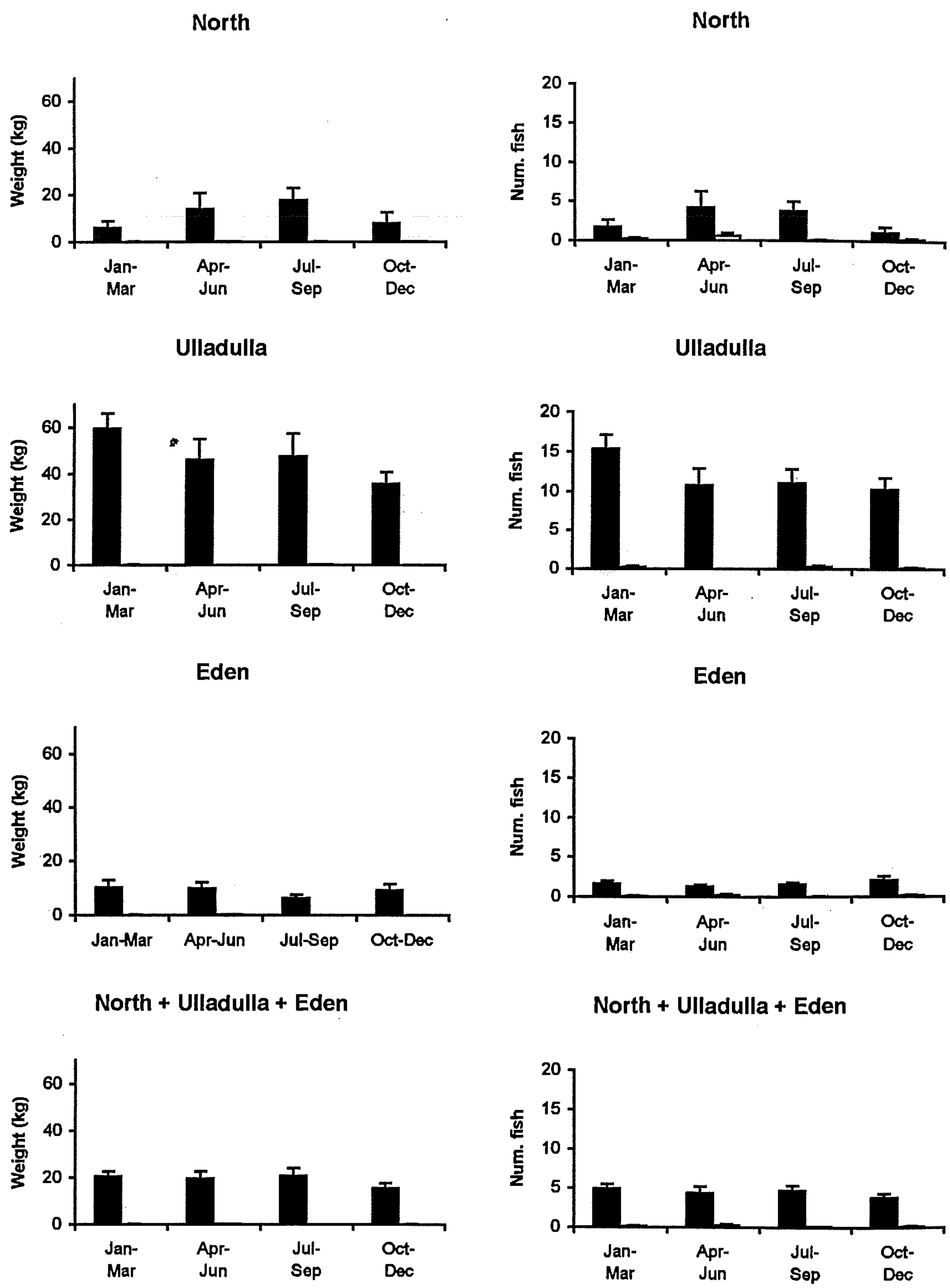


Table 20.1

Annual retained and discarded catches - Angel sharks (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	9	6	9	6	0	0	*2*
	1994	9	4	9	4	0	0	*1*
	1995	37	10	36	10	0	0	*1*
	Mean 1993-95	18	4	18	4	0	0	*1*
Ulladulla	1993	65	11	65	11	0	0	*0*
	1994	55	7	54	7	0	0	*0*
	1995	50	7	50	7	0	0	*0*
	Mean 1993-95	56	5	56	5	0	0	*0*
Eden	1993	14	3	14	3	0	0	*2*
	1994	26	5	26	5	0	0	*1*
	1995	14	3	14	3	0	0	*0*
	Mean 1993-95	18	2	18	2	0	0	*1*
N+U+E	1993	89	13	88	13	1	0	*1*
	1994	90	10	90	10	0	0	*0*
	1995	100	12	100	12	0	0	*0*
	Mean 1993-95	93	7	93	7	0	0	*1*

Table 20.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	2	1	2	1	0	0	*14*
	1994	2	1	2	1	0	0	*6*
	1995	10	3	10	3	1	0	*9*
	Mean 1993-95	5	1	4	1	0	0	*9*
Ulladulla	1993	16	2	16	2	0	0	*2*
	1994	14	2	13	2	0	0	*1*
	1995	13	2	13	2	0	0	*1*
	Mean 1993-95	14	1	14	1	0	0	*1*
Eden	1993	3	1	2	0	0	0	*14*
	1994	5	1	5	1	0	0	*7*
	1995	3	1	3	1	0	0	*0*
	Mean 1993-95	4	0	3	0	0	0	*7*
N+U+E	1993	20	3	19	2	1	0	5
	1994	20	2	20	2	1	0	3
	1995	27	4	26	3	1	0	4
	Mean 1993-95	22	2	22	2	1	0	4

Appendix A.21

Blue grenadier

Macruronus novaezelandiae

Figure 21.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 21.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 21.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 21.1
Annual retained and discarded catches (t)

Table 21.2
Annual retained and discarded catches (number of fish)

Figure 21.1

Retained and discarded catches (kg per fisher-day) - Blue grenadier
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

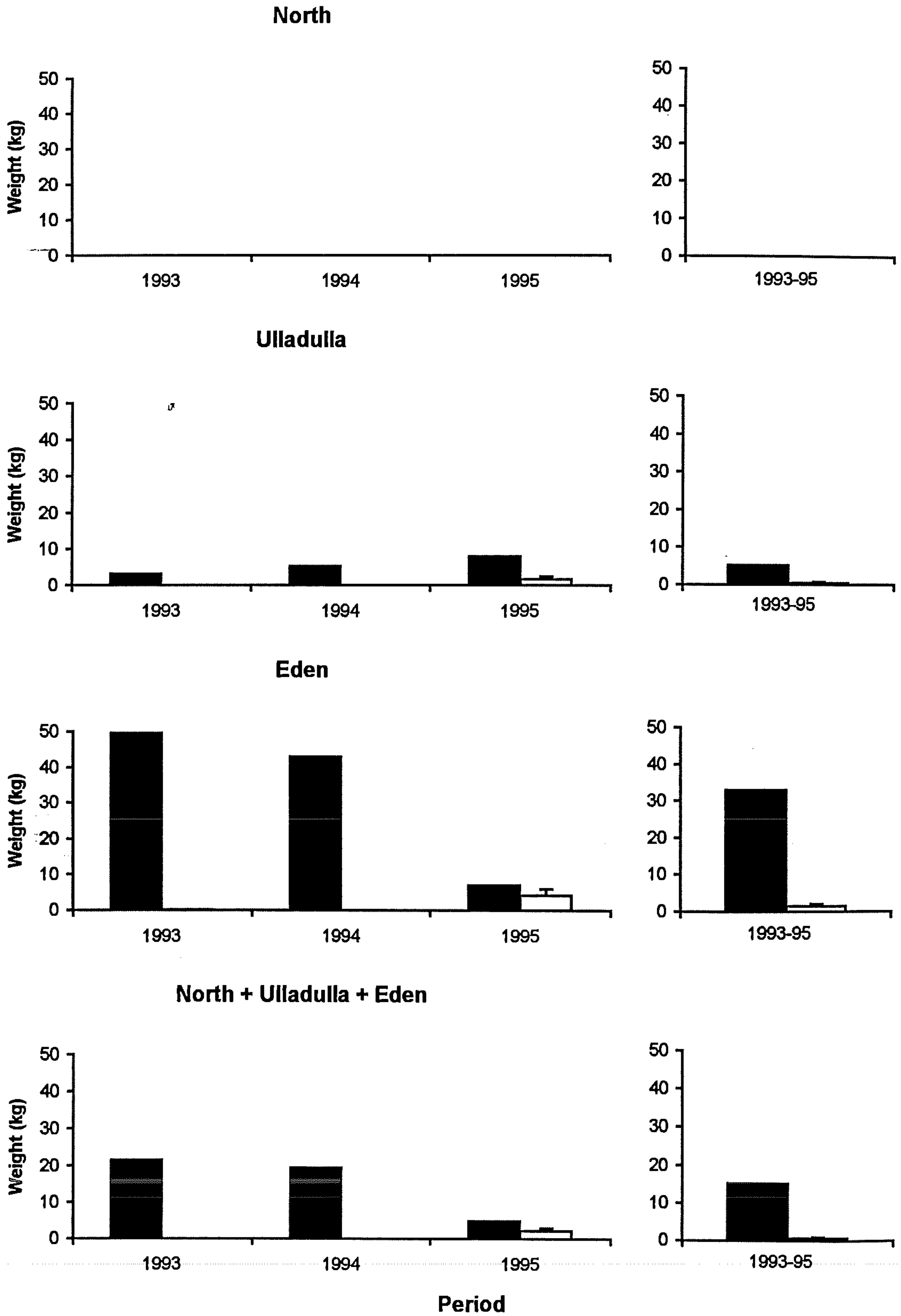


Figure 21.2

Retained and discarded catches (number of fish per fisher-day) - Blue grenadier
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

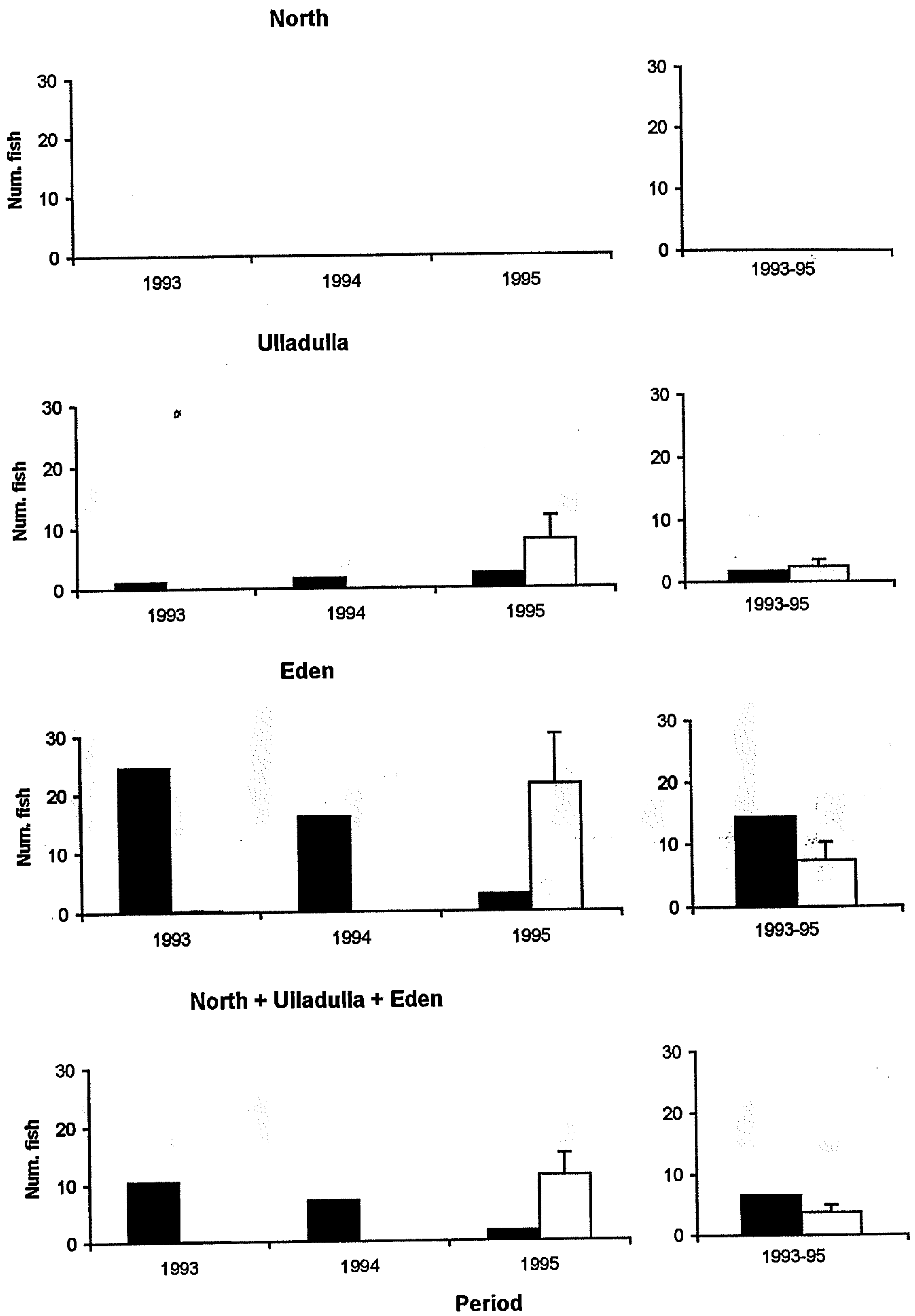


Figure 21.3

Retained and discarded catches (per fisher-day) - Blue grenadier
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

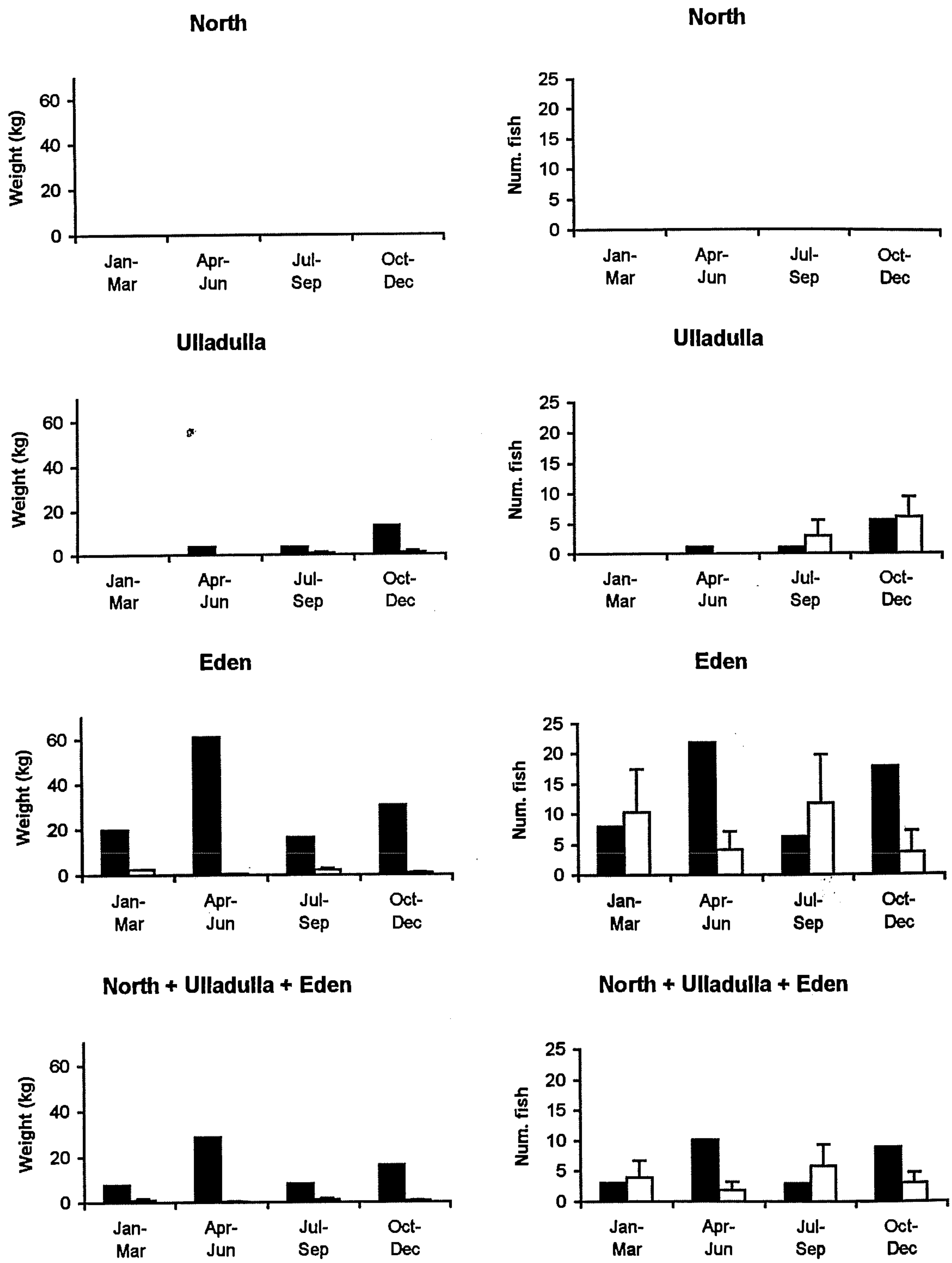


Table 21.1

Annual retained and discarded catches - Blue grenadier (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	4	0	4	0	0	0	*0*
	1994	6	0	6	0	0	0	*0*
	1995	10	1	9	0	2	1	*17*
	Mean 1993-95	7	0	6	0	1	0	*8*
Eden	1993	103	0	102	0	0	0	*0*
	1994	88	0	88	0	0	0	*0*
	1995	23	4	15	0	9	4	*37*
	Mean 1993-95	71	1	68	0	3	1	*4*
N+U+E	1993	107	0	106	0	0	0	*0*
	1994	94	0	94	0	0	0	*0*
	1995	34	4	23	0	10	4	*31*
	Mean 1993-95	78	1	75	0	4	1	*4*

Table 21.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	1	0	1	0	0	0	*0*
	1994	2	0	2	0	0	0	*0*
	1995	11	4	3	0	9	4	*77*
	Mean 1993-95	5	1	2	0	3	1	*59*
Eden	1993	51	0	51	0	0	0	*1*
	1994	33	0	33	0	0	0	*0*
	1995	51	18	6	0	45	18	*88*
	Mean 1993-95	45	6	30	0	15	6	*34*
N+U+E	1993	52	0	52	0	0	0	*1*
	1994	35	0	35	0	0	0	*0*
	1995	63	19	9	0	54	19	*86*
	Mean 1993-95	50	6	32	0	18	6	*36*

Appendix A.22

Cuttlefish

Sepia spp.

Figure 22.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 22.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 22.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 22.1
Annual retained and discarded catches (t)

Table 22.2
Annual retained and discarded catches (number of fish)

Figure 22.1

Retained and discarded catches (kg per fisher-day) - Cuttlefish

by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

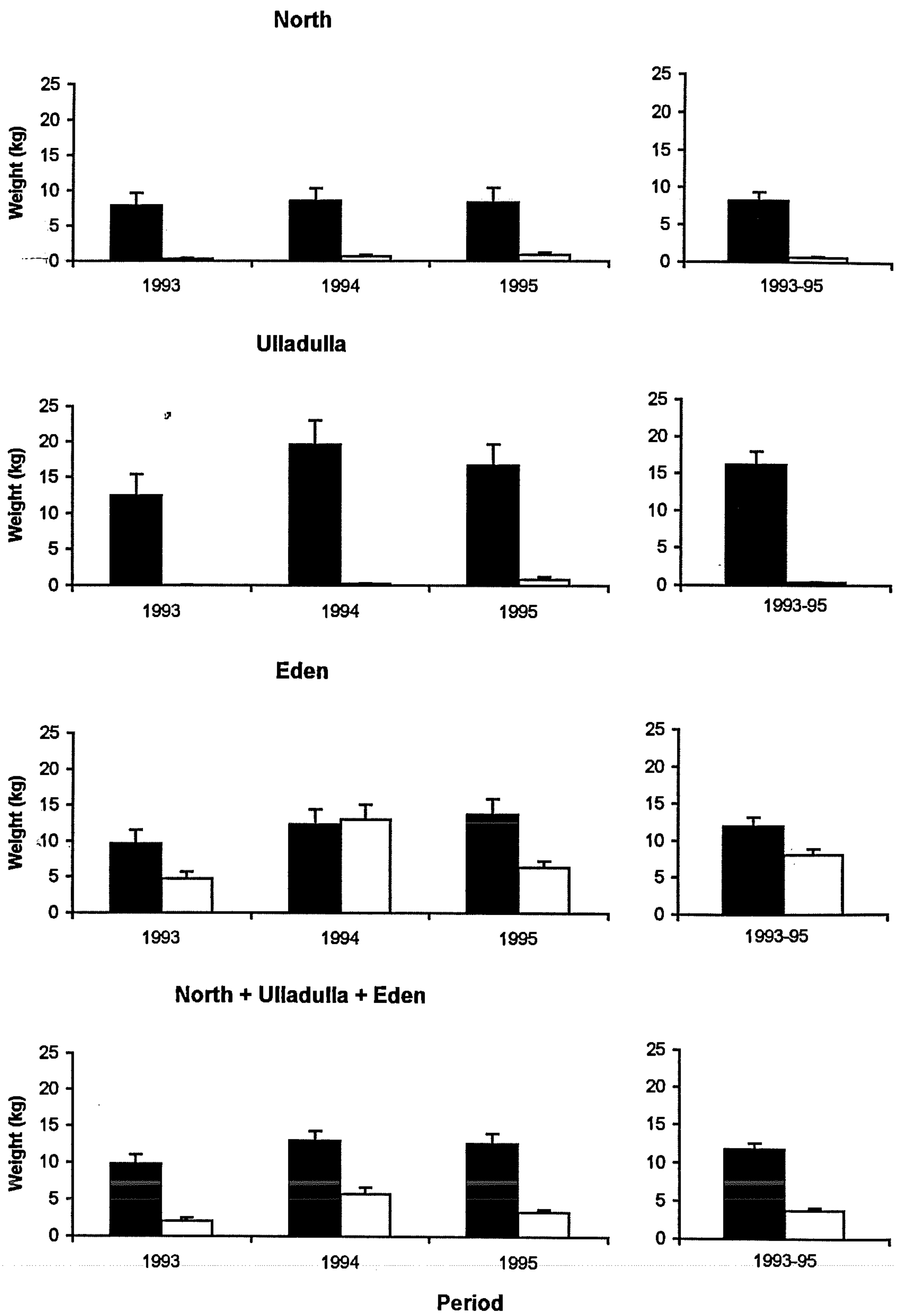


Figure 22.2

Retained and discarded catches (number of fish per fisher-day) - Cuttlefish
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

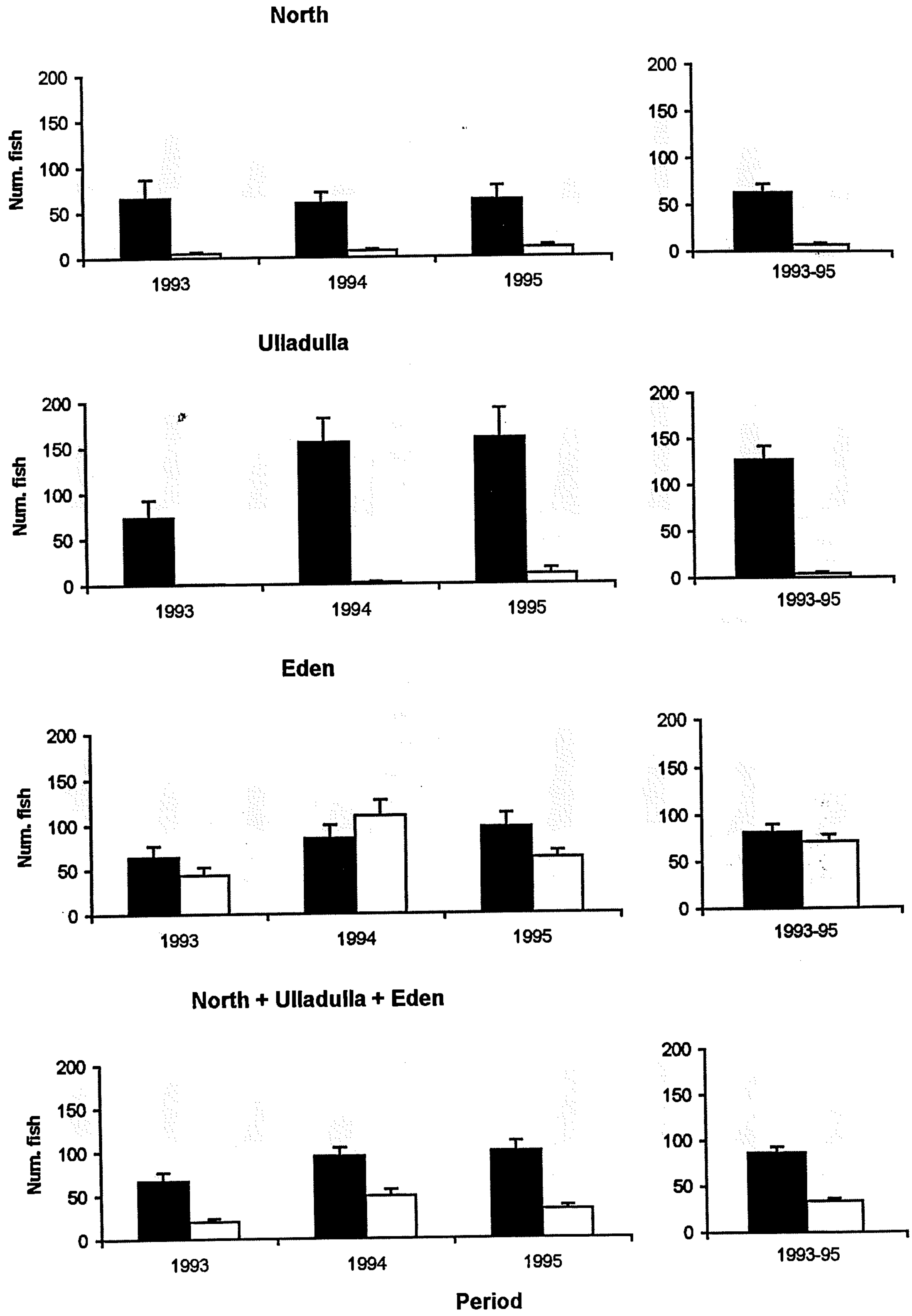


Figure 22.3

Retained and discarded catches (per fisher-day) - Cuttlefish
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

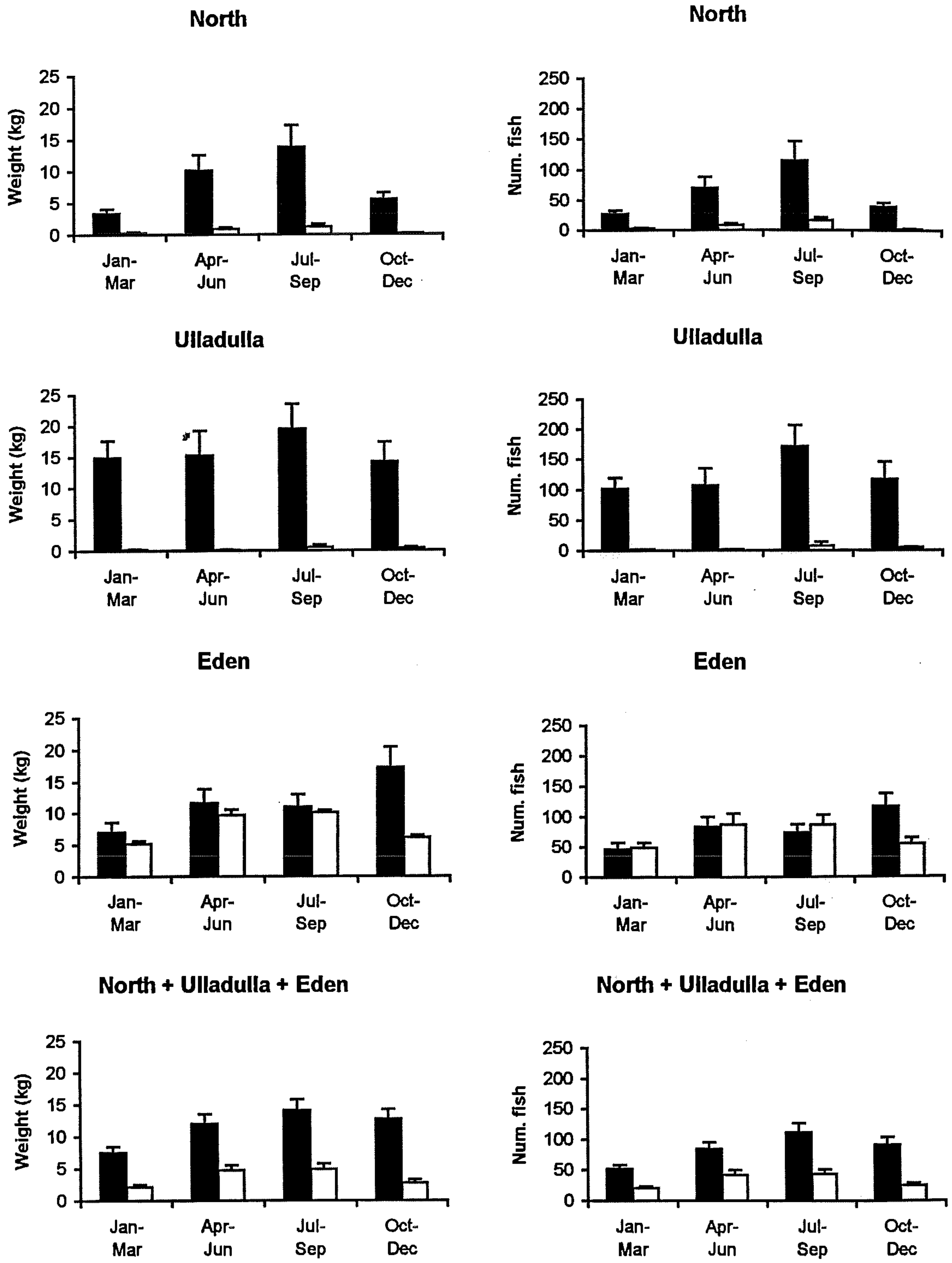


Table 22.1

Annual retained and discarded catches - Cuttlefish (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	13 +/-	3	13 +/-	3	1 +/-	0	*4*
	1994	15	3	14	3	1	0	*7*
	1995	15	4	13	3	1	0	*10*
	Mean 1993-95	14	2	13	2	1	0	*7*
Ulladulla	1993	16	4	16	4	0	0	*0*
	1994	24	4	24	4	0	0	*1*
	1995	19	3	18	3	1	0	*5*
	Mean 1993-95	20	2	19	2	0	0	*2*
Eden	1993	30	5	20	4	10	2	*33*
	1994	52	7	25	4	27	4	*51*
	1995	43	5	29	5	14	2	*32*
	Mean 1993-95	41	3	25	2	17	2	*40*
N+U+E	1993	59	7	48	6	10	2	*18*
	1994	91	8	63	7	28	4	*31*
	1995	76	7	60	7	16	2	*21*
	Mean 1993-95	75	4	57	4	18	2	*24*

Table 22.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	112 +/-	35	105 +/-	33	8 +/-	3	*7*
	1994	106	21	95	19	11	3	*10*
	1995	116	28	100	24	16	5	*14*
	Mean 1993-95	111	16	100	15	12	2	*10*
Ulladulla	1993	94	25	94	25	0	0	*0*
	1994	194	33	191	33	2	1	*1*
	1995	185	37	174	35	12	7	*6*
	Mean 1993-95	158	18	153	18	5	2	*3*
Eden	1993	222	41	132	26	90	18	*41*
	1994	397	55	173	30	224	36	*56*
	1995	334	41	203	33	131	17	*39*
	Mean 1993-95	318	27	169	17	148	15	*47*
N+U+E	1993	428	59	330	49	98	18	*23*
	1994	697	68	459	49	238	36	*34*
	1995	635	62	477	54	158	19	*25*
	Mean 1993-95	587	36	422	29	165	15	*28*

Appendix A.23

Silver dory

Cyttus australis

Figure 23.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 23.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 23.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 23.1
Annual retained and discarded catches (t)

Table 23.2
Annual retained and discarded catches (number of fish)

Figure 23.1

Retained and discarded catches (kg per fisher-day) - Silver dory
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

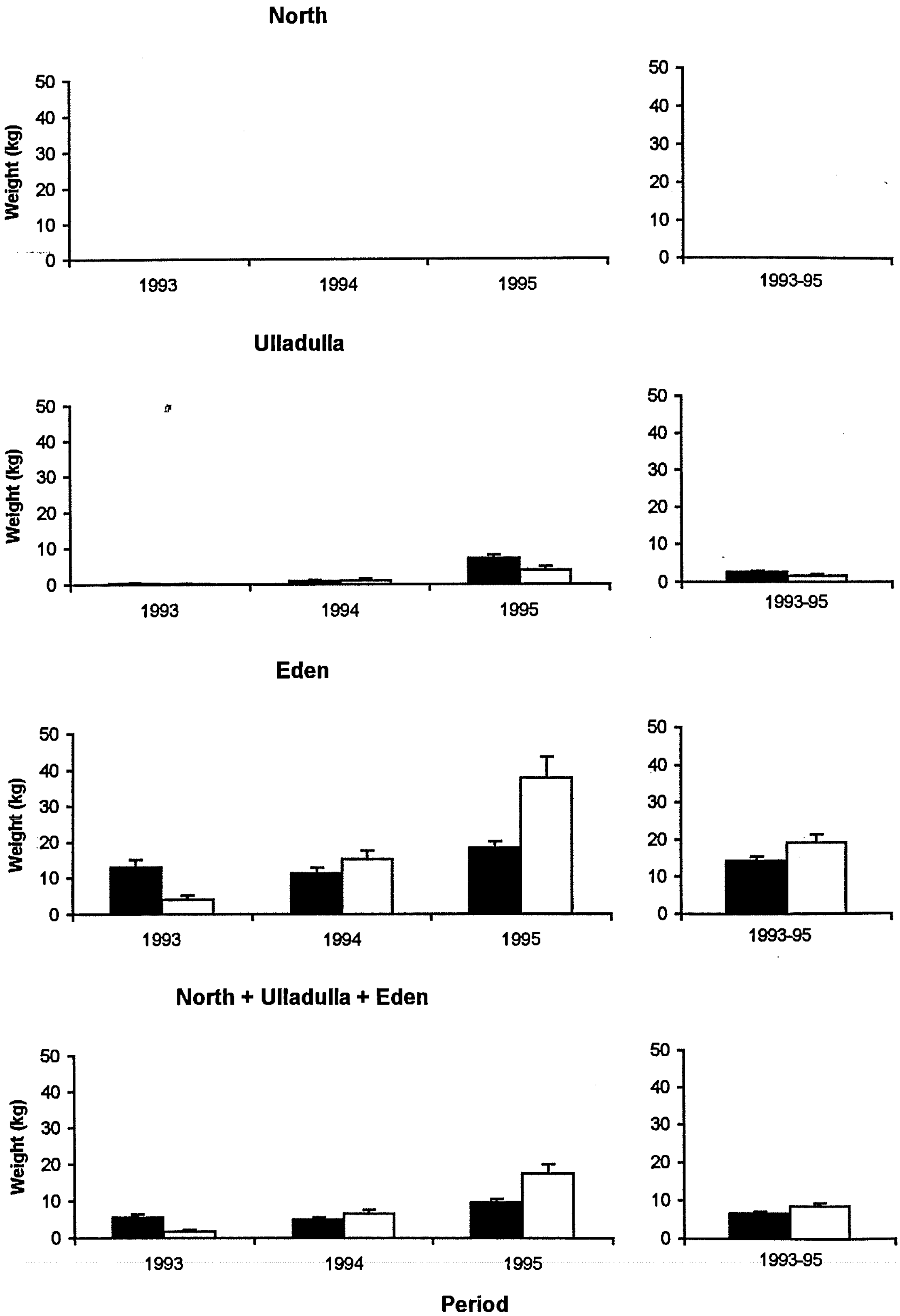


Figure 23.2

Retained and discarded catches (number of fish per fisher-day) - Silver dory
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

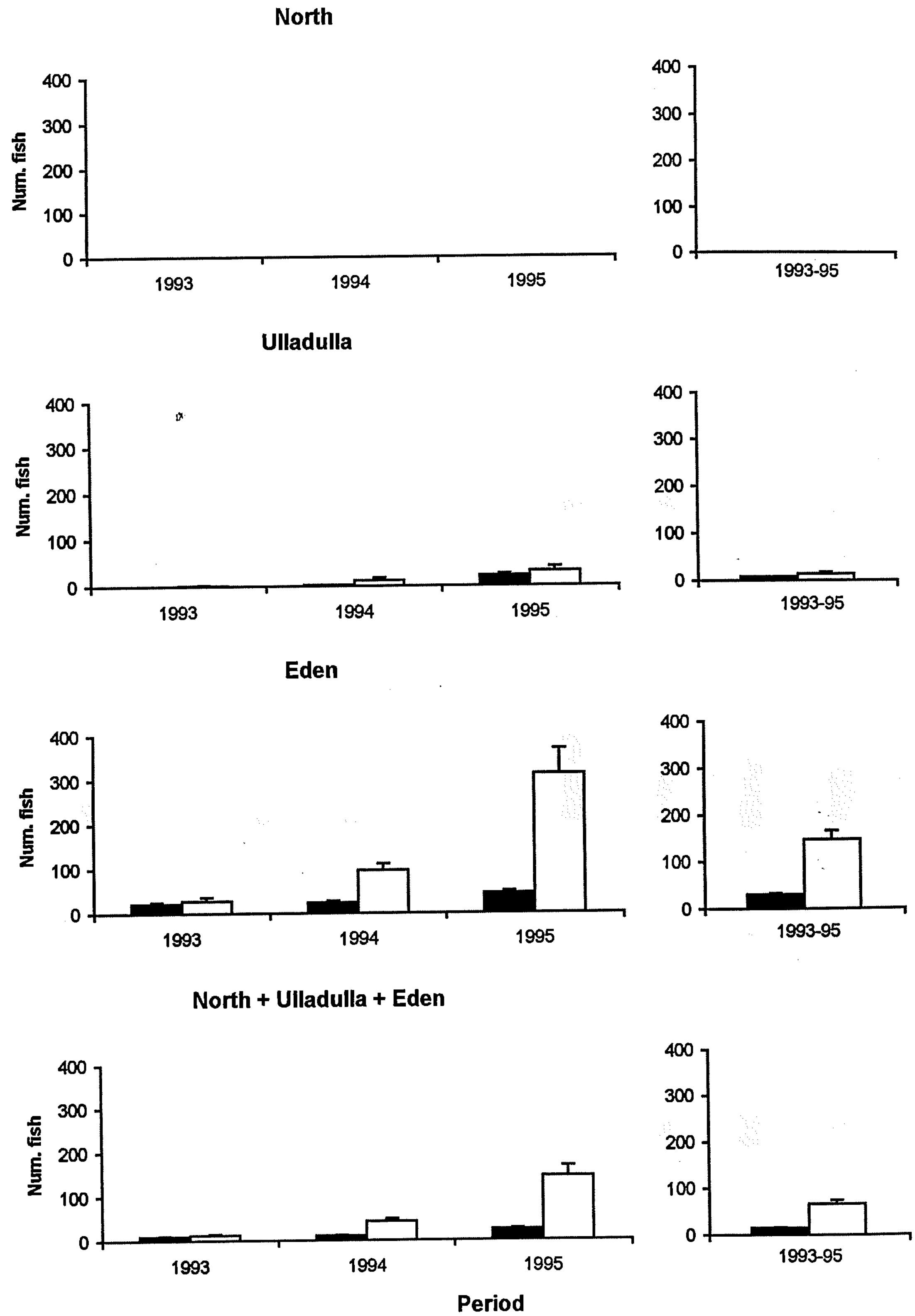


Figure 23.3

Retained and discarded catches (per fisher-day) - Silver dory
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

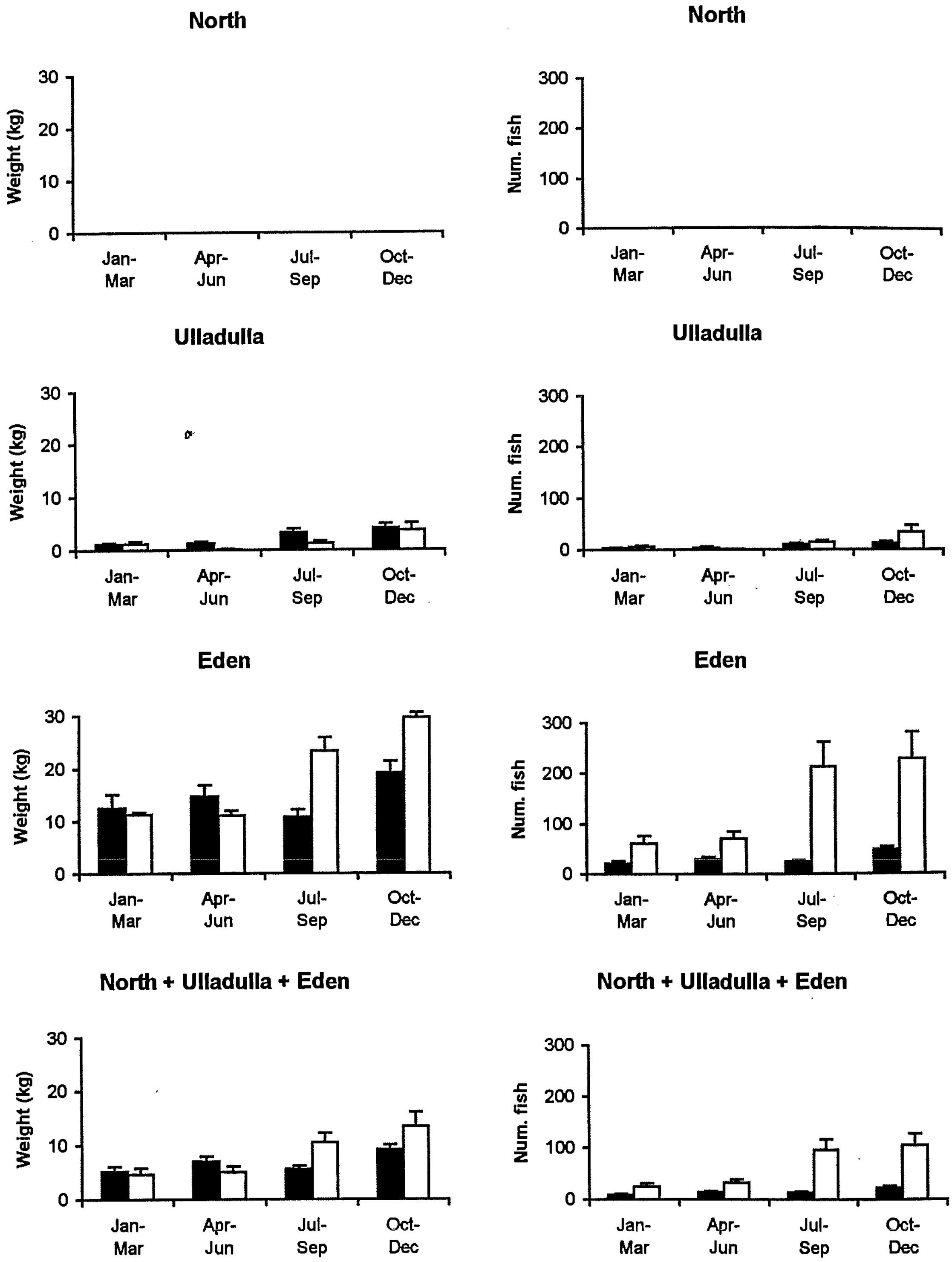


Table 23.1

Annual retained and discarded catches - Silver dory (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	1	0	0	0	0	0	38
	1994	2	1	1	0	1	1	56
	1995	12	2	8	1	4	1	35
	Mean 1993-95	5	1	3	0	2	0	39
Eden	1993	35	5	27	4	8	2	24
	1994	54	7	23	3	31	5	57
	1995	118	15	39	4	80	12	67
	Mean 1993-95	69	6	30	2	40	4	57
N+U+E	1993	36	5	27	4	9	2	24
	1994	57	7	24	3	33	5	57
	1995	130	15	47	4	84	12	64
	Mean 1993-95	74	6	33	2	42	4	56

Table 23.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	1	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
Ulladulla	1993	2	1	1	0	2	1	75
	1994	17	8	2	1	15	7	87
	1995	59	13	25	4	34	10	58
	Mean 1993-95	26	5	9	1	17	4	65
Eden	1993	103	19	46	8	58	17	56
	1994	246	35	49	7	196	32	80
	1995	758	122	95	10	663	117	87
	Mean 1993-95	369	43	63	5	306	41	83
N+U+E	1993	105	19	46	6	59	17	56
	1994	263	38	52	7	211	33	80
	1995	817	123	120	11	697	118	85
	Mean 1993-95	395	43	73	5	323	41	82

Appendix A.24

Octopus

Order Octopoda

Figure 24.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 24.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 24.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 24.1
Annual retained and discarded catches (t)

Table 24.2
Annual retained and discarded catches (number of fish)

Figure 24.1

Retained and discarded catches (kg per fisher-day) - Octopus
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

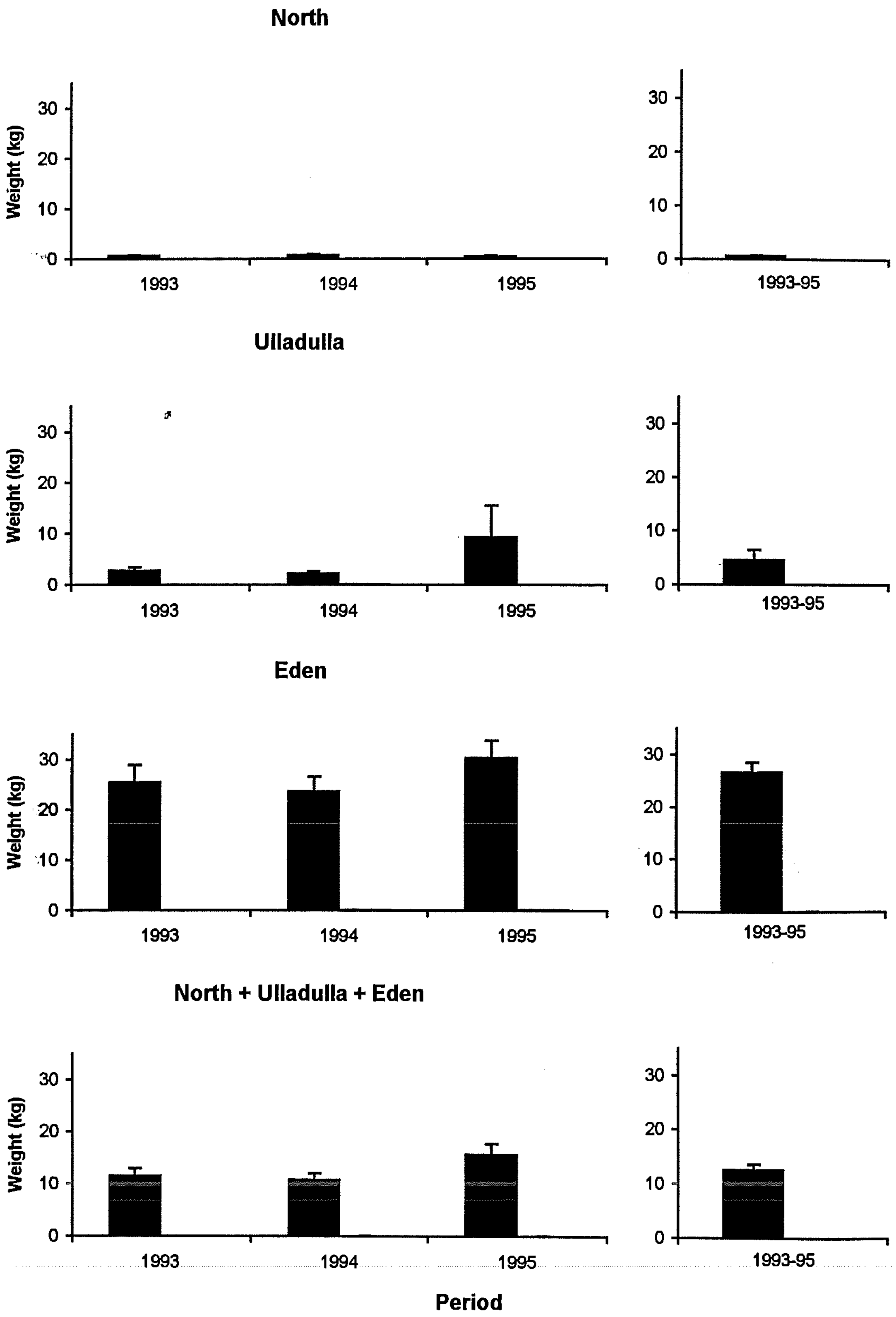


Figure 24.2

Retained and discarded catches (number of fish per fisher-day) - Octopus
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

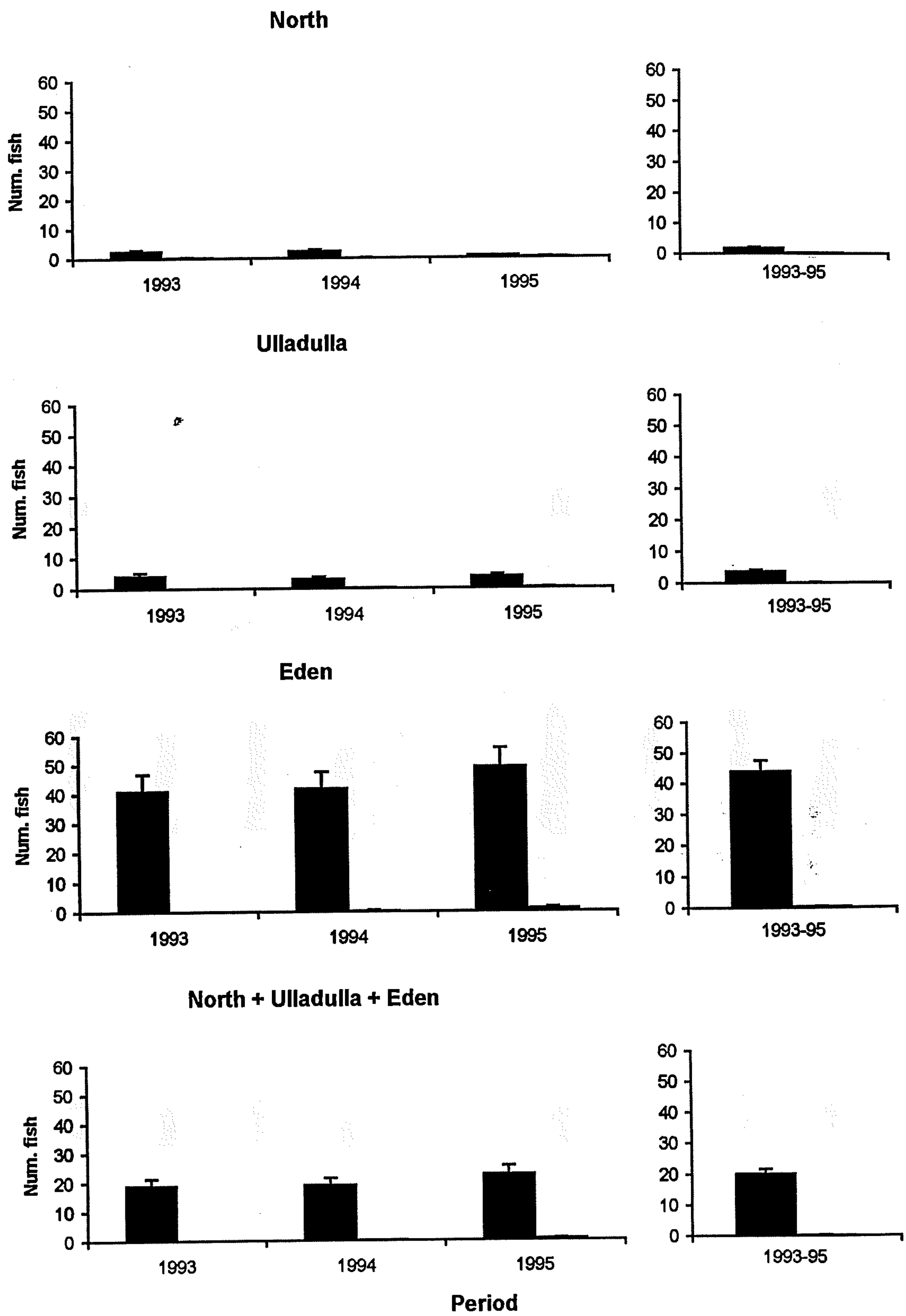


Figure 24.3

Retained and discarded catches (per fisher-day) - Octopus
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

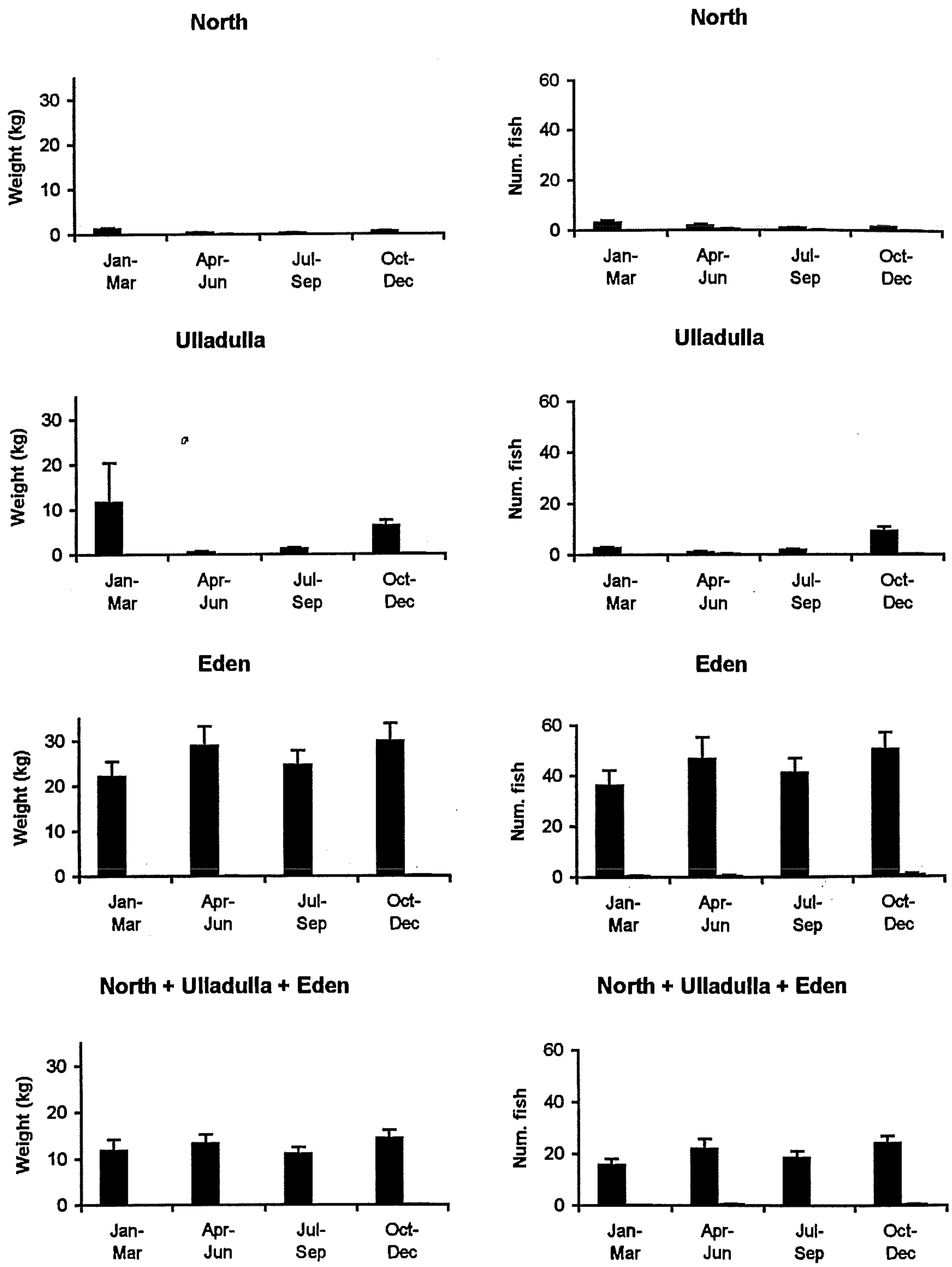


Table 24.1

Annual retained and discarded catches - Octopus (t)

		Total (t)			Retained (t)			Discarded (t)			% Discarded
North	1993	1	+/-	0	1	+/-	0	0	+/-	0	*4*
	1994	1		0	1		0	0		0	*1*
	1995	1		0	1		0	0		0	*5*
	Mean 1993-95	1		0	1		0	0		0	*3*
Ulladulla	1993	3		1	3		1	0		0	*0*
	1994	3		1	3		1	0		0	*3*
	1995	10		7	10		7	0		0	*0*
	Mean 1993-95	5		2	5		2	0		0	*1*
Eden	1993	53		7	53		7	0		0	*0*
	1994	49		6	49		6	0		0	*0*
	1995	64		7	64		7	0		0	*0*
	Mean 1993-95	55		4	55		4	0		0	*0*
N+U+E	1993	57		7	57		7	0		0	*0*
	1994	53		6	52		6	0		0	*0*
	1995	75		10	75		10	0		0	*0*
	Mean 1993-95	62		5	62		5	0		0	*0*

Table 24.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)			Retained (x1000)			Discarded (x1000.)			% Discarded
North	1993	4	+/-	1	4	+/-	1	0	+/-	0	*8*
	1994	4		1	4		1	0		0	*4*
	1995	1		0	1		0	0		0	*26*
	Mean 1993-95	3		1	3		0	0		0	*9*
Ulladulla	1993	5		1	5		1	0		0	*0*
	1994	4		1	4		1	0		0	*4*
	1995	4		1	4		1	0		0	*4*
	Mean 1993-95	4		1	4		1	0		0	*2*
Eden	1993	84		12	84		12	0		0	*0*
	1994	86		12	86		12	0		0	*1*
	1995	105		14	104		14	2		1	*2*
	Mean 1993-95	92		7	91		7	1		0	*1*
N+U+E	1993	93		13	93		13	0		0	*0*
	1994	94		12	93		12	1		1	*1*
	1995	111		14	109		14	2		1	*2*
	Mean 1993-95	99		8	98		7	1		0	*1*

Appendix A.25

Sawsharks

Pristiophorus spp.

Figure 25.1

Retained and discarded catches (kg per fisher-day) - Sawsharks
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

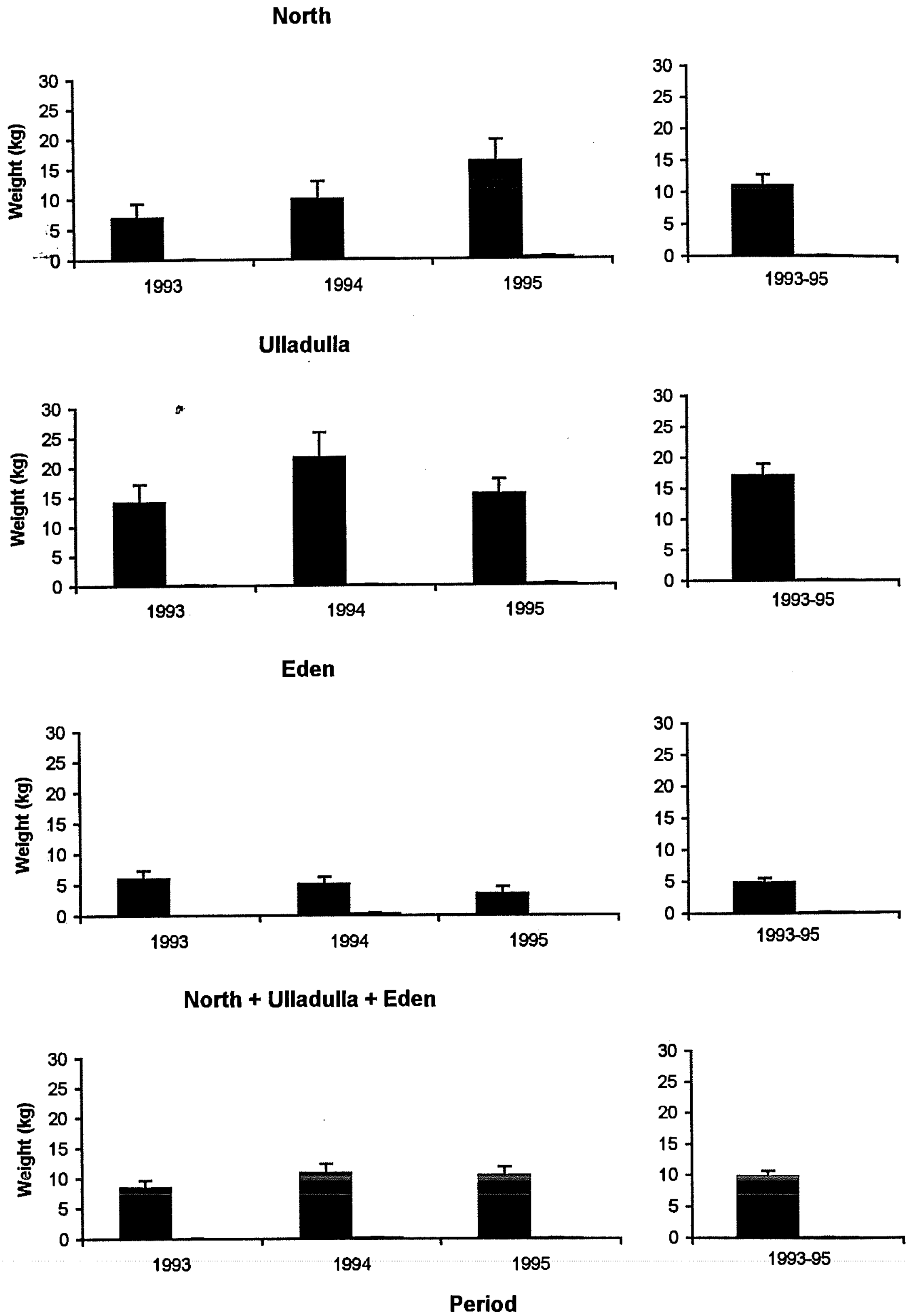


Figure 25.2

Retained and discarded catches (number of fish per fisher-day) - Sawsharks
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

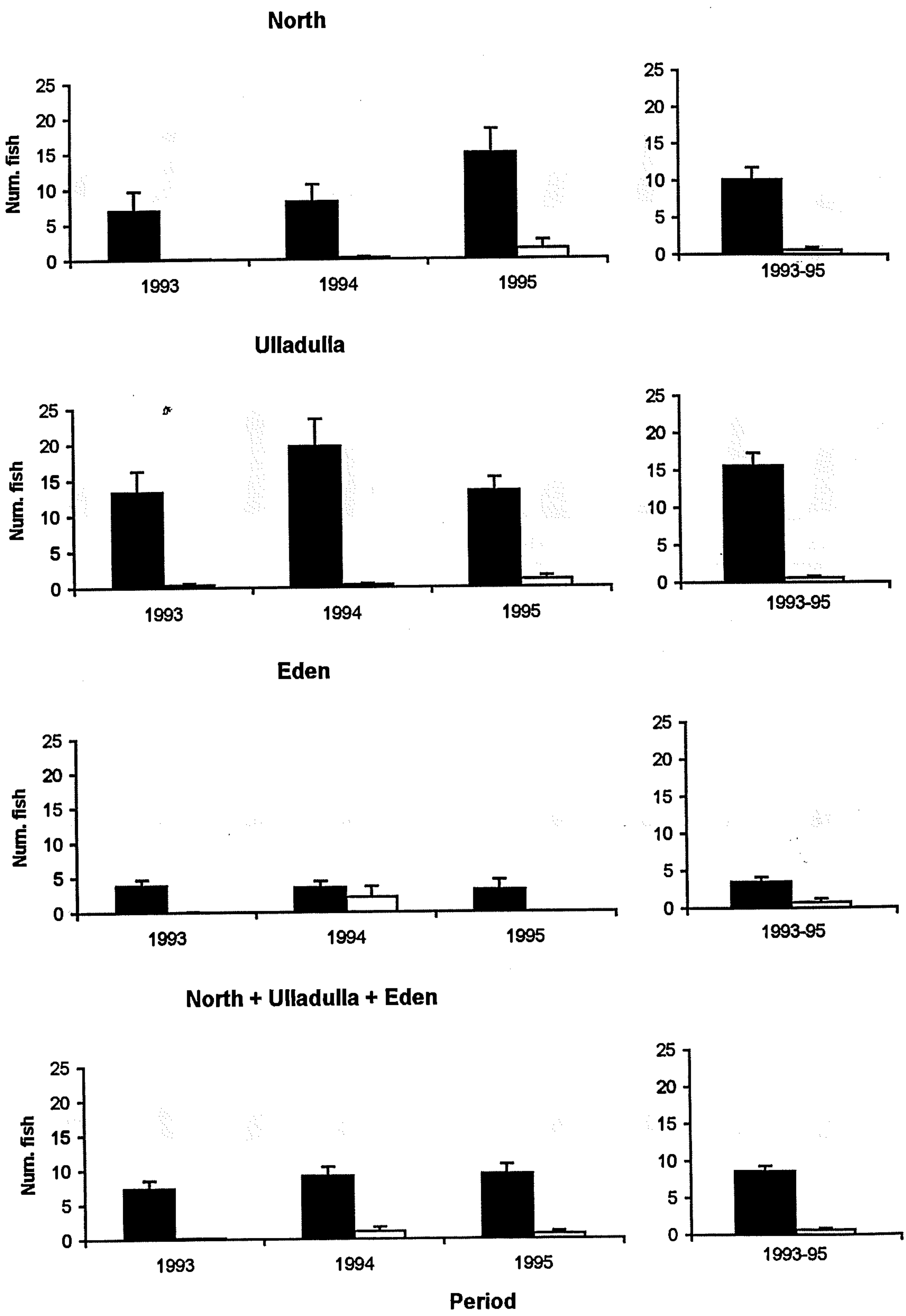


Figure 25.3

Retained and discarded catches (per fisher-day) - Sawsharks
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

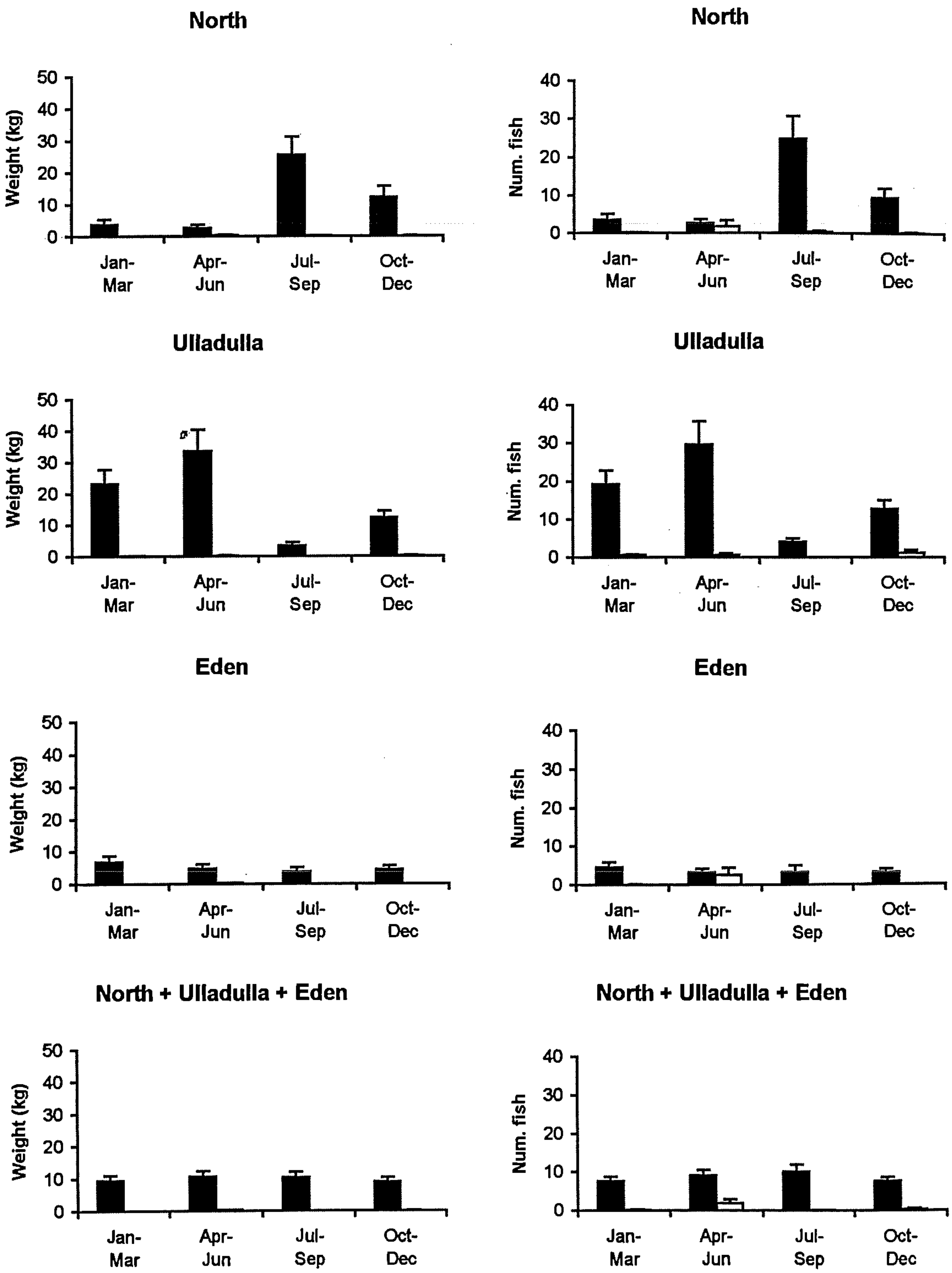


Table 25.1

Annual retained and discarded catches - Sawsharks (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	11 +/-	4	11 +/-	4	0 +/-	0	*0*
	1994	16	5	16	5	0	0	*1*
	1995	26	6	26	6	0	0	*2*
	Mean 1993-95	18	3	18	3	0	0	*1*
Ulladulla	1993	18	4	18	4	0	0	*1*
	1994	27	5	27	5	0	0	*0*
	1995	17	3	17	3	0	0	*1*
	Mean 1993-95	21	2	21	2	0	0	*1*
Eden	1993	12	3	12	3	0	0	*0*
	1994	11	3	10	2	1	0	*5*
	1995	7	2	7	2	0	0	*0*
	Mean 1993-95	10	2	10	1	0	0	*2*
N+U+E	1993	42	6	41	6	0	0	*0*
	1994	54	8	53	7	1	0	*1*
	1995	51	7	50	7	1	0	*1*
	Mean 1993-95	49	4	48	4	1	0	*1*

Table 25.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	11 +/-	4	11 +/-	4	0 +/-	0	*1*
	1994	13	4	13	4	0	0	*3*
	1995	26	6	24	5	2	2	*9*
	Mean 1993-95	17	3	16	3	1	1	*5*
Ulladulla	1993	18	4	17	4	1	0	*3*
	1994	25	5	24	5	0	0	*2*
	1995	16	2	15	2	1	1	*7*
	Mean 1993-95	19	2	19	2	1	0	*4*
Eden	1993	8	2	8	2	0	0	*1*
	1994	12	4	7	2	4	3	*38*
	1995	7	3	7	3	0	0	*0*
	Mean 1993-95	9	2	7	1	1	1	*17*
N+U+E	1993	37	6	36	6	1	0	*2*
	1994	50	8	45	6	5	3	*10*
	1995	49	7	45	7	3	2	*7*
	Mean 1993-95	45	4	42	4	3	1	*7*

Appendix A.26

Rubberlip morwong

Nemadactylus douglasi

Figure 26.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 26.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 26.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 26.1
Annual retained and discarded catches (t)

Table 26.2
Annual retained and discarded catches (number of fish)

Figure 26.4
Size distributions of retained and discarded catches

Figure 26.1

Retained and discarded catches (kg per fisher-day) - Rubberlip morwong
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

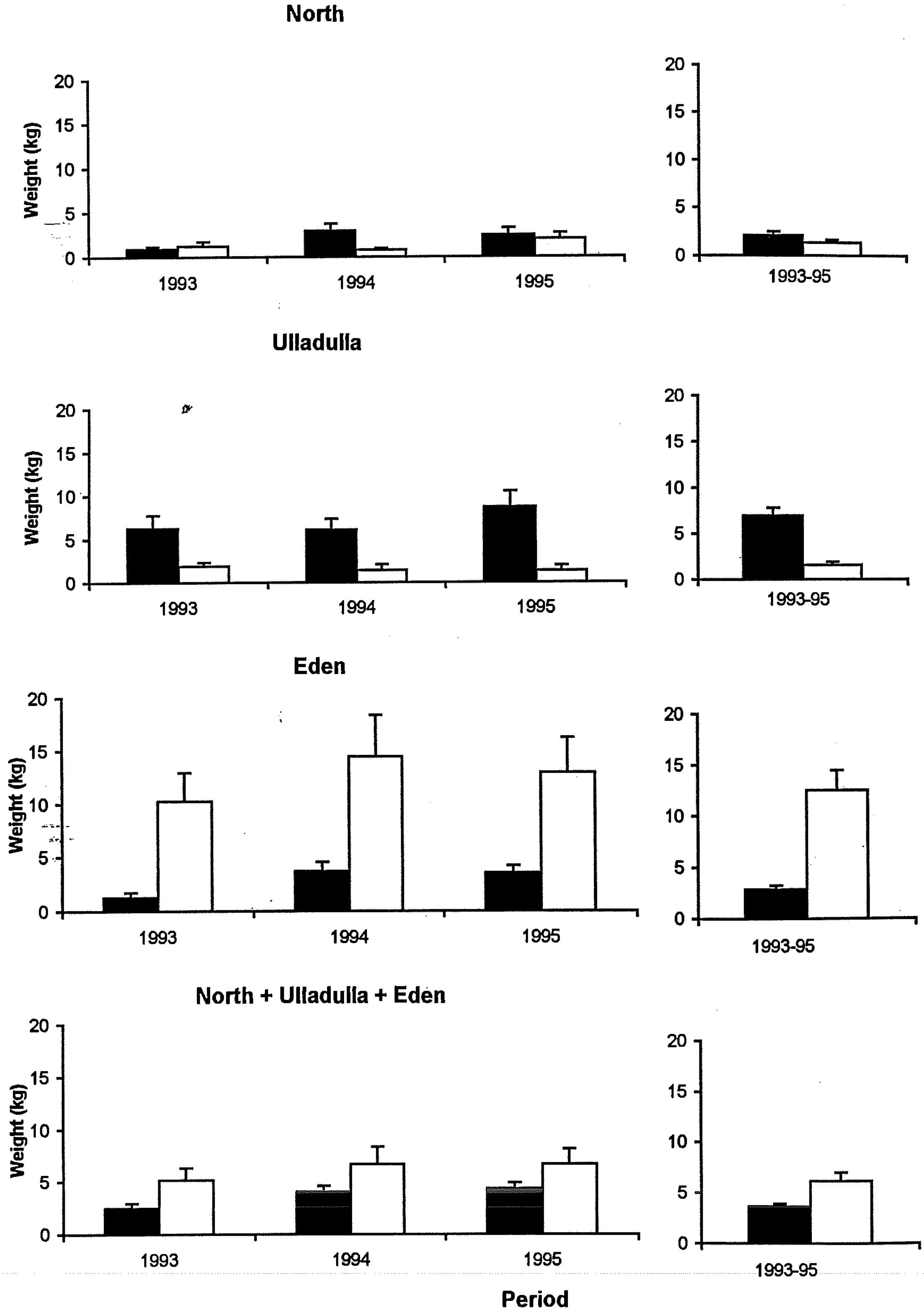


Figure 26.2

Retained and discarded catches (number of fish per fisher-day) - Rubberlip morwong
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

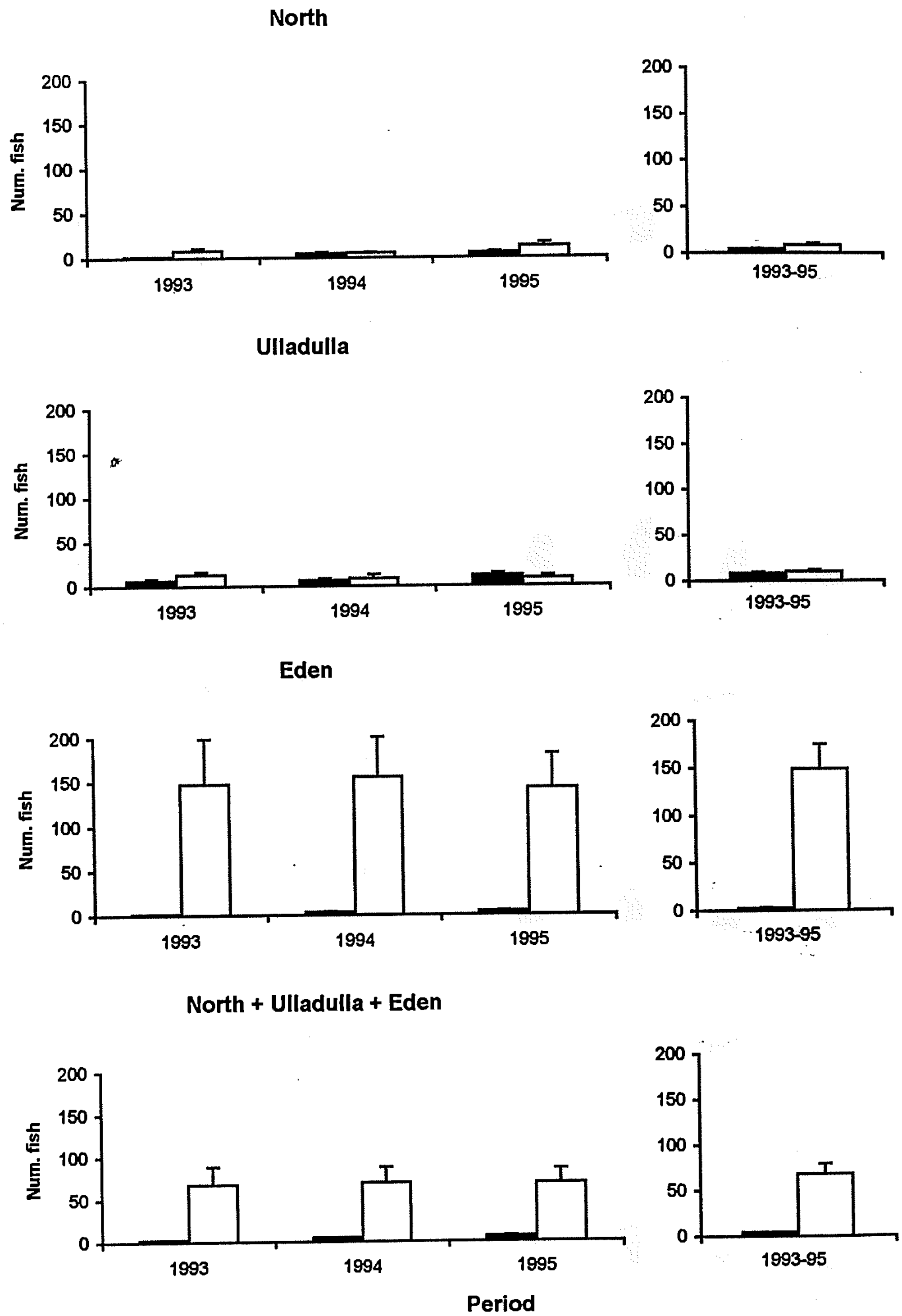


Figure 26.3

Retained and discarded catches (per fisher-day) - Rubberlip morwong
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

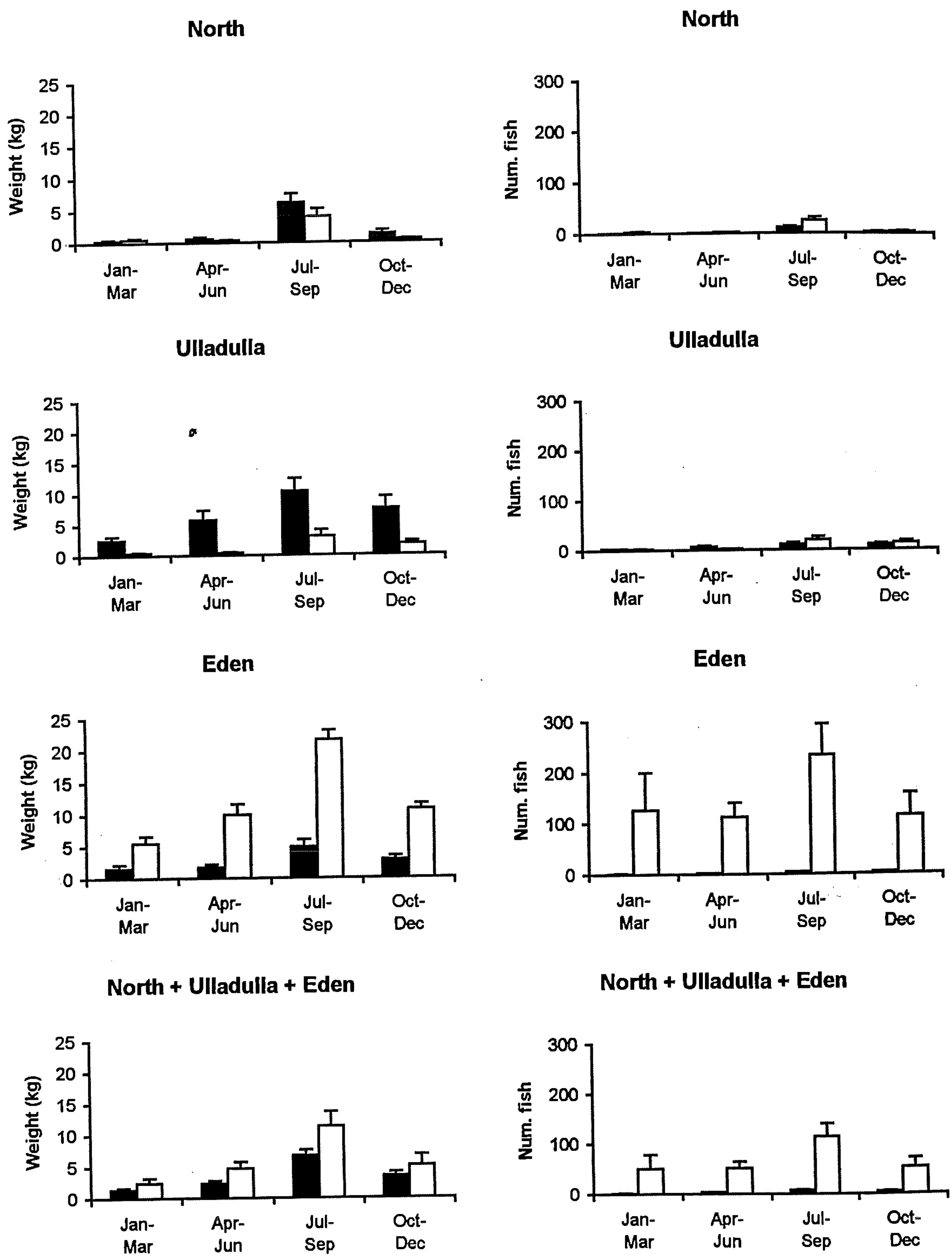


Table 26.1

Annual retained and discarded catches - Rubberlip morwong (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	3 +/-	1	2 +/-	0	2 +/-	1	*57*
	1994	6	1	5	1	1	0	*21*
	1995	7	2	4	1	3	1	*45*
Mean 1993-95		5	1	3	1	2	0	*39*
Ulladulla	1993	10	2	8	2	2	1	*23*
	1994	9	2	7	2	2	1	*18*
	1995	11	2	9	2	1	1	*13*
Mean 1993-95		10	1	8	1	2	0	*18*
Eden	1993	24	6	3	1	21	6	*89*
	1994	37	8	8	2	30	8	*80*
	1995	35	7	7	1	27	7	*79*
Mean 1993-95		32	4	6	1	26	4	*82*
N+U+E	1993	38	6	12	2	26	6	*68*
	1994	52	9	20	3	33	8	*62*
	1995	53	8	21	3	32	7	*61*
Mean 1993-95		48	4	18	1	30	4	*63*

Table 26.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	14 +/-	5	2 +/-	0	12 +/-	4	*86*
	1994	15	3	7	2	8	2	*53*
	1995	27	9	8	2	19	7	*71*
Mean 1993-95		19	4	6	1	13	3	*70*
Ulladulla	1993	25	5	8	2	16	4	*66*
	1994	19	7	8	2	11	5	*56*
	1995	21	6	12	3	9	4	*42*
Mean 1993-95		22	3	10	1	12	3	*55*
Eden	1993	308	105	2	1	305	105	*99*
	1994	326	92	6	1	319	92	*98*
	1995	309	83	8	1	301	82	*97*
Mean 1993-95		314	54	6	1	309	54	*98*
N+U+E	1993	347	106	13	2	334	105	*96*
	1994	360	92	22	3	338	92	*94*
	1995	358	83	28	4	330	83	*92*
Mean 1993-95		355	54	21	2	334	54	*94*

Figure 26.4, page 1

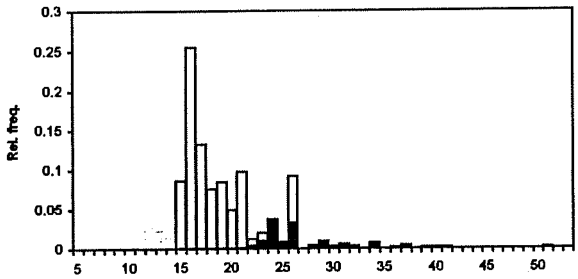
Size distributions of retained and discarded catches of Rubberlip morwong

Retained catch: black bars Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

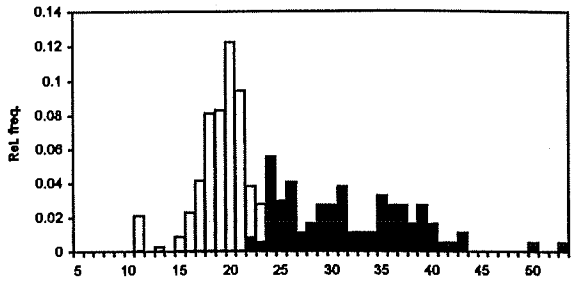
North, 1993

	Retained	Discarded	Total
Obs:	33 (8)	259 (53)	
Co-op:	0 (0)		
Mean L:	28.3	18.7	20.0



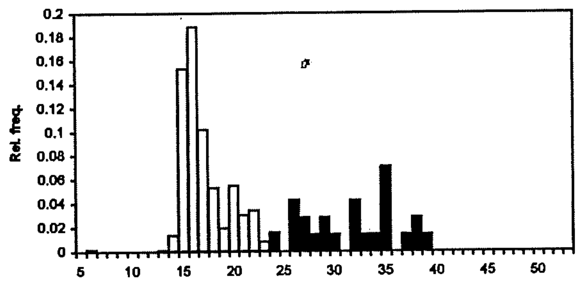
North, 1994

	Retained	Discarded	Total
Obs:	85 (6)	179 (67)	
Co-op:	0 (0)		
Mean L:	32.3	19.6	25.6



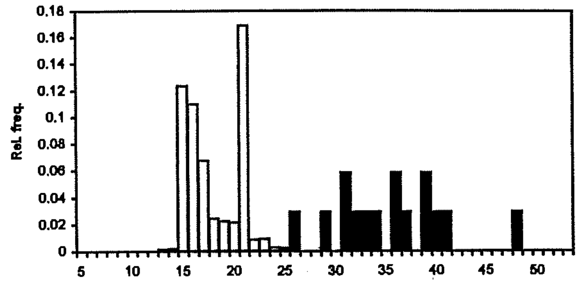
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	24 (5)	188 (63)	
Co-op:	0 (0)		
Mean L:	32.3	17.6	22.6



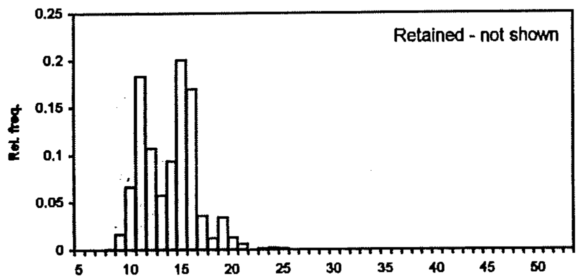
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	15 (1)	98 (36)	
Co-op:	0 (0)		
Mean L:	36.0	18.5	26.1



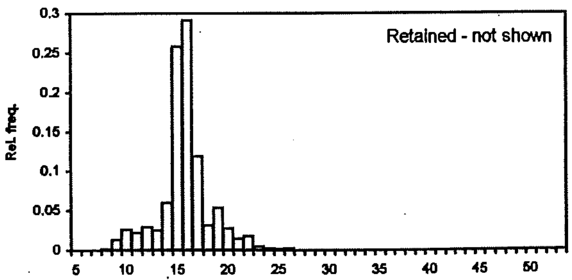
Eden, 1993

	Retained	Discarded	Total
Obs:	25 (2)	679 (61)	
Co-op:	0 (0)		
Mean L:		14.4	



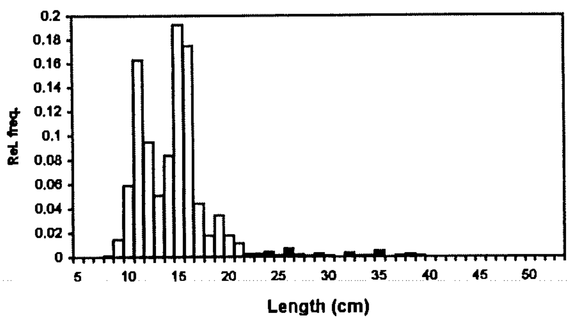
Eden, 1994

	Retained	Discarded	Total
Obs:	0 (0)	399 (65)	
Co-op:	0 (0)		
Mean L:		16.3	



N + U + E, 1993

	Retained	Discarded	Total
Obs:	82 (15)	1126 (177)	
Co-op:	0 (0)		
Mean L:	31.5	14.7	15.2



N + U + E, 1994

	Retained	Discarded	Total
Obs:	100 (6)	676 (158)	
Co-op:	0 (0)		
Mean L:	34.3	16.4	17.2

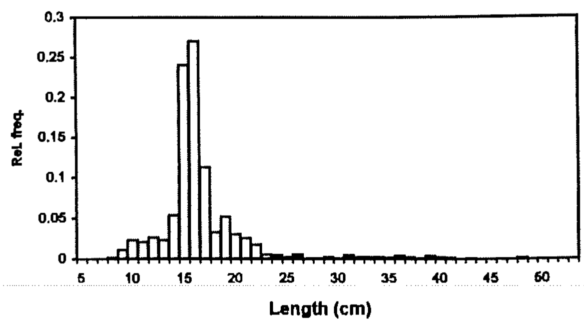
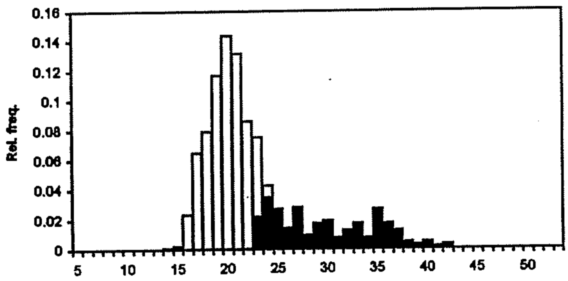


Figure 26.4, page 2

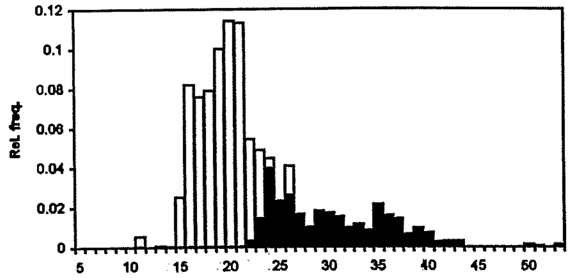
North, 1995

	Retained	Discarded	Total
Obs:	165 (8)	215 (46)	
Co-op:	0 (0)		
Mean L:	30.3	20.4	23.3



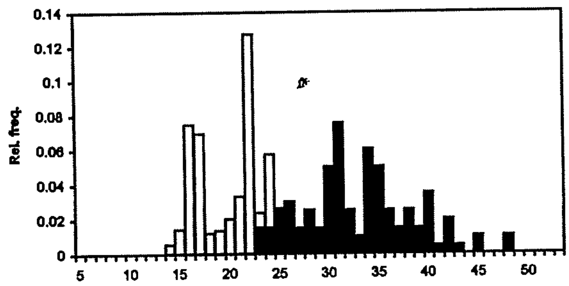
North, 1993-95

	Retained	Discarded	Total
Obs:	283 (21)	653 (156)	
Co-op:	0 (0)		
Mean L:	30.9	19.7	23.0



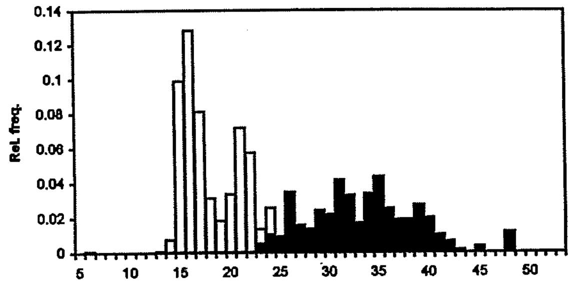
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	71 (2)	107 (39)	
Co-op:	0 (0)		
Mean L:	33.5	20.1	27.8



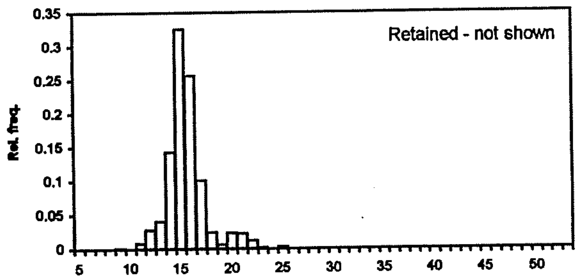
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	110 (8)	393 (138)	
Co-op:	0 (0)		
Mean L:	33.8	18.5	25.3



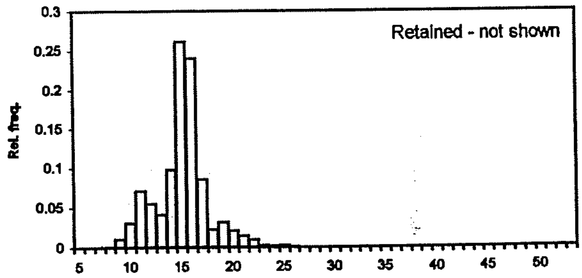
Eden, 1995

	Retained	Discarded	Total
Obs:	0 (0)	523 (68)	
Co-op:	0 (0)		
Mean L:		16.1	



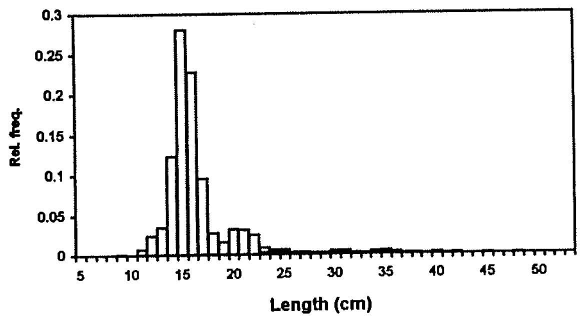
Eden, 1993-95

	Retained	Discarded	Total
Obs:	25 (2)	1601 (194)	
Co-op:	0 (0)		
Mean L:		15.6	



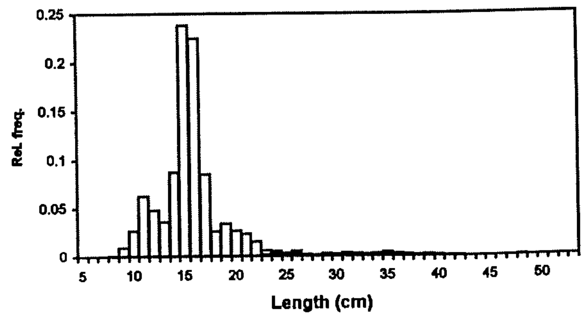
N + U + E, 1995

	Retained	Discarded	Total
Obs:	236 (10)	845 (153)	
Co-op:	0 (0)		
Mean L:	32.3	16.5	17.4



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	418 (31)	2647 (488)	
Co-op:	0 (0)		
Mean L:	32.8	15.9	16.6



Appendix A.27

Red gurnard

Chelidonichthys kumu

Figure 27.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 27.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 27.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 27.1
Annual retained and discarded catches (t)

Table 27.2
Annual retained and discarded catches (number of fish)

Figure 27.1

Retained and discarded catches (kg per fisher-day) - Red gurnard
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

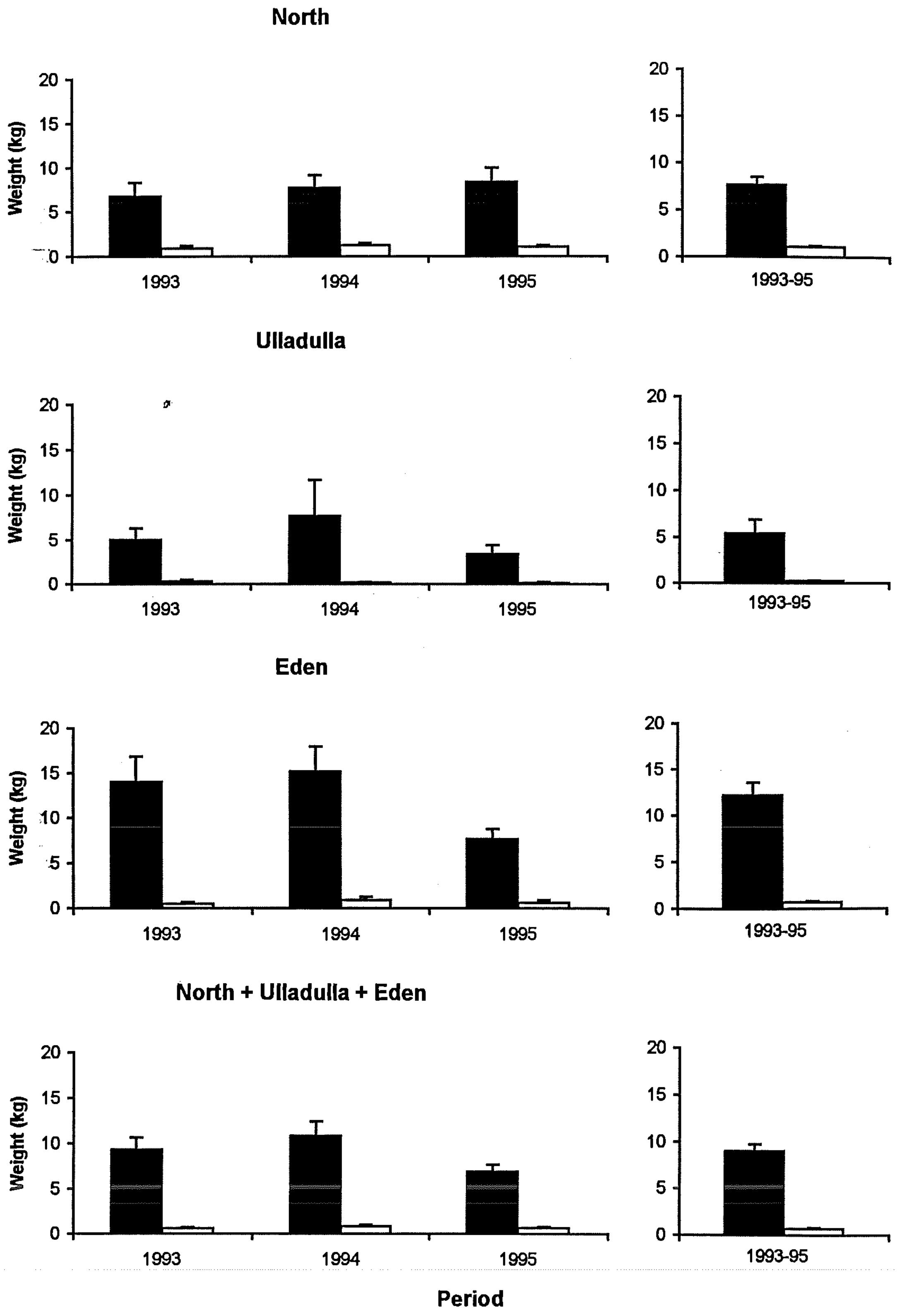


Figure 27.2

Retained and discarded catches (number of fish per fisher-day) - Red gurnard
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

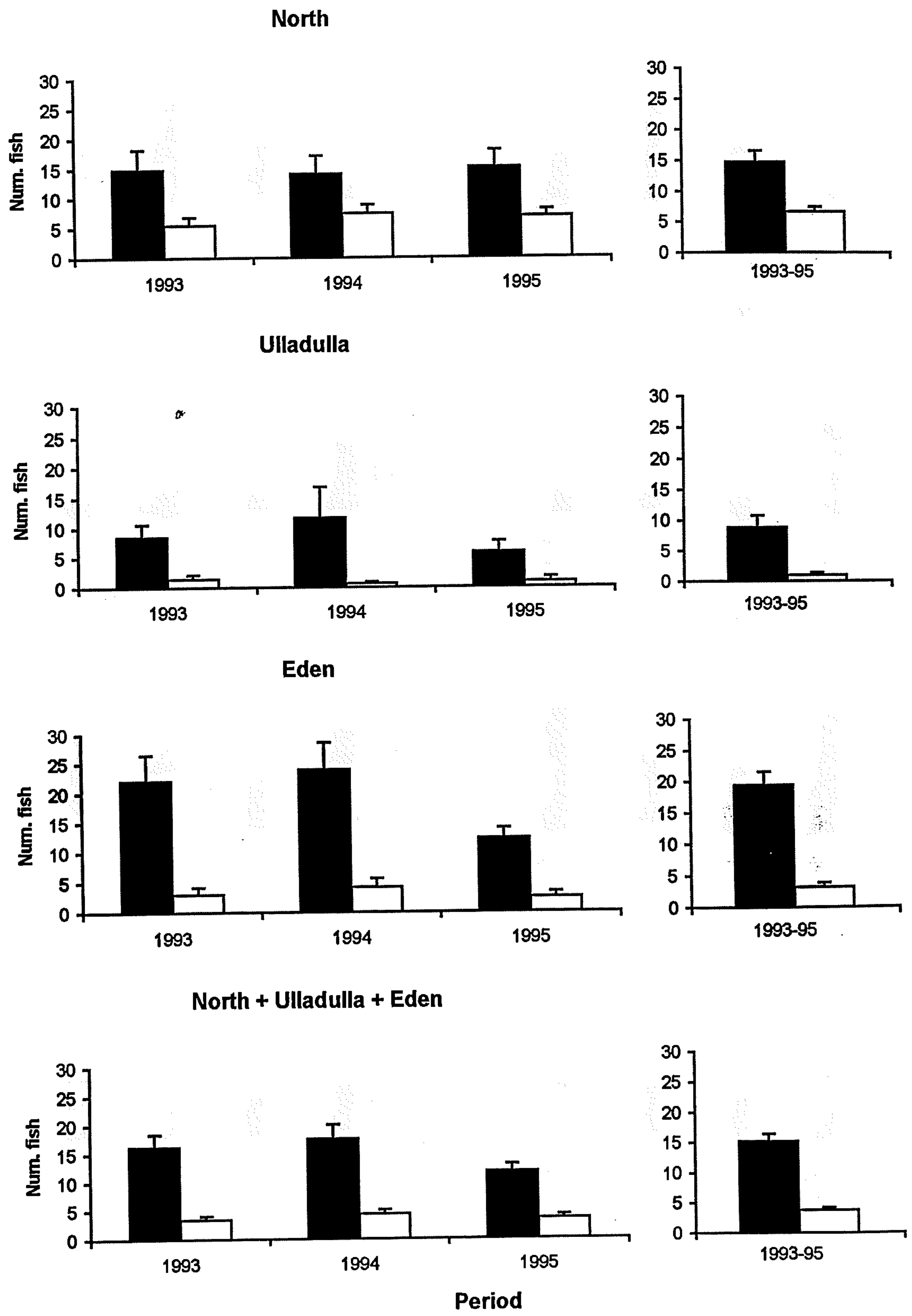


Figure 27.3

Retained and discarded catches (per fisher-day) - Red gurnard
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

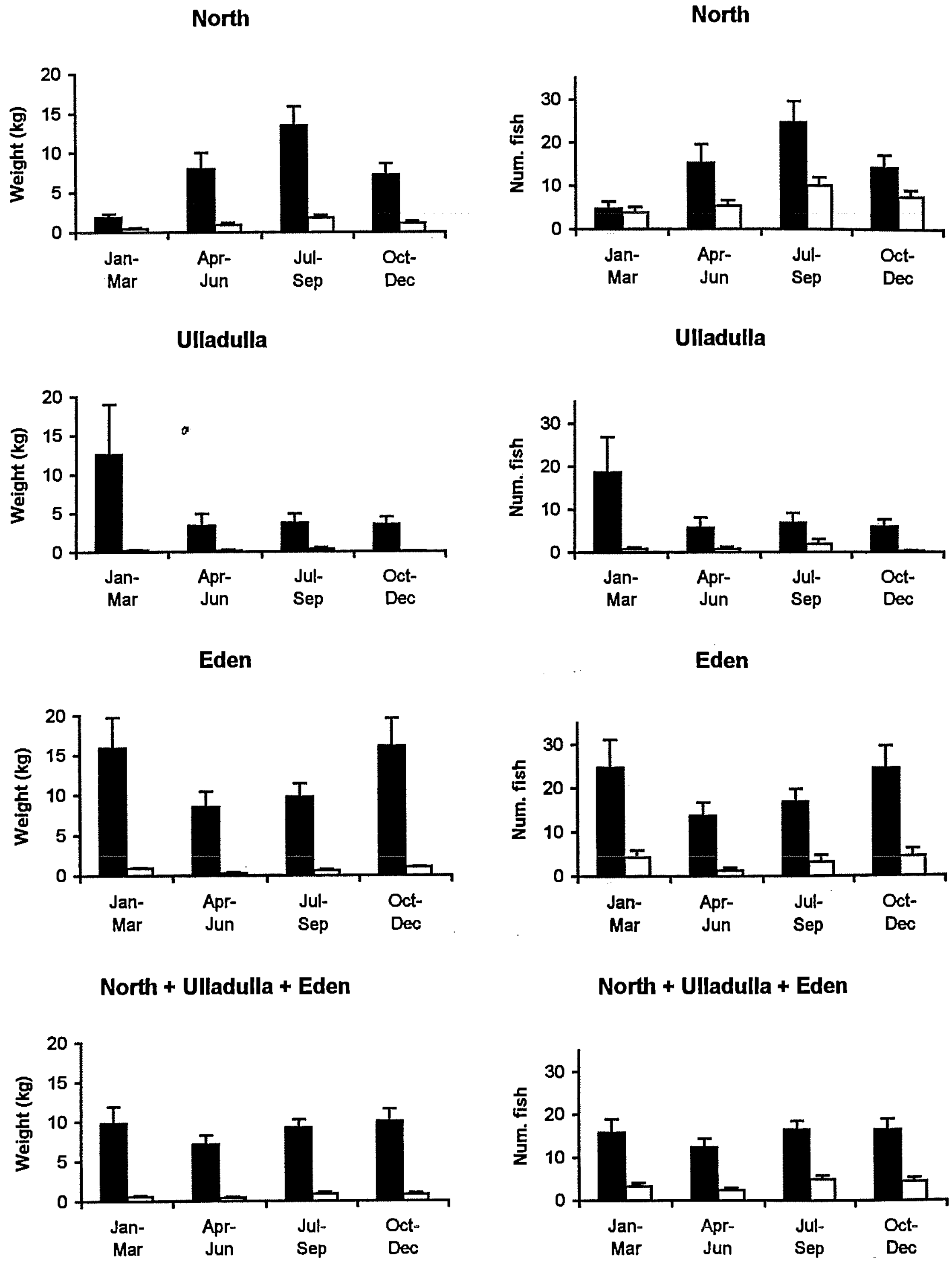


Table 27.1

Annual retained and discarded catches - Red gurnard (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	12	+/- 3	11	+/- 2	1	+/- 0	*12*
	1994	14	3	12	2	2	0	*14*
	1995	15	3	13	3	2	0	*11*
	Mean 1993-95	14	2	12	1	2	0	*12*
Ulladulla	1993	7	2	6	2	0	0	*6*
	1994	10	5	9	5	0	0	*2*
	1995	4	1	4	1	0	0	*4*
	Mean 1993-95	7	2	7	2	0	0	*4*
Eden	1993	30	6	29	6	1	0	*3*
	1994	33	6	31	6	2	1	*6*
	1995	17	2	16	2	1	1	*7*
	Mean 1993-95	27	3	25	3	1	0	*5*
N+U+E	1993	49	7	46	7	3	1	*6*
	1994	57	8	53	8	4	1	*7*
	1995	36	4	33	4	3	1	*9*
	Mean 1993-95	47	4	44	4	3	0	*7*

Table 27.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	32	+/- 7	24	+/- 6	9	+/- 2	*27*
	1994	34	6	23	5	12	2	*35*
	1995	35	5	24	5	11	2	*31*
	Mean 1993-95	34	4	23	3	11	1	*31*
Ulladulla	1993	13	3	11	3	2	1	*14*
	1994	15	6	14	6	1	0	*5*
	1995	7	3	6	2	1	1	*13*
	Mean 1993-95	12	3	11	2	1	0	*10*
Eden	1993	52	10	46	9	6	2	*12*
	1994	58	11	49	9	9	3	*15*
	1995	31	5	26	4	5	2	*16*
	Mean 1993-95	47	5	40	5	7	1	*14*
N+U+E	1993	97	13	80	11	17	3	*17*
	1994	107	14	86	12	21	4	*20*
	1995	74	8	56	6	17	3	*23*
	Mean 1993-95	93	7	74	8	18	2	*20*

Appendix A.28

Shovelnose ray

Aptychotrema rostrata

Figure 28.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 28.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 28.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 28.1
Annual retained and discarded catches (t)

Table 28.2
Annual retained and discarded catches (number of fish)

Figure 28.1

Retained and discarded catches (kg per fisher-day) - Shovelnose ray
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

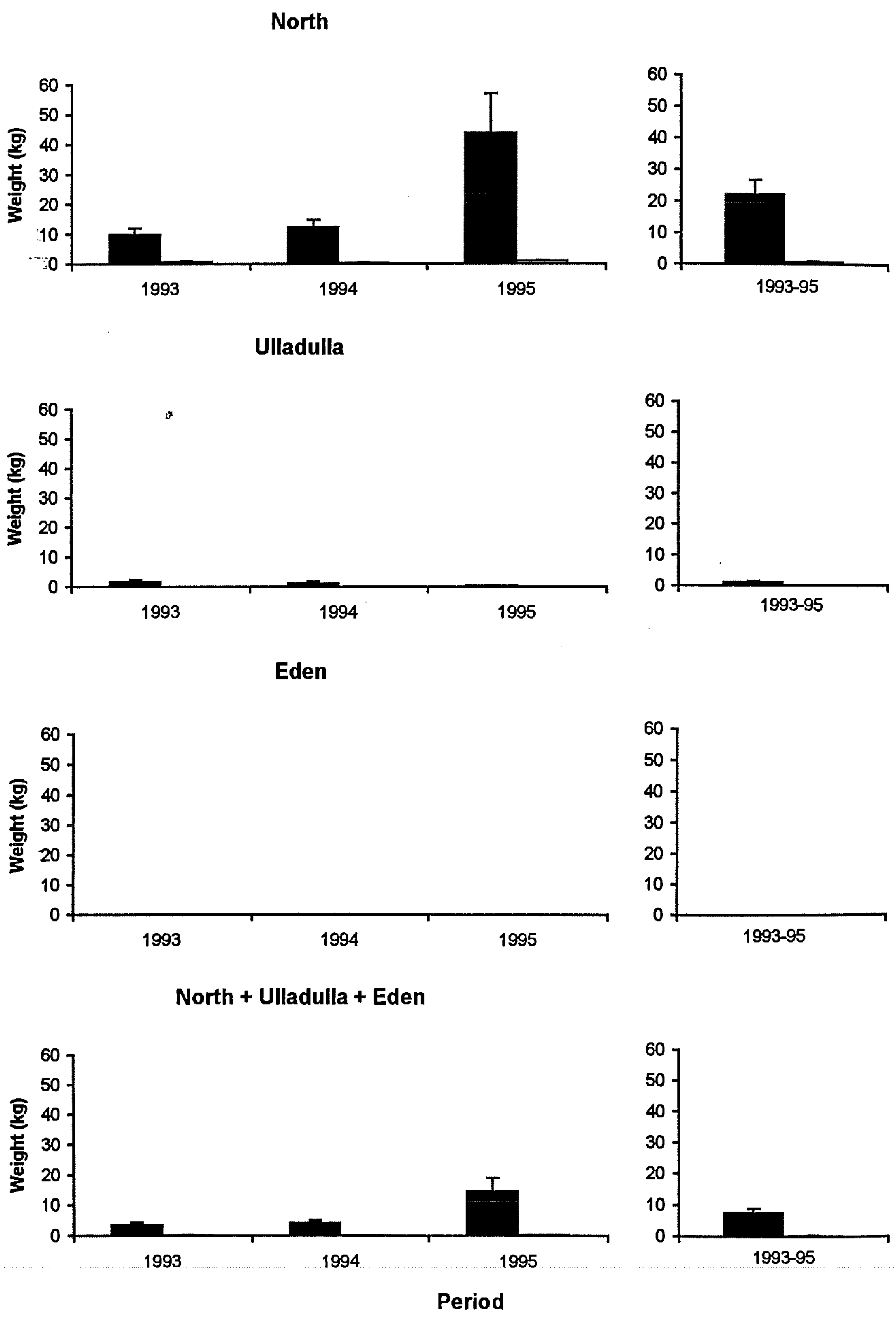


Figure 28.2

Retained and discarded catches (number of fish per fisher-day) - Shovelnose ray
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

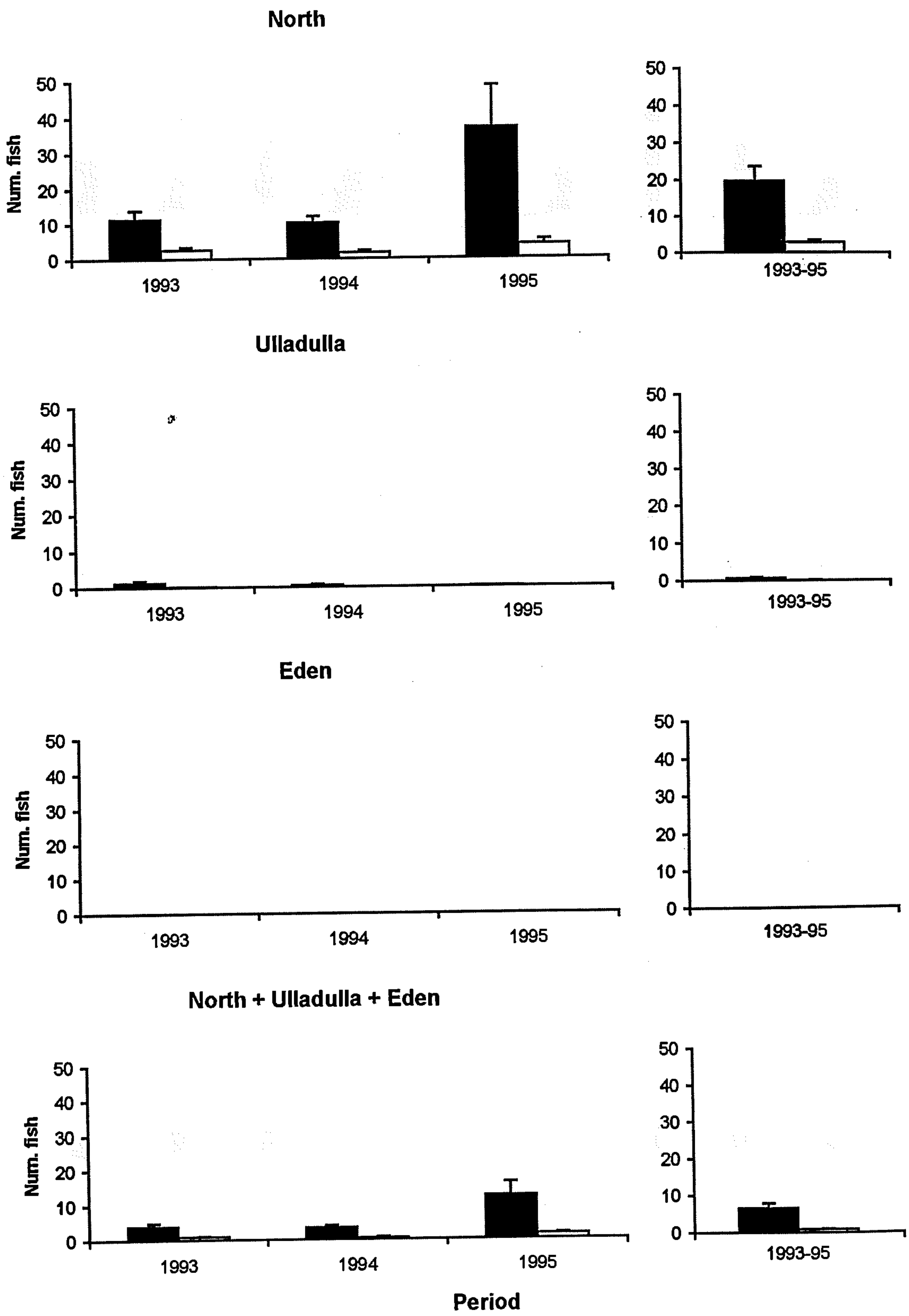


Figure 28.3

Retained and discarded catches (per fisher-day) - Shovelnose ray
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

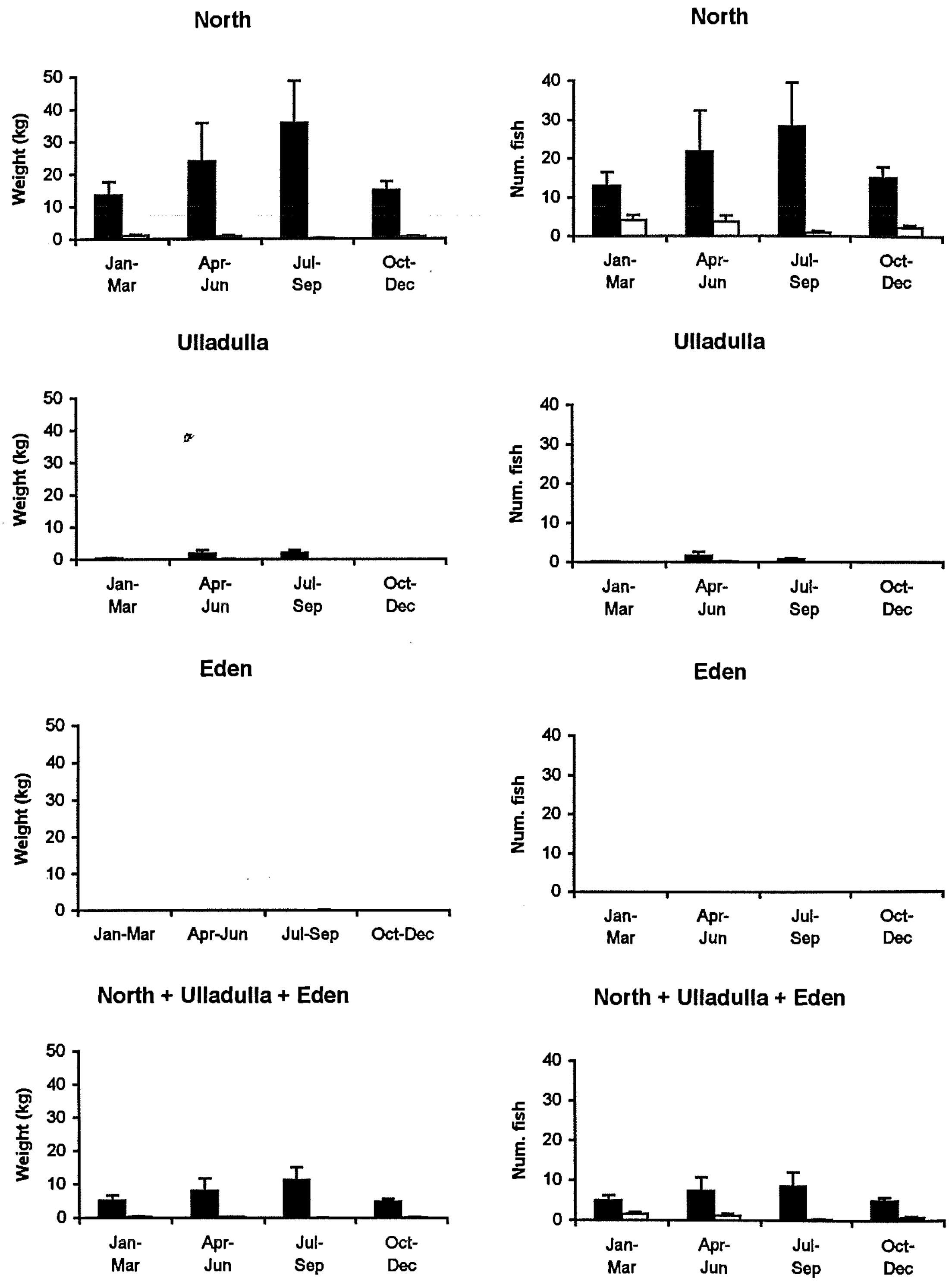


Table 28.1

Annual retained and discarded catches - Shovelnose ray (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	17 +/-	4	16 +/-	4	1 +/-	0	*6*
	1994	20	4	20	4	1	0	*3*
	1995	72	22	70	21	2	1	*2*
	Mean 1993-95	36	7	35	7	1	0	*3*
Ulladulla	1993	2	1	2	1	0	0	*3*
	1994	1	1	1	1	0	0	*0*
	1995	0	0	0	0	0	0	*0*
	Mean 1993-95	1	0	1	0	0	0	*2*
Eden	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
N+U+E	1993	19	4	18	4	1	0	*6*
	1994	22	4	21	4	1	0	*3*
	1995	72	22	71	21	2	1	*2*
	Mean 1993-95	38	7	36	7	1	0	*3*

Table 28.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	22 +/-	5	18 +/-	4	4 +/-	1	*19*
	1994	19	3	16	3	3	1	*14*
	1995	66	20	59	19	6	2	*10*
	Mean 1993-95	36	7	31	6	4	1	*12*
Ulladulla	1993	2	1	1	1	0	0	*9*
	1994	1	0	1	0	0	0	*0*
	1995	0	0	0	0	0	0	*0*
	Mean 1993-95	1	0	1	0	0	0	*6*
Eden	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
N+U+E	1993	24	5	19	4	4	1	*18*
	1994	19	3	17	3	3	1	*13*
	1995	66	20	59	19	6	2	*10*
	Mean 1993-95	36	7	32	6	4	1	*12*

Appendix A.29

Sharp-beaked gurnard

Pterygotrigla polyommata

Figure 29.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 29.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 29.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 29.1
Annual retained and discarded catches (t)

Table 29.2
Annual retained and discarded catches (number of fish)

Figure 29.1

Retained and discarded catches (kg per fisher-day) - Sharp-beaked gurnard

by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

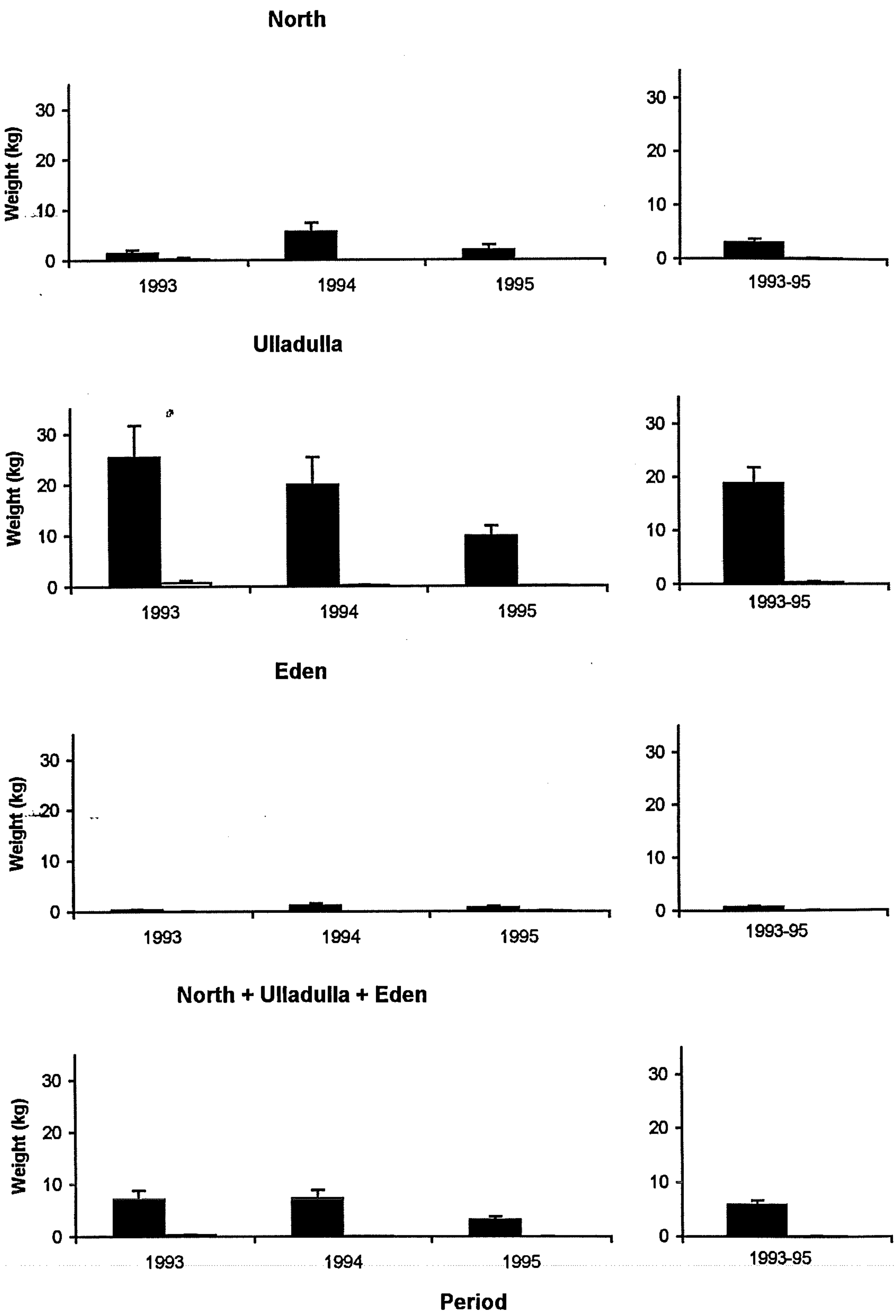


Figure 29.2

Retained and discarded catches (number of fish per fisher-day) - Sharp-beaked gurnard
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

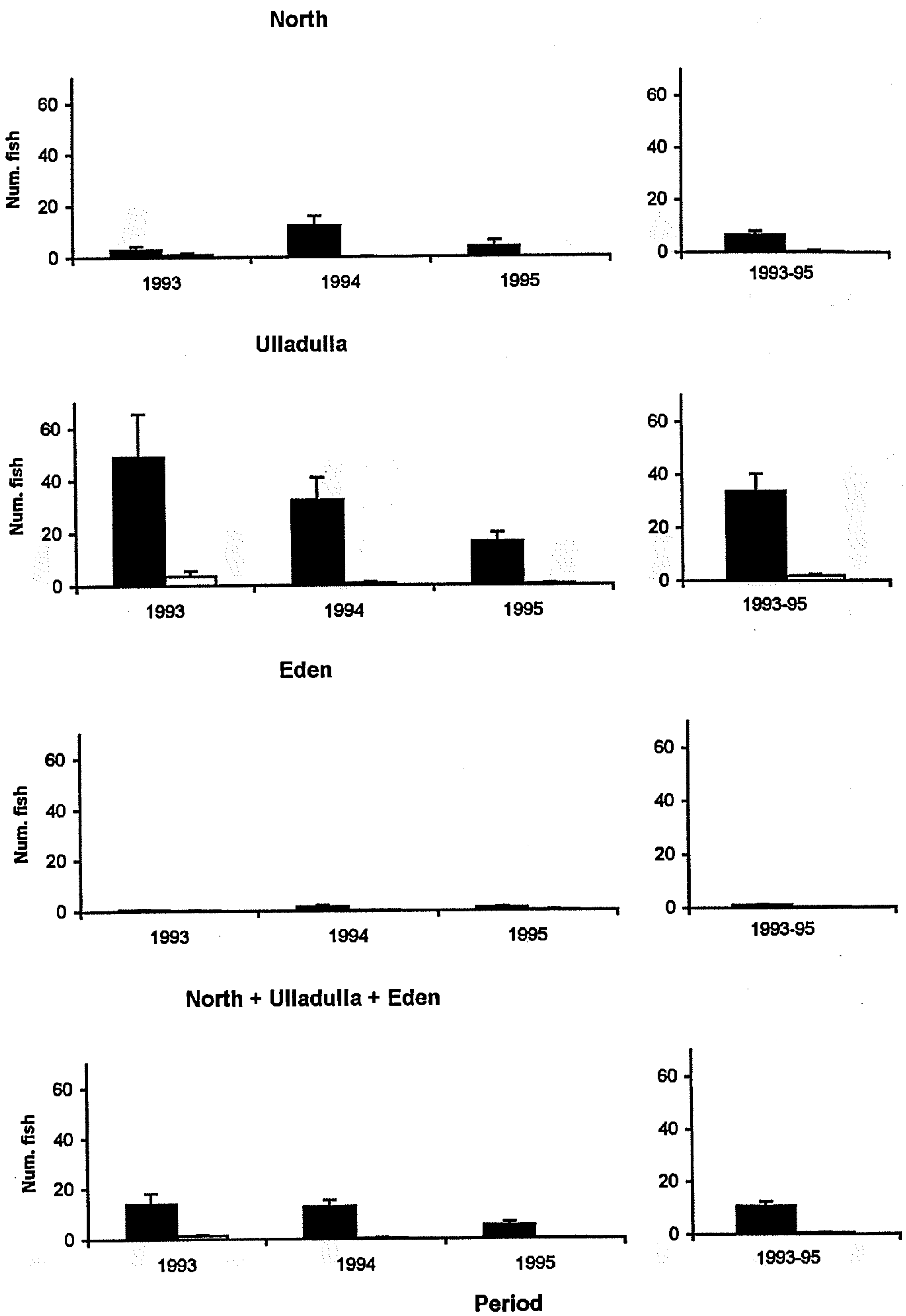


Figure 29.3

Retained and discarded catches (per fisher-day) - Sharp-beaked gurnard

by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

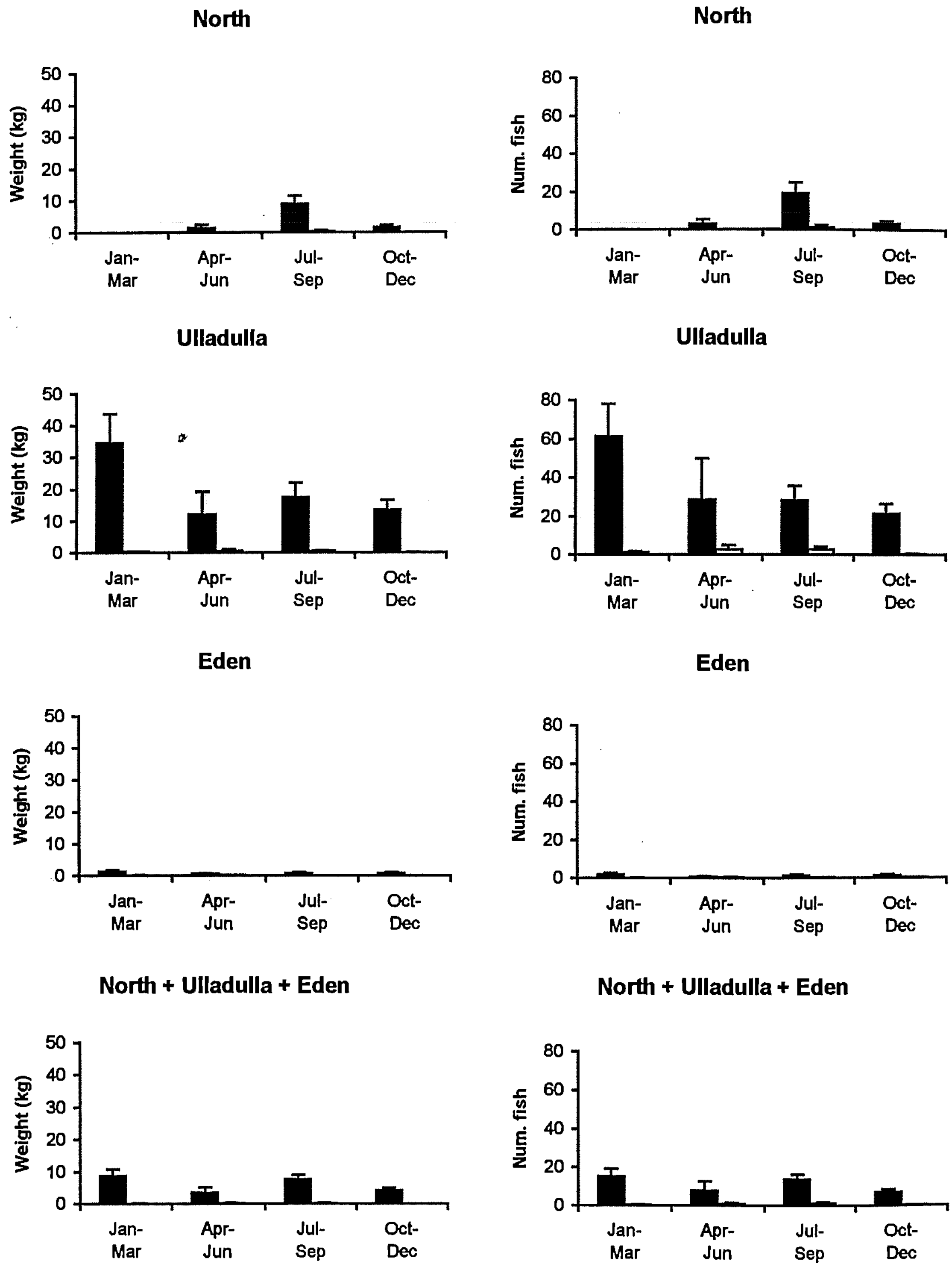


Table 29.1

Annual retained and discarded catches - Sharp-beaked gurnard (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	3 +/-	1	2 +/-	1	0 +/-	0	*15*
	1994	9	3	9	3	0	0	*0*
	1995	3	2	3	2	0	0	*0*
	Mean 1993-95	5	1	5	1	0	0	*3*
Ulladulla	1993	33	9	33	8	1	1	*3*
	1994	25	7	24	7	0	0	*1*
	1995	11	2	11	2	0	0	*1*
	Mean 1993-95	23	4	23	4	0	0	*2*
Eden	1993	1	0	1	0	0	0	*12*
	1994	2	1	2	1	0	0	*2*
	1995	2	1	2	1	0	0	*10*
	Mean 1993-95	2	0	1	0	0	0	*6*
N+U+E	1993	37	9	35	8	1	1	*4*
	1994	36	8	36	7	0	0	*1*
	1995	15	3	15	3	0	0	*2*
	Mean 1993-95	29	4	29	4	1	0	*2*

Table 29.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	6 +/-	3	5 +/-	2	1 +/-	1	*22*
	1994	19	6	19	6	0	0	*1*
	1995	6	4	6	4	0	0	*0*
	Mean 1993-95	11	3	10	3	0	0	*5*
Ulladulla	1993	68	23	63	21	5	3	*7*
	1994	41	11	40	11	1	0	*3*
	1995	18	4	18	4	0	0	*2*
	Mean 1993-95	42	9	40	8	2	1	*5*
Eden	1993	2	1	1	1	0	0	*31*
	1994	4	2	3	1	0	0	*7*
	1995	3	1	2	1	1	1	*21*
	Mean 1993-95	3	1	2	1	0	0	*17*
N+U+E	1993	75	23	69	21	6	3	*9*
	1994	64	12	63	12	2	1	*2*
	1995	27	6	26	6	1	1	*3*
	Mean 1993-95	56	9	53	8	3	1	*5*

Appendix A.30

Eagle ray

Myliobatis australis

Figure 30.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 30.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 30.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 30.1
Annual retained and discarded catches (t)

Table 30.2
Annual retained and discarded catches (number of fish)

Figure 30.1

Retained and discarded catches (kg per fisher-day) - Eagle ray
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

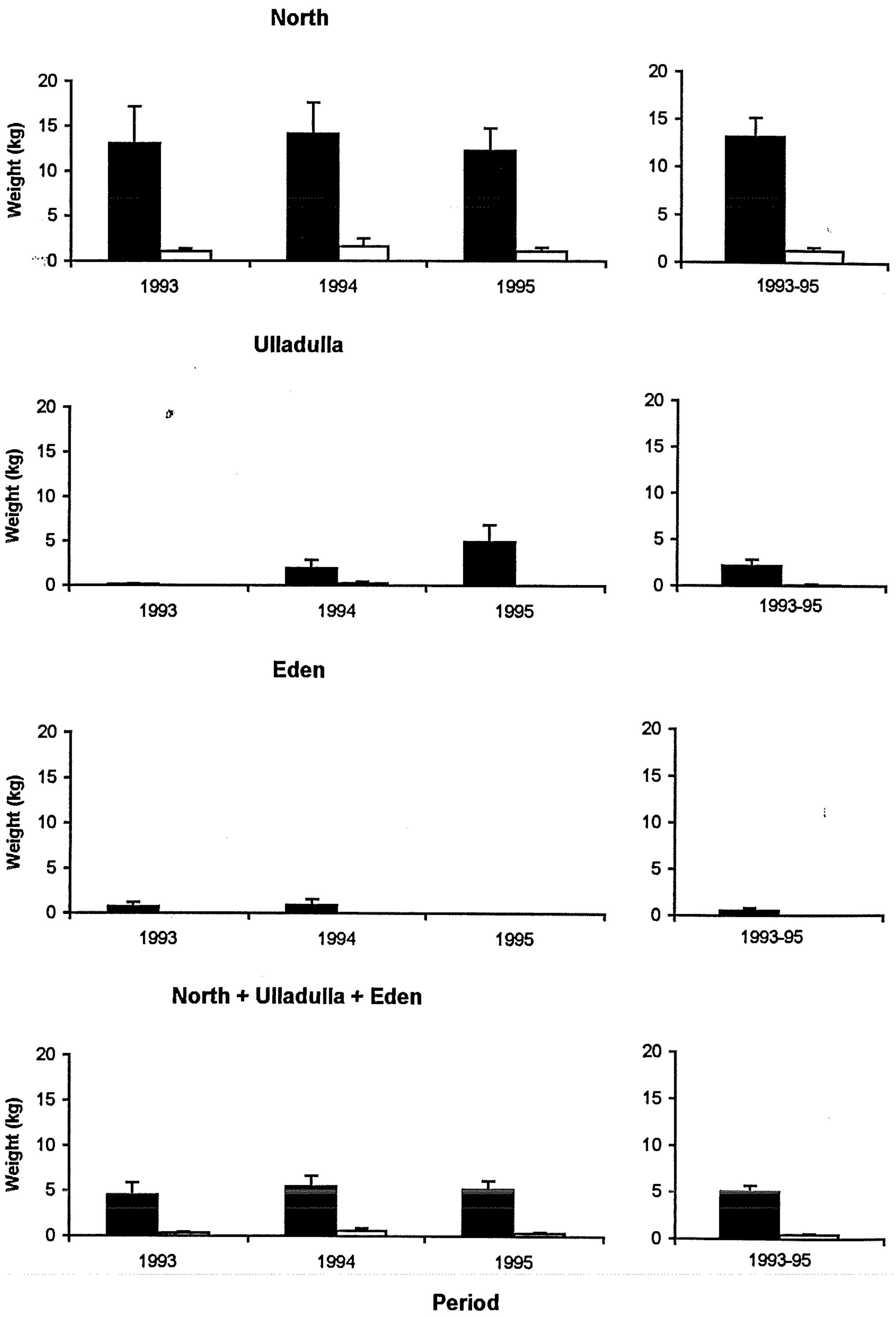


Figure 30.2

Retained and discarded catches (number of fish per fisher-day) - Eagle ray
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

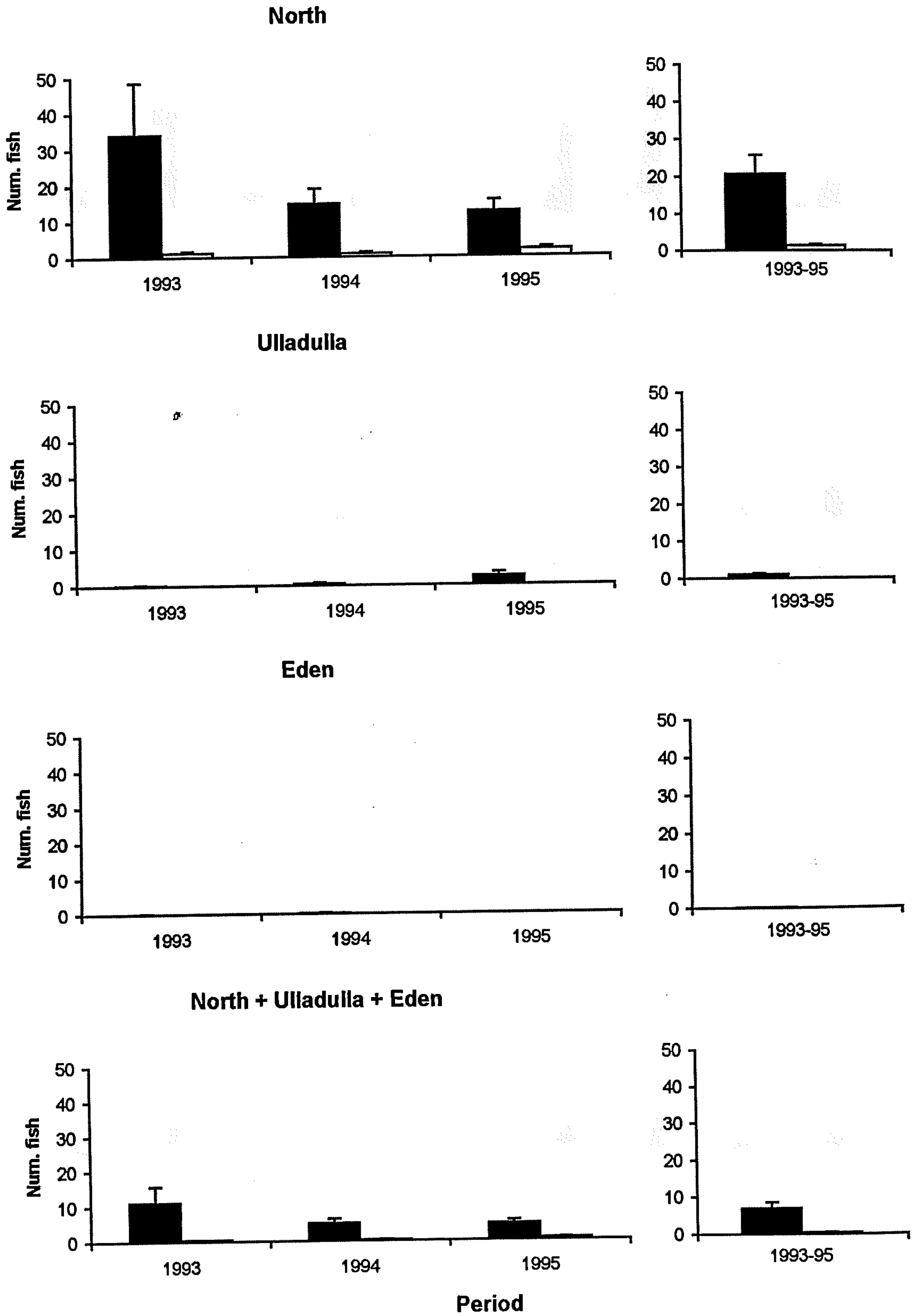


Figure 30.3

Retained and discarded catches (per fisher-day) - Eagle ray
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

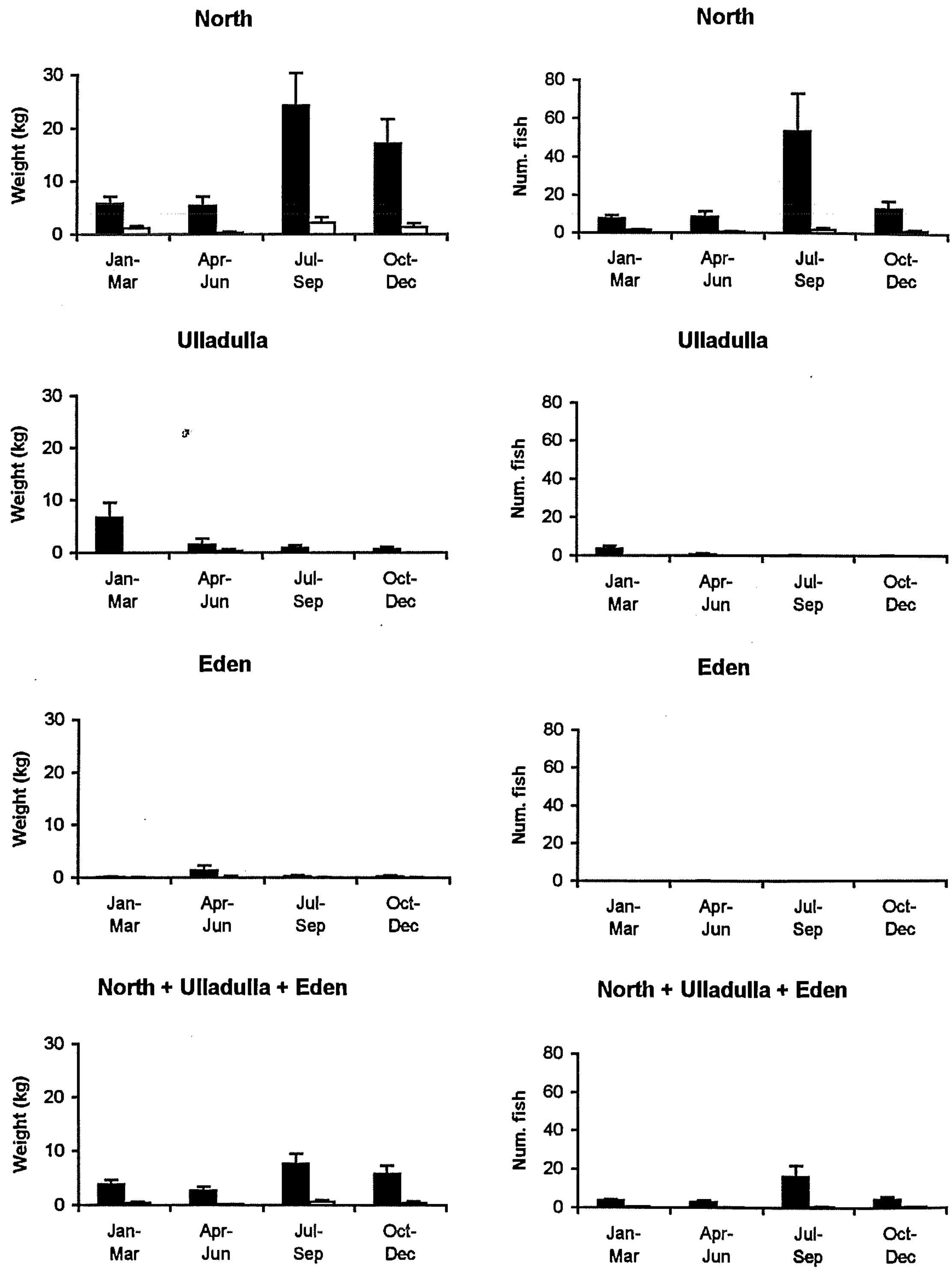


Table 30.1

Annual retained and discarded catches - Eagle ray (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	23 +/-	7	21 +/-	7	2 +/-	1	*8*
	1994	25	6	23	6	3	1	*10*
	1995	21	4	20	4	2	1	*8*
	Mean 1993-95	23	3	21	3	2	1	*9*
Ulladulla	1993	0	0	0	0	0	0	*0*
	1994	3	1	2	1	0	0	*10*
	1995	5	2	5	2	0	0	*0*
	Mean 1993-95	3	1	3	1	0	0	*3*
Eden	1993	1	1	1	1	0	0	*0*
	1994	2	1	2	1	0	0	*0*
	1995	0	0	0	0	0	0	
	Mean 1993-95	1	1	1	1	0	0	*0*
N+U+E	1993	24	7	22	7	2	1	*7*
	1994	30	6	27	6	3	1	*10*
	1995	27	4	25	4	2	1	*7*
	Mean 1993-95	27	3	25	3	2	1	*8*

Table 30.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	57 +/-	23	54 +/-	23	2 +/-	1	*4*
	1994	25	7	24	7	1	1	*5*
	1995	23	5	20	5	3	1	*13*
	Mean 1993-95	35	8	33	8	2	0	*6*
Ulladulla	1993	0	0	0	0	0	0	*0*
	1994	1	0	1	0	0	0	*0*
	1995	3	1	3	1	0	0	*0*
	Mean 1993-95	1	0	1	0	0	0	*0*
Eden	1993	0	0	0	0	0	0	*0*
	1994	0	0	0	0	0	0	*0*
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	*0*
N+U+E	1993	57	23	55	23	2	1	*4*
	1994	26	7	25	7	1	1	*5*
	1995	26	5	23	5	3	1	*12*
	Mean 1993-95	36	8	34	8	2	0	*6*

Appendix A.31

Gummy shark

Mustelus antarcticus

Figure 31.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 31.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 31.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 31.1
Annual retained and discarded catches (t)

Table 31.2
Annual retained and discarded catches (number of fish)

Figure 31.1

Retained and discarded catches (kg per fisher-day) - Gummy shark
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

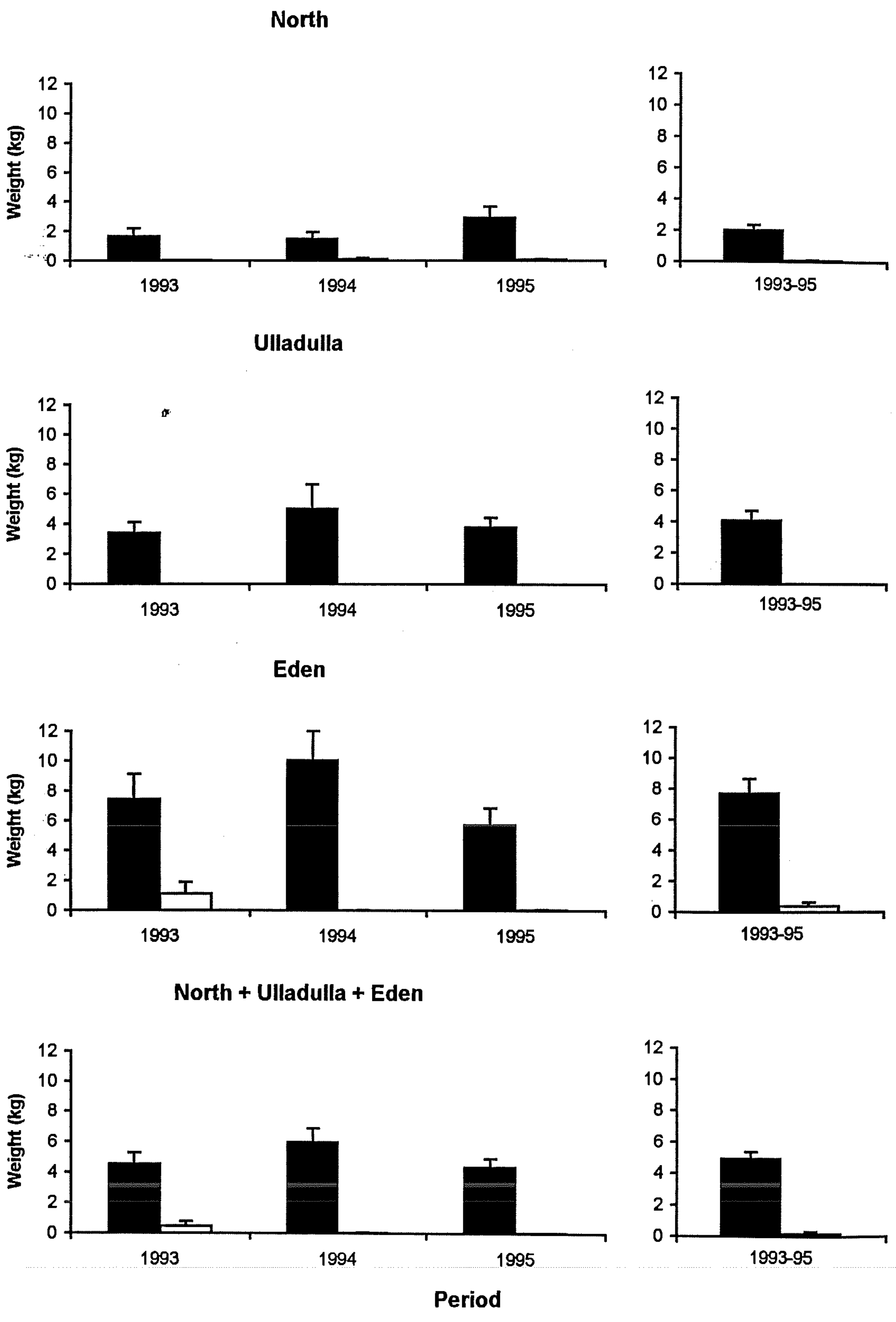


Figure 31.2

Retained and discarded catches (number of fish per fisher-day) - Gummy shark
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

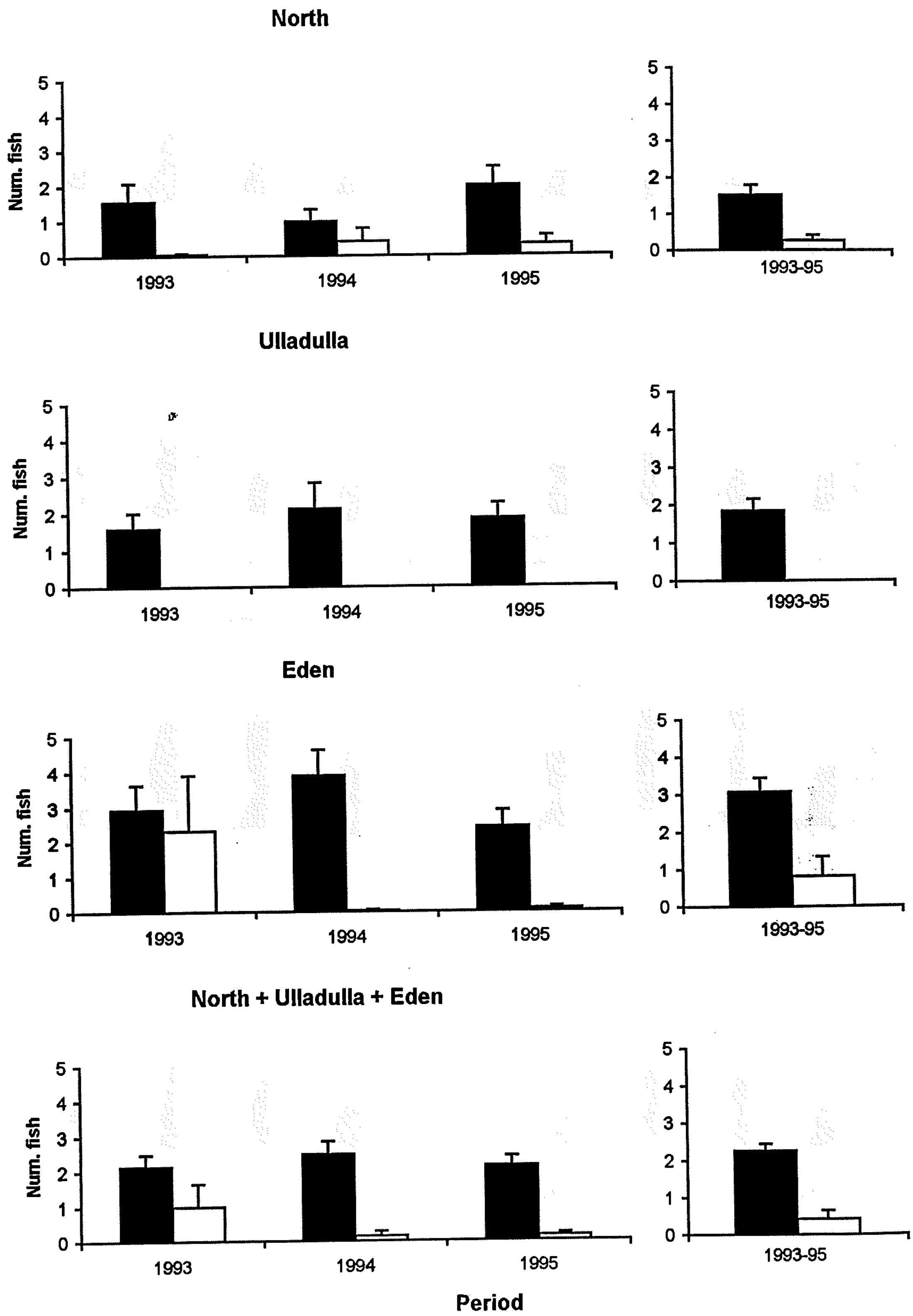


Figure 31.3

Retained and discarded catches (per fisher-day) - Gummy shark

by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

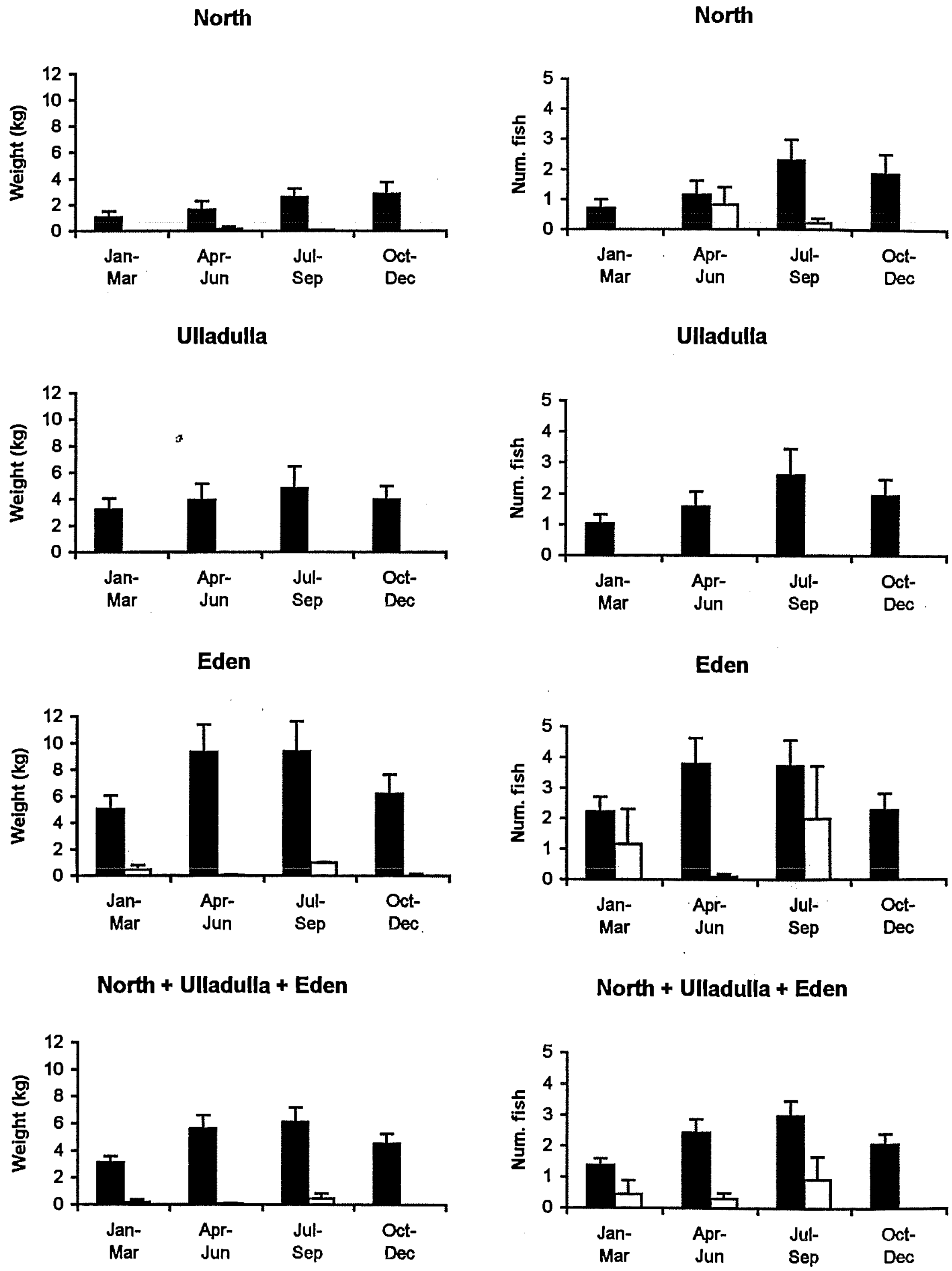


Table 31.1

Annual retained and discarded catches - Gummy shark (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	3 +/-	1	3 +/-	1	0 +/-	0	2
	1994	3	1	2	1	0	0	6
	1995	5	1	5	1	0	0	2
	Mean 1993-95	3	1	3	1	0	0	3
Ulladulla	1993	4	1	4	1	0	0	0
	1994	6	2	6	2	0	0	0
	1995	4	1	4	1	0	0	0
	Mean 1993-95	5	1	5	1	0	0	0
Eden	1993	18	4	15	4	2	2	13
	1994	21	4	21	4	0	0	0
	1995	12	2	12	2	0	0	1
	Mean 1993-95	17	2	16	2	1	1	5
N+U+E	1993	25	4	22	4	2	2	9
	1994	29	5	29	5	0	0	1
	1995	21	3	21	3	0	0	1
	Mean 1993-95	25	2	24	2	1	1	4

Table 31.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	3 +/-	1	2 +/-	1	0 +/-	0	3
	1994	2	1	2	1	1	1	29
	1995	4	1	3	1	1	0	14
	Mean 1993-95	3	1	2	0	0	0	15
Ulladulla	1993	2	1	2	1	0	0	0
	1994	3	1	3	1	0	0	0
	1995	2	0	2	0	0	0	0
	Mean 1993-95	2	0	2	0	0	0	0
Eden	1993	11	4	6	1	5	3	44
	1994	8	2	8	2	0	0	1
	1995	5	1	5	1	0	0	3
	Mean 1993-95	8	1	6	1	2	1	21
N+U+E	1993	15	4	11	2	5	3	32
	1994	13	2	12	2	1	1	5
	1995	11	1	10	1	1	0	6
	Mean 1993-95	13	2	11	1	2	1	16

Appendix A.32

Centrophorus spp.

Figure 32.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 32.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 32.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 32.1
Annual retained and discarded catches (t)

Table 32.2
Annual retained and discarded catches (number of fish)

Figure 32.1

Retained and discarded catches (kg per fisher-day) - Centrophorus spp.
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

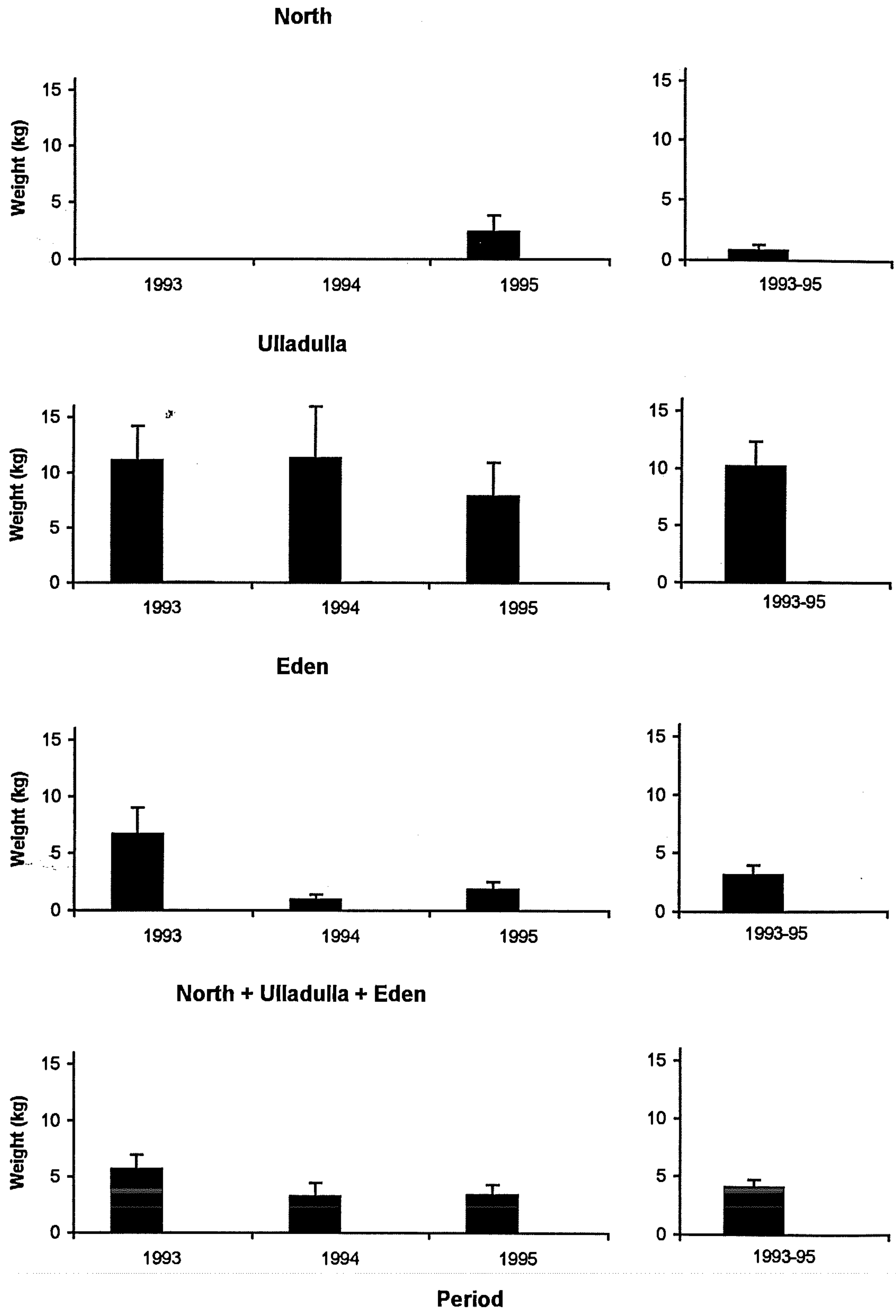


Figure 32.2

Retained and discarded catches (number of fish per fisher-day) - Centrophorus spp.
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

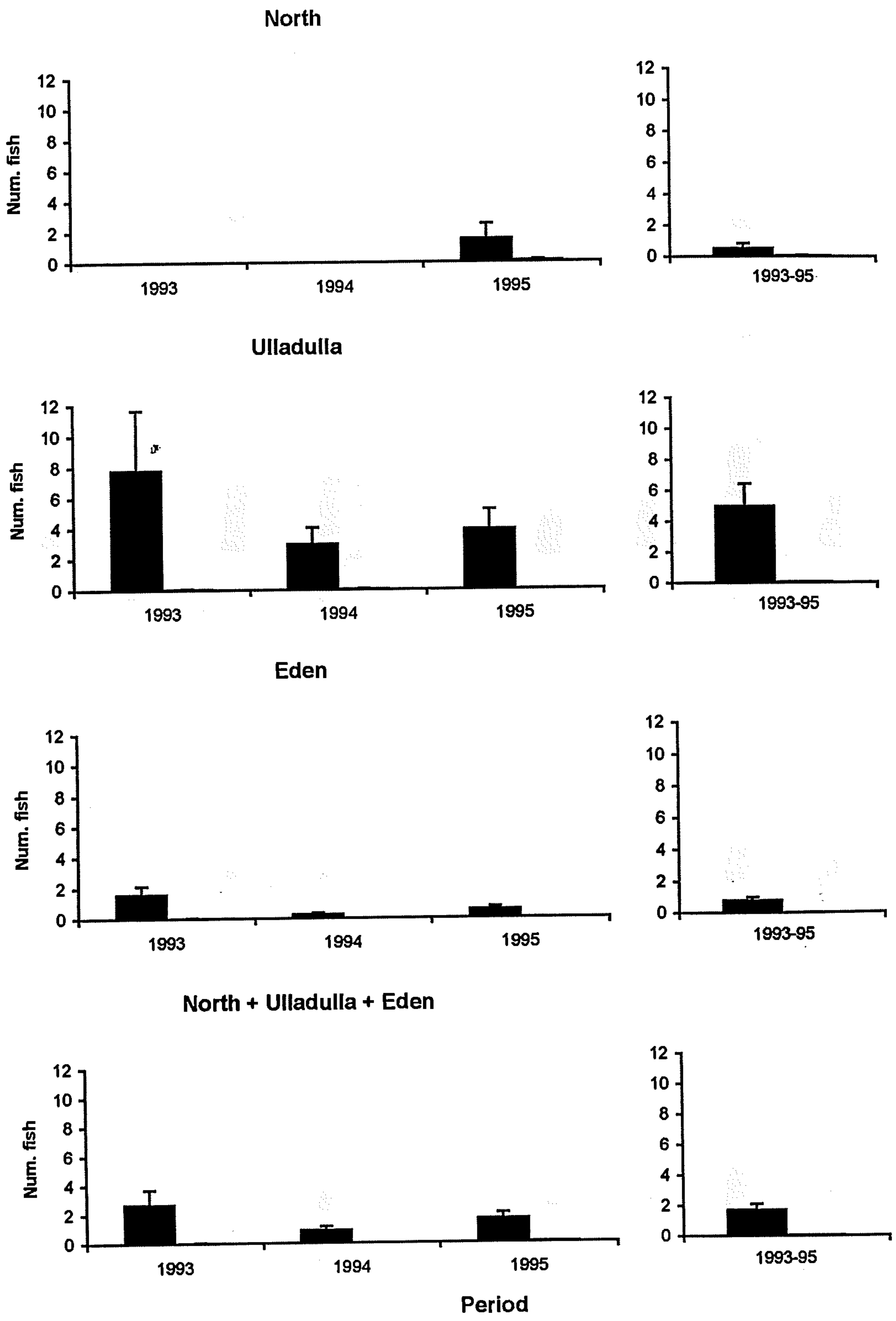


Figure 32.3

Retained and discarded catches (per fisher-day) - Centrophorus spp.
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

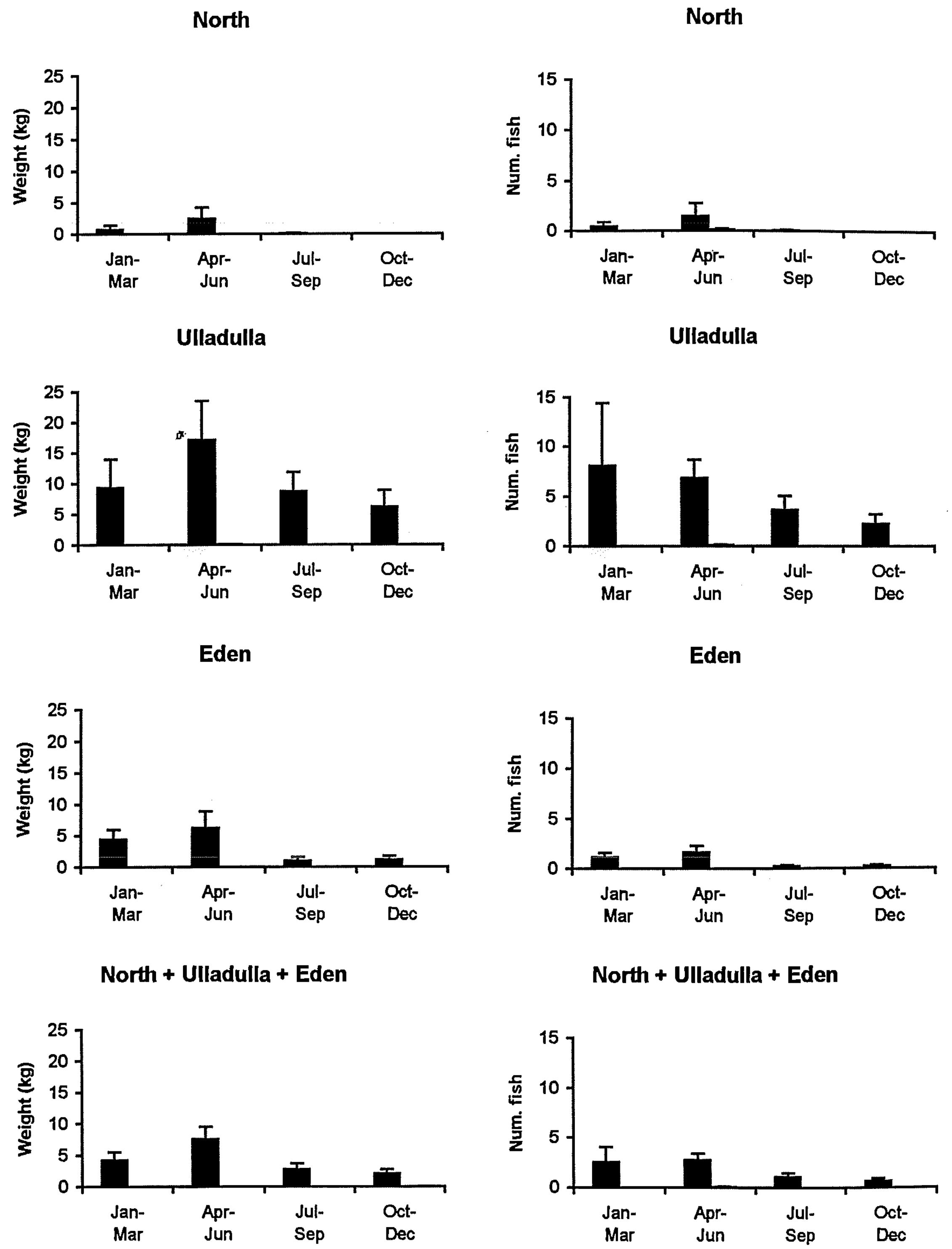


Table 32.1

Annual retained and discarded catches - Centrophorus spp. (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	0 +/-	0	0 +/-	0	0 +/-	0	
	1994	0	0	0	0	0	0	
	1995	4	2	4	2	0	0	*0*
	Mean 1993-95	1	1	1	1	0	0	*0*
Ulladulla	1993	14	4	14	4	0	0	*0*
	1994	14	6	14	6	0	0	*0*
	1995	9	3	9	3	0	0	*0*
	Mean 1993-95	12	3	12	3	0	0	*0*
Eden	1993	14	5	14	5	0	0	*0*
	1994	2	1	2	1	0	0	*0*
	1995	4	1	4	1	0	0	*0*
	Mean 1993-95	7	2	7	2	0	0	*0*
N+U+E	1993	28	6	28	6	0	0	*0*
	1994	16	6	16	6	0	0	*0*
	1995	16	4	16	4	0	0	*0*
	Mean 1993-95	20	3	20	3	0	0	*0*

Table 32.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	0 +/-	0	0 +/-	0	0 +/-	0	
	1994	0	0	0	0	0	0	
	1995	3	2	2	2	0	0	*5*
	Mean 1993-95	1	1	1	1	0	0	*5*
Ulladulla	1993	10	5	10	5	0	0	*1*
	1994	4	1	4	1	0	0	*1*
	1995	4	1	4	1	0	0	*0*
	Mean 1993-95	6	2	6	2	0	0	*1*
Eden	1993	3	1	3	1	0	0	*1*
	1994	1	0	1	0	0	0	*0*
	1995	1	0	1	0	0	0	*0*
	Mean 1993-95	2	0	2	0	0	0	*0*
N+U+E	1993	13	5	13	5	0	0	*1*
	1994	4	1	4	1	0	0	*1*
	1995	8	2	8	2	0	0	*2*
	Mean 1993-95	9	2	8	2	0	0	*1*

Appendix A.33

Eastern blue-spot flathead

Platycephalus caeruleopunctatus

Figure 33.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 33.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 33.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 33.1
Annual retained and discarded catches (t)

Table 33.2
Annual retained and discarded catches (number of fish)

Figure 33.4
Size distributions of retained and discarded catches

Figure 33.1

Retained and discarded catches (kg per fisher-day) - Eastern blue-spot flathead
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

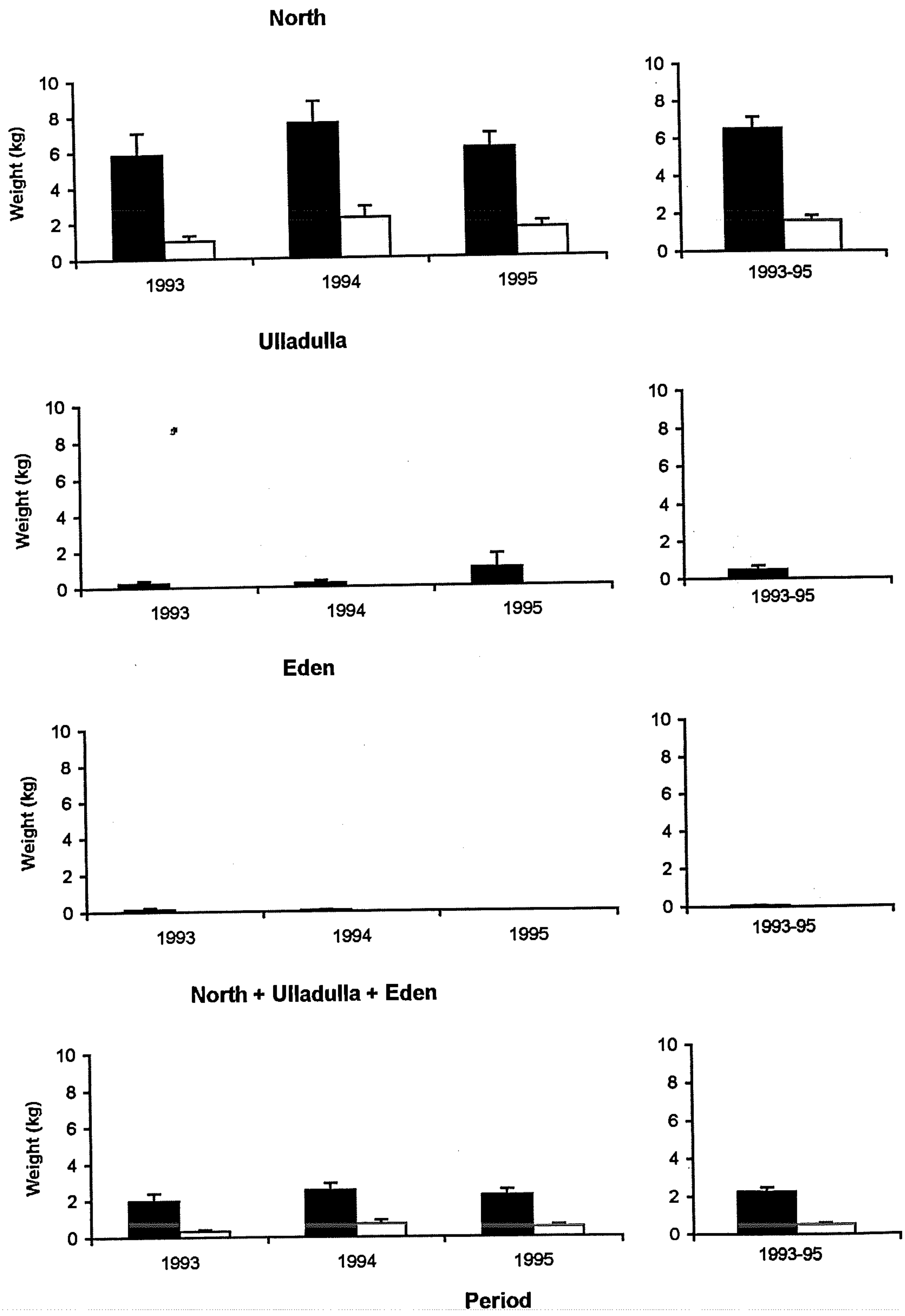


Figure 33.2

Retained and discarded catches (number of fish per fisher-day) - Eastern blue-spot flathead

by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

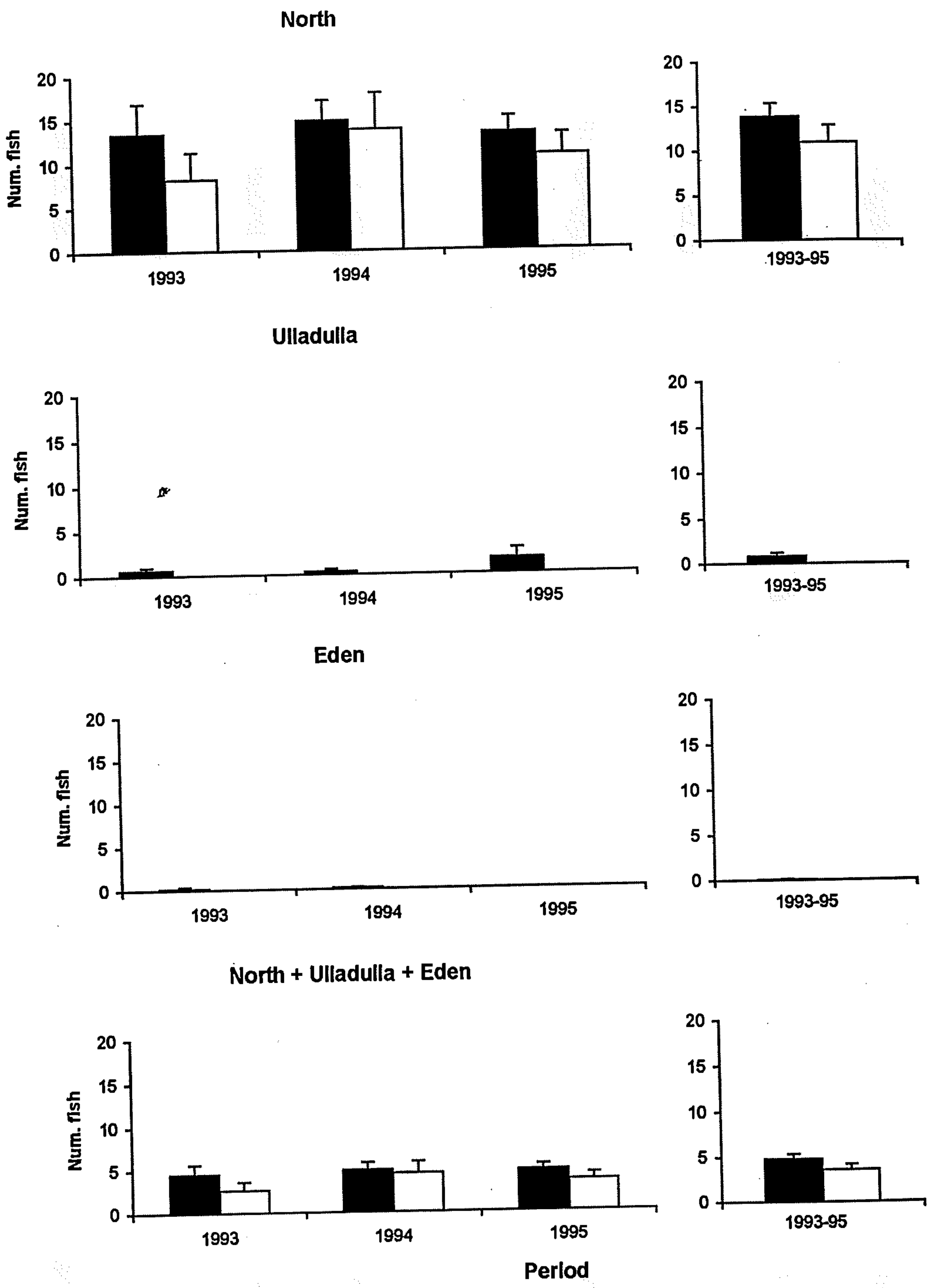


Figure 33.3

Retained and discarded catches (per fisher-day) - Eastern blue-spot flathead
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

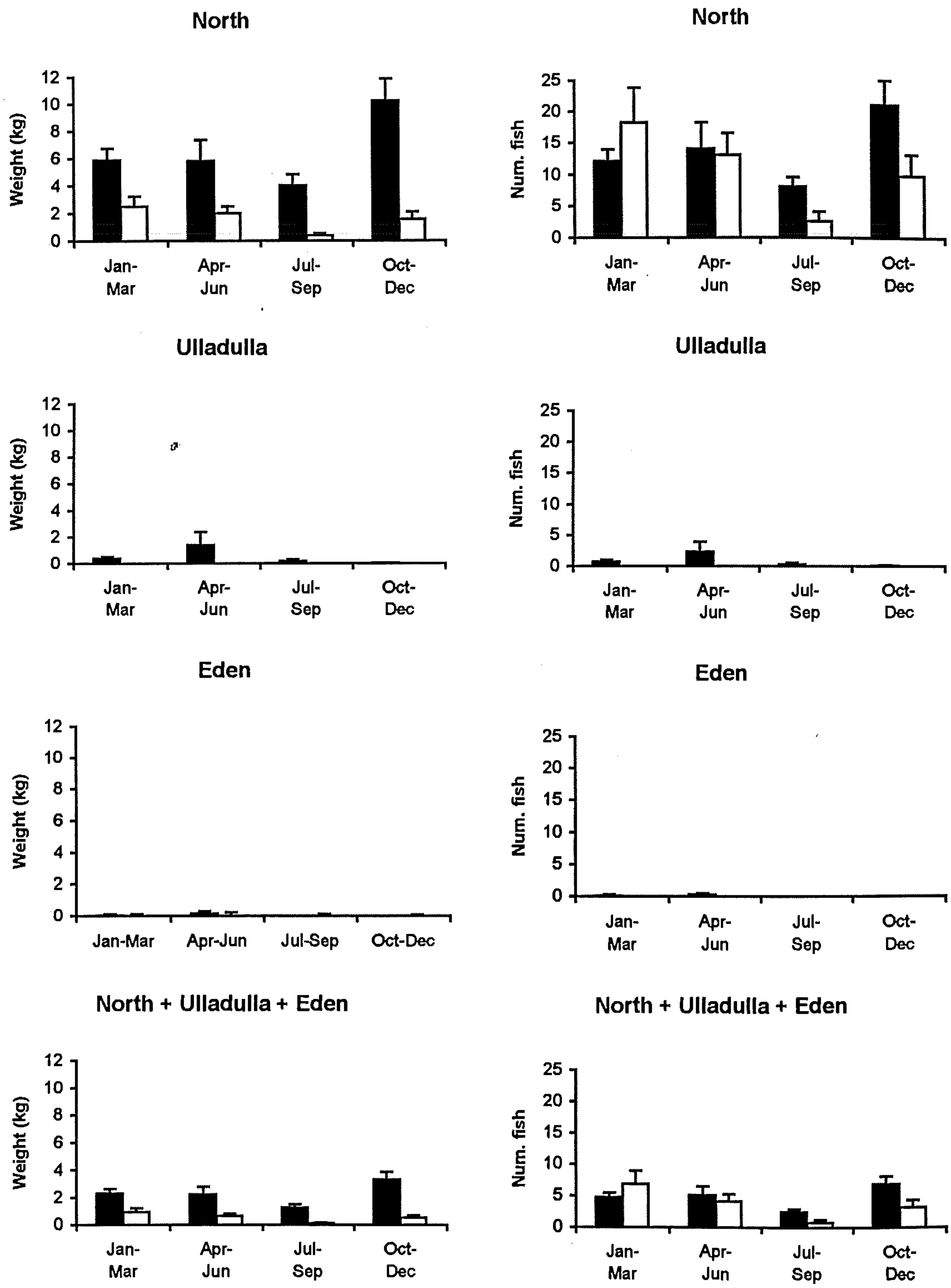


Table 33.1

Annual retained and discarded catches - Eastern blue-spot flathead (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	11	2	9	2	2	0	*15*
	1994	16	2	12	2	4	1	*23*
	1995	12	2	10	1	3	1	*21*
	Mean 1993-95	13	1	10	1	3	0	*20*
Ulladulla	1993	0	0	0	0	0	0	*0*
	1994	0	0	0	0	0	0	*0*
	1995	1	1	1	1	0	0	*0*
	Mean 1993-95	1	0	1	0	0	0	*0*
Eden	1993	0	0	0	0	0	0	*0*
	1994	0	0	0	0	0	0	*0*
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	*0*
N+U+E	1993	11	2	10	2	2	0	*14*
	1994	16	2	12	2	4	1	*22*
	1995	13	2	11	2	3	1	*19*
	Mean 1993-95	14	1	11	1	3	0	*19*

Table33.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	34	9	21	6	13	5	*38*
	1994	46	9	24	4	22	7	*48*
	1995	39	6	21	3	17	4	*45*
	Mean 1993-95	40	5	22	2	17	3	*44*
Ulladulla	1993	1	0	1	0	0	0	*0*
	1994	0	0	0	0	0	0	*0*
	1995	2	1	2	1	0	0	*0*
	Mean 1993-95	1	0	1	0	0	0	*0*
Eden	1993	0	0	0	0	0	0	*0*
	1994	0	0	0	0	0	0	*0*
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	*0*
N+U+E	1993	36	9	22	6	13	5	*37*
	1994	46	9	24	4	22	7	*48*
	1995	40	6	23	3	17	4	*43*
	Mean 1993-95	41	5	23	3	17	3	*43*

Figure 33.4, page 1

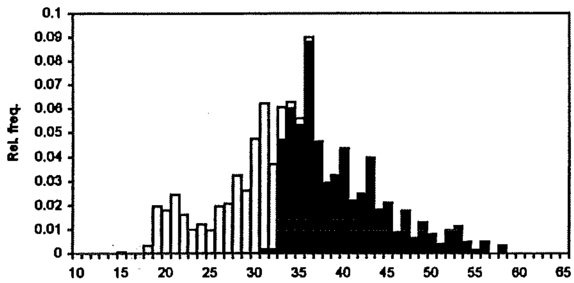
Size distributions of retained and discarded catches of Eastern blue-spot flathead

Retained catch: black bars Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

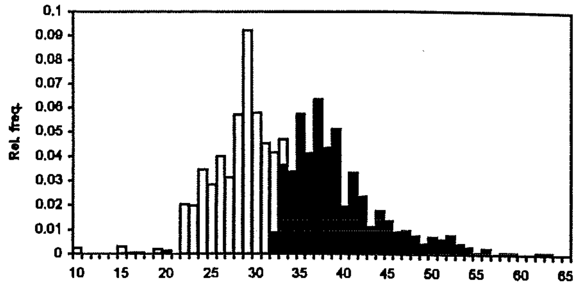
North, 1993

	Retained	Discarded	Total
Obs:	384 (40)	280 (48)	
Co-op:	0 (0)		
Mean L:	40.1	27.8	35.5



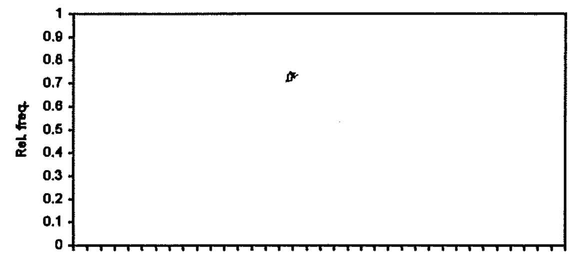
North, 1994

	Retained	Discarded	Total
Obs:	478 (34)	450 (53)	
Co-op:	0 (0)		
Mean L:	39.8	28.2	34.2



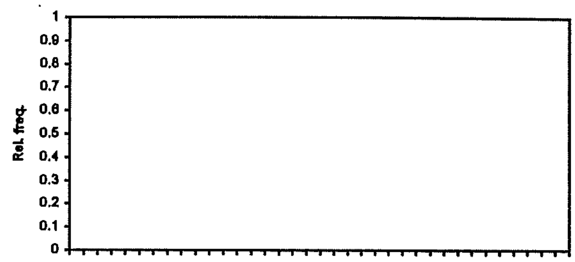
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



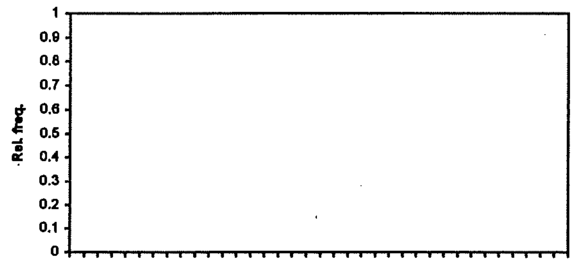
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



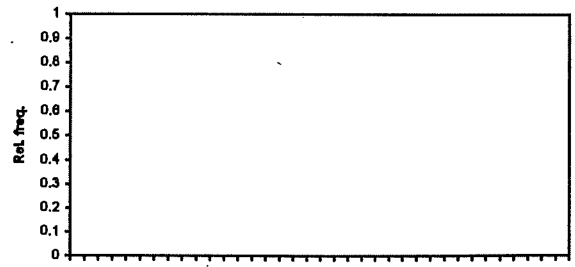
Eden, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



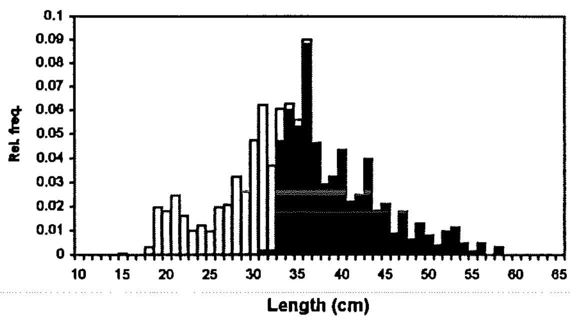
Eden, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



N + U + E, 1993

	Retained	Discarded	Total
Obs:	384 (40)	280 (48)	
Co-op:	0 (0)		
Mean L:	40.1	27.8	35.5



N + U + E, 1994

	Retained	Discarded	Total
Obs:	478 (34)	450 (53)	
Co-op:	0 (0)		
Mean L:	39.8	28.2	34.2

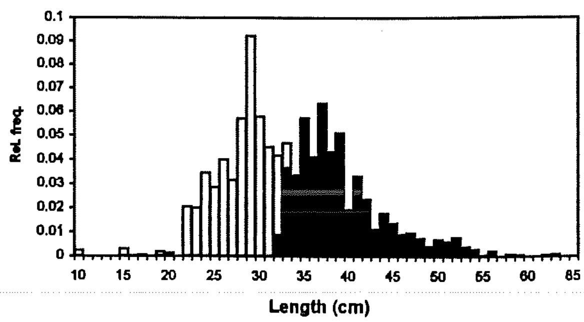
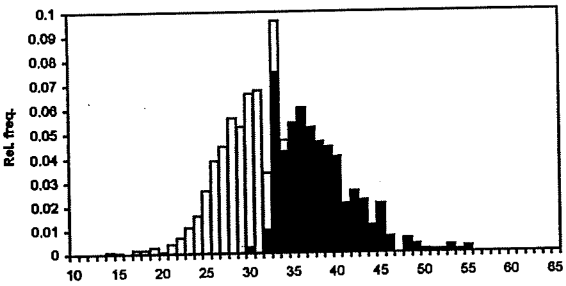


Figure 33.4, page 2

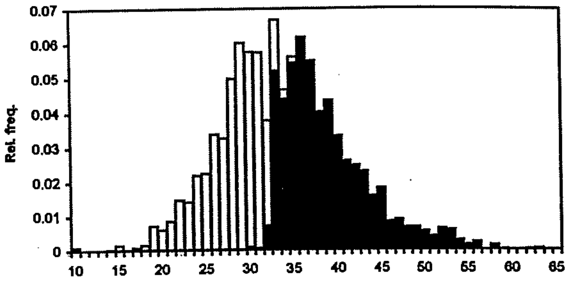
North, 1995

	Retained	Discarded	Total
Obs:	326 (30)	666 (61)	
Co-op:	0 (0)		
Mean L:	38.4	28.8	34.1



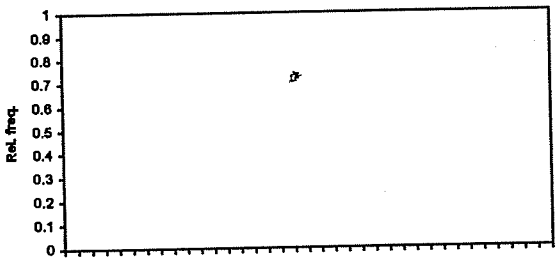
North, 1993-95

	Retained	Discarded	Total
Obs:	1188 (104)	1396 (162)	
Co-op:	0 (0)		
Mean L:	39.5	28.3	34.5



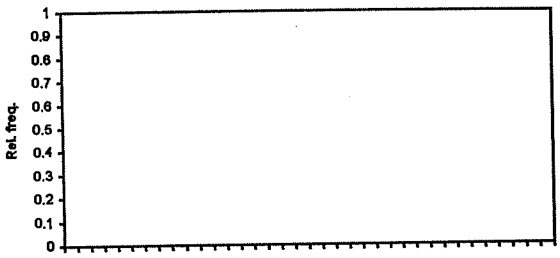
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



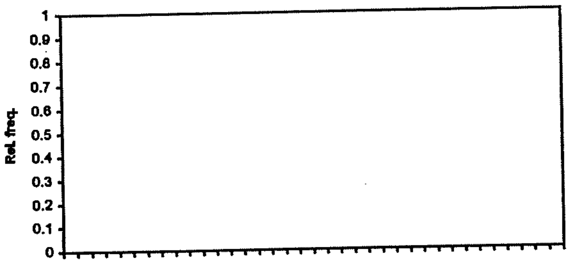
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:	#DIV/0!		



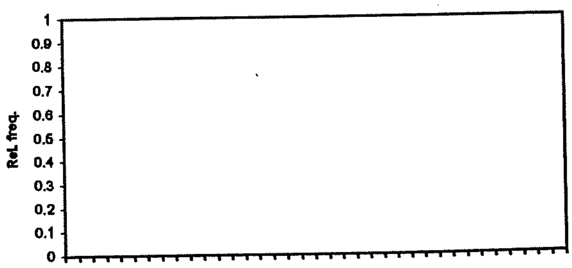
Eden, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



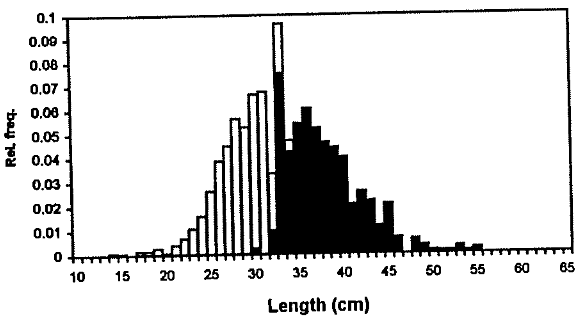
Eden, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:	#DIV/0!		



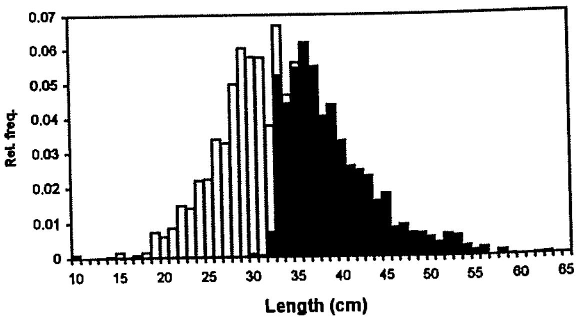
N + U + E, 1995

	Retained	Discarded	Total
Obs:	326 (30)	666 (61)	
Co-op:	0 (0)		
Mean L:	38.4	28.8	34.1



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	1188 (104)	1396 (162)	
Co-op:	0 (0)		
Mean L:	39.5	28.3	34.5



Appendix A.34

Yellowfin bream

Acanthopagrus australis

Figure 34.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 34.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 34.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 34.1
Annual retained and discarded catches (t)

Table 34.2
Annual retained and discarded catches (number of fish)

Figure 34.4
Size distributions of retained and discarded catches

Figure 34.1

Retained and discarded catches (kg per fisher-day) - Yellowfin bream
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

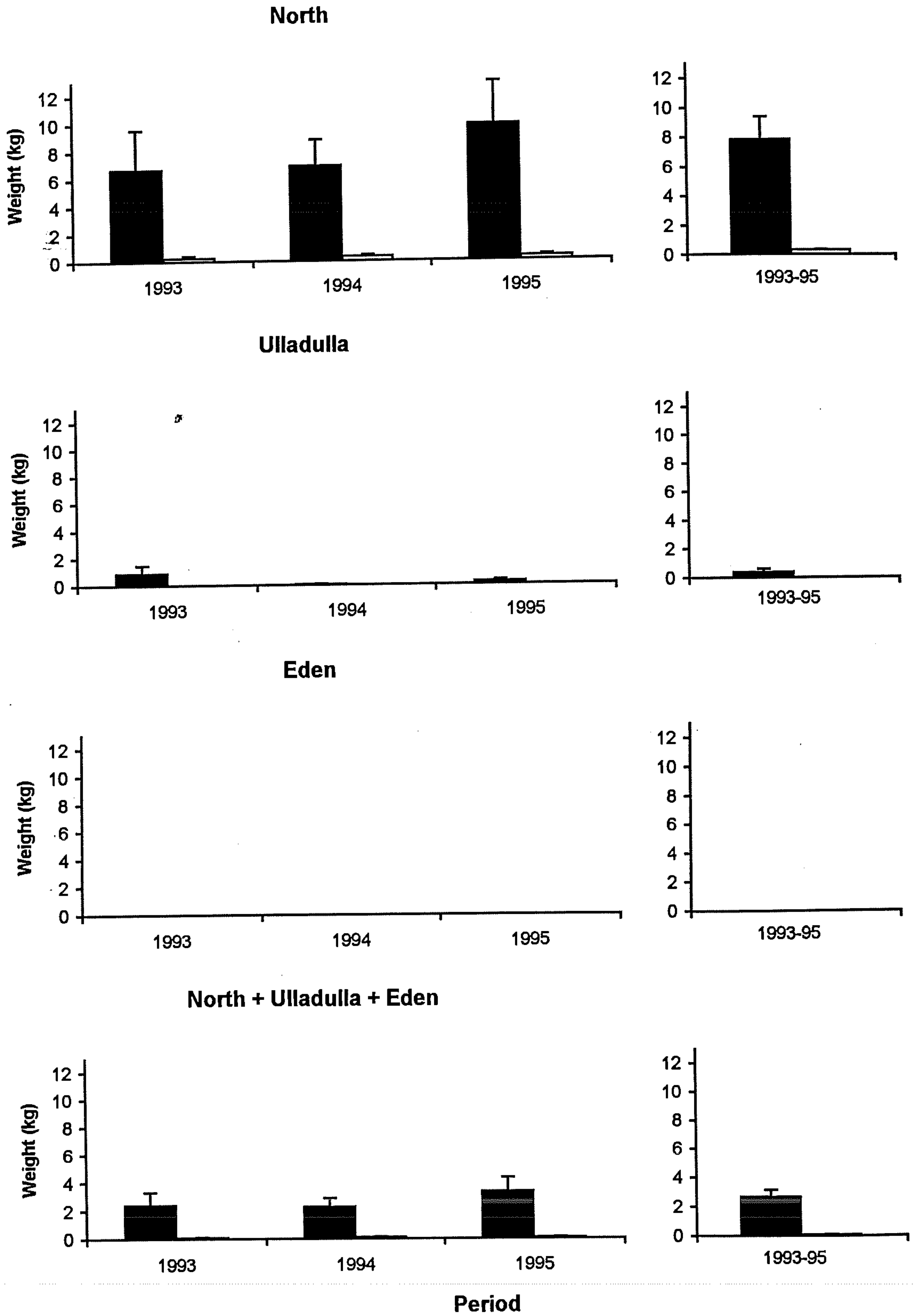


Figure 34.2

Retained and discarded catches (number of fish per fisher-day) - Yellowfin bream
by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

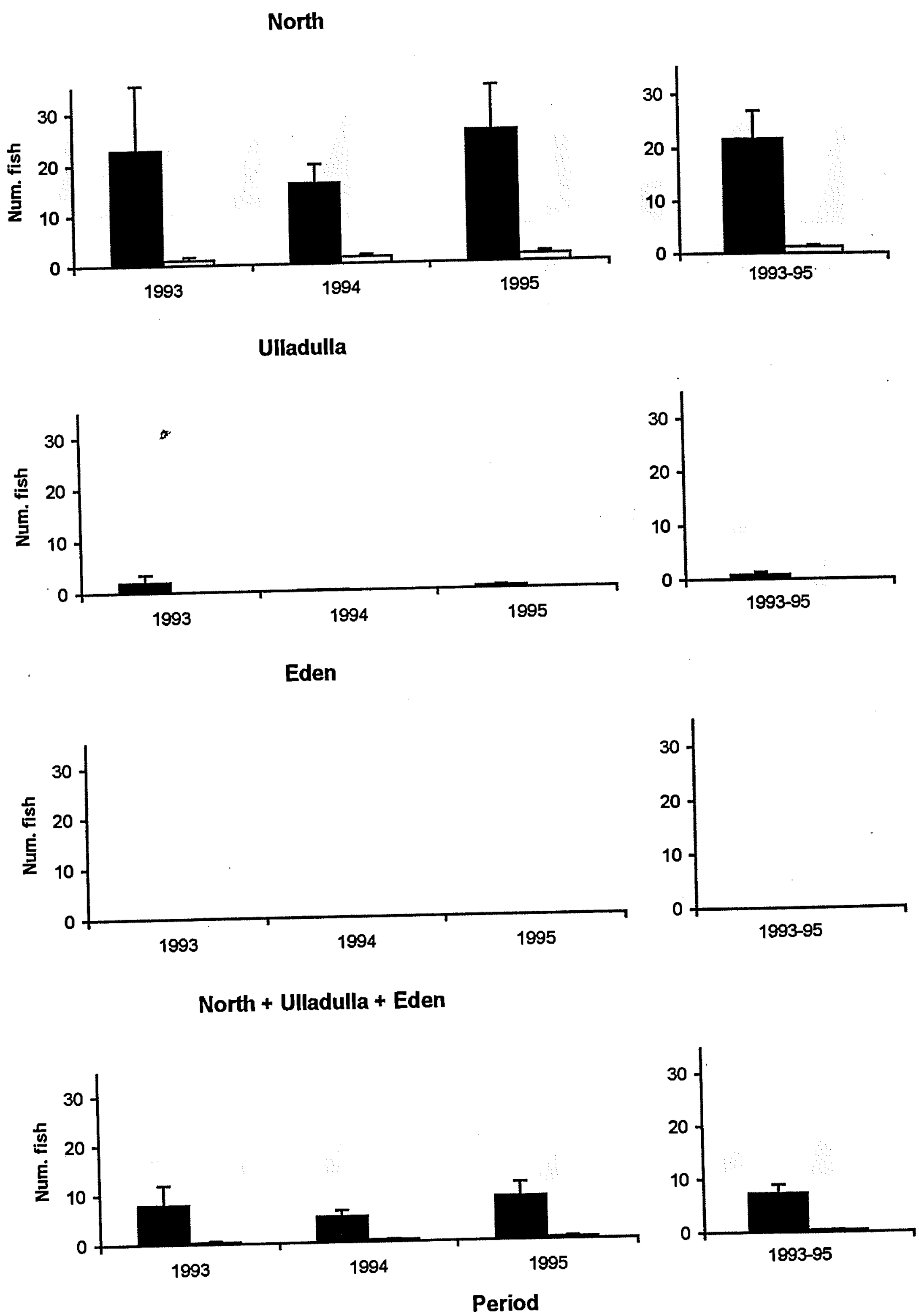


Figure 34.3

Retained and discarded catches (per fisher-day) - Yellowfin bream
by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

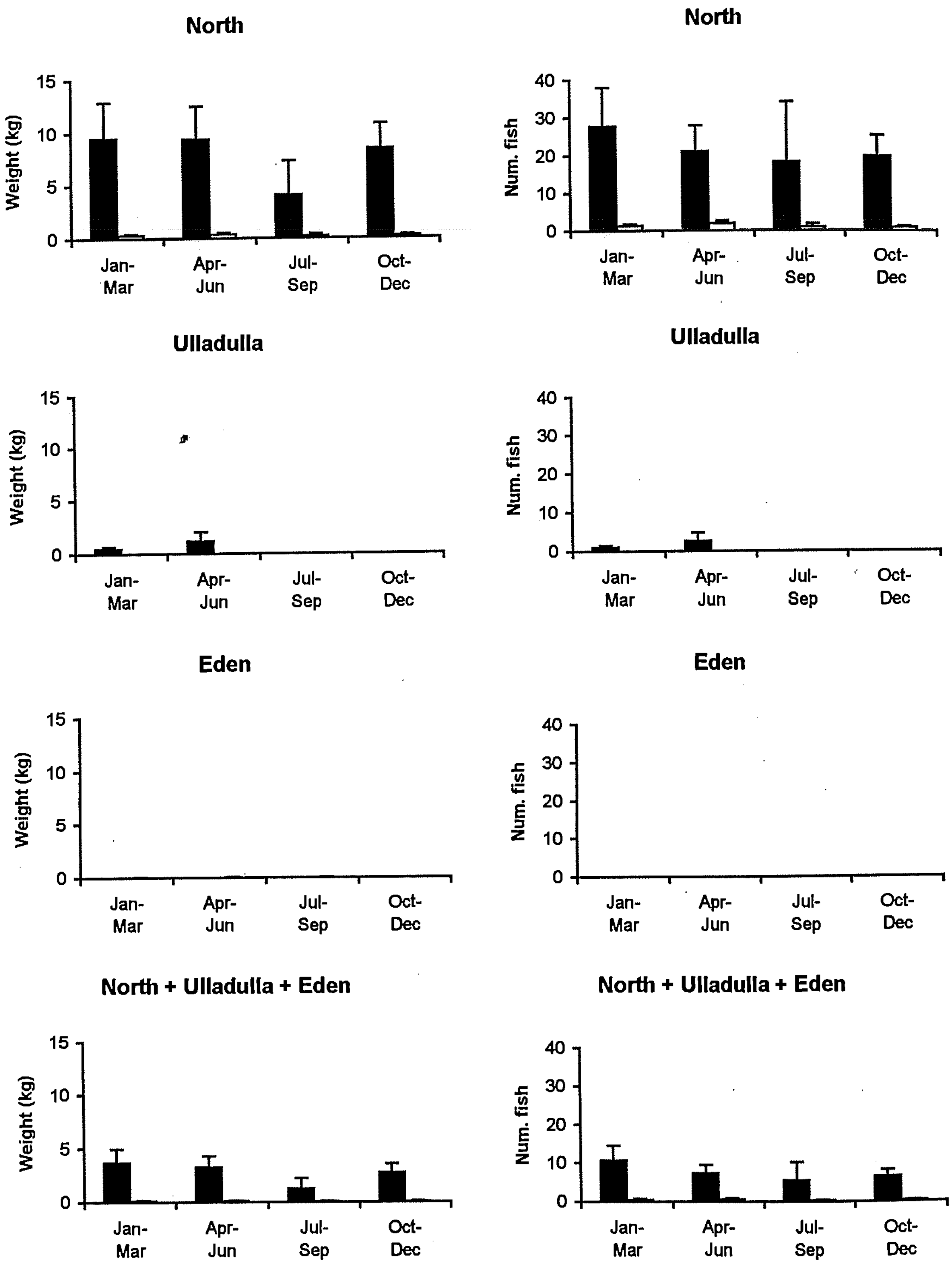


Table 34.1

Annual retained and discarded catches - Yellowfin bream (t)

		Total (t)	+/-	Retained (t)	+/-	Discarded (t)	+/-	% Discarded
North	1993	11	5	11	5	0	0	*3*
	1994	12	3	11	3	0	0	*4*
	1995	16	5	16	5	0	0	*3*
	Mean 1993-95	13	3	13	2	0	0	*3*
Ulladulla	1993	1	1	1	1	0	0	*0*
	1994	0	0	0	0	0	0	*0*
	1995	0	0	0	0	0	0	*0*
	Mean 1993-95	0	0	0	0	0	0	*0*
Eden	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
N+U+E	1993	12	5	12	5	0	0	*3*
	1994	12	3	11	3	0	0	*4*
	1995	16	5	16	5	0	0	*3*
	Mean 1993-95	13	3	13	2	0	0	*3*

Table 34.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)	+/-	Retained (x1000)	+/-	Discarded (x1000.)	+/-	% Discarded
North	1993	38	21	36	20	2	1	*4*
	1994	28	7	26	6	2	1	*7*
	1995	44	15	42	14	2	1	*5*
	Mean 1993-95	36	9	35	8	2	0	*5*
Ulladulla	1993	3	2	3	2	0	0	*0*
	1994	0	0	0	0	0	0	*0*
	1995	0	0	0	0	0	0	*0*
	Mean 1993-95	1	1	1	1	0	0	*0*
Eden	1993	0	0	0	0	0	0	
	1994	0	0	0	0	0	0	
	1995	0	0	0	0	0	0	
	Mean 1993-95	0	0	0	0	0	0	
N+U+E	1993	41	21	39	20	2	1	*4*
	1994	28	7	26	6	2	1	*7*
	1995	44	15	42	14	2	1	*5*
	Mean 1993-95	37	9	36	8	2	0	*5*

Figure 34.4, page 1

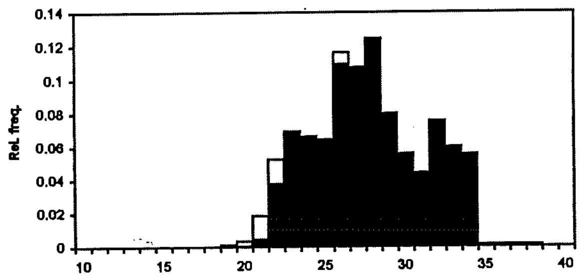
Size distributions of retained and discarded catches of Yellowfin bream

Retained catch: black bars Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

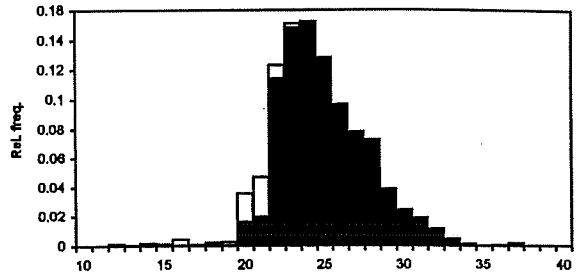
North, 1993

	Retained	Discarded	Total
Obs:	621 (19)	36 (10)	
Co-op:	0 (0)		
Mean L:	28.4	22.6	28.2



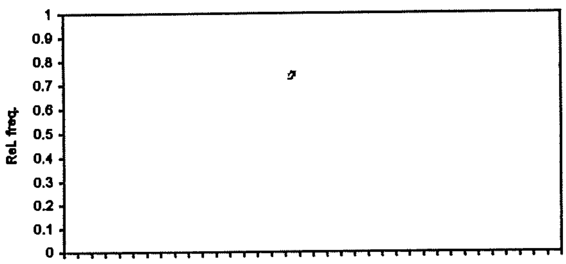
North, 1994

	Retained	Discarded	Total
Obs:	612 (19)	62 (22)	
Co-op:	0 (0)		
Mean L:	25.6	20.4	25.2



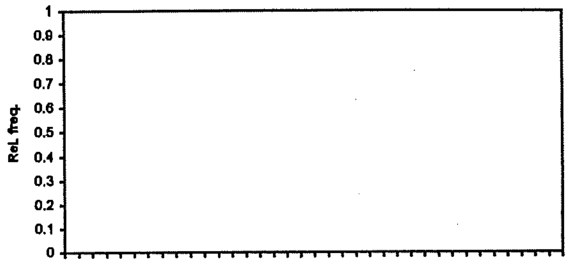
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



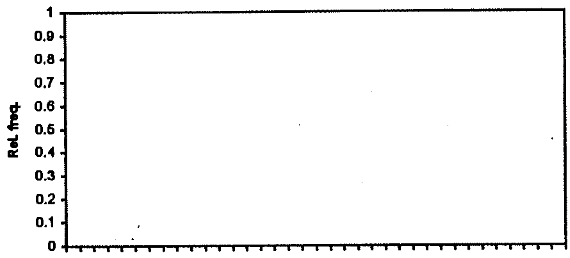
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



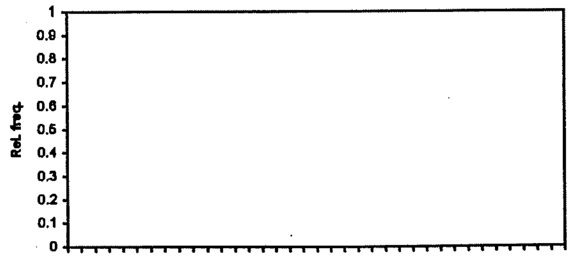
Eden, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



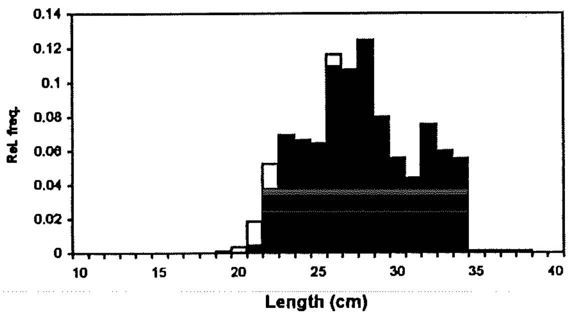
Eden, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



N + U + E, 1993

	Retained	Discarded	Total
Obs:	621 (19)	36 (10)	
Co-op:	0 (0)		
Mean L:	28.4	22.6	28.2



N + U + E, 1994

	Retained	Discarded	Total
Obs:	612 (19)	62 (22)	
Co-op:	0 (0)		
Mean L:	25.6	20.4	25.2

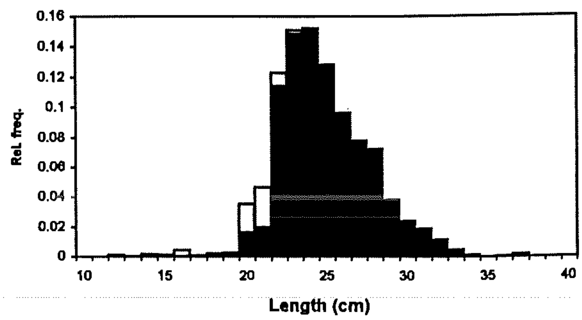
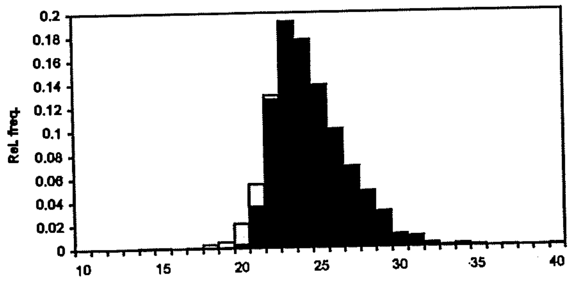


Figure 34.4, page 2

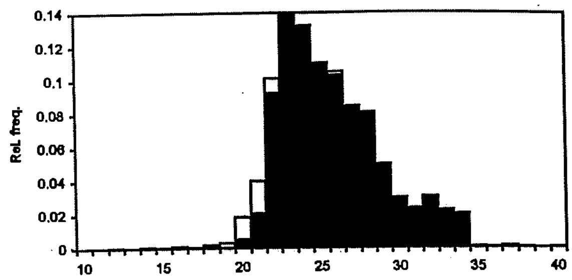
North, 1995

	Retained	Discarded	Total
Obs:	1429 (35)	82 (23)	
Co-op:	0 (0)		
Mean L:	25.1	20.7	24.8



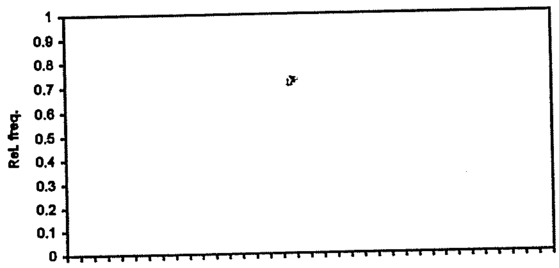
North, 1993-95

	Retained	Discarded	Total
Obs:	2562 (73)	180 (55)	
Co-op:	0 (0)		
Mean L:	26.4	21.1	26.1



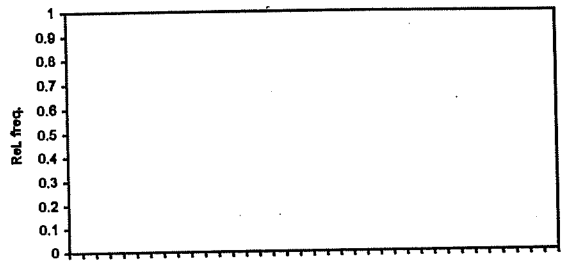
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



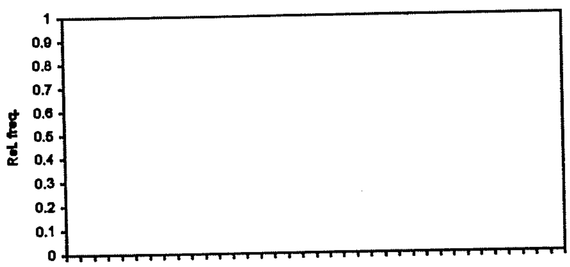
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:	#DIV/0!		



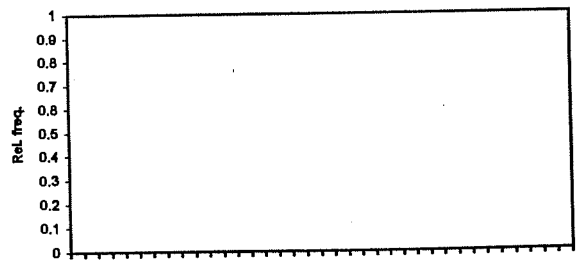
Eden, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



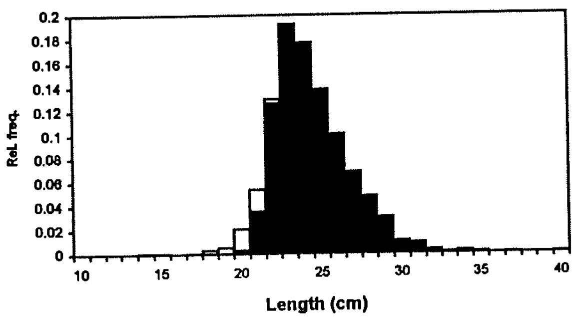
Eden, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



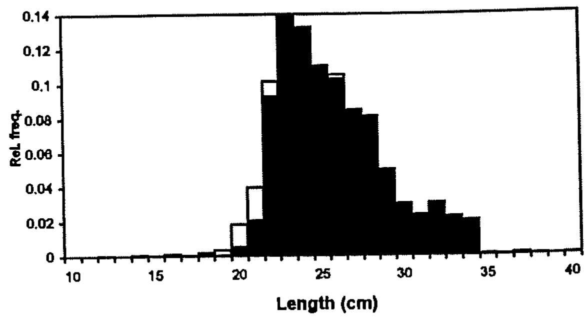
N + U + E, 1995

	Retained	Discarded	Total
Obs:	1429 (35)	82 (23)	
Co-op:	0 (0)		
Mean L:	25.1	20.7	24.8



N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	2562 (73)	180 (55)	
Co-op:	0 (0)		
Mean L:	26.4	21.1	26.1



Appendix A.35

Snapper

Pagrus auratus

Figure 35.1
Retained and discarded catches (kg per fisher-day), by year, by region

Figure 35.2
Retained and discarded catches (number of fish per fisher-day), by year, by region

Figure 35.3
Retained and discarded catches (per fisher-day), by quarter, by region

Table 35.1
Annual retained and discarded catches (t)

Table 35.2
Annual retained and discarded catches (number of fish)

Figure 35.4
Size distributions of retained and discarded catches

Figure 35.1

Retained and discarded catches (kg per fisher-day) - Snapper
by Year, by Region

(mean kg. per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

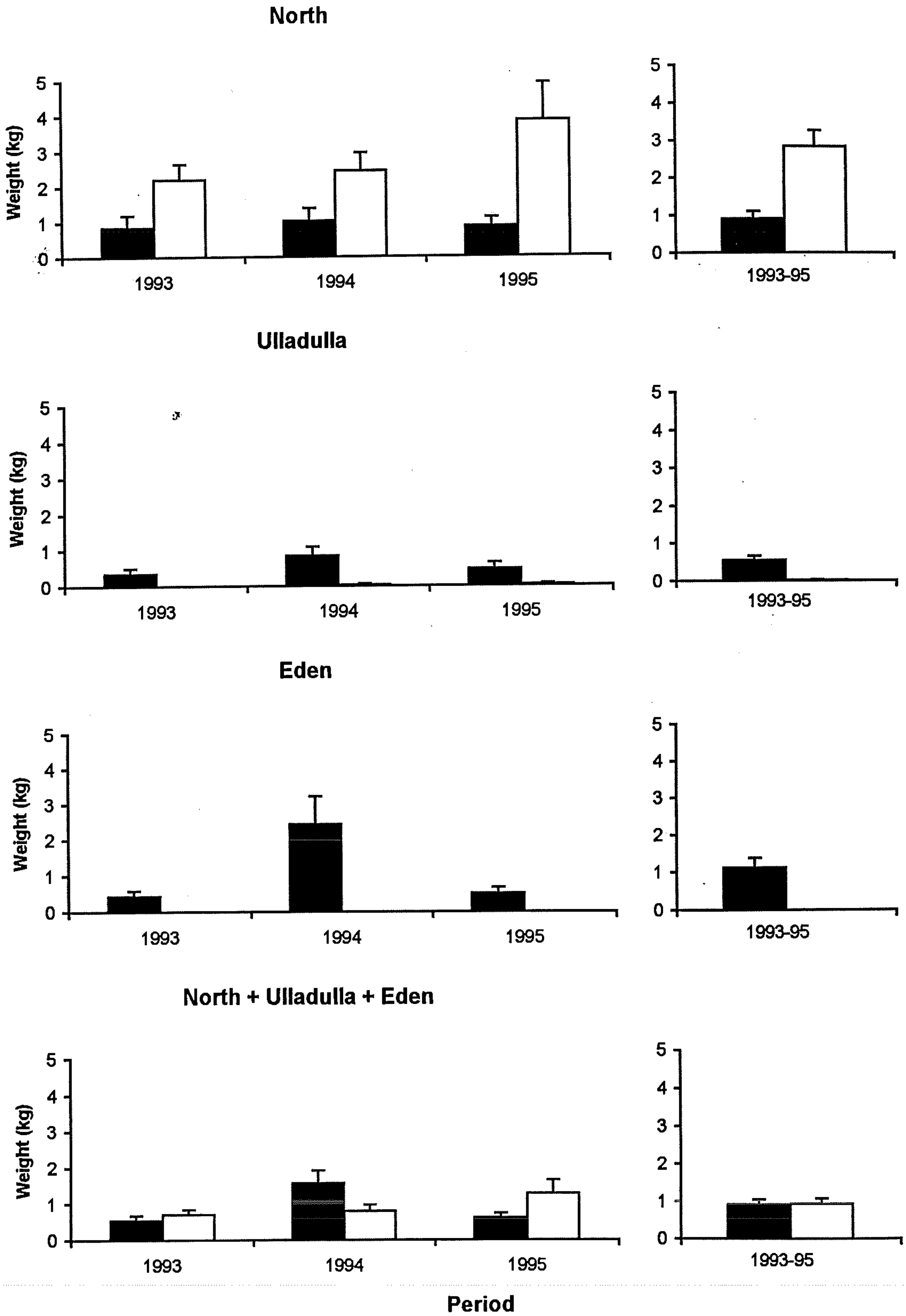


Figure 35.2

Retained and discarded catches (number of fish per fisher-day) - Snapper

by Year, by Region

(mean number of fish per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

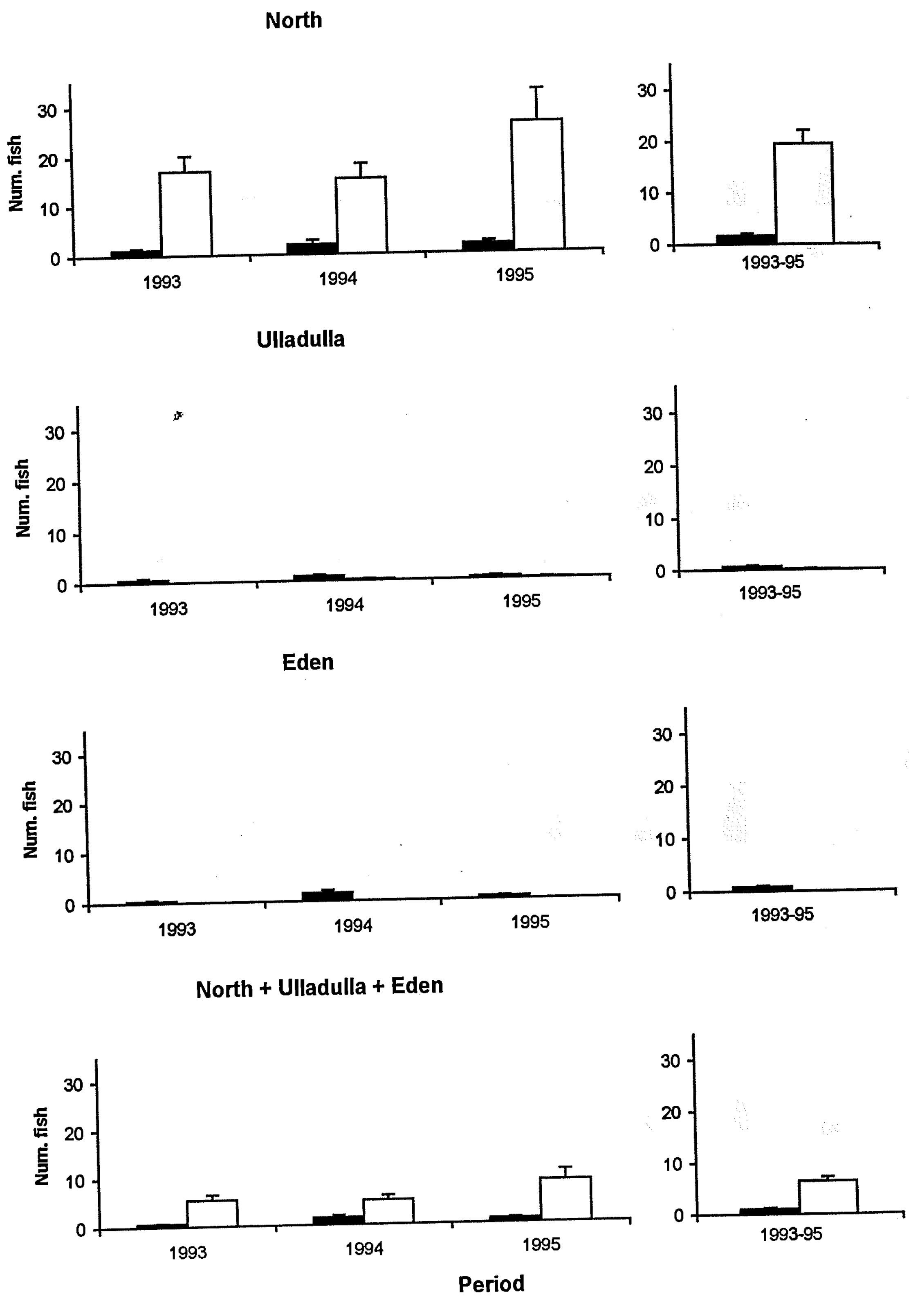


Figure 35.3

Retained and discarded catches (per fisher-day) - Snapper

by Quarter, by Region

(mean weight and number per fisher-day, +/- 1 se; Black bars - Retained, White bars - Discarded catch)

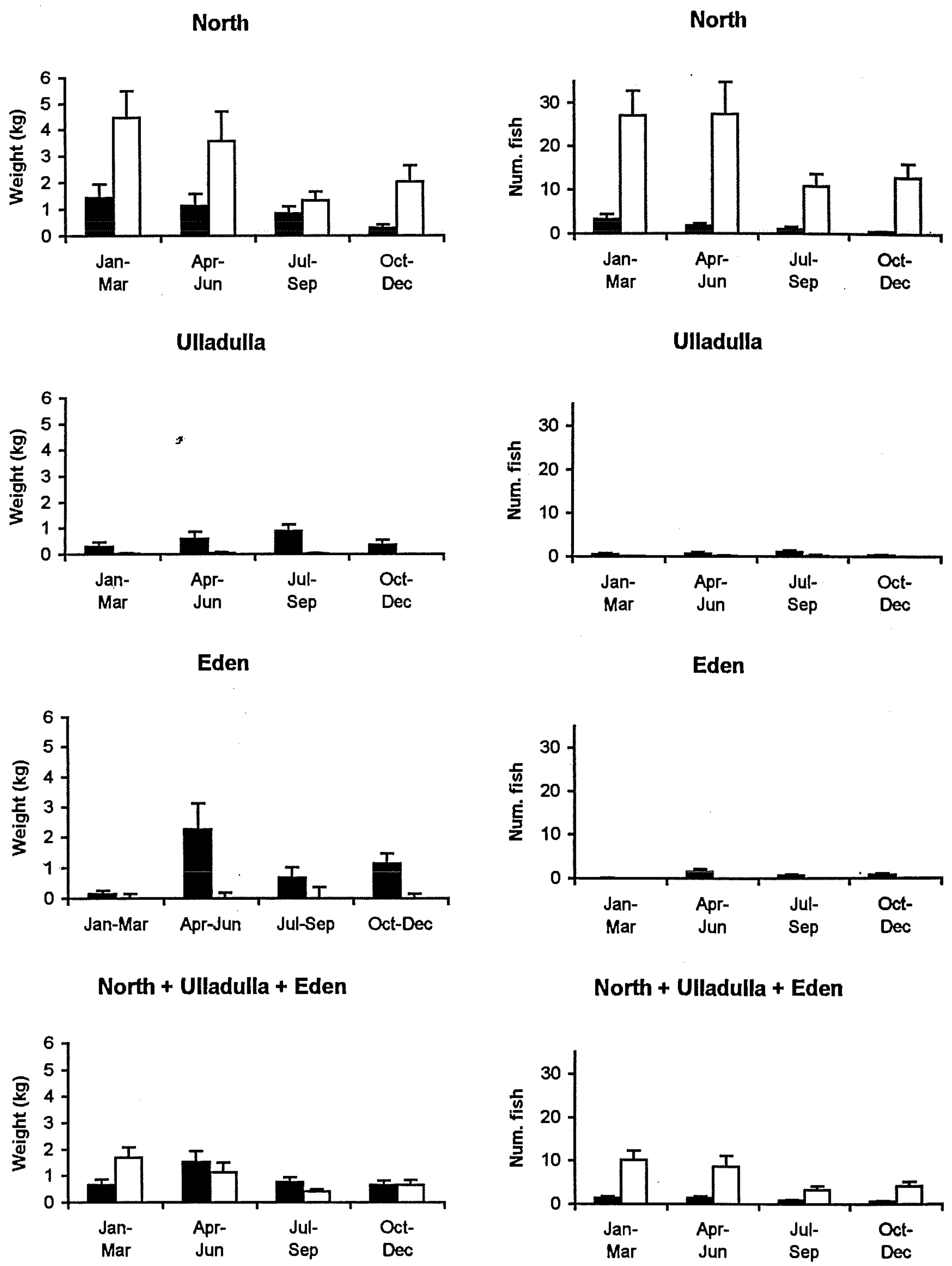


Table 35.1

Annual retained and discarded catches - Snapper (t)

		Total (t)		Retained (t)		Discarded (t)		% Discarded
North	1993	5 +/-	1	1 +/-	1	4 +/-	1	*72*
	1994	6	1	2	1	4	1	*70*
	1995	8	2	1	0	6	2	*82*
	Mean 1993-95	6	1	1	0	5	1	*76*
Ulladulla	1993	0	0	0	0	0	0	*0*
	1994	1	0	1	0	0	0	*4*
	1995	1	0	1	0	0	0	*6*
	Mean 1993-95	1	0	1	0	0	0	*4*
Eden	1993	1	0	1	0	0	0	*0*
	1994	5	2	5	2	0	0	*0*
	1995	1	0	1	0	0	0	*0*
	Mean 1993-95	2	1	2	1	0	0	*0*
N+U+E	1993	6	1	3	1	4	1	*57*
	1994	12	2	8	2	4	1	*34*
	1995	9	2	3	1	6	2	*68*
	Mean 1993-95	9	1	4	1	5	1	*51*

Table 35.2

Annual retained and discarded catches - (number of fish, x1000)

		Total (x1000)		Retained (x1000)		Discarded (x1000.)		% Discarded
North	1993	29 +/-	5	2 +/-	1	27 +/-	5	*94*
	1994	28	6	3	1	24	5	*88*
	1995	45	11	3	1	42	10	*94*
	Mean 1993-95	34	4	3	1	31	4	*92*
Ulladulla	1993	1	0	1	0	0	0	*1*
	1994	1	0	1	0	0	0	*17*
	1995	1	0	0	0	0	0	*20*
	Mean 1993-95	1	0	1	0	0	0	*14*
Eden	1993	1	0	1	0	0	0	*0*
	1994	3	1	3	1	0	0	*0*
	1995	1	0	1	0	0	0	*0*
	Mean 1993-95	2	0	2	0	0	0	*0*
N+U+E	1993	30	5	3	1	27	5	*89*
	1994	32	6	8	2	25	5	*76*
	1995	46	11	4	1	42	10	*91*
	Mean 1993-95	36	4	5	1	31	4	*86*

Figure 35.4, page1

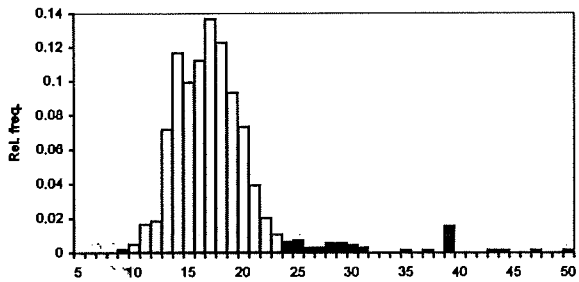
Size distributions of retained and discarded catches of Snapper

Retained catch: black bars   Discarded catch: white bars

Sample sizes: x (y) denotes a total sample of x fish from y shots (observer survey), or from y landings (co-op survey)

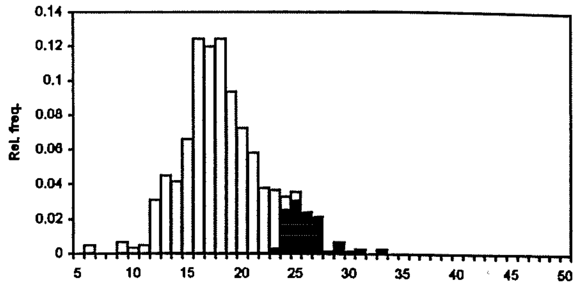
North, 1993

	Retained	Discarded	Total
Obs:	33 (9)	1143 (89)	
Co-op:	0 (0)		
Mean L:	32.8	17.1	18.1



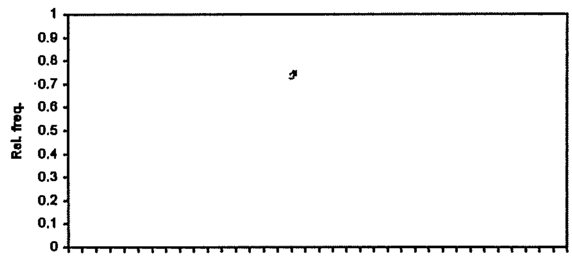
North, 1994

	Retained	Discarded	Total
Obs:	88 (7)	669 (59)	
Co-op:	0 (0)		
Mean L:	26.4	17.9	18.9



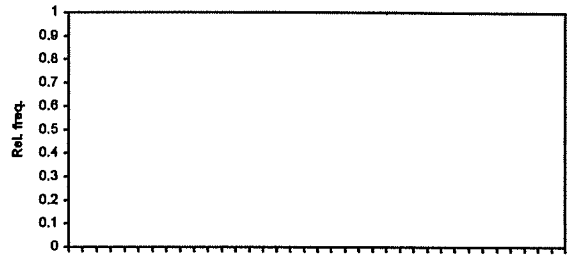
Ulladulla, 1993

	Retained	Discarded	Total
Obs:	0 (0)	1 (1)	
Co-op:	0 (0)		
Mean L:			



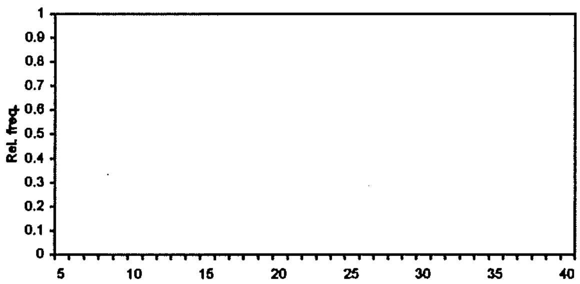
Ulladulla, 1994

	Retained	Discarded	Total
Obs:	0 (0)	4 (2)	
Co-op:	0 (0)		
Mean L:			



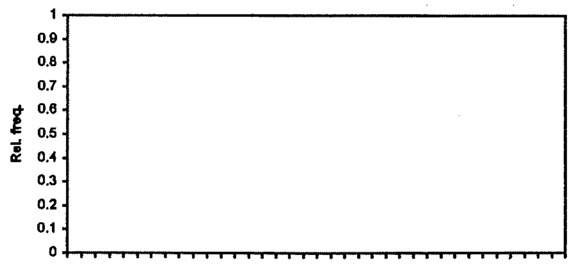
Eden, 1993

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



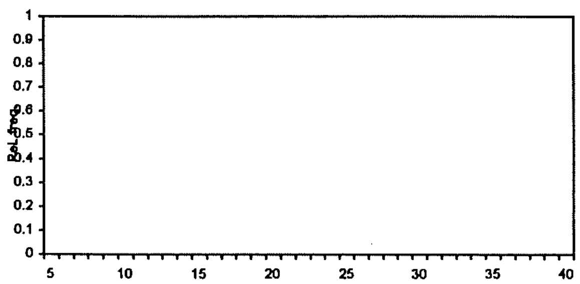
Eden, 1994

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



N + U + E, 1993

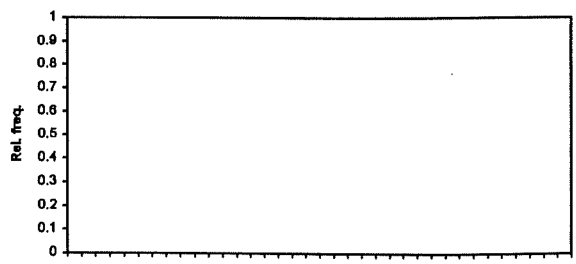
	Retained	Discarded	Total
Obs:	33 (9)	1144 (90)	
Co-op:	0 (0)		
Mean L:			



Length (cm)

N + U + E, 1994

	Retained	Discarded	Total
Obs:	88 (7)	673 (61)	
Co-op:	0 (0)		
Mean L:			

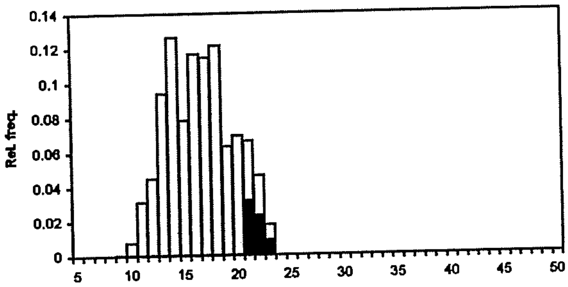


Length (cm)

Figure 35.4, page 2

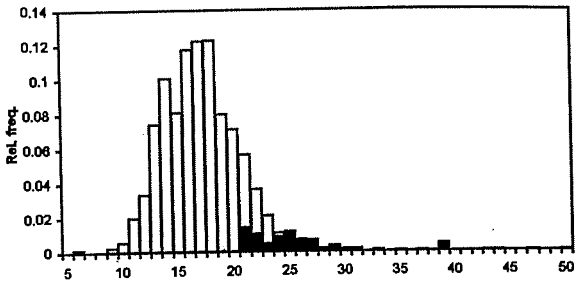
North, 1995

	Retained	Discarded	Total
Obs:	22 (1)	970 (81)	
Co-op:	0 (0)		
Mean L:	22.1	16.7	17.1



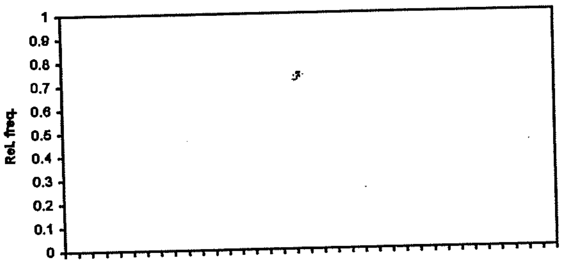
North, 1993-95

	Retained	Discarded	Total
Obs:	143 (17)	2682 (229)	
Co-op:	0 (0)		
Mean L:	26.3	17.2	17.9



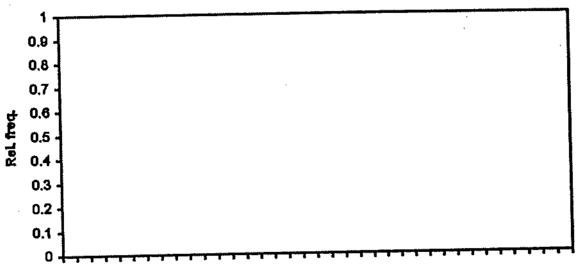
Ulladulla, 1995

	Retained	Discarded	Total
Obs:	0 (0)	3 (1)	
Co-op:	0 (0)		
Mean L:			



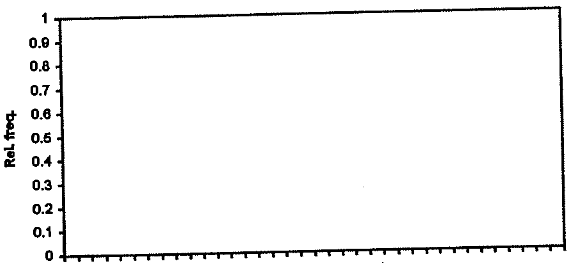
Ulladulla, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	8 (4)	
Co-op:	0 (0)		
Mean L:			



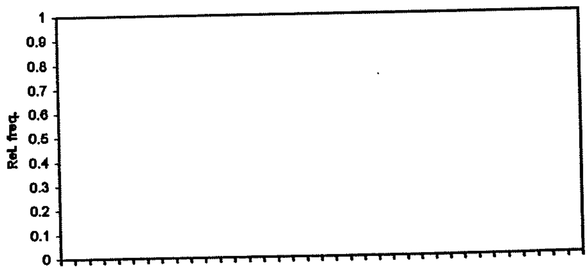
Eden, 1995

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



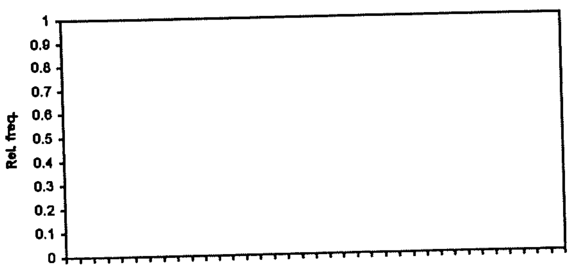
Eden, 1993-95

	Retained	Discarded	Total
Obs:	0 (0)	0 (0)	
Co-op:	0 (0)		
Mean L:			



N + U + E, 1995

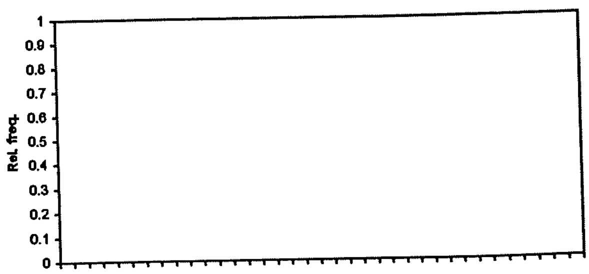
	Retained	Discarded	Total
Obs:	22 (1)	973 (82)	
Co-op:	0 (0)		
Mean L:			



Length (cm)

N + U + E, 1993-95

	Retained	Discarded	Total
Obs:	143 (17)	2690 (233)	
Co-op:	0 (0)		
Mean L:			



Length (cm)

Appendix B

List of taxa (Observer survey)

List of taxa

C : commercial species, CQ : SEF quota species

Family	Species		Common name
ALOPIIDAE	*Alopias vulpinus*	C	Thintail thresher
ANTENNARIIDAE	*Antennarius striatus*		
ARRIPIDAE	*Arripis trutta*	C	Australian salmon
AULOPIDAE	*Aulopus curtirostris*		
	Aulopus purpurissatus		
BATRACHOIDIDAE	*Batrachonoeus dubius*		
BERYCIDAE	*Beryx decadactylus*	C	Imperador
	Beryx splendens	C	Alfonsin
	Centroberyx affinis	CQ	Redfish
BOTHIDAE	*Chascanopsetta lugubris*		
	Lophonectes gallus		
	Pseudorhombus arsius	C	Large-toothed flounder
	Pseudorhombus jenynsii	C	Rough small-toothed flounder
	Pseudorhombus tenuirastrum	C	Smooth small-toothed flounder
BRACHAELURIDAE	*Brachaelurus waddi*	C	Blind shark
BRANCHIOSTEGIDAE	*Branchiostegus serratus*		
	Branchiostegus wardi	C	Pink tilefish
CALLIONYMIDAE	*Callionymus moretonensis*		
	Eocallionymus papilio		
	Foetorepus calauropomus		
	Repomucenus calcaratus		
CALLORHYNCHIDAE	*Callorhynchus milii*	C	Elephant fish
CAPROIDAE	*Antigonia rhomboidea*		
CARANGIDAE	*Alectis indicus*	C	Diamond trevally
	Carangoides chrysophrys	C	Long-nosed trevally
	Pseudocaranx dentex	CQ	Silver trevally
	Seriola dumerili	C	Amberjack
	Seriola hippos	C	Samson fish
	Seriola lalandi	C	Yellowtail kingfish
	Trachurus declivis	C	Jack mackerel
	Trachurus novaezelandiae		
CARCHARHINIDAE	*Carcharhinus brevipinna*	C	Long-nosed whaler
	Carcharhinus spp.	C	Whaler sharks
CENTROLOPHIDAE	*Centrolophus niger*	C	Rudderfish
	Hyperoglyphe antarctica	CQ	Blue-eye trevalla
	Seriolella brama	CQ	Blue warehou
	Seriolella caerulea	C	White trevalla
	Seriolella punctata	CQ	Spotted trevalla (Blue warehou)
CHAETODONTIDAE	*Chelmonops howensis*		
CHAUNACIDAE	*Chaunax endeavouri*		
CHEILODACTYLIDAE	*Cheilodactylus fuscus*	C	Red morwong
	Cheilodactylus vestitus		
	Nemadactylus douglasi	C	Blue morwong (Rubberlip morwong)
	Nemadactylus macropterus	CQ	Jackass morwong
CHIMAERIDAE	*Chimaera* sp. A	C	Deepwater (Southern) ghostshark

	Hydrolagus ogilbyi	C	Ogilby's ghost shark
CHLOROPHTHALMIDAE	*Chlorophthalmus nigripinnis*		
CLINIDAE	*Cristiceps aurantiacus*		
CLUPEIDAE	*Hyperlophus vittatus*		
	Sardinops neopilchardus		
CONGRIDAE	*Conger* spp., *Gnathophis* spp.		
CYNOGLOSSIDAE	*Paraplagusia unicolor*		
DACTYLOPTERIDAE	*Dactyloptera orientalis*		
DASYATIDIDAE	*Dasyatis brevicaudata*		
	Dasyatis fluviorum		
	Dasyatis guileri		
	Dasyatis kuhlii		
	Dasyatis thetidis		
	(unidentified stingrays)		
DINOLESTIDAE	*Dinolestes lewini*		
DIODONTIDAE	*Allomycterus pilatus*		
	Dicotylichthys punctulatus		
	Diodon nicthemerus		
ECHENEIDIDAE	*Remora remora*		
EMMELICHTHYIDAE	*Emmelichthys nitidus*		
ENGRAULIDIDAE	*Engraulis australis*		
ENOPLOSIDAE	*Enoplosus armatus*		
FISTULARIIDAE	*Fistularia commersonii*		
	Fistularia petimba		
GEMPYLIDAE	*Rexea antefurcata*	C	
	Rexea solandri	CQ	Gemfish
	Ruvettus pretiosus	C	Oilfish
	Thyrsites atun	C	Barracouta
GERREIDAE	*Gerres subfasciatus*		
GIRELLIDAE	*Girella tricuspidata*	C	Luderick
HALOSAURIDAE	*Halosaurus pectoralis*		
HARPADONTIDAE	*Saurida* spp.		
HETERODONTIDAE	*Heterodontus galeatus*		
	Heterodontus portusjacksoni		
HEXANCHIDAE	*Heptranchias perlo*		
	Hexanchus griseus		
	Notorynchus cepedianus		
HOPLICHTHYIDAE	*Hoplichthys haswelli*		
HYPNIDAE	*Hypnos monopterygium*		
LABRIDAE	*Bodianus* sp. 1	C	Eastern foxfish
	Bodianus vulpinus	C	Blackspot pigfish
LAMNIDAE	*Carcharodon carcharias*	C	White shark
LATRIDIDAE	*Latridopsis forsteri*	C	Bastard trumpeter
	Latris lineata	C	Tasmanian trumpeter
LOPHIIDAE	*Lophioides mutulis/naresi*		
MACRORHAMPHOSIDAE	*Centriscops humerosus*		
	Macrorhamphosus scolopax		
	Notopogon fernandezianus		
	Notopogon lilliei		
MACROURIDAE	*Coelorinchus australis*		
	Coelorinchus fasciatus		
	Coelorinchus innotabilis		
	Coelorinchus kaiyomaru		
	Coelorinchus matamua		
	Coelorinchus mirus		

	Coelorinchus sp. C		
	Coelorinchus sp. D		
	Coryphaenoides leonis		
	Lepidorhynchus denticulatus		
	Malacocephalus laevis		
	Mesobius antipodum		
	Ventrifossa nigromaculata		
	(unidentified whiptails)		
MERLUCCIIDAE	*Macruronus novaezelandiae*	CQ	Blue grenadier
MITSUKURINIDAE	*Mitsukurina owstoni*	C	Goblin shark
MOLIDAE	*Mola ramsayi*		
MONACANTHIDAE	*Aluterus monoceros*	C	Unicorn leatherjacket
	Eubalichthys bucephalus	C	Black reef leatherjacket
	Eubalichthys mosaicus	C	Mosaic leatherjacket
	Meuschenia freycineti	C	Six-spined leatherjacket
	Meuschenia hippocrepis	C	Horseshoe leatherjacket
	Meuschenia scaber	C	Velvet leatherjacket
	Meuschenia trachylepis	C	Yellowfin leatherjacket
	Nelusetta ayraudi	C	Chinaman leatherjacket
	Penicipelta vittiger		
	Scobinichthys granulatus	C	Rough leatherjacket
	Thamnaconus modestoides	C	Modest leatherjacket
MONOCENTRIDIDAE	*Cleidopus gloriamaris*		
MORIDAE	*Halargyreus johnsonii*		
	Lepidion microcephalus		
	Lotella rhacinus	C	Beardie
	Mora moro	C	Ribaldo
	Pseudophycis spp.	C	Red cod
MULLIDAE	*Upeneichthys lineates*	C	Red mullet
	Upeneus tragula	C	Bar-tailed goatfish
MURAENESOCIDAE	*Muraenesox bagio*	C	Common pike eel
MYLIOBATIDIDAE	*Myliobatis australis*	C	Eagle ray
NARCINIDAE	*Narcine tasmaniensis*		
NEOSCOPELIDAE	*Neoscopelus macrolepidotus*		
NOTACANTHIDAE	*Notocanthus sexspinus*		
ODONTASPIDIDAE	*Odontapsis ferox*	C	Herbst's nurse shark (Sand tiger shark)
OGCOCEPHALIDAE	*Halieutaea brevicauda*		
OPHICHTHIDAE	*Myrichthys colubrinus*		
OPHIDIIDAE	*Genypterus blacodes*	CQ	Pink ling
OPICHTHIDAE	*Ophisurus serpens*		
ORECTOLOBIDAE	*Orectolobus maculatus*	C	Spotted wobbegong
	Orectolobus ornatus		
OREOSOMATIDAE	*Neocyttus rhomboidalis*	C	Spiky oreo
	Pseudocyttus maculatus	C	Smooth oreo
OSTRACIDAE	*Lactoria fornasini*		
	Anoplocapros inermis		
	Aracana aurita		
	Kentrocapros flavofasciatus		
	Lactoria cornuta		
	Lactoria diaphana		
	Tetrasomus republicae		
OXYNOTIDAE	*Oxynotus bruniensis*		
PARASCYLLIDAE	*Parascyllium collare*		
PATAECIDAE	*Pataecus fronto*		
PEMPHERIDIDAE	*Pempheris affinis*		

	Pempheris compressa		
	Pempheris multiradiata		
PENTACEROTIDAE	*Paristiopterus labiosis*	C	Giant boarfish
	Pentaceropsis recurvirostris		
	Pentaceros decacanthus		
	Zanclistius elevatus		
PERCICHTHYIDAE	*Apogonops anomalus*		
	Macquaria novemaculeata	C	Australian bass
	Polyprion moeone	C	Bass groper
	Polyprion oxygeneios	C	Hapuku
	Synagrops japonicus		
PINGUIPEDIDAE	*Parapercis allporti*		
PLATYCEPHALIDAE	*Neoplatycephalus richardsoni*	CQ	Tiger flathead
	Platycephalus arenarius	C	Northern sand flathead
	Platycephalus caeruleopunctatus	C	Eastern blue-spot flathead
	Platycephalus fuscus	C	Dusky flathead
	Platycephalus longispinus		
	Platycephalus marmoratus	C	Marble flathead
	Ratabulus diversidens	C	Spiky flathead
PLEURONECTIDAE	*Ammotretis rostratus*		
	Azygopus pinnifasciatus		
PLOTOSIDAE	*Cnidoglanis macrocephalus*		
	Plotosus lineatus		
POMATOMIDAE	*Pomatomus saltatrix*	C	Tailor
PRIACANTHIDAE	*Cookeolus boops*		
	Priacanthus macracanthus		
PRISTIOPHORIDAE	*Pristiophorus* spp.	C	Sawsharks
PSYCHROLUTIDAE	*Psychrolutes marcidus*		
RACHYCENTRIDAE	*Rachycentron canadus*	C	Cobia
RAJIDAE	*Irolita waitii*		
	Notoraja sp. A		
	Pavoraja nitida		
	Raja australis		
	Raja gudgeri		
	Raja lemprieri		
	Raja polyommata		
	Raja sp. 1		
	Raja sp. B		
	Raja whitleyi		
REGALECIDAE	*Regalecus glesne*		
RHINOBATIDAE	*Aptychotrema rostrata*	C	Shovelnose ray
	Trygonorrhina sp.	C	Banjo shark
RHINOCHIMAERIDAE	*Harriotta raleighana*		
RHYNCHOBATIDAE	*Rhynchobatus djiddensis*	C	White-spotted shovelnose ray
SCIAENIDAE	*Argyrosomus hololepidotus*	C	Mulloway
	Atractoscian aequidens	C	Teraglin
SCOMBRIDAE	*Euthynnus affinis*	C	Mackeral tuna
	Sarda australis	C	Australian bonito
	Scomber australasicus		
SCORPAENIDAE	*Centropogon australis*		
	Gymnapistes marmoratus		
	Helicolenus percoides (inshore form)	CQ	Inshore ocean perch
	Helicolenus percoides (offshire form)	CQ	Offshore ocean perch
	Neosebastes incipinnis		
	Neosebastes scorpaenoides		

	Neosebastes thetidis		
	Notesthes robusta		
	Scorpaena cardinalis	C	Red rock cod
	Scorpaena papillosus		
SCORPIDIDAE	*Atypichthys strigatus*		
	Microcanthis strigatus		
	Scorpis aequipinnis	C	Sea sweep
SCYLIORHINIDAE	*Apristurus longicephalus*		
	Asymbolus analis		
	Cephaloscyllium laticeps		
	Cephaloscyllium sp. a		
	Galeus boardmani		
SERRANIDAE	*Anthias pulchellus*		
	Caesioperca lepidoptera		
	Callanthias allporti	C	Splendid perch
	Caprodon longimanus	C	Long-finned perch
	Epinephelus septemfasciatus	C	Bar cod
	Lepidoperca brochata		
SIGANIDAE	*Siganus fuscescens*		
SILLAGINIDAE	*Sillago ciliata*	C	Sand whiting
	Sillago flindersi	CQ	Red spot whiting (Eastern school whiting)
	Sillago maculata	C	Trumpeter whiting
	Sillago robusta	C	Stout whiting
SOLEIDAE	*Aesopia microcephala*		
	Pardachirus hedleyi		
	Synaptura nigra	C	Black sole
	Synclidopus macleayanus		
SPARIDAE	*Acanthopagrus australis*	C	Yellowfin bream
	Allotaius spariformes		
	Pagrus auratus	C	Snapper
	Rhabdosargus sarba	C	Tarwhine
SPHYRAENIDAE	*Sphyraena africana*		
SPHYRNIDAE	*Sphyrna zygaena*	C	Smooth hammerhead
SQUALIDAE	*Centrophorus spp.*	C	
	Centroscymnus crepidater		
	Centroscymnus owstoni		
	Dalatias licha	C	Seal shark
	Deania calcea, Deania quadrispinosa	C	Brier shark, Long-snouted dogfish
	Etmopterus lucifer		
	Etmopterus puscillus		
	Squalus acanthias	C	White-spotted dogfish
	Squalus megalops	C	Piked dogfish
	Squalus mitsukurii	C	Green-eyed dogfish
SQUATINIDAE	*Squatina spp.*	C	Angel sharks
STEGOSTOMATIDAE	*Stegostoma fasciatum*		
SYNGNATHIDAE	*Solegnathus spinosissimus*		
	(unidentified sea-horse)		
SYNODONTIDAE	*Trachinocephalus myops*		
TERAPONIDAE	*Pelates quadrilineatus*		
TETRAODONTIDAE	*Arothron firmamentum*		
	Contusus richei		
	Lagocephalus chesmonia		
	Lagocephalus inermis		
	Omegophora armilla		
	Reicheltia halsteadi		

	Sphoeroides pachygaster		
	Tetractenos hamiltoni		
	Torquigener altipinnis		
	Torquigener hicksi		
	Torquigener pleurogramma		
TORPEDINIDAE	*Torpedo macneilli*		
TRACHICHTHYIDAE	*Gephyroberyx darwini*	C	Darwin's roughy
	Hoplostethus atlanticus	CQ	Orange roughy
	Hoplostethus intermedius		
	Optivus sp. 1		
	Paratrachichthys sp. 1		
TRIAKIDAE	*Galeorhinus galeus*	C	School shark
	Mustelus antarcticus	C	Gummy shark
TRICHIURIDAE	*Benthodesmus elongatus*		
	Lepidopus caudatus	C	Southern frostfish
	Trichiurus lepturus	C	Hairtail
TRIGLIDAE	*Chelidonichthys kumu*	C	Red gurnard
	Lepidotrigla argus		
	Lepidotrigla modesta		
	Lepidotrigla mulhalli		
	Lepidotrigla papilio		
	Peristedion picturatum		
	Pterygotrigla picta	C	Spotted gurnard
	Pterygotrigla polyommata	C	Sharp-beaked gurnard (Latchet)
URANOSCOPIDAE	*Gnathagnus innotabilis*		
	Kathetostoma laeve		
	Kathetostoma sp. 1		
	Pleuroscopus pseudodorsalis		
UROLOPHIDAE	*Trygonoptera* sp. B		
	Trygonoptera testaceus		
	Urolophus bucculentus		
	Urolophus cruciatus		
	Urolophus paucimaculatus		
	Urolophus sufflavus		
	Urolophus viridis		
	Urolophus hybrid sp.		
	(unidentified stingarees)		
VELIFERIDAE	*Metavelifer multiradiatus*		
XIPHIIDAE	*Xiphias gladius*	C	Broadbill swordfish
ZEIDAE	*Cyttus australis*	C	Silver dory
	Cyttus novaezelandiae		
	Cyttus traversi	C	King dory
	Zenopsis nebulosis	CQ	Mirror dory
	Zeus faber	CQ	John dory

Annelids

(POLYCHAETE WORM)	(polychaete worm)

Cnidarians

(ANEMONE)	(anemone)
(JELLYFISH)	(jellyfish)
(SPONGE)	(sponge)

Crustaceans

ARISTAEIDAE	*Aristeomorpha foliacea*	C	Red prawn
CALAPPIDAE	*Calappa philargius*		
	Matuta planipes		
LATRIELLIDAE	*Latriellopsis petterdi*		
MAJIDAE	*Leptomithrax tuberculata*		
	Leptomithrax waitei		
PALINURIDAE	*Jasus lalandii*	C	Southern crayfish
	Jasus verreauxi	C	Eastern crayfish
	Linuparis trigonus	C	Slipper lobster
PENAEIDAE	*Metapenaeus macleayi*	C	School prawn
	Penaeus esculentus	C	Tiger prawn
	Penaeus plebejus	C	King prawn
	Plesiopenaeus edwardsianus		
PORTUNIDAE	*Charybdis bimaculata*		
	Charybdis cruciata	C	Coral crab
	Charybdis miles		
	Charybdis natator		
	Ovalipes australiensis		
	Ovalipes molleri		
	Portunus pelagicus	C	Blue swimmer crab
	Portunus sanguinolentus		
	Scylla serrata	C	Mud crab
RANINIDAE	*Lyreidus tridentatus*		
	Ranina ranina	C	Spanner crab
SCYLLARIDAE	*Ibacus altricrenatus*	C	Deepwater bug
	Ibacus peronii	C	Balmain bug
	Ibacus sp.	C	Smooth bug
	Ibacus brucei	C	Bruce's bug
SOLENOCERIDAE	*Haliproides sibogae*	CQ	Royal red prawn
XANTHIDAE	*Pseudocarcinus gigas*	C	Giant deepsea crab
(CARID PRAWN)	(carid prawn)		
(HERMIT CRAB)	(hermit crab)		
(UNID. CRAB)	(unidentified crabs)		
(UNID. MANTIS SHRIMP)	(unidentified mantis shrimps)		

Echinoderms

(HOLOTHURIAN)	(holothurian)		
(SAND DOLLAR)	(sand dollar)		
(SEA URCHIN)	(sea urchin)		
(STARFISH)	(starfish)		

Mammals

(FUR SEAL)	(Fur seal)		

Molluscs

LOLIGINIDAE	*Loligo chinensis*	C	Broad squid
	Loligo sp.	C	Slender squid
	Loliolus sp.	C	Bottle squid
	Sepioteuthis australis	C	Southern calamary
	(unidentified squid)		

SEPIIDAE	*Sepia* spp.	C	Cuttlefish
SEPIOLIDAE	*Sepioloida lineolata*		
TEUTHOIDAE	*Nototodarus gouldi*	C	Arrow squid
(BIVALVE)	(Bivalves)		
(GASTROPOD)	(Gastropods)		
(NUDIBRANCH)	(Nudibranchs)		
(OCTOPUS)	*Octopus spp.*	C	Octopus

Reptiles

(TURTLE)	(Turtles)		

Appendix C

Observer-based estimates of discarded and total catch: relative reliability of mean-per-unit, ratio and regression estimators

G.W. Liggins

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Observer-based estimates of discarded and total catch: relative reliability of mean-per-unit, ratio and regression estimators.

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Abstract

Simple mean-per-unit and ratio estimators are commonly applied to data from observer-based surveys to estimate quantities of discards and by-catches. The rationale for using a particular estimator is, however, rarely discussed and many studies provide no estimate of the variance associated with estimates of discards or by-catch. In this study, the application and relative accuracy and precision of stratified mean-per-unit (SMPU), combined ratio (Rc) and combined linear regression (LRc) estimators of catch were compared using data from a stratified observer survey of a multi-species fish trawl fishery in New South Wales, Australia. SMPU, Rc and LRc estimates of catch did not differ significantly for any component of catch. Precision of Rc and LRc estimators was no better than the precision of the SMPU estimator for the 5 partitions of catch and for 8 of the 10 species examined. The precision of Rc and LRc estimates of discarded catches of 2 species, using the retained catch of each species as auxiliary variable, exceeded those of SMPU estimates by an average of 17% (tiger flathead) and 8% (jackass morwong). The performance of the Rc estimator, relative to SMPU, was generally poor for other species and partitions of catch. Using these results, strategies are formulated for the routine estimation of discards and total catches from the observer survey operating in this fishery. To maximise the precision of observer-based estimates of catch in any fishery, relative reliability of alternative estimators should be evaluated.

Introduction

There has been widespread interest in estimating quantities of by-catch and discards in trawl fisheries over the last decade (Alverson et al. 1994). By-catch is "that part of the gross catch which is captured incidentally to the species toward which there is directed effort" and all, some or none of it may be discarded at sea (Saila 1983). Catches of targeted species may also be discarded, particularly in fisheries managed using minimal legal lengths or output controls such as trip or annual quotas (e.g. Saila 1983; Pikitch 1991; Alverson et al. 1994; Tilzey 1994). Although the mortalities of discards are highly variable and are dependent on biological, environmental and operational factors, it is apparent that a large proportion of fish discarded at sea die (Neilson et al. 1989; Andrew and Pepperell 1992; Alverson et al. 1994; Richards et al. 1995). Consequently, discarded fish represent real losses from populations, so stock assessments that ignore the discarded component of catch are biased by an unknown amount (Saila 1983; Hilborn and Walters 1992; Alverson et al. 1994).

Observer-based surveys have been used to estimate quantities and size/age distributions of by-catches and discarded catches from fish trawling (e.g. Jean 1963; Jermyn and Robb 1981; Howell and Langan 1987; Alverson et al. 1994) and prawn trawling (e.g. Andrew and Pepperell 1992; Alverson et al. 1994; Kennelly 1995; Liggins and Kennelly 1996). Such information is fundamental to assessing impacts of discarding on populations, losses to fisheries, and potential solutions to these problems. The method most commonly used to estimate discards (or by-catches) by whole fleets from observed rates of discarding (or by-catch) uses a ratio estimator. The observed ratio of discarded catch to retained catch is scaled to total discards over some time period using the known total landed catch as the multiplier (e.g. Hoag 1971, cited in Richards et al. 1995; Keiser 1977; Atkinson 1984). Estimates of discards (or by-catches) by whole fleets have also been calculated using a simple mean-per-unit estimator, in which the observed quantity of discards per unit of effort is used to estimate total by-catch by multiplying by the known total effort (e.g. Gutherz and Pellegrin 1988; Harris and Poiner 1990).

The precision of such estimates reported in the literature is highly variable with many studies reporting estimates of poor precision. Many studies provide no information about variances of estimates (Andrew and Pepperell 1992; Alverson et al. 1994). Moreover, the rationale for adopting a particular estimator is rarely presented. In a recent review of the literature concerning the bycatch of shrimp-trawl fisheries, Andrew and Pepperell (1992) found no direct comparisons of the reliability of ratio and mean-per-unit methods. This is surprising since the theory of mean-per-unit, ratio and linear regression estimators in simple random samples is described in frequently-cited references: Saila (1983) and Cochran (1963, 1977). It is also surprising that the stratified mean-per-unit estimator and the forms of ratio and regression estimator appropriate to stratified designs (Cochran 1977; Sukhatme et al. 1984) are rarely used in the analysis of observer data (but see Liggins and Kennelly 1996).

The term "reliability" is used to encompass both the concepts of accuracy and precision. Accuracy refers to the value of an estimate relative to its true value in the population whereas precision refers to the consistency of a number of values or estimates sampled from a population (e.g. Cochran 1977; Andrew and Mapstone 1987). An inaccurate estimate is said to be biased. It is necessary to consider these components of reliability separately because an accurate estimate is not necessarily precise and a precise estimate is not necessarily accurate. The precision and bias of mean-per-unit, ratio and regression estimators of catch in simple random sampling and in stratified survey designs depends on several factors: survey design and sample size; efficiency of the survey execution; availability and reliability of auxiliary catch and effort data for whole fleets; and the strength of relationship between observed discards and auxiliary data (e.g. observed retained catches) (e.g. Cochran 1977; Saila 1983).

Retained and discarded catches of fish trawlers operating along the coast of NSW have been sampled by observers since 1993. A subset of this data, from 2 ports (Ulladulla and Eden), during 2 years (1993 and 1994), was used for comparisons of estimators. Trawlers from these ports fish mainly in the South East Fishery (SEF), a multi-species fishery off the coast south eastern Australia. Discarding juveniles and unmarketable quantities of commercial species and non-commercial species by trawlers is a long-established, but little studied practice in the SEF (Tilzey 1994). The introduction, in 1992 of "total allowable catches" (TACs) and "individual transferable quotas" (ITQs) for 16 species increased concerns about amounts of fish discarded.

The objective of this study was to compare a range of estimators and determine an optimal method for estimating annual discards and total catches from the observer survey in this fishery. The application and relative reliability of stratified mean-per-unit, combined ratio and combined regression estimators were examined for estimating mean catch per fisher-day and annual catches of 15 components of catch chosen to represent the various types of catch taken in this fishery.

Materials and methods

Survey data

Retained and discarded catches were surveyed on approximately 24 fisher-days during each quarter (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec), of each of 2 years (1993, 1994), in each of 2 regions (Ulladulla, Eden) (Figure 1). The survey was designed to estimate catches from fish trawling so trips targeting royal red prawns, *Haliporoides sibigae*, were excluded from the survey. Trips from Eden that were expected to be longer than 3 days were also excluded because fishing generally took place far to the south of study area.

At Ulladulla, fishing trips are of single day duration. On each day observed, a trawler was selected randomly from all those working that day. At Eden, fishing trips sampled were between 1 and 3 days long. In each quarter, trips were selected randomly for inclusion in the survey until the desired number of days had been observed. Ninety-six fisher-days were sampled on 67 fishing trips during 1993 and 94 days were sampled from 62 trips in 1994. It is assumed that fisher-days sampled at Eden are independent. This seems reasonable because trawlers generally stayed out for the pre-planned number of days. There was no obvious relationship between catch rates and the duration (number of days at sea) of trips.

On each tow of each fisher-day sampled, observers recorded weights, numbers and size distributions for the retained and discarded catches of each commercial species. Operational data (location, depth, time, duration of tow) and a list of non-commercial species present in the catch were also recorded.

All fishers in the SEF are required to report landed catches of quota species and the duration of each fishing trip to the Australian Fisheries Management Authority ("SEF-2, Disposal of catch" returns). Quarterly fishing effort (in units of fisher-days) and mean weights of landed catches of each of the quota species and for the combined catches of quota species (per fisher-day) at Ulladulla and Eden were calculated from these data. Only trips that conformed to the criteria of the observer survey were included in these calculations. Landed catches were only calculated for SEF quota species because landed catches of other species are not consistently reported.

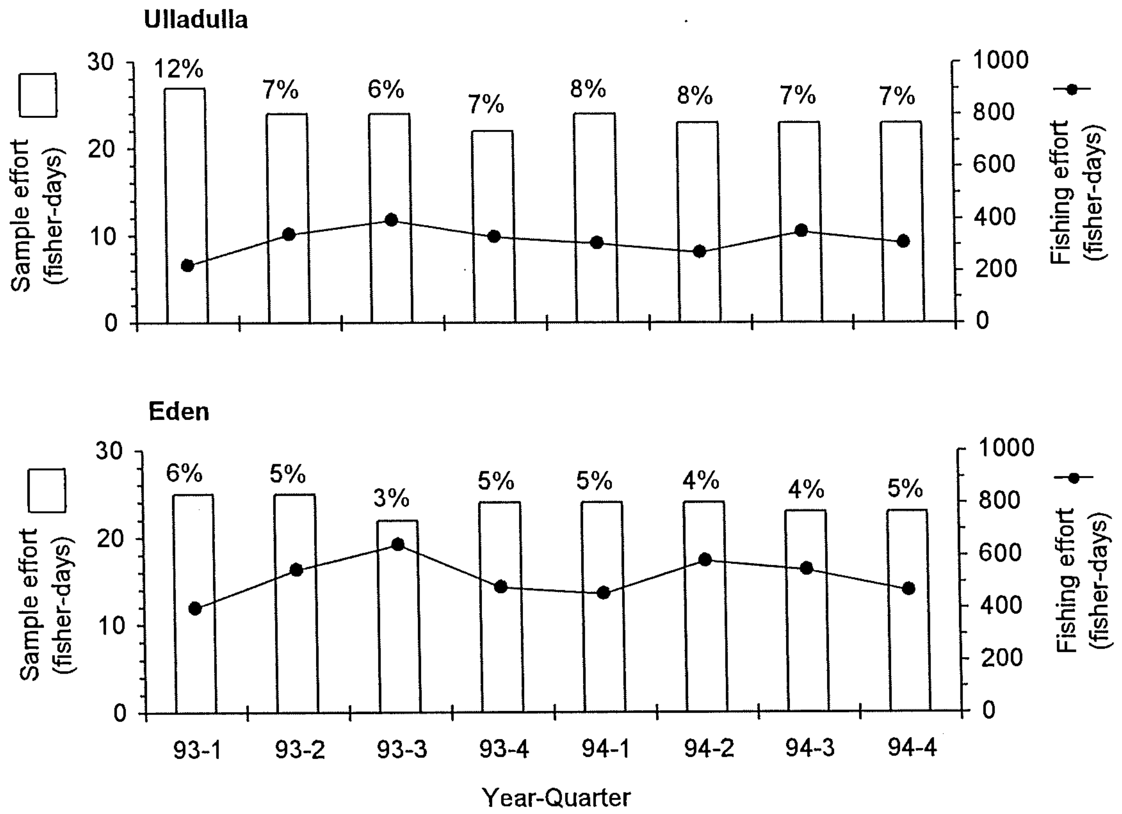
<u>Comparison of estimators</u>

Stratified mean-per-unit, combined ratio and combined regression estimates of mean catches per fisher-day were calculated annually (1993, 1994) for each region (Ulladulla, Eden), for 15 components of catch.

Estimates were made for 5 partitions of total catch, each comprising multiple species: (i) discards of all species; (ii) discarded non-commercial species; (iii) discarded quota species; (iv) discarded non-quota commercial species; (v) the retained catch of non-quota commercial species. The weight of all retained (landed) quota species ("ARQS"), was used as the auxiliary variable for the combined ratio and combined regression estimators.

Estimates of the total catches (retained and discarded catches combined) were made for 5 non-quota commercial species: (i)

Figure 1. Sampling effort, fishing effort and sampling fraction, quarterly and annually, for Ulladulla and Eden



blue morwong, *Nemadactylus douglasi*; (ii) piked dogfish, *Squalus megalops*; (iii) angel shark, *Squatina spp.*; (iv) barracouta, *Thyrsites atun*; (v) arrow squid, *Nototodarus gouldi*.

Discarded catches were estimated for 5 quota species: (i) redfish, *Centroberyx affinis*; (ii) tiger flathead, *Neoplatycephalus richardsoni*; (iii) mirror dory, *Zenopsis nebulosis*; (iv) jackass morwong, *Nemadactylus macropterus*; (v) john dory, *Zeus faber*. In addition to using ARQS, ratio and regression estimates were made for these species using the retained weight of the individual species in question ("IRQS") as the auxiliary variable.

The non-quota commercial species and quota species included in the study were selected as being broadly representative of all species caught in the fishery. The selection includes species taken as targeted catch and as by-catch; of high and low market value; caught seasonally and year-round; with and without minimal size limits and for which rates of discarding range from low to high.

Stratified mean-per-unit, combined ratio and combined regression estimators (e.g. Cochran 1977; Sukhatme et al. 1984) were applied to auxiliary data and data from the observer survey as follows:

Stratified mean-per-unit estimator

With a simple random sample of fisher-days taken in each quarter of each year, the estimated mean catch (discards, retained or total catch) per fisher-day (for a region), $\overline{y}$, and its estimated variance, $s^2(\overline{y})$, were calculated using the stratified mean-per-unit ("SMPU") estimator as follows:

$$\overline{y}_{SMPU} = \sum_{q=1}^{4} W_q . \overline{y}_q \tag{1}$$

$$s^2(\overline{y}_{SMPU}) = \sum_{q=1}^{4} \frac{W_q^2 . (1-f_q)}{n_q} . \frac{\sum_{i=1}^{n_q} (y_{qi}-\overline{y}_q)^2}{(n_q-1)} \tag{2}$$

which can also be expressed in the form:

$$s^2(\overline{y}_{SMPU}) = \sum_{q=1}^{4} \frac{W_q^2 . (1-f_q)}{n_q} . s^2(y_q) \tag{3}$$

in which $W_q = N_q/N$ is the relative size of the stratum, $\overline{y}_q$ is the mean discarded catch (or retained or total catch), y_{qi} is the discarded catch (or retained or total catch) taken on the i'th fisher-day, $s^2(y_q)$ is the variance of discarded catch, n_q

is the sample size, N_q is the number of fisher-days by the fleet, and $f_q = n_q/N_q$ is the sampling fraction, in quarter q of the year. N is the number of fisher-days completed by the fleet in the year.

Combined Ratio estimator

A ratio estimator may be applied to a stratified survey by calculating a single "combined" ratio across strata or by calculating a "separate" ratio and estimate of mean discards within each stratum and then taking a weighted mean across strata. Only the combined ratio estimator (Rc) was applied here. Sample sizes were not considered sufficient for reliable estimates of variances using the separate ratio estimator (see discussion).

Rc provides increased precision, relative to the SMPU estimator, if the relationship between the variable of interest (i.e. discards) and an auxiliary variable (e.g. retained catch) is a straight line through the origin and this relationship does not vary among strata. Rc uses the ratio of the SMPU estimate of catch (discards, retained or total) to the SMPU estimate of the auxiliary variable (ARQS or IRQS), $\hat{R}_c$, to estimate mean catch per fisher-day, $\overline{y}_{Rc}$, and its estimated variance, $s^2(\overline{y}_{Rc})$, by:

$$\hat{R}_C = \frac{\overline{y}_{SMPU}}{\overline{x}_{SMPU}} \tag{4}$$

$$\overline{y}_{RC} = \hat{R}_C . \overline{X} \tag{5}$$

$$s^2(\overline{y}_{Rc}) = \sum_{q=1}^{4} \frac{W_q^2 . (1-f_q)}{n_q} . \frac{\sum_{i=1}^{n_q} (y_{qi} - \hat{R}_c . x_{qi})^2}{(n_q-1)} \tag{6}$$

which can also be expressed as:

$$s^2(\overline{y}_{Rc}) = \sum_{q=1}^{4} \frac{W_q^2 . (1-f_q)}{n_q} . [s^2(y_q) + \hat{R}_c^2 . s^2(x_q) - 2 . \hat{R}_c . s(y_q, x_q)] \tag{7}$$

in which y_{qi} and x_{qi} are catches taken on the i'th fisher-day, $s^2(x_q)$ is the variance of the auxiliary variable and $s(y_q, x_q)$ the covariance of the sample in each quarter q. $\overline{X}$ is the mean landed catch (reported ARQS or IRQS).

Unlike the SMPU estimator, ratio estimates are biased, particularly so when the relationship between the x and y is non-linear. The quantity (bias/se) is of order $(1/\sqrt{n})$, so bias is negligible if samples are large. The formula for the variance of the estimate is approximate, valid only for large samples.

Combined regression estimator

As for the stratified ratio estimator, "combined" and "separate" forms of the linear regression estimator may be used, but only the combined estimator was applied in this study. Like Rc, the combined linear regression estimator (LRc), provides increased precision, relative to SMPU, if the variable of interest (e.g. discards) and the auxiliary variable (e.g. retained catch) are correlated and the relationship is similar among strata. The precision of LRc will exceed that of Rc if the relationship is a straight line than does not pass through the origin.

The combined regression estimator ("LRc") calculates mean catch per fisher-day, $\overline{y}_{LRc}$, and its estimated variance, $s^2(\overline{y}_{LRc})$, by:

$$\overline{y}_{LRc} = \overline{y}_{st} + \hat{B}_C(\overline{X} - \overline{x}_{SMPU}) \tag{8}$$

$$s^2(\overline{y}_{LRc}) = \sum_{q=1}^{4} \frac{W_q^2.(1-f_q)}{n_q} . \frac{\sum_i [(y_{qi}-\overline{y}_q) - \hat{B}_C.(x_{qi}-\overline{x}_q)]^2}{(n_q-2)} \tag{9}$$

which can be expressed as:

$$s^2(\overline{y}_{LRc}) = \sum_{q=1}^{4} \frac{W_q^2.(1-f_q)}{n_q} . s^2(y_q).(1-\hat{\rho}_C^2).\frac{(n_q-1)}{(n_q-2)} \tag{10}$$

in which $\hat{\rho}_c$ is the combined correlation coefficient, and $\hat{B}_C$ is the estimate of the combined regression coefficient. These are calculated as weighted means of stratum correlation and regression coefficients as follows:

$$\hat{B}_C = \frac{s(\overline{y}_{SMPU}, \overline{x}_{SMPU})}{s^2(\overline{x}_{SMPU})} = \frac{\sum_{q=1}^{4} \frac{W_q^2.(1-f_q)}{n_q}.s(y_q, x_q)}{\sum_{q=1}^{4} \frac{W_q^2.(1-f_q)}{n_q}.s^2(x_q)} \tag{11}$$

$$\hat{\rho}_c = \frac{s(\overline{y}_{SMPU}, \overline{x}_{SMPU})}{s(\overline{y}_{SMPU}) \cdot s(\overline{x}_{SMPU})} \qquad (12)$$

Note that some texts use the term (n_q-1) in place of (n_q-2) in equation 9 and omit the term $(n_q-1)/(n_q-2)$ from equation 10. in these circumstances, the assumption is made that B_c estimates the true combined regression coefficient of the population, B_c, without error.

Like the ratio estimate, the regression estimate is biased and variance likely to be underestimated unless sample size is large.

Comparisons of accuracy

Relative accuracy of estimators was examined by comparing the difference between SMPU, Rc and LRc estimates of mean catch, relative to the size of 95 % confidence intervals for these estimates. Assuming that the distribution of mean estimates is approximately normally distributed, confidence intervals may calculated as:

$$\pm\, t.\sqrt{s(\overline{y})^2} \qquad (13)$$

in which t is taken from Student's t table with (n_e-1) degrees of freedom. The effective sample size, n_e, associated with annual estimates of mean catch per fisher-day is somewhere between 20 and 96 (the smallest of the values (n_q-1) and their sum) (Cochran, 1977). Degrees of freedom can be approximated by Satterthwaite's (1946) method, as described by Cochran (1977). In this study, the difference between values of t (for 95% confidence intervals) for 20 df (t=2.086) and for 96 df (t=1.98) was minimal. Consequently, a t-value of 2 was used.

Comparisons of precision

Relative precisions of SMPU, Rc and LRc estimates were examined for each component of catch, in each year, in each region. A coefficient of variation, CV^*, was defined as:

$$CV^*_{est} = \frac{s(\overline{y}_{est})}{\overline{y}_{SMPU}} . 100\% \qquad (14)$$

in which the numerator is the standard error of the estimate

($s(\overline{y}_{SMPU})$, $s(\overline{y}_{Rc})$ or $s(\overline{y}_{LRc})$) and the denominator is, for all estimators, the SMPU estimate of mean catch. The calculation of $s^2(\overline{y})$ for each estimator (see equations 3, 7 and 10) is independent of the calculation of $\overline{y}$, so the relative magnitude of $s(\overline{y}_{est})$ indicates the relative precision of each estimator. Estimates of $\overline{y}$ by each estimator will differ unless the estimated mean catch rate of the auxiliary variable, $\overline{x}$, is identical to the mean catch rate calculated from the reported landings, $\overline{X}$, (see equations 4 and 5 for the ratio estimator, equation 8 for the regression estimator). Consequently, the measure of precision specified above (Equation 14) allows comparison of the fit of estimators without confounding by any variation in estimates of $\overline{y}$.

The increase or decrease in precision of ratio and regression estimates, relative to SMPU estimates, was calculated as:

$$\frac{CV^*_{est} - CV^*_{SMPU}}{CV^*_{SMPU}} \cdot 100\% \qquad (15)$$

In comparing the precision, CV^*, of Rc and LRc estimators with the SMPU estimator, an increase in precision of 10% was defined as a "useful" increase, an increase of 5% as a "minimal" increase and an increase of less than 5% was considered inconsequential.

Precision of estimates of mean catch across regions and years

Mean catches (and associated variances) calculated for each year, in each region, were used to calculate mean catches (i) during the period 1993-94 for each region; (ii) for Ulladulla and Eden combined, in each year; and (iii) for both years and both regions combined. Using an SMPU estimator, estimates of mean catch, $\overline{y}_h$, and variance, $s^2(\overline{y}_h)$, in each year for each region were combined to estimate mean catch, $\overline{y}$, and associated variance, $s^2(\overline{y})$, over k strata, as follows:

$$\overline{y} = \sum_{h=1}^{k} W_h \cdot \overline{y}_h \qquad (16)$$

$$s^2(\overline{y}) = \sum_{h=1}^{k} W_h^2 \cdot s^2(\overline{y}_h) \qquad (17)$$

in which W_h is the proportion fishing effort contributed to the total by stratum h. For estimates of mean catch across both years for each region and across both regions for each year, k = 2. For estimates of mean catch across both regions and both years, k = 4. For all components of catch, except discarded tiger flathead and jackass morwong, SMPU estimates of catch during each year at each location were used. For tiger flathead and jackass morwong, Rc estimates of discards during each year, in each region were used (the rationale for this is explained in the Discussion). Conventional coefficients of variation (CV = SE x 100% /mean) were calculated for each estimate of mean catch.

Results

SMPU, Rc and LRc estimates of mean catch rate per fisher-day did not differ significantly for any species or partition of catch in either of the 2 years or 2 regions examined (Figure 2). Confidence intervals (95%) of catches estimated using each method overlap by a considerable margin for each component of catch for each year and each region (95% confidence intervals are +/- twice the magnitude of the standard errors shown in Figure 2). Consequently, at the levels of precision achieved, it is concluded that estimators were equally accurate. That is, whether or not biases were present, estimators were biased by similar amounts.

The Rc estimator, using ARQS as the auxiliary variable, achieved no useful gain in precision, compared to the SMPU estimator, for any of the 15 components of catch, in either year at Ulladulla or Eden (Table 1). In 24 of 56 instances, precision of the ratio estimate was descreased by 10% or more, relative to the SMPU estimate. Using IRQS as the auxiliary variable, the ratio estimator did, however, result in a useful gain in precision in 3 out of 4 instances for tiger flathead. This gain was substantial for Ulladulla in 1994, the ratio estimator producing a gain in precision of 46% (14% precision compared to 26% precision using the SMPU estimator). For Eden, improvements in precision were 11% and 13% in 1993 and 1994, respectively. Rc also produced minimal gains in precision of estimates of discarded jackass morwong (7% and 9% gains for Eden in 1993 and 1994, respectively).

The LRc estimator using ARQS achieved no useful improvement or reduction in precision relative to the SMPU estimator. Using IRQS as the auxiliary variable, there was a gain in precision of 50% for tiger flathead at Ulladulla in 1994, a minimal gain of 7% for Eden in 1994 and a gain of 10% for Eden in 1993. An 11% gain in precision was made for jackass morwong at Eden in 1993. For tiger flathead discards across the 2 years and 2 regions, mean CV* of each of the ratio and regression estimates was 24%, compared to 29% for SMPU estimates, an average increase of 17%. Averaging the precisions calculated for jackass morwong (by the Eden fleet), mean precision of ratio and regression estimates was 29% compared to 32% for the SMPU estimates, an average increase of 8%.

Relative to SMPU estimates, combined ratio and combined regression estimators produced the greatest gain in precision

Figure 2. Estimated catch rates (kg per fisher-day, +/- 1 SE) using SMPU, Rc and LRc estimators for Ulladulla (U) and Eden (E), 1993 and 1994

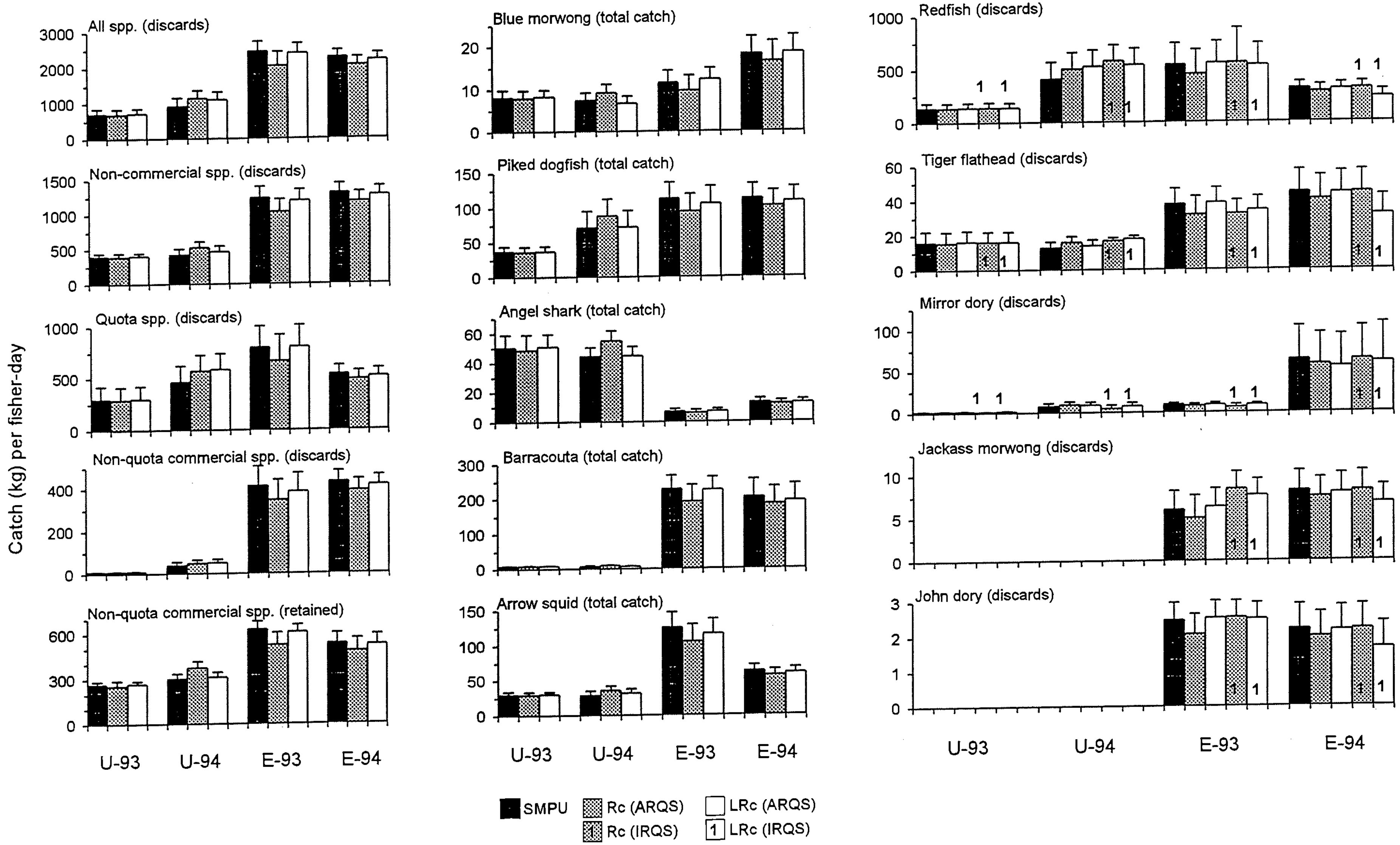


Table 1. Precision of stratified mean-per-unit, combined ratio and combined regression estimates of annual catch rates (per fisher-day).

SMPU: stratified mean-per-unit Rc: combined ratio estimate LRc: combined regression estimate
ARQS: weight of all retained quota species used as auxilliary variate IRQS: retained weight of the given species used as auxilliary variate

Precision of SMPU estimate is calculated as (se x 100% / mean). Precision of Rc and LRc estimates are relative to SMPU as follows:
o: gain/loss of precision less than 5% <: loss of precision exceeds 5% (x) : gain in precision exceeds 5%, precision is "x"%
<<: loss of precision exceeds 10% [x] : gain in precision exceeds 10%, precision is "x"%

Region, Year:	Ulladulla, 1993					Ulladulla, 1994					Eden, 1993					Eden, 1994				
Estimator:	SMPU	Rc	LRc	Rc	LRc	SMPU	Rc	LRc	Rc	LRc	SMPU	Rc	LRc	Rc	LRc	SMPU	Rc	LRc	Rc	LRc
Auxilliary variable:		ARQS	ARQS	IRQS	IRQS		ARQS	ARQS	IRQS	IRQS		ARQS	ARQS	IRQS	IRQS		ARQS	ARQS	IRQS	IRQS
Partitions of catch																				
Discards, All spp.	19	<<	o			25	o	o			12	<<	o			9	<	(8)		
Discards, Non-commercial spp.	10	<<	o			19	o	o			13	<<	o			10	<	o		
Discards, Quota spp.	42	o	o			35	o	o			26	<<	o			15	o	o		
Discards, Non-quota commercial spp.	24	o	o			44	o	o			22	o	o			12	o	o		
Retained, Non-quota commercial spp.	8	<<	o			11	<<	o			8	<<	o			13	<<	o		
Non-quota species, Total catch																				
Blue morwong	21	<<	o			23	<<	o			24	<<	o			22	<<	o		
Piked dogfish	20	<	o			33	o	o			21	<	o			19	o	o		
Angel shark	17	<<	o			13	<<	o			22	<<	o			18	o	o		
Barracouta	21	<<	o			23	<<	o			16	<<	o			25	o	o		
Arrow squid	14	<	o			21	o	o			17	<<	o			13	o	o		
Quota species, Discards																				
Redfish, Discarded	32	o	o	<<	o	39	o	o	(37)	o	38	<<	o	<<	o	19	<	o	<<	(18)
Tiger flathead, Discarded	37	<	o	o	o	26	o	o	[14]	[13]	23	<<	o	[20]	(21)	29	<	o	[25]	(26)
Mirror dory, Discarded	31	o	o	<<	o	48	o	o	<<	o	25	<	o	<<	o	63	(59)	o	<<	o
Jackass morwong, Discarded											36	<<	o	(34)	[32]	28	o	o	(25)	o
John dory, Discarded											20	<<	o	o	o	31	o	o	<	o

for estimates of tiger flathead discarded by Ulladulla trawlers in 1993. This case provides a useful illustration of the circumstances under which combined ratio and combined regression estimators result in increased precision. The relationship between discarded and retained tiger flathead catches during each quarter was approximately linear, in all cases intersecting the y-axis close to the origin (Figure 3a). For both estimators, the gradients of relations among quarters were similar and, consequently, either the combined ratio or combined regression relations provided a better fit to the combined data than the line of no relationship (Figure 3b). As the regression line of best fit intersects the y axis close to the origin, the scatter of data points around the combined ratio line of best fit ($y = 0.114x$) and the combined regression line of best fit ($y = 0.153x - 4.397$) is similar (Figure 3b). Consequently, estimates from each relationship are of similar precision.

Figure 3c provides a graphic demonstration of the derivation of SMPU, Rc and LRc estimates of mean discards per fisher-day. Note that if the mean catch rate of retained tiger flathead estimated from the observer survey (which was 113.3 kg per fisher-day), was equal to the mean landed catch reported by fishers (146.3 kg per fisher-day), all estimators would generate the same estimate of mean discards. All differences between SMPU and combined ratio estimates of catches (in Figure 1) result from a similar discrepancy. Such differences cannot be considered significant, given the level of uncertainty associated with each estimate.

The precision of mean catches estimated for each year, in each region, varied among the components of catch examined, but was generally poor for estimates of discards of quota species (Table 2). Coefficients of variation ranged between 11% (tiger flathead, Ulladulla, 1994) and 63% (mirror dory, Eden, 1994) but were generally within the range 20% - 40%. However, precision of estimates of catches across combinations of regions, years, or both, was much improved (Table 2). With the exception of mirror dory, coefficients of variation of mean discarded catches of quota species during the period 1993-94 for Ulladulla and Eden combined, ranged between 17% and 20%. At the same spatial and temporal scale, coefficients of variation for estimates of partitions of catch and total catches of non-quota commercial species ranged between 6% and 14%.

Discussion

Observer-based estimates of catches may be biased for reasons associated with design or execution of the survey or the application of a particular estimator to survey data. Sources of bias associated with design and execution include: (i) non-random selection of fisher-days; (ii) refusals by owners or masters of vessels to participate in the survey; (iii) non-random subsampling of catches by observers; (iv) measurement

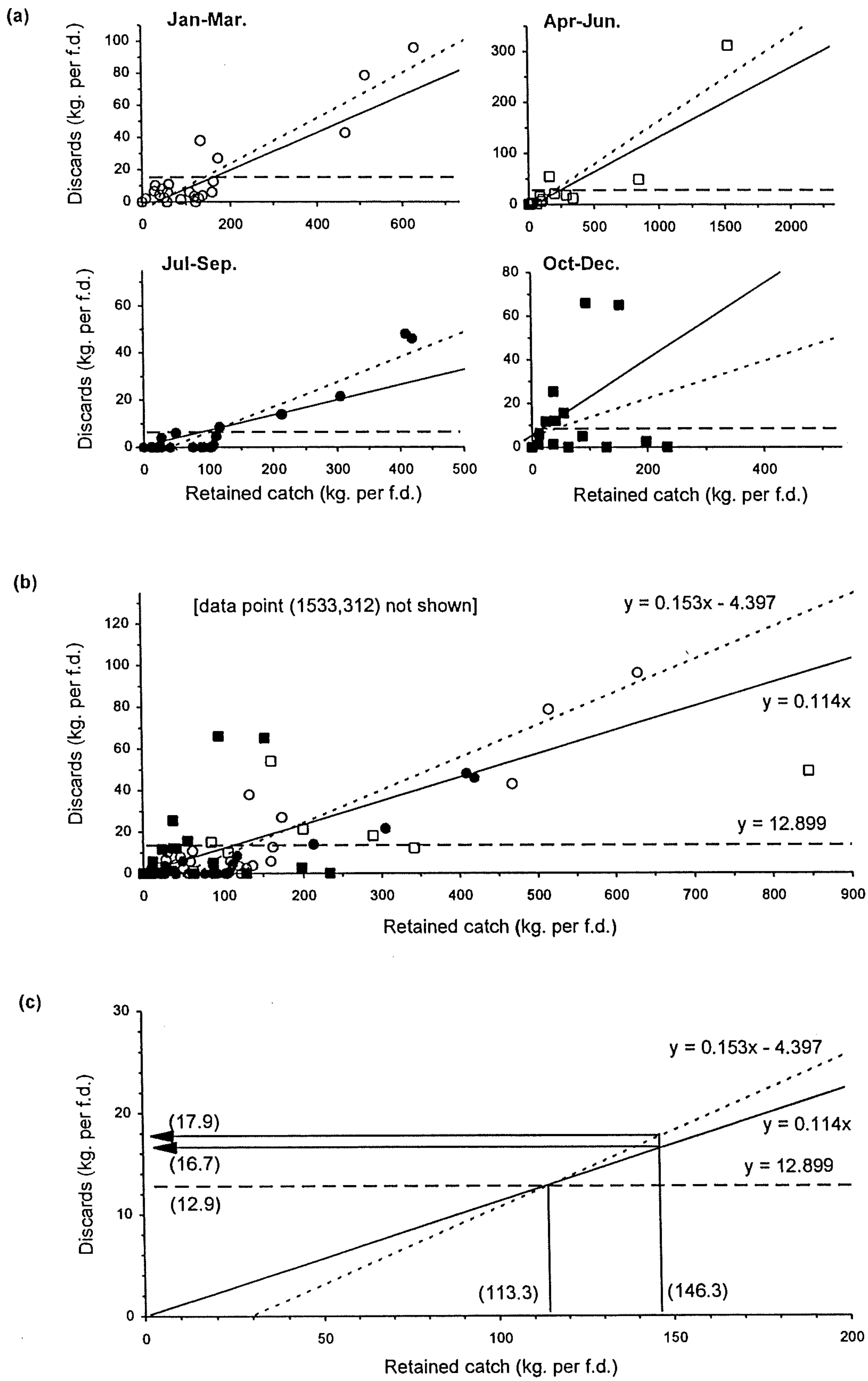


Figure 3. Relation between observered discards and retained catches of tiger flathead (kg per fisher-day) at Ulladulla in 1994: (a) by quarter, (b) in year; (c) calculation of annual estimates of discards.

Aspect ratios of all graphs are identical, so that slopes of lines on graphs can be directly compared.

Table 2. Precision (% CVs) of estimates of catch for combinations of regions and years.

CVs for Tiger flathead and Jackass morwong for individual regions in individual years are based on Rc estimates
CVs for all other species and partitions of catch are based on SMPU estimates

	Ulladulla		Eden		Both years		Both regions		Both regions
	1993	1994	1993	1994	Ulladulla	Eden	1993	1994	Both years
Partitions of catch									
Discards, All spp.	19	25	12	9	16	7	10	9	7
Discards, Non-commercial spp.	10	19	13	10	11	8	11	9	7
Discards, Quota spp.	42	35	26	15	27	17	22	16	14
Discards, Non-quota commercial spp.	24	44	22	12	36	12	22	11	12
Retained, Non-quota commercial spp.	8	11	8	13	7	7	7	10	6
Non-quota species, Total catch									
Blue morwong	21	23	24	22	15	17	18	19	13
Piked dogfish	20	34	21	19	23	14	18	16	12
Angel shark	17	13	22	18	11	14	14	11	9
Barracouta	21	23	17	25	15	15	16	24	14
Arrow squid	14	22	17	13	13	12	15	11	11
Quota species, Discards									
Redfish	32	39	38	19	30	25	33	20	20
Tiger flathead	37	11	24	35	19	21	20	27	17
Mirror dory	31	48	25	63	39	55	23	59	51
Jackass morwong			24	31		19	24	31	19
John dory			20	31		18	20	31	18

errors by observers, or resulting from faulty equipment; or, (v) changes to catch rates or discarding practices due to the presence of an observer. In the application of particular types of estimator to data collected from an observer survey, biases may result from: (i) characteristics of particular estimators (e.g. the intrinsic bias of ratio and regression estimators with small sample size); or (ii) the use of inaccurate auxiliary data (e.g. reported landings and effort) (e.g. Cochran 1977; Saila 1983). Bias in observations on the variable of interest (e.g. discards) affects the accuracy of mean-per-unit estimators. In contrast, bias in the observed relationship between the variable of interest (e.g. discards) and the auxiliary variable (e.g. retained catch) affects the accuracy of ratio and regression estimators. Consequently, biases may affect the accuracy of mean-per-unit, ratio and regression estimators by differing amounts.

The accuracy achieved with the estimators compared in this study was similar. No significant differences were detected among SMPU, Rc and LRC estimates of mean catches for any component of catch. This does not mean that the estimates are free of the types of bias described above. The conclusion is that the estimators are biased by a similar amount, whether or not biases are present. Consequently, there is no reason to select one estimator, rather than another, in an attempt to maximise accuracy.

There were, however, differences in the relative precisions (measured by CV^*) of estimators. Precision of Rc and LRc estimates of discarded tiger flathead and jackass morwong exceeded the precision of SMPU estimates. For each species, weights of discards were correlated with weights of retained catches. The Rc and LRc estimators were no more precise than the SMPU estimator for all other components of catch and in many instances the Rc estimator was less precise.

These conclusions suggest two alternative strategies for the routine estimation of catches from the observer survey. One option is the use of the linear regression estimator in all circumstances, using IRQS as auxiliary variable in preference to ARQS when possible (i.e. for quota species). In contrast to the combined ratio estimator, precision of combined regression estimates was never worse than that of the SMPU estimator by more than 5% (Table 1). Nor can it be, given that the formula for the variance of the LRc estimator (Equation 10) differs from the corresponding formula for the SMPU estimator (Equation 2), in each stratum, by the factor

$$(1-\hat{\rho}_c^2) \cdot \frac{(n_q-1)}{(n_q-2)}$$

and this factor must be between 0 and $((n_q-1)/(n_q-2))$. In the few instances that the combined ratio estimator produced minimal or useful gains in precision over the SMPU estimator, the regression estimator produced similar gains.

The second approach (and the one recommended) involves the routine use of the SMPU estimator except for discards of tiger flathead and jackass morwong, for which the ratio estimator (using IRQS) is superior. No gain in precision was achieved for the other components of catch. Complexity of calculation and exposure to inaccuracies of estimated variances using ratio and regression estimators (see below) would be minimised using this approach. Total catches of quota species (for which the weights of landings are known) can then be calculated as the sum of the reported weights of landings and estimated discards. Consequently, the standard error (and confidence interval) of estimated total catch will be equal to that of estimated discards. For all other species, retained, discarded and total catches must be estimated from observer data, using reported effort data to scale quarterly estimates to annual estimates of mean catch. For all components of catch, annual catches can be calculated as the product of mean catches (per fisher-day) and annual effort (number of fisher-days).

It is interesting to note that a minimal legal length (MLL) is regulated for tiger flathead and for jackass morwong, but for no other quota species. Tiger flathead and jackass morwong are the only species for which there was a relationship between the weight of retained and discarded catches in more than a single instance (see Table 1). For each of these species, particularly tiger flathead, legal-sized and undersized fish were caught together and the MLL was the main factor that determined whether fish were retained or discarded (Liggins, unpubl. data). In such circumstances, some relationship between retained catches and discards is expected. Moreover, variation in the relative weights of legal and undersized components of catch determines the strength of the relationship and therefore the gain in precision of ratio and regression estimators over the stratified mean-per-unit estimator.

The sampling estimate of the variance associated with ratio and regression estimators is an approximation, valid only in large samples (Cochran, 1977; Sukhatme et al, 1984). For estimates in a single stratum, Cochran (1977) suggested that large-sample results may generally be used if sample size exceeds 30 and coefficients of variation of $\overline{x}$ and $\overline{y}$ are less than 10%. The reliable application of large sample results to stratified surveys is even less clearly defined. In each region, during each year of this study, sample size was approximately 24 in each of the 4 strata (quarters), a total sample of approximately 96. While the sample size appears reasonable, coefficients of variation of $\overline{x}_{SMPU}$ and $\overline{y}_{SMPU}$ were generally greater than 10%.

Prerequisites for the application of separate ratio and separate regression estimators are even more restrictive. Because separate estimates of $\overline{y}$ are made in each stratum using these methods, conditions for the application of the approximate variance formulae must be met in each stratum. Separate estimators will be more precise than combined estimators if the relationship between x and y varies among strata. Nevertheless, unless (i) the requirements for the application of large-sample variance formulae are met in each stratum and (ii) the cumulative bias that can affect the estimate of the mean is negligible, use of the combined estimator is appropriate (Cochran 1977; Sukhatme 1984). Consequently, separate estimators were not used in this study to estimate mean catches within regions and years.

Confidence intervals calculated for estimates of catch, using any estimator (including SMPU), must be considered approximate. In general, frequency distributions of retained and discarded catches and of ratios were positively skewed. In these circumstances, it is likely that: (i) the probability that the population mean will be outside the calculated 95% confidence interval exceeds 5%; (ii) the probability that the population mean will be below the lower confidence bound of the estimate is less than 2.5%; (iii) the probability that the population mean will be greater than the upper confidence bound of the estimate exceeds 2.5% (Cochran 1977). Underestimates will occur more frequently than overestimates. A conservative bound may be placed on the actual probability of calculated 95% confidence intervals using the Chebyshev inequality (Mood et al., 1974) which states that at least 75% of observations for any probability distribution will be within 2 standard deviations of their mean (e.g. as used by Crone 1995, for estimates of landings). Resampling procedures such as the jack-knife estimator and bootstrap analysis may also be used to calculate confidence intervals, based on the distribution of the sample data (Saila 1983; Stanley 1992).

It may also be beneficial to reconsider strategies for estimation when understanding of factors affecting discarding and by-catch increases. Factors other than retained catches, may be identified that correlate with discarded catches (or other components of catch). Ratio or regression estimators using these variables, or multivariate ratio or regression estimators (e.g. Sukhatme et al. 1984), or combinations of different estimators may offer increased precision in such circumstances.

Increasing emphasis is being placed on the estimation and consequences of by-catch and discards in fisheries in Australia and throughout the world (Alverson et al. 1994; Kennelly 1995). If the discarded component of catch is included in models of fishery dynamics, conclusions drawn from such models may be drastically altered (e.g. Saila 1983; Pikitch 1987 and 1991; Alverson et al. 1994). Recognition of the sampling error associated with estimates of catch is vital to the effective use of models of fishery dynamics and the confidence that can be placed on conclusions drawn from them (e.g. Pope and Gray 1983; Pelletier and Gros 1991; McAllister and Peterman 1992). If it is important to acknowledge the confidence associated with an estimate of total catch, then it is clearly desirable to maximise the precision of estimates of the weight, abundance or sizes of discards. While there is a trend toward increased statistical rigour in the design and implementation of surveys of landings (e.g. Sen 1986; Crone 1995), the relative merits of various estimation techniques in the analysis of catch data from observer surveys have received little attention (Andrew and Pepperell 1992). To maximise the precision of estimates of discarded catch (or by-catch) and total catch, the relative reliability of alternative estimators should be evaluated. This study has demonstrated the benefits of such an approach.

Acknowledgments

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Captions to figures

Figure 1. Sampling effort, fishing effort and sampling fraction, quarterly and annually for Ulladulla and Eden.

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Appendix D

Detection of bias in observer-based estimates of retained and discarded catches from a multi-species trawl fishery

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Detection of bias in observer-based estimates of retained and discarded catches from a multi-species trawl fishery

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Running head: Detection of bias in observer surveys

Abstract

Observer-based estimates of quantities, size and age distributions of by-catches and discarded catches may be biased by non-representative selection of sampling units (fisher-days or trips) or by changes in fishing practices onboard trawlers when observers are present. In this study, we examined the accuracy of estimates of catch derived from an observer survey of retained and discarded catches in a multi-species fish trawl fishery off the coast of NSW, Australia. Observer-based estimates of magnitudes and size-distributions of retained catches were compared with independent, unbiased estimates that were available for a subset of species (species managed by catch quotas) caught in the fishery. Conclusions about bias in estimates of other components of catch (especially discards) are based on the premise that bias is unlikely to affect these estimates without also affecting estimates of retained catches of quota species. We conclude that estimates of catch, based on the 3 year period 1993-95, were unaffected by significant bias. Observer-based estimates of magnitudes of retained catches did not differ significantly from reported landings for 6 out of 7 species and the combined catch of quota species (CQS) for the Ulladulla fleet, 11 out of 11 species and CQS for the Eden fleet and 10 out of 11 species and CQS for the 2 fleets combined. There was, however, some evidence of bias in estimates of catch for each fleet in 1 of the 3 years. Observer-based size-distributions were not significantly biased. We conclude that our approach to validating observer-based estimates of catch would also be of use in observer surveys of other fisheries.

Introduction

Observer-based surveys, in which data is collected onboard fishing vessels during normal commercial fishing, have been used in a variety of fisheries. In particular, they have been used to estimate quantities and size/age distributions of by-catches and discarded catches from demersal trawling (e.g. Jean, 1963; Howell and Langan, 1987; Liggins and Kennelly, 1996; see also reviews by: Andrew and Pepperell, 1992; Alverson et al, 1994; Kennelly, 1995). Such information is fundamental to assessing effects of discarding on fish populations and resultant losses to fisheries (Gulland, 1973; Saila, 1983; Hilborn and Walters, 1992; Alverson et al., 1994).

An implicit assumption of observer-based surveys of retained, discarded or total catches is that the errors associated with estimates of catch (e.g. magnitudes and size-distributions) arise solely from random sampling error. If, however, non-sampling errors are present, estimates of catch will be inaccurate, or biased, reducing the reliability of subsequent fishery assessments. Non-sampling errors may arise from many sources (e.g. Cochran, 1977; Andrew and Mapstone, 1987; Thompson, 1992) but several are of particular concern in observer surveys of fisheries (Saila, 1983; Alverson et al, 1994). Non-random selection of sampling units (e.g. observed fisher-days or trips) from the sampled population may result in bias. Random selection of sampling units is difficult when the sample population cannot be enumerated until the period from which the sample is taken is complete. Refusals by masters of vessels to allow an observer onboard will also bias estimates unless the retained and discarded catches of respondents and non-respondents are similar. Another problem for observer-based surveys is the influence that the process of observation may have on the process being observed. Bias could occur if fishers perceive that their interests may be enhanced by changing their normal practices when an observer is present (e.g. by discarding more/less or by fishing in an area or in a way such that discards will be maximised/minimised).

Despite warnings regarding the dangers of ignoring potential biases in observer surveys (e.g. Saila, 1983), few attempts have been made to detect the presence or absence of bias in estimates of catch from such surveys. In this study, we present an evaluation of the accuracy of estimates of catch derived from an observer-based survey of a multi-species fish trawl fishery off the coast of New South Wales (NSW), Australia.

The observer-based survey of the retained and discarded catches of fish trawlers operating along the coast of NSW was established in 1993. Trawlers working from two of the ports surveyed, Ulladulla and Eden, fish mainly in the South East Fishery (SEF), a multi-species fishery in which 16 species are managed by a system of total allowable catches (TACs) and individual transferable quotas (ITQs). In this fishery, fishers are legally required to report the landed catches of quota species to the Australian Fisheries Management Authority (AFMA) but discarding of juveniles and unmarketable quantities of commercial and non-commercial species is a long established and little studied practice (Tilzey, 1994). The principal objectives of the observer survey were to estimate quantities and size-distributions of discarded quota species and total catches (retained and discarded components) of non-quota species, with a view to evaluating the effects of discarding on the SEF and other interacting fisheries.

Perceptions of fishers concerning the likely results and consequences of the survey (anecdotal accounts) were diverse and these perceptions each had particular consequences for the accuracy of the survey. That is, there was a potential for fishers to increase or decrease the quantities of discarded catches seen by observers, and so bias observer-based estimates of catch. Some fishers believed that eventual publication of estimates of discarded catches could have a negative effect on their future livelihoods and so provided a potential motive for fishers to reduce the amount of discarding seen by observers. Other fishers asserted that the introduction of TACs and ITQs in this fishery (in 1992) resulted in increased high-grading and discarding of quota species. They argued that TACs (and ITQs) should be increased to reduce discarding and so provided a potential motive to increase the amount of discarding seen by observers. Further, non-representative selection of fisher-days could also positively or negatively bias observer-based estimates of discarded catches and retained and discarded catches of non-quota species.

We examined the accuracy of observer-based estimates of catch magnitudes and size-distributions (of all components of catch) by comparing such estimates for retained catches of quota species with independent and unbiased measures of catch and size distribution. Observer-based estimates of retained catches of quota species were compared with reported landings. Size-distributions (and mean sizes and variances of mean sizes of samples) derived from the observer survey were compared with estimates from an auxiliary survey of catches landed at fishing co-operatives. In assessing the accuracy of observer-based estimates of discards, we assume that such estimates for retained catches of quota species would be biased if similar estimates for non-quota species and discarded quota species were biased. This is a reasonable assumption for this fishery because quota species are the main species targeted in the fishery and subsets of these species are caught across the full range of depths and latitudes encompassed by the fishery (Tilzey, 1994). Consequently, it is difficult to construct scenarios whereby discarded catches of quota species and catches of non-quota species could be biased without affecting magnitudes or size-distributions of retained catches of quota species. Consider, for example, a scenario whereby: (i) total catches are the same on observed and unobserved fisher-days;

but (ii) fewer (or more) fish are discarded on observed fisher-days. With this scenario, retained catches will be greater (or less) on observed than on unobserved fisher-days. Moreover, observer-based estimates of retained catches will be greater (or less) than reported landings. Other, more complex scenarios, in which (i) quantities of retained catches are the same on observed and unobserved fisher-days; but (ii) quantities and/or size-distributions of discarded catches differ, result in differences in size-distributions of retained catches of quota species on observed and unobserved fisher-days.

Given the above premise, significant differences between observer-based and independent, unbiased estimates of quantities and sizes of retained catches of quota species would indicate that observer-based estimates of other components of catch were also biased.

Materials and Methods

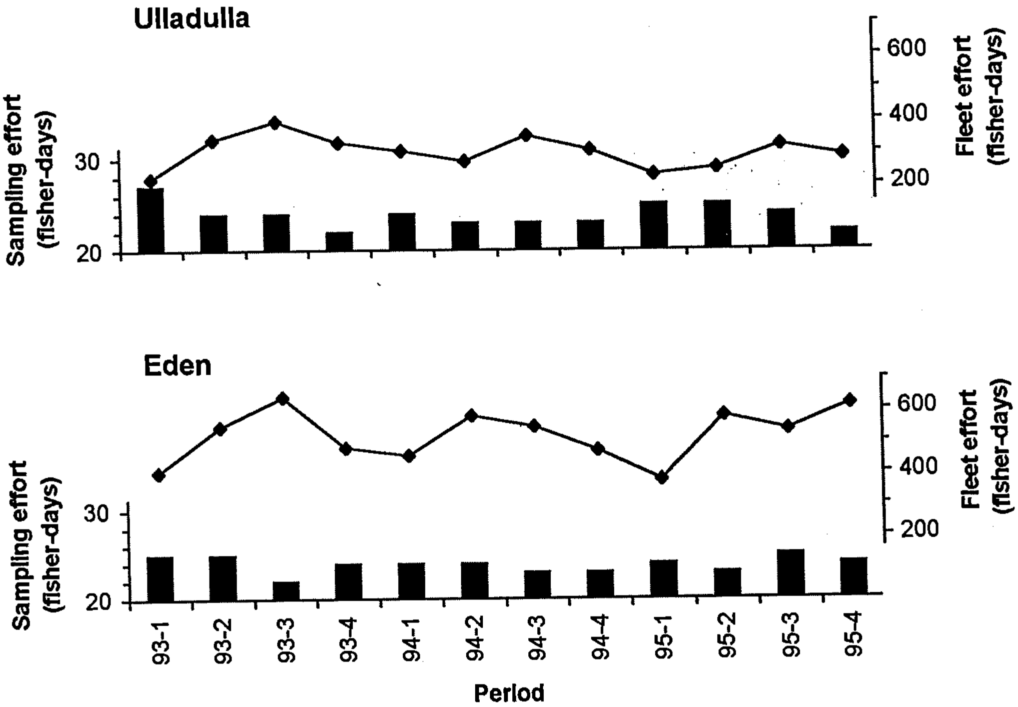
Observer survey

Retained and discarded catches of fish trawlers were surveyed on approximately 24 fisher-days during each quarter (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec) of each of 3 years (1993, 1994, 1995) in each of 2 regions (fleets based in Ulladulla and Eden) in NSW, Australia. Fishing trips out of Eden, of intended duration of more than 3 days were excluded from the sampled population of the survey because fishing generally took place far to the south of the study area. Fishing trips targeting royal red prawns, *Haliporoides sibigae*, were also excluded from the sampled population because the survey was designed to estimate catches from fish trawling. In each region, we attempted to select fisher-days at random for inclusion in the survey. At Eden, where fishing trips were between 1 and 3 days duration, we attempted to select fishing trips randomly until the targeted number of fisher-days had been observed. We assumed that fisher-days on multi-day trips at Eden were independent because trawlers generally stayed out for the pre-planned number of days and there was no obvious relationship between catch rates and decisions to reduce or extend the duration of trips.

The number of fisher-days sampled during each quarter, in each year, in each region, averaged 23.8 fisher-days, the minimal sample being 22 fisher-days and the maximum 27 fisher-days (Figure 1). During the 3 years surveyed, 97, 93 and 96 fisher-days were observed at Ulladulla. These represented sampling fractions of 7.5%, 7.5% and 8.8% for the 3 years. At Eden, 96, 94 and 96 fisher-days were surveyed during the 3 years, with sampling fractions of 4.6%, 4.6% and 4.5%, respectively.

Although sample sizes of approximately 24 fisher-days were achieved in each quarter, of each year, in each region (Figure 1), estimated catches may be biased if the fisher-days sampled

Figure 1. Quarterly sampling effort and fishing effort, Ulladulla and Eden, 1993-95



were not representative of fisher-days completed by the fleets. A variety of factors (e.g. weather patterns, availability of fish) contributed to the pattern of effort by individual vessels within each quarter. Thus, the distribution of fishing effort within a quarter cannot be predicted in advance. Consequently, the fairly even distribution of sampling effort across the 90 or so days in each quarter (approximately 2 fisher-days per week in each region) will not always reflect the distribution of fishing effort by the fleets.

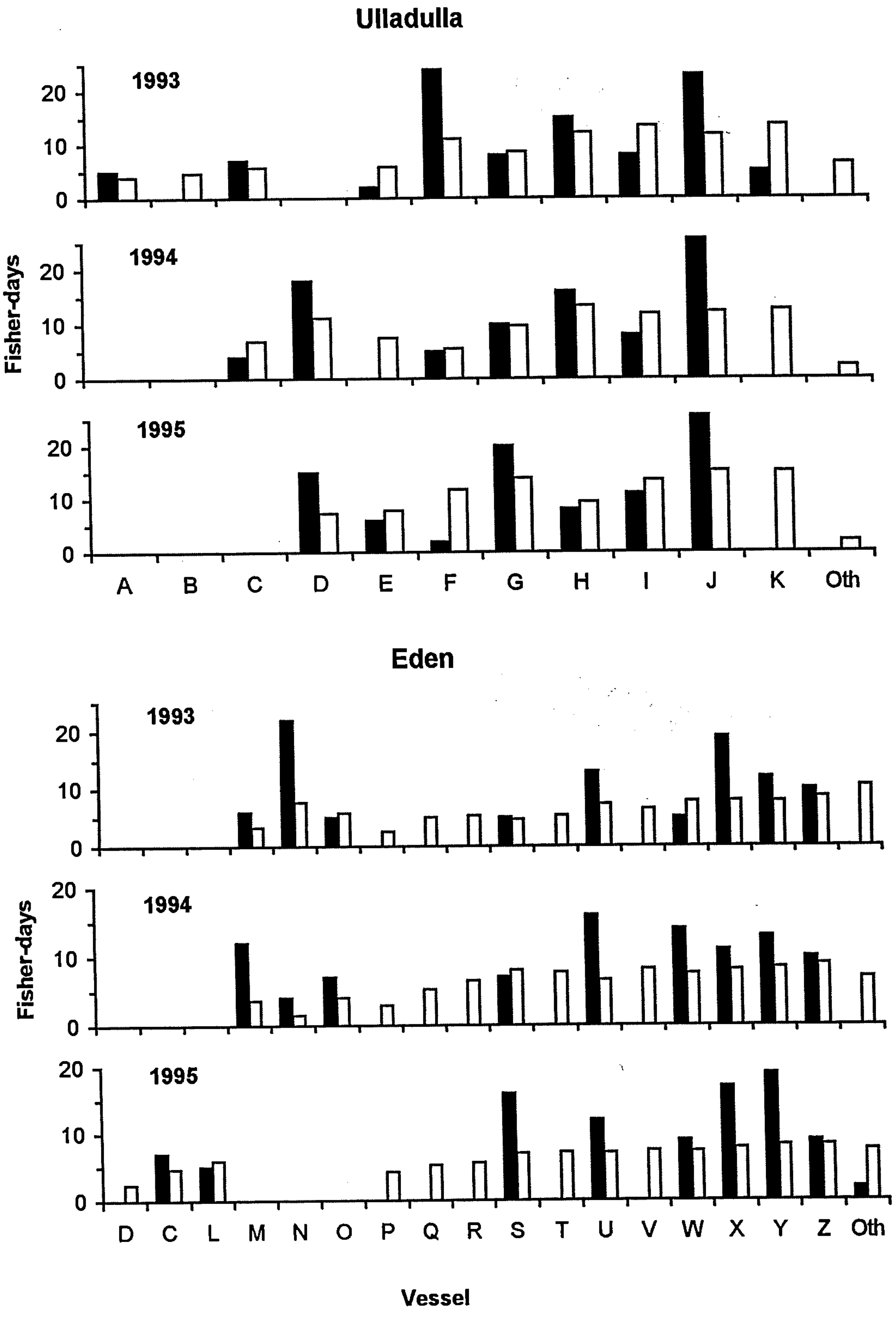
Bias may also result from disproportionate sampling of individual vessels within each quarter and throughout the year (Figure 2). Discrepancies between "ideal" sampling coverage of vessels and that achieved occur for several reasons. Target sampling effort could not be determined for individual trawlers because fishing effort (the population of fisher-days being sampled) could not be enumerated until after the completion of each year. Furthermore, individual vessels were not surveyed if: (i) skippers or owners refused access to observers, or (ii) vessels did not meet the minimal safety requirements necessary for carrying an additional person. Differences in the ease with which skippers of different boats could be contacted when observers were attempting to arrange trips also influenced the disproportionate sampling coverage of vessels.

For each tow of each fisher-day sampled, observers recorded weights and numbers of the retained and discarded catches of each commercial species and size-distributions for each commercial species present in the discards. Size-distributions of retained catches were recorded opportunistically as time permitted. Operational data (location, depth, time, duration of tow) and a list of non-commercial species present in the catch were also recorded.

Retained weights of each species were estimated by weighing each box of fish or a subsample of boxes and counting the total number of boxes. On occasions when fishers graded species into separate size-classes for marketing purposes, the average weight of fish was estimated from a subsample of each grade of each species (usually a 30 - 40 kg box of fish) and used to estimate the total number of each species of each grade, and consequently, the total number of each species retained. The total weight of discards was estimated using one of two methods. If the catch was relatively small, total weight of discards was estimated from the catch remaining on deck after the crew had sorted out the fish to be retained. If the catch was relatively large, the crew discarded fish as the catch was sorted. In these circumstances, the weight of total catch was estimated and an estimate of total discards was calculated by subtracting the estimated total weight of retained catch from estimated weight of total catch. Composition and abundances of species and size-distributions were estimated from a subsample of discards (usually a 30-40 kg box) and an estimate of the sampling fraction. All species

Figure 2. Actual (black bars) and 'ideal' (white bars) sampling effort for individual trawlers at each port in each year.

The number of fisher-days observed on each trawler is actual sampling effort. 'Ideal' sampling effort represents the number of fisher-days that would have been observed on each trawler if the sampling fraction was constant across all trawlers in the port. Individual trawlers that completed a minimum of 50 fisher-days effort are denoted by 'A", 'B', 'C', etc. Trawlers not meeting this criteria are combined in the category 'Oth.'



present in the discards were recorded.

Reported fishing effort and weights of landings

All fishers in the SEF are required to report landed catches of quota species and the duration of each fishing trip (dates of departure and return to port) to the Australian Fisheries Management Authority (on "SEF-2", "Disposal of catch" returns). Only those fishing trips that conformed to the criteria for the sampled population of the observer survey were included in calculations of fishing effort and landed catch (i.e. trips of less than 3 days' duration and trips not targeting *H. sibogae*).

Quarterly fishing effort (in units of fisher-days), for the ports of Ulladulla and Eden, was calculated as follows: (i) trips for which the reported dates of departure and return to port were identical each contributed 1 fisher-day of effort; (ii) trips for which the dates of departure and return to port differed by d days contributed an estimated $d - 0.5$ fisher-days.

Annual weights of landed catches of each quota species and the combined weight of all quota species (CQS) were calculated from the data reported by fishers making landings into Ulladulla and Eden. Landed weights that were reported for "processed" fish (gutted, or headed and gutted) were converted to "whole" weights using approximate conversion factors (1.1 for pink ling, *Genypterus blacodes*; 1.25 for gemfish, *Rexea solandri*; 1.5 for blue grenadier, *Macruronus novaezelandiae*) .

Survey of size-distributions of landed catches

Size-distributions of catches landed at Ulladulla and Eden were surveyed during May/June and September/October of 1994 and 1995. Fishers' co-operatives in each port were visited on each of 8 days during each period of each year. On each visit, we attempted to estimate the size-distributions for the 2 most abundant species in the catch of each trawler landing fish on that day.

If the catch of a species was landed ungraded, a minimum of one box was weighed and measured. When catches were graded prior to landing, a minimum of one box (approximately 30 kg) of each grade of fish was weighed and its contents measured. The total landed weight of each grade of each species from each trawler was recorded from the records maintained by the co-operative. Using the number and weight of fish in the sample of each grade and the size distribution of the sample, the total weight of each grade landed, the size distribution of the landed catch was estimated.

Comparison of reported landings and observer-based estimates of retained catches

Reported annual catches of the quota species landed into Ulladulla and Eden were compared with observer-based estimates of retained catches (with 95 % confidence limits). For each region, comparisons were made only for species with average annual landings exceeding 20 t during the period 1993-95. Consequently, comparisons were made for 7 species at Ulladulla (redfish, *Centroberyx affinis*; pink ling, *Genypterus blacodes*; tiger flathead, *Neoplatycephalus richardsoni*; silver trevally, *Pseudocaranx dentex*; gemfish, *Rexea solandri*; mirror dory, *Zenopsis nebulosis*; and john dory, *Zeus faber*), 11 species at Eden (as for Ulladulla, plus blue grenadier, *Macruronus novaezelandiae*; jackass morwong, *Nemadactylus macropterus*; blue warehou, *Seriolella brama*; and spotted trevalla, *Seriolella punctata*) and the combined weight of all quota species (CQS) for each region. Observer-based estimates of annual retained catches were calculated using a stratified mean-per-unit estimator (e.g. Cochran, 1977). With a simple random sample of fisher-days taken in each quarter of each year, the estimated annual catch, $\hat{Y}$, and associated standard error, $s(\hat{Y})$, were calculated as follows:

$$\hat{Y} = \sum_{q=1}^{4} N_q . \bar{y}_q \qquad (1)$$

$$s(\hat{Y}) = \sqrt{\sum_{q=1}^{4} \frac{N_q^2 . (1-f_q)}{n_q} . s^2(y_q)} \qquad (2)$$

in which N_q is the number of fisher-days done by the fleet (see below) in quarter q, $\bar{y}_q$ is the mean retained catch, $s^2(y_q)$ is the variance of retained catch, n_q is the sample size and $f_q = n_q/N_q$ is the sampling fraction, in each quarter of the year. Confidence limits (95%) were calculated as:

$$\hat{Y} \; +/- \; t'.s(\hat{Y}) \qquad (3)$$

in which t' is the value of Student's t corresponding to the "effective" number of degrees of freedom associated with annual estimates. The effective number of degrees of freedom is somewhere between 21 and 92, the smallest of the values (n_q-1) and their sum (Cochran, 1977). Because the difference between values of t for 21 df (t = 2.08) and 93 df (t = 1.99) is minimal, a t' value of 2 was used.

Comparisons of landed catches from the 2 sources of data, were also made at larger spatial and temporal scales, i.e. combined annual catches of the Ulladulla and Eden fleets in each of the

3 years (1993-95); mean annual catches across the 3 years for each region; mean annual catches for the combined fleets of Ulladulla and Eden across the 3 years. Observer-based estimates of annual catches (+/- standard errors) for each region ($\hat{Y}_U$ and $\hat{Y}_E$) were used to estimate annual catches of the combined fleets of Ulladulla and Eden, $\hat{Y}_{UE}$ as follows (e.g. Cochran, 1977):

$$\hat{Y}_{UE} = \hat{Y}_U + \hat{Y}_E \tag{4}$$

$$s(\hat{Y}_{UE}) = \sqrt{s(\hat{Y}_U)^2 + s(\hat{Y}_E)^2} \tag{5}$$

Estimates of mean annual catches across the period 1993-95, $\overline{Y}_{3y}$, were calculated as:

$$\overline{Y}_{3y} = \frac{\sum_{i=93}^{95} \hat{Y}_i}{3} \tag{6}$$

$$s(\overline{Y}_{3y}) = \frac{\sqrt{\sum_{i=93}^{95} s(\hat{Y}_i)^2}}{3} \tag{7}$$

for $\hat{Y}_i = \hat{Y}_U$, $\hat{Y}_E$ and $\hat{Y}_{UE}$. Confidence limits of estimates were calculated as $\hat{Y}$ +/- $2.s(\hat{Y})$.

At all spatial and temporal scales, significant differences between observer-based estimates of retained catches and reported landings were indicated if the weight of reported landings was outside the 95% confidence limits of the observer-based estimate.

<u>Comparison of shore-based and observer-based estimates of size-distributions of retained catches</u>

Size-distributions derived from the observer survey between April and November of each year were compared with size-distributions from the shore-based survey of co-operatives in each port (Ulladulla, Eden) and year (1994, 1995). It is assumed that size-distributions derived from the shore-based survey during the periods May-June and September-October are representative of size-distributions landed at the ports during the period April - November. Comparisons were made for each species, in each region and in each year (1994, 1995), if the following criteria were met: (i) a minimum of 400 fish measured across a minimum of 10 tows from the observer-based survey and (ii) a minimum of 400 fish measured across 10 landings from the co-operative survey. Two types of comparison were made.

Firstly, for both the observer-based and shore-based surveys, annual size-distributions (for the period April - November) were calculated by combining the sizes from each sample after weighting each sample by the inverse of the sampling fraction (i.e. by the number of fish in the retained or landed catch / the number measured). Resulting size-distributions from each source were converted to relative frequency distributions and graphed.

Secondly, two-sample *t*-tests were used to detect significant differences between the means (of mean lengths of samples) from the observer-based and shore-based surveys. Variances (of mean lengths of samples) were calculated for each source of data and significant differences were detected by calculating an F ratio (maximum variance / minimum variance). In these procedures, each sample received equal weighting, regardless of sampling fraction.

Results

Comparisons of reported landings and observer-based estimates of retained catches

For 1993, observer-based estimates of the weights of retained catches of all quota species and of CQS were consistent with reported landings (ie. no significant differences at $p = 0.05$) for the fleets of Ulladulla and Eden (Table 1) and for the combined fleets of these ports (Figure 3).

For the Ulladulla fleet, in 1994, observer-based estimates of retained catches of 4 out of 7 species were consistent with reported landings. Observer-based estimates of catches of redfish, silver trevally, john dory and CQS were underestimated (Table 1). Observer-based estimates and reported landings were consistent for CQS and all but one species (tiger flathead) taken by the Eden fleet (Table 1). Observer-based estimates of catches of each quota species and CQS by the combined fleets of Ulladulla and Eden were consistent with reported landings (Figure 3).

For 1995, comparisons of landings of each quota species and of CQS, derived from the two sources of data, were consistent for the Ulladulla fleet (Table 1). Observer-based estimates of retained catches of 8 out of 11 species were consistent with reported landings into Eden. Retained catches of jackass morwong, silver trevally and john dory were underestimated (Table 1). The combined catches of the Ulladulla and Eden fleets were underestimated for two of these species (jackass morwong and john dory) (Figure 3).

Observer-based estimates of mean annual landings (for the

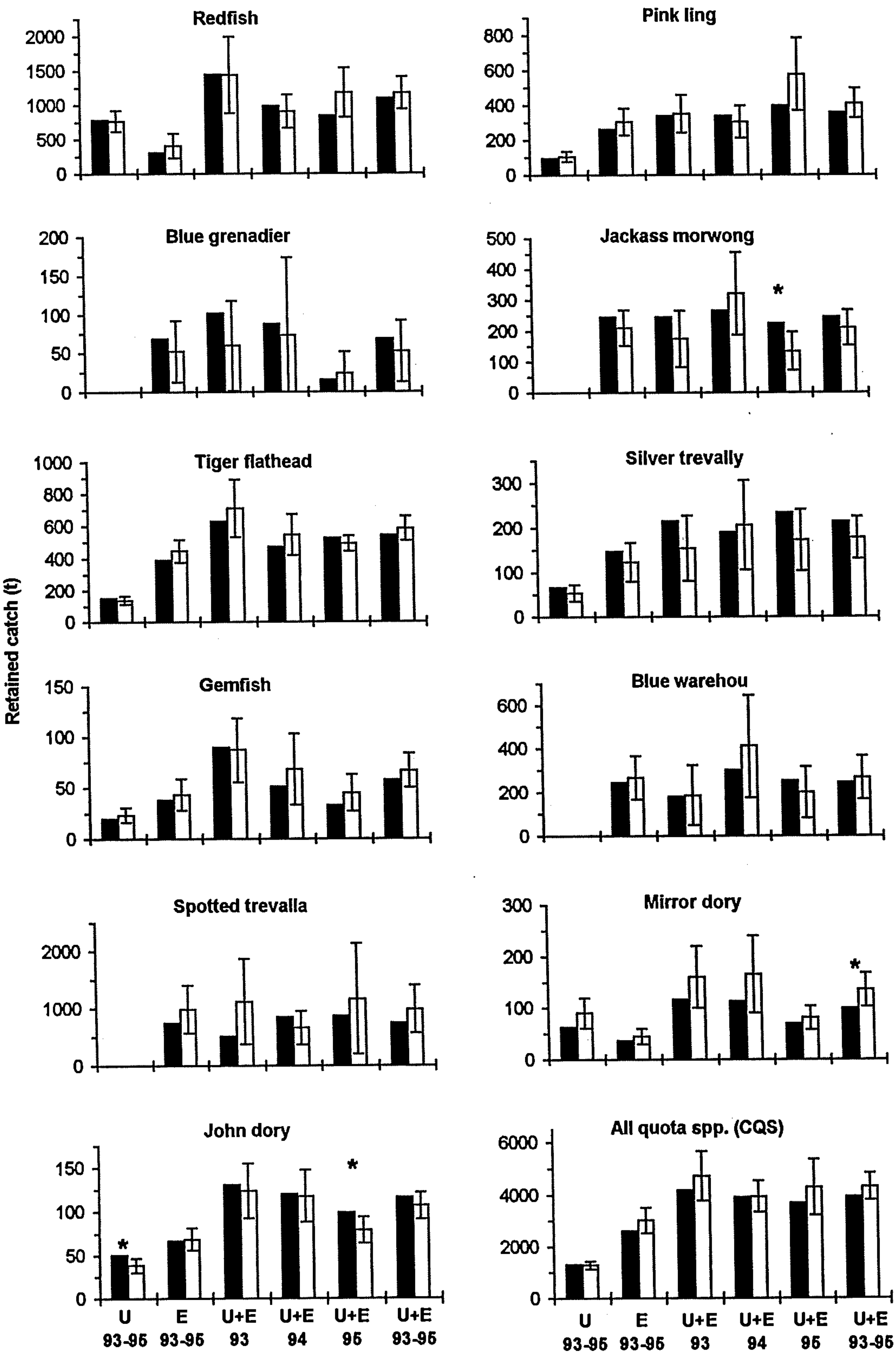
Table 1. Observer-based estimates (with 95% C.I.) of retained catches and reported landings (t) of quota species for Ulladulla and Eden during 1993, 1994 and 1995

'Diff.' indicates that the observer-based estimates is greater than (+) or less than (-) the reported tonnage
* indicates the difference is significant at p = 0.05

Species	Year	Ulladulla Reported landings	Ulladulla Observed (with 95% C.I.)		Ulladulla Diff.		Eden Reported landings	Eden Observed (with 95% C.I.)		Eden Diff.	
Redfish	93	1078	1086	+/- 346	+		365	351	+/- 436	-	
	94	644	454	172	-	*	338	453	166	+	
	95	625	761	242	+		222	418	263	+	
Pink ling	93	96	147	72	+		242	203	80	-	
	94	104	86	34	-		233	218	86	-	
	95	89	84	44	-		307	491	203	+	
Blue grenadier	93	0					102	60	68	-	
	94	3					88	73	100	-	
	95	4					15	24	28	+	
Jackass morwong	93	14					244	174	92	-	
	94	17					265	321	134	+	
	95	15					224	133	62	-	*
Tiger flathead	93	167	169	64	+		463	543	170	+	
	94	181	140	50	-		290	407	116	+	*
	95	109	106	22	-		417	386	44	-	
Silver trevally	93	50	42	34	-		165	112	64	-	
	94	76	46	26	-	*	114	160	96	+	
	95	73	73	35	-		160	99	69	-	*
Gemfish	93	36	34	14	-		53	53	28	-	
	94	15	22	14	+		36	46	32	+	
	95	8	14	8	+		25	31	16	+	
Blue warehou	93	2					181	186	136	+	
	94	0					300	411	236	+	
	95	12					252	199	117	-	
Spotted trevalla	93	1					514	1120	748	+	
	94	0					848	659	294	-	
	95	2					870	1167	966	+	
Mirror dory	93	77	101	46	+		39	59	38	+	
	94	75	125	72	+		38	40	20	+	
	95	37	46	21	+		32	35	9	+	
John dory	93	52	47	20	-		79	77	24	-	
	94	56	33	10	-	*	64	85	28	+	
	95	43	35	10	-		56	44	11	-	*
All quota species (CQS)	93	1646	1711	342	+		2536	3011	869	+	
	94	1231	996	189	-	*	2676	2943	567	+	
	95	1054	1168	241	+		2634	3113	1042	+	

Figure 3. Reported landings (black bars) and observer-based estimates of retained catches (white bars, with 95% C.I.) of quota species at Ulladulla and Eden, 1993-95

U 93-95' and 'E 93-95' denote annual catches for Ulladulla and Eden across all years
U+E 93', 'U+E 94' and 'U+E 95' denote combined Ulladulla and Eden catches in each year
U+E 93-95' denotes the mean annual combined catch of Ulladulla and Eden
* Indicates significant differences between observer-based estimates and reported landings ($p < 0.05$)



period 1993-95) were consistent with reported landings for CQS and 6 out of 7 species taken by Ulladulla trawlers (john dory the exception), CQS and all 11 species taken by Eden trawlers and for CQS and 10 of the 11 species taken by the combined fleets (mirror dory being the exception; Figure 3).

The discrepancies between observer-based estimates and reported landings described above were all detected using a critical *p*-value of 0.05. In interpreting the results of such comparisons, note that Type I errors across the sets of tests will exceed the nominal $p = 0.05$ for each test. For each year of the survey, comparisons were made for landings of 7 species and of CQS (a total of 8 comparisons) by the Ulladulla fleet. Twelve comparisons were made for the Eden fleet. The probability of detecting 2 out of 8 or more inconsistencies for the Ulladulla data, and 2 out of 12 or more inconsistencies for the Eden data, by chance alone, is less than 0.05 (based on binomial distributions for 2 or more out of $n = 8$ and 2 or more out of $n = 12$ events, each with a chance $p = 0.05$ of occurring). Consequently, we conclude that bias is present in observer-based estimates of catches by the Ulladulla fleet in one of the 3 years surveyed (1994), by the Eden fleet in one of the 3 years (1995) and by the combined fleets of Ulladulla and Eden in one of the 3 years (1995) (Table 2).

Biases in observer-based estimates were not consistent across years for Ulladulla, Eden nor for the combined fleets of these ports. Nor were they consistent across the fleets of the 2 ports. Furthermore, at neither port was the retained catch of a given species under- or over-estimated (significantly) in more than one year. Similarly, estimated retained catches of no individual species was under- or over-estimated at both ports in any one year (Table 2).

Having concluded that bias is not constant across ports or across years it is not surprising that observer-based estimates of retained catches were inconsistent with reported landings in fewer instances when compared at larger spatial and temporal scales (Figure 3 and Table 2). In 1994, inconsistencies were detected for 3 species at Ulladulla and 1 species at Eden, but no inconsistencies were detected for the combined catches of the 2 ports in that year. Similarly, in 1995, the number of inconsistencies identified for catches by the combined fleets was less than the number identified for individual ports. Landings of a given species may be overestimated (not necessarily significantly) in some years and underestimated (not necessarily significantly) in others or overestimated at one port and underestimated at the other (Table 1).

Not only were fewer inconsistencies detected at larger spatial and temporal scales, but the power to detect differences at these scales was increased (Figure 4). Coefficients of variation of estimated retained catches made over 3 years were improved by approximately ($1/\sqrt{3}$, i.e. a 42% increase in

Table 2. Incidence of significant differences between observer-based estimates of retained catches and reported landings at different spatial and temporal scales.

x / y indicates that x (of a total y) observer-based estimates of retained catch were significantly different from reported landings
Species for which differences were detected are listed. ' -' indicates an underestimate, '+' indicates an overestimate.
* indicates the presence of bias (i.e. the probability of detecting the given number, or more, significant differences by chance alone < 0.05)

TEMPORAL SCALE		SPATIAL SCALE					
		Single fleets				Combined fleets	
		U		E			
Annual	1993	0 / 8		0 / 12		0 / 12	
	1994	4 / 8 *	Redfish - Silver trevally - John dory - CQS -	1 / 12	Tiger flathead +	0 / 12	
	1995	0 / 8		3 / 12 *	Jackass morwong - Silver trevally - John dory -	2 / 12 *	Jackass morwong - John dory -
3-year		1 / 8	John dory -	0 / 12		1 / 12	Mirror dory +

precision), relative to annual estimates (Figure 4a). Precision is associated with size of sample and, in this comparison, size of sample is associated with the number of years over which mean catches are calculated. Similarly, CVs of estimates made for the combined catches of Ulladulla and Eden fleets were improved, with several exceptions, by approximately ($1/\sqrt{2}$, i.e. a 29% increase in precision) (Figure 4b). In addition to size of sample, the precision of estimates made across fleets is related to the relative magnitude and precision of estimates for each fleet. In the most extreme case, there was no improvement in the precision of estimates of retained catches for the four species caught only at Eden (blue grenadier, jackass morwong, blue warehou and spotted trevalla; Figure 4b). In summary, both accuracy and precision of observer-based estimates of retained catches of quota species increased with spatial and temporal scale (Figure 5).

Comparisons of shore-based and observer-based estimates of size-distributions of retained catches

Annual observer-based and shore-based size-distributions were similar for all species examined (Figure 6). Amongst the 12 comparisons shown in Figure 6, observer-based and shore-based size-distributions corresponded most closely when sample sizes (number of samples and number of fish measured across samples) were relatively large. This suggests that differences between size-distributions result from sampling error rather than bias.

No significant differences were detected between mean lengths (means of mean lengths calculated from each sample) calculated from the 2 sources of data, for any of the combinations of species, port and year examined (Table 3). The ability of *t*-tests to detect differences in mean length is indicated by "minimal significant difference" (MSD) specified in Table 3. Differences of approximately 1 cm would have been detected as significant for redfish or jackass morwong, approximately 1.5 cm for tiger flathead and approximately 2 cm for spotted trevalla. The ability of the *t*-tests to detect differences for blue warehou and mirror dory was less useful.

Note that the discrepancy between observer-based and shore-based estimates of mean lengths of redfish at Eden in 1995 was 0.04 cm when all samples were given equal weighting in the determination of mean length (Table 3). In contrast, when samples were given a weighting in the overall distribution in proportion to magnitude of catch (from which each sample was obtained), the discrepancy between mean lengths was 1.2 cm and the observer-based distribution was shifted to the left of the shore-based distribution (Figure 6). Two of the 12 samples of redfish from the observer survey came from particularly large catches of comparatively small fish. These two catches represent 56% of the total catch sampled and consequently, these catches of small fish contribute more than 56% of the information to the weighted distribution.

Figure 4. Precision of observer-based estimates of retained catches at different spatial and temporal scales

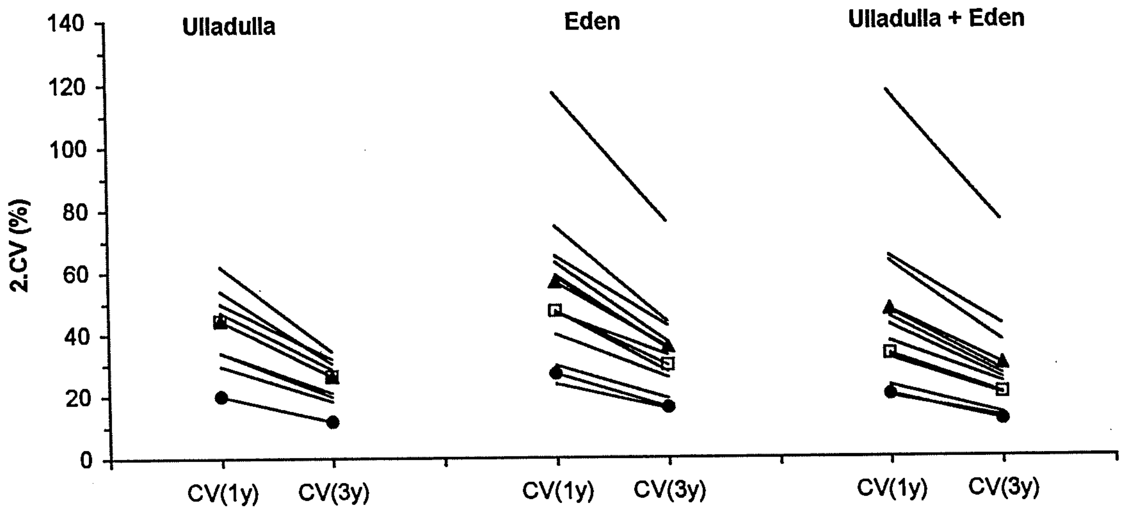
(a) compares the mean coefficient of variation of annual estimates of catch, 'CV(1y)', with the CV of mean annual estimates, 'CV(3y)', for the fleets of individual ports and for the combined fleets

(b) compares the mean CV of estimates of catch for individual fleets, 'CV(1f)', with the CV of estimates of catch by the combined fleets, 'CV(2f)', for each year and for the 3 year period.

individual quota species
mean CV for the 7 species taken by both the Ulladulla and Eden fleets
mean CV for all 11 species examined
CQS

Note that the unit of measurement on the y-axis is 2.CV (%) so that the relative magnitude of +/- half the 95% confidence interval to the estimate is shown.

(a)



(b)

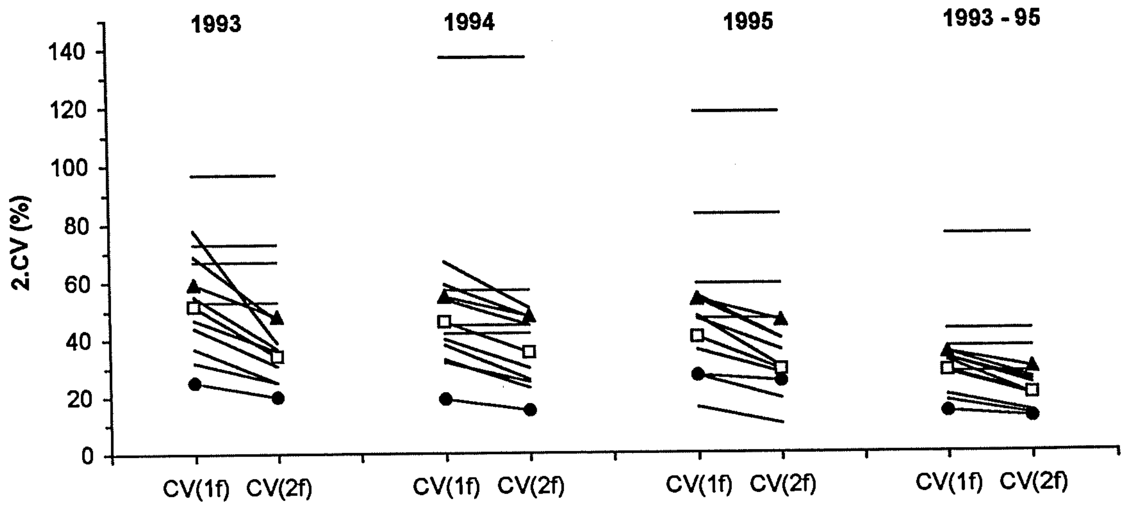


Figure 5. Reported landings versus observer-based estimates of retained catches (with 95% C.I.) of quota species

Data points above the line of equality (dashed line) indicate that observer-based estimates overestimate landings; points below the line are underestimates

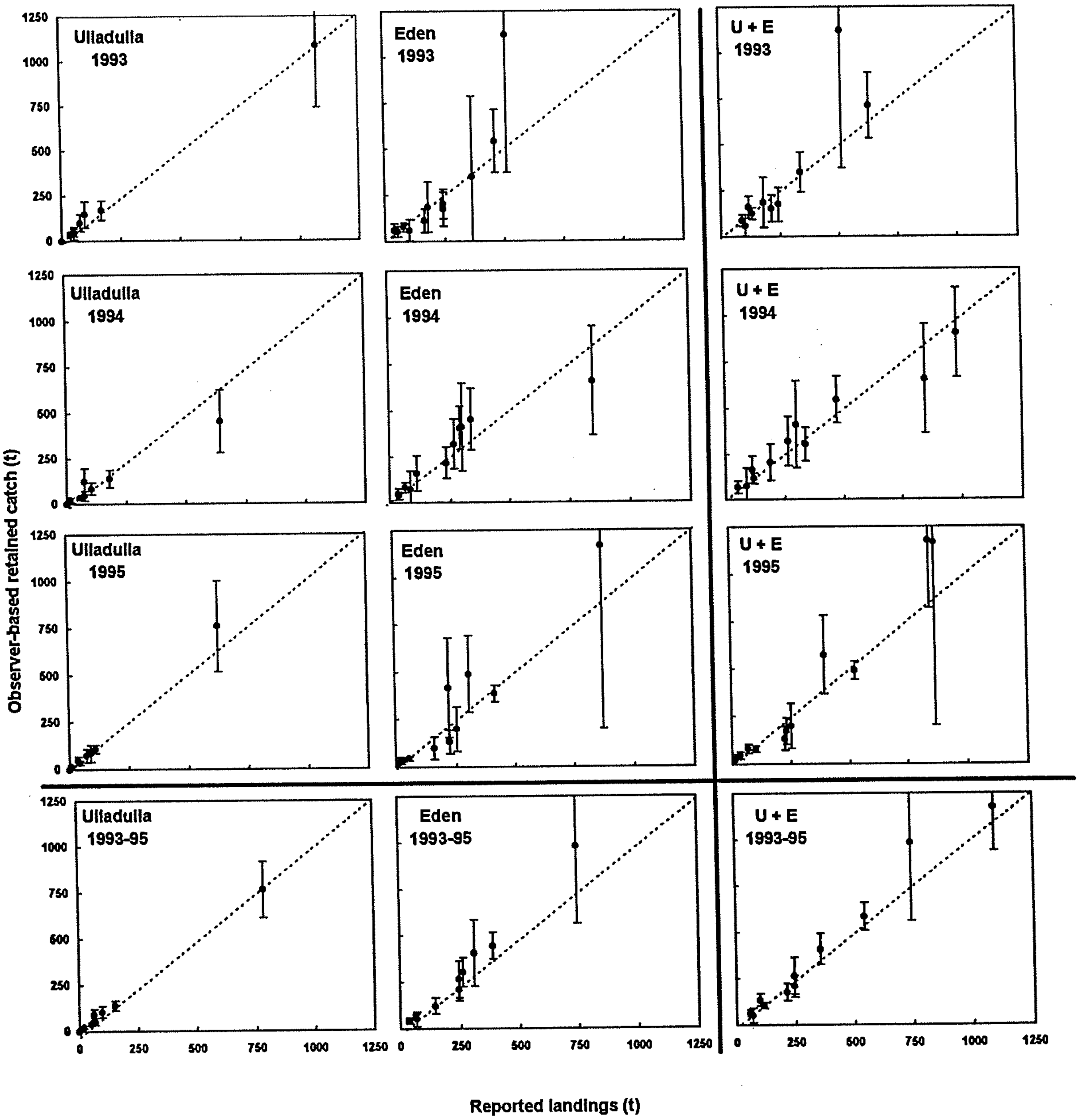


Figure 6. Observer-based (bold line) and shore-based (thin line) size-distributions of retained/landed catches for Ulladulla and Eden during 1994 and 1995

Number of samples and the number of fish measured, for observer-based and shore-based surveys are shown above each graph.
Lo and Lc are the mean lengths of fish sampled from the observer and shore-based surveys respectively

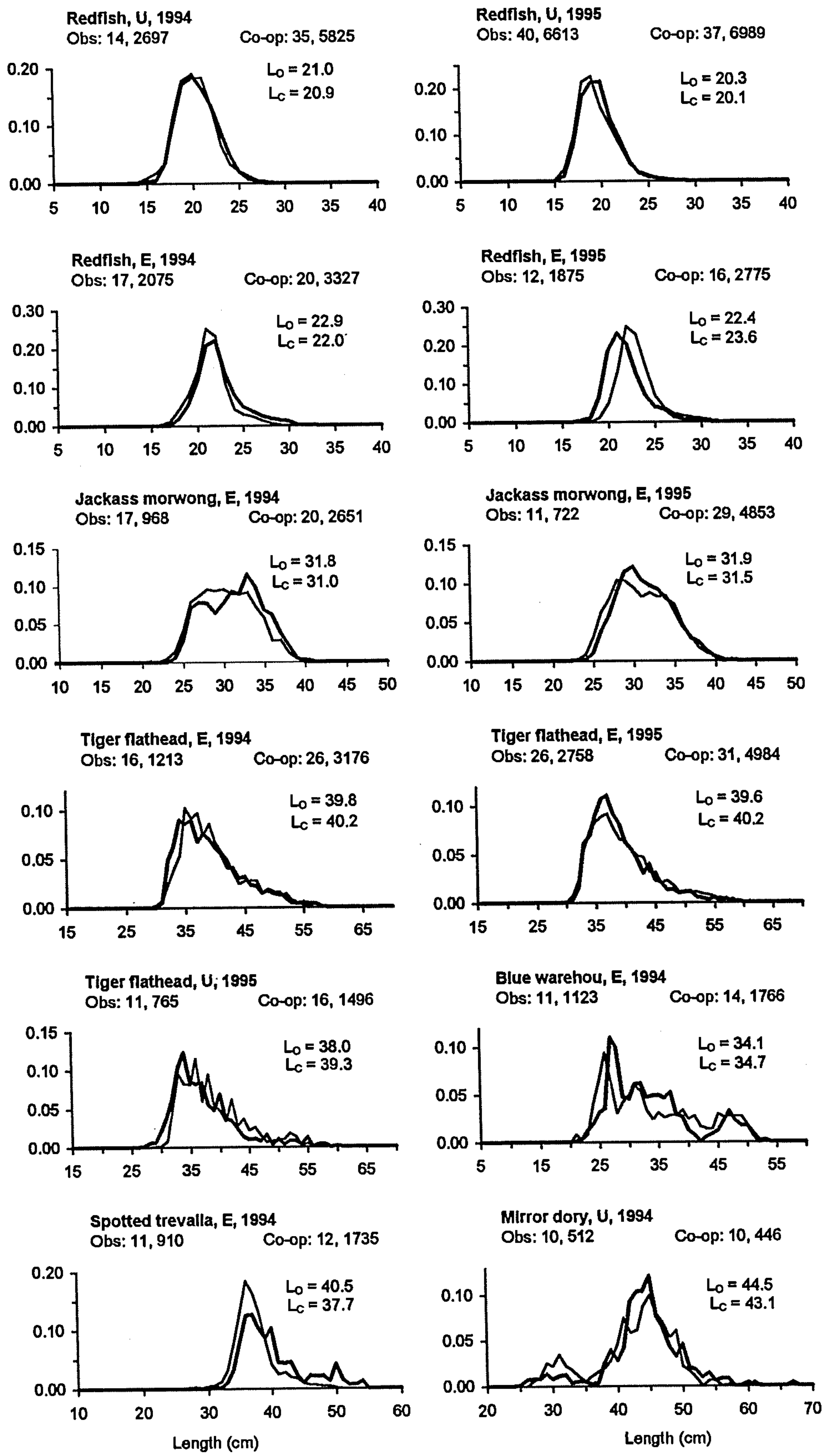


Table 3. Observer-based and port-based mean sizes of catch: comparisons of variances (F ratio) and of mean lengths (t tests)

Sample size (**n**), variance (**Var.**), mean length (**Mean L**) and standard error (**se**) of observer-based and co-op-based estimates of mean length of fish

Ratio of variances = largest variance / smallest variance, **ns** indicates no significant difference by F ratio, * indicates significance at p = 0.05

Difference between means = difference between mean lengths from observer survey and co-op survey, **ns** denotes no significant difference by t-test, * indicates significance at p = 0.05
t-tests for all species except Spotted trevalla use pooled estimates of variance, MSD is the minimum difference between means that would have been significant

			Observer survey				Co-op. survey				Ratio of variances		Difference between means		MSD
Species	**Region**	**Year**	**n**	**Var.**	**Mean L**	**se**	**n**	**Var.**	**Mean L.**	**se**					
Redfish	U	1994	14	2.59	21.70	0.43	35	2.94	21.17	0.29	1.14	ns	0.53	ns	1.08
	U	1995	40	1.60	20.74	0.20	37	2.50	20.49	0.26	1.56	ns	0.25	ns	0.65
	E	1994	17	4.25	23.69	0.50	20	4.05	22.45	0.45	1.05	ns	1.24	ns	1.35
	E	1995	12	2.43	23.49	0.45	16	1.08	23.45	0.26	2.25	ns	0.04	ns	1.01
Jackass morwong	E	1994	17	2.08	31.65	0.35	20	2.45	31.27	0.35	1.18	ns	0.38	ns	1.00
	E	1995	11	2.43	31.86	0.47	29	1.81	31.44	0.25	1.34	ns	0.42	ns	1.00
Tiger flathead	U	1995	11	9.51	39.03	0.93	16	6.15	38.73	0.62	1.55	ns	0.30	ns	2.22
	E	1994	16	5.20	40.35	0.57	26	4.37	39.82	0.41	1.19	ns	0.53	ns	1.40
	E	1995	26	4.59	39.75	0.42	31	4.02	40.57	0.36	1.14	ns	-0.82	ns	1.11
Blue warehou	E	1994	11	37.65	33.80	1.85	14	59.99	35.95	2.07	1.59	ns	-2.15	ns	5.90
Spotted trevalla	E	1994	11	6.87	38.12	0.79	12	2.32	37.88	0.44	3.28	*	0.24	ns	1.93
Mirror dory	U	1995	10	34.23	44.92	1.85	10	21.32	42.87	1.46	1.61	ns	2.05	ns	4.95

There were no significant differences between variances (of mean lengths calculated from each sample) for 11 of the 12 comparisons (Table 3). The variance of sample means from the observer survey was greater than that derived from the shore-based survey for spotted trevalla at Eden in 1994. The probability, however, of detecting one or more significant difference (from the set of 11 tests) by chance alone is greater than 0.05. Thus, one significant difference does not provide evidence that variances actually differed between observer-based and shore-based estimates.

Discussion

Observer-based estimates of the magnitudes and size-distributions of catches by the trawl fleets of Ulladulla, Eden, and the combined fleets of both ports, over the 3 year period 1993-95, were not significantly biased. Over this 3 year period, the effects of (i) non-representative selection of fisher-days, (ii) any changes in fishing practices when an observer was onboard and (iii) other potential sources of bias, were insignificant.

Observer-based estimates of catch were unaffected by bias in 2 of the 3 years surveyed in each region. There was, however, evidence of bias for the Ulladulla fleet in 1994, the Eden fleet in 1995 and the combined fleets in 1995. Observer-based estimates of catch for these regions in these years must be considered less reliable than estimates for other years in these regions. Note that, despite evidence of bias, the majority of observer-based estimates of retained catches of quota species in these regions in these years were consistent with reported landings (4 out of 7 species for Ulladulla in 1994, 8 out of 11 species for Eden in 1995, 9 out for 11 species at Eden in 1995). Furthermore, no significant differences were detected from comparisons of size-distributions for these regions in these years. Intuitively, this suggests that observer-based estimates of catch for the majority of species, in these regions in these years, were unaffected by bias. In practice, it is probably reasonable to assume that observer-based estimates of catch for the combined fleets of Ulladulla and Eden in 1995 (comparisons for 9 out of 11 species were consistent) were unaffected by bias.

These conclusions have implications for the analysis of data collected from this observer survey during the period 1993-95. Analyses based on data collected across 3 year period, will be unaffected by bias. Analyses based on year to year changes in catches from a single region must be interpreted with more caution.

It is particularly important to obtain reliable estimates of magnitudes and size-distributions of discarded catches of commercial species. Discarded catches represent real losses from stocks and may reduce the potential biomass and yield from stocks (Gulland, 1973; Howell and Langan, 1987) and inclusion of data about discards in standard assessment models may alter the conclusions derived from these models (Pikitch, 1991; Alverson et al., 1994). Changes in discarding practices over time may be confused with trends in abundance if discarding is not properly documented throughout the period examined (Gulland and Garcia, 1984). Just as stock assessments may be biased by absence of data about discarding, they may be biased by the inclusion of inaccurate data about discarding (eg Saila 1983, Alverson et al., 1984). The need for scientifically supportable estimates of rates of discarding and consideration of bias have been stressed by several authors (Saila, 1983; Howell and Langan, 1987; Alverson et al., 1994). In particular, Saila (1993) noted that "the fishery scientist will sometimes have to assess the level of accuracy of obtained information using his/her own quality control techniques." It is therefore somewhat surprising that the issue of detecting bias in observer-based estimates of catch has received such little attention.

The approach used in this study would seem to have application for examining the accuracy of observer-based estimates of catch in other fisheries for which landings statistics are available. The recommended strategy is to examine the accuracy of observer-based estimates of catch for all components of catch for which independent, unbiased estimates are available. In prawn (shrimp) fisheries, this may be limited to a comparison of observer-based estimates of prawn catch with reported landings. This strategy, however, has greater utility in multi-species fisheries for which landings statistics are available for several species. If shore-based surveys of size-distributions of landings exist, comparisons of another dimension of catch can be made but in their absence, a survey designed specifically to validate observer-based size-distributions of retained catches should be considered.

We reinforce the argument made by Saila (1983) that assessment of the accuracy of observer-based estimates of catch is of fundamental importance. While direct assessment of accuracy of observer-based estimates of discarded catches is impossible, accuracy should be assessed for all components of catch for which independent, unbiased estimates are available.

Acknowledgments

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Appendix E

Modelling the length-dependent offshore distribution of redfish, *Centroberyx affinis*

Y. Chen, G.W. Liggins, K.J. Graham and S.J. Kennelly

In press

Fisheries Research

Modelling the length-dependent offshore distribution of redfish, *Centroberyx affinis*

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Abstract

Redfish, *Centroberyx affinis*, are distributed on the continental shelf and slope along the south-eastern coast of Australia from northern New South Wales (NSW) to eastern Tasmania, the main fishery being on the southern coast of NSW. During 1993-94, the NSW Fisheries research vessel "Kapala" conducted an independent stratified survey of abundances and length distributions of fish on the continental shelf of the NSW coast. Three depth strata were surveyed: inshore (< 60 m), mid-shelf (90 m to 125 m), and outer-shelf (125 m to 165 m). Redfish showed a strong length-dependent offshore distribution, with small fish occurring more frequently in the shallow inshore waters and large fish in the deeper mid-shelf and outer-shelf waters. Two logistic-type functions were used to model this length-dependent offshore distribution. There are two parameters to be estimated in each of these two logistic functions, one being the length at which 50% of fish remain inshore (L50) and the other is a parameter that determines the shape of the logistic curve (m). The estimation of the parameters was tested with a simulated fishery under different assumptions for annual recruitment, fishing mortality, variation in length at age, sampling errors, and sampling intensity. In this simulation study, the estimation of L50 was robust while the estimation of m was sensitive to error variations. The estimated L50 of redfish varied from 12.4 cm to 17.4 cm over sampling years and seasons, indicating a temporal variation in redfish length-dependent offshore distribution. The estimated L50 provides fisheries managers with a quantitative estimate of the length of redfish migrating onto the commercial fishing grounds. The proposed model provides an approach to incorporating a size-dependent offshore distribution of fish into models of fish population dynamics and stock assessment.

Keywords: length-dependent spatial distribution, sequential fishery, Monte Carlo simulation, *Centroberyx affinis*.

1. Introduction

Redfish, *Centroberyx affinis*, are distributed along the south-eastern coast of Australia, from northern New South Wales (NSW) to eastern Tasmania. They are most abundant off the NSW coast where the main fishery is located (Rowling, 1994). Tagging studies indicate a single stock off the NSW coast although the genetic relationship with fish from other areas is unknown (Rowling, 1994). Redfish have been reported to undertake diurnal movement, schooling near the sea bed during the day and moving to upper layers to feed at night. However, recently a significant proportion of the trawl catch has been taken at night, suggesting that this diurnal movement may not occur consistently throughout the entire population (Tilzey et al., 1990).

While no distinct patterns in long-distance migration have been observed along the NSW coast (Rowling, 1994), juvenile redfish have been reported to inhabit estuaries and shallow inshore waters while adults are found in continental shelf and slope waters to a depth of 450 m (Kailola et al., 1993). Commercial trawl catches are greatest in depths of 100 m to 200 m, indicating that adult redfish are most abundant in these depths (Rowling, 1994). Thus, it can be hypothesized that redfish along the NSW coast have a length-dependent offshore distribution that results from length-dependent offshore movement (or migration), inhabiting shallow inshore waters when they are small in size, and moving to deeper offshore waters as they increase in size.

In this study, using data from a two year, independent stratified survey conducted off the NSW coast, we test the hypothesis that the offshore distribution of redfish is length-dependent. A two-parameter logistic function is proposed to model the length-dependent offshore distribution of redfish, one parameter being the length at which 50% of fish remain in inshore waters; and the other defining the shape of the logistic curve and relating to the instantaneous rate of length-dependent movement from inshore to offshore waters. We simulate a hypothetical fishery in which fish undertake length-dependent offshore movement and have population parameters similar to redfish along the NSW coast. With this simulated fishery, we examine the robustness of modelling the length-dependent offshore distribution with the proposed logistic function. Fishing intensity in the hypothetical fishery is assumed to be different between inshore and offshore waters, with fish inshore being subject to low incidental mortality (e.g. due to by-catch), while fish in offshore waters are subject to a relatively higher fishing mortality due to targeted commercial fishing activities. The proposed logistic function is then applied to the simulated fishery to model the length-dependent offshore distribution. Its performance is evaluated using a Monte Carlo approach under different assumptions concerning annual recruitment, fishing mortality, sampling intensity, and errors associated with fish stock parameters. The proposed logistic function is then applied to model the length-dependent offshore distribution observed for redfish and temporal variations are examined.

2. Methods and materials

2.1. Survey

During 1993 and 1994 the NSW Fisheries research vessel "Kapala" conducted a stratified randomised survey of the abundances and length distributions of commercial fish species on the continental shelf off the NSW coast between Newcastle and Eden (Figure 1). Quarterly surveys were completed in each of the two years (Table 1), in each of three depth strata (Table 2). Three locations were chosen randomly from the trawlable ground within each depth stratum for inclusion in the survey (Figure 1). Two tows of 60 minutes duration were completed during pre-dawn (night) and post-dawn (day) periods on each of two days during each quarter, in each year, in each depth stratum, at each location. The starting position and direction of each tow were selected at random within the defined location on each day/night.

Trawling gear consisted of an Engel balloon trawl with a 60 m headline, 152 mm rubber discs in the bosom of the ground-rope and a 45 mm-mesh cod-end liner. The trawl was towed at 3 knots using 180 m sweeps and 45 m bridles and was spread with 2.44 m Vee doors. This gear configuration is similar to that used by many of the large commercial trawlers in this fishery, with the exception of the 45 mm cod-end liner. The small-mesh cod-end liner was included to retain smaller sizes of fish than would have been retained using the standard 90 mm cod-end mesh.

Data collected from each tow included weights, numbers and length-distributions of each commercial finfish species present in the catch. Redfish was one of the most abundant species present in the catch for each sampling year and season (Table 1). Operational data recorded included the depth range of the tow, ambient sea and weather conditions.

2.2. Preliminary data analysis

Catch per unit effort (CPUE) of redfish in the survey was defined as the total catch in weight (kg) per 60 minute trawl. For each survey year and season, CPUE was estimated for day and night in each depth stratum at each location. Differences in CPUEs estimated for day and night were tested in each depth stratum at each location to determine whether catch rates of redfish differed significantly at this temporal scale. Mean lengths of catch were compared among the three depth strata for each sampling year and season using a nonparametric test, Friedman's randomization test, to avoid possible errors in statistical inference due to the distributional requirement (e.g. a variable follows the normal distribution) by a parametric test method (Zar, 1984). Length frequency distributions were compared using the Kolmogorov-Smirnov two-sample test among different depth strata for each sampling year, season and location (Sokal and Rohlf, 1981). If differences were not significant, data were pooled for further analyses.

2.3. A two-parameter logistic model

If fish exhibit length-dependent offshore migration with small fish being in inshore waters and moving to deeper offshore waters as their lengths increase, the proportion of fish in length interval L_i, P_i, tends to change from 1 to 0 in inshore waters with increasing length L_i. This distribution of P_i with length L_i can be described by a logistic type model.

A two-parameter logistic model is proposed in this study to describe the relationship between fish length and proportion of fish in this length present in inshore shallow waters. For location k, this model can be written as

$$P_i = \frac{1}{1 + e^{m(L_i - L50)}} + \varepsilon_i \tag{1}$$

where L_i is the median value of length interval i, P_i is proportion of fish at length L_i in inshore waters, ε_i is an error term, and m and L50 are two parameters to be estimated. Parameter L50 is the length at which 50% of fish remain in inshore waters. Parameter m defines the shape of the logistic curve and describes the rate of changes in P_i from 1 to 0, the larger the m value, the faster P_i changing from 1 (all fish inshore) to 0 (all fish offshore). Thus, m can be defined as an index relating to the instantaneous rate of fish movement from inshore to offshore waters. However, based on a simulation study, Chen and Paloheimo (1994) found that Equation (1) tended to have larger errors in estimating the parameters compared to the following model

$$Sin^{-1}\sqrt{P_i} = \frac{\frac{\pi}{2}}{1 + e^{m(L_i - L50)}} + \xi_i \tag{2}$$

where ξ_i is an error term and $\sin^{-1}\sqrt{P_i}$ is measured in radians (i.e. ranging from 0 to $\pi/2$). It should be noted that Equation (2) is not derived from Equation (1) by applying a $\sin^{-1}\sqrt{\ }$ transformation to both sides of Equation (1) (see Chen and Paloheimo, 1994). Parameter m in Equations (1) and (2) represents different rates: m in Equation (1) measures the rate of P_i changing from 1 to 0 while m in Equation (2) measures the rate of $\sin^{-1}\sqrt{P_i}$ changing from $\pi/2$ to 0. Both equations (1) and (2) are included in this study, and are referred to as 'original' and 'transformed' logistic models, respectively. The Marquardt method (SAS 1987) was employed in the nonlinear least squares

(3) $$L_a = L_\infty(1 - e^{-K(a - t_0)})e^{\varepsilon_{L_a}}$$

where a = 1 for age 1 fish and $\varepsilon_{L_a} \in N(0, \sigma_L^2)$. The log-normally distributed error included in the VBGF ensures that there are variations in length among individuals of the same age. Growth parameters estimated for redfish (Diplock, 1984) were used in the simulation. Each of the $N_{h,1}$ fish was then allocated randomly to inshore or offshore based on its length and corresponding P value. The random allocation was accomplished with the following procedures: (a) a number q was randomly drawn between 0 and 1 from a uniform distribution, and (b) an individual fish with length L at age 1 was assigned to inshore if q <= P_L, otherwise this fish was assigned to offshore. Applying this procedure to all N_h fish, $IN_{h,1}$ and $OUT_{h,1}$ were calculated. The number of fish in the h^{th} cohort alive in the fishery at the beginning of the next year (i.e. age 2) was then calculated as

$$N_{h,2} = IN_{h,1}e^{-Fin_g - M} + OUT_{h,1}e^{-Fout_g - M}$$

where subscript g = h + 1 - 1 = h (because a = 1). The above procedure was repeated to calculate the number of fish left at the beginning of ages 3, 4, .. until the maximum age in year 19 (maximum age in year 19 is 20 - h for the h^{th} cohort; see Figure 2) for the h^{th} cohort. Based on the numbering of cohorts in Figure 2, the age of fish in the h^{th} cohort in year 20 is 20 - h + 1. Using these parameters, the number of fish from the h^{th} cohort remaining in the fishery at the beginning of year 20 was calculated for both inshore and offshore (i.e. $IN_{h,21-h}$ and $OUT_{h,21-h}$).

(3) Procedure (2) was repeated for all 20 cohorts and so the number of fish in each age group was calculated for inshore and offshore before samples were taken.

(4) If the number of fish in age a was $IN_{20,a}$ for the inshore and $OUT_{20,a}$ for the offshore before samples were taken, sample catches of fish at age a from inshore and offshore regions of the hypothetical fishery were calculated as

$$Cin_a = IN_{20,a}\frac{Eqe^{\varepsilon_{f_a}}}{Eqe^{\varepsilon_{f_a}} + M}(1 - e^{-Eqe^{\varepsilon_{f_a}} - M})e^{\varepsilon_{C_a}},$$

$$Cout_a = OUT_{20,a}\frac{Eqe^{\varepsilon_{f_a}}}{Eqe^{\varepsilon_{f_a}} + M}(1 - e^{-Eqe^{\varepsilon_{f_a}} - M})e^{\varepsilon_{C_a}},$$

where $\varepsilon_{C_a} \in N(0, \sigma_c^2)$, and $\varepsilon_{f_a} \in N(0, \sigma_f^2)$. The lengths of the sampled fish at age a from inshore and offshore were calculated using equation (3). This calculation was repeated for each age group. We calculated the sample size in each age group inshore and offshore, Cin_a and $Cout_a$, and the sample size at length L_i, Cin_{Li} and $Cout_{Li}$.

(5) The proportion of fish at length L_i in the inshore (i.e. $P_{Li,1}$) were then estimated from the sampled catch as $P_{Li,1} = Cin_{Li}/(Cin_{Li} + Cout_{Li})$.

Parameter L50 in the logistic equation was fixed at 15 cm in the simulation study. Parameter m was assigned two values (m = 0.5 and 1.5 1/cm) and they represent two different rates of length-dependent fish migration from inshore to offshore. Two recruitment patterns were considered in the hypothetical fishery: equilibrium and nonequilibrium. For the equilibrium recruitment, recruitment was set at 5,000, unchanged over 20 years, while in the case of the nonequilibrium recruitment, annual recruitment was simulated as a random number between 500 and 9000 sampled from the uniform distribution (Figure 3). These simulated recruits (Figure 3) were kept the same for each simulation run and data set. Two levels of variation were considered for length at age (σ_L = 0.05 and 0.15): the catchability coefficient of sampling gears (σ_f = 0.1 and 0.2); and the sample catch (σ_c = 0.1 and 0.2; Table 3). Two sets of historical fishing mortalities

(NLS) estimation of m and L50 using both Equations (1) and 92). The NLS estimation was weighted by the samle size at each length interval (Chen and Paloheimo, 1994).

2.4. Simulation study

Estimation of L50 and m can be affected by many factors, including variations in year-class strength, sampling intensity which determines the size of samples taken in the survey in each depth stratum, spatial distribution of fish, and variations in fish population parameters. A simulation study was conducted to evaluate the robustness of parameter estimation in modelling length-dependent offshore distribution under different assumptions on: annual recruitment; historical fishing mortalities that determine the abundance and length composition of the simulated fish population *prior to* sampling; variations in length at age; sampling errors; and sampling intensity.

A hypothetical fishery was simulated as follows. The fishery is divided into two segments: inshore and offshore. Fish undertake length-dependent offshore migration with small fish inhabiting inshore waters and moving offshore after attaining a certain length. The relationship between length and the proportion of fish at this length inshore is defined by Equation (1). Maximum age of fish that contribute to the fishery is defined as 20. Fish are assumed to be subject to fishing mortality at age 1. Thus, twenty fish cohorts exist in the hypothetical fishery when the sample is taken from the fishery (Figure 2). Samples are taken randomly at the beginning of year 20 (Figure 2). The abundance of fish at different lengths *prior to* sampling depends on the recruitment of each fish cohort, growth, and fishing and natural mortalities. Each cohort of fish is subject to an incidental fishing mortality (e.g. due to by-catch) while inshore (due to their small lengths), and subject to commercial fishing mortality when they move to offshore at increased length. However, the number of years that each cohort is present in the fishery differs (Figure 2). For example, fish from the first cohort have been in the fishery for 19 years before they are subject to sampling, while fish from the 20th cohort have not been subject to any fishing mortality before they are randomly sampled. Natural mortality is assumed to be constant over all ages for all cohorts in the simulated fishery. The relationship between age and corresponding length is described by the von Bertalanffy growth function (VBGF; Ricker, 1975).

Thus, for the hypothetical fishery, let

h = number of cohort in the fishery, h = 1, ..., 20;

a = age, a = 1, ..., 20;

$N_{h,a}$ = size of the hth cohort at the beginning of age a;

M = natural fishing mortality, constant over all ages of fish in all cohorts;

Fin_g = inshore incidental fishing mortality in year g, for fish of age a from the hth cohort, g = h + a - 1;

$Fout_g$ = offshore commercial fishing mortality in year g;

$IN_{h,a}$ = number of the hth cohort of fish at the beginning of their a age inshore;

$OUT_{h,a}$ = number of the hth cohort of fish at the beginning of their a age offshore;

Cin_a = catch at age a from sampling inshore;

$Cout_a$ = catch at age a from sampling offshore;

q = catchability coefficient for fishing gears used in sampling;

E = effective fishing efforts used in sampling, assumed to be the same between inshore and offshore; and

L_∞, K, and t_0 = parameters in the VBGF (Ricker, 1975).

The following procedures were taken in simulating the hypothetical fishery.

(1) Proportion of fish at length L_i inshore was calculated using Equation (1);

(2) For the hth cohort of fish with the size of N_h, length at age 1 for each individual was calculated as

were defined for fish present offshore and were defined to be much higher than corresponding fishing mortalities occurring inshore (Figure 4). The effects of differences in historical fishing mortalities between inshore and offshore on the estimation of parameters m and L50 were evaluated. Three levels of sampling intensity were included in the simulation with sampling fishing mortalities = 0.1, 0.01, and 0.001. Twenty data sets were simulated (Table 3). One hundred runs were conducted for each. The Marquardt method (SAS, 1987) was used in the nonlinear least squares (NLS) estimation of m and L50 using Equations (1) and (2). The NLS estimation was weighted by the total sample size at each length and the initial assigned values for m and L50 required by the NLS estimation procedures were 0.8 and 10 for all simulated data sets. The performance of the models given in Equations (1) and (2) was also compared using the simulated data. A simulation study such as this facilitates the systematic examination of the estimation of m and L50 with respect to various assumptions made concerning fish stock and sampling parameters.

For the simulated data in Table 2, the true values of parameters m and L50 were known *a priori*. Thus, it was possible to determine whether the proposed models were able to locate the true solutions and how the models were influenced by the different assumptions incorporated into the simulated fishery. To measure the extent to which the estimates of parameters Q (i.e. m and L50) differed from the true values of the Q, the following indices were computed based on the 100 simulation runs. They are the relative estimation bias (REB)

$$REB = \frac{\frac{\sum_{k=1}^{100} \hat{Q}_k}{100} - Q}{Q} 100\% ,$$

and relative estimation error (REE)

$$REE = \frac{\sqrt{\frac{\sum_{k=1}^{100} (\hat{Q}_k - Q)^2}{100}}}{Q} 100\% .$$

The REB measures the accuracy of the estimated parameters, while the REE measures both accuracy and precision (i.e. among-run variance) for the estimated parameters over the 100 runs.

2.5. Application to the redfish data

For redfish sampled in the survey, let

i = length interval, i = 1, ..., I;
L_i = median value of fish length interval i (cm);
j = depth stratum, j = 1, ..., D;
k = sampling location, k = 1, ..., G;
$C_{Li,j,k}$ = CPUE in number in length L_i caught from depth stratum j at location k; and
$P_{Li,j}$ = proportion of fish in length L_i present in depth stratum j.

If $C_{Li,j,k}$ is a good indicator of the abundance of fish at length L_i present in stratum j at location k, $P_{Li,j}$ for each sampling year and season can be estimated as

$$P_{L_i,j} = \frac{\sum_{k=1}^{G} C_{L_i,j,k}}{\sum_{j=1}^{D}\sum_{k=1}^{G} C_{L_i,j,k}} .$$

Thus, for each sampling year and season, the proportion of fish at length L_i in inshore waters $P_{Li,1}$ (i.e. j = 1) can be estimated as

$$P_{L_i,1} = \frac{\sum_{k=1}^{G} C_{L_i,1,k}}{\sum_{j=1}^{D}\sum_{k=1}^{G} C_{L_i,j,k}}$$

This P was calculated over all lengths for each sampling year and season. Both equations (1) and (2) were applied to describe the relationship between $P_{Li,1}$ and L_i. The differences in the length-dependent offshore distribution among sampling seasons in a year were compared using an analysis of the residual sum of squares (ARSS) suggested by Chen et al. (1992).

3. Results

3.1. Simulation study

Estimates of the parameter L50 using both the original and transformed methods tended to have small REE and REB for all 20 simulated data sets (Table 4). The transformed model provided consistently smaller REEs and REBs compared with the original although the fishery was actually simulated using the original model. Compared with the small REEs and REBs associated with the estimates of L50, estimates of parameter m using both the original and transformed methods were associated with large REEs and REBs for all simulated data sets. The original method tended to yield consistently smaller REEs and REBs relative to the transformed method in estimating parameter m (Table 4).

Increased variation in length at age, effective sampling effort, and sample catch resulted in increased REE and REB for parameters m and L50 for both the original and transformed methods (i.e. data sets I, III, V, and VI with low variations versus II, IV, VII, and VIII with high variations; Tables 3 and 4). However, the increase of REB with the increased variation tended to be much smaller than the increase of REE (Table 4), indicating that the increase in REB was mainly due to the increase in variation among simulation runs, rather than the increase in the inaccuracy.

The REE and REB of the estimates of m and L50 tended to be smaller in the case of equilibrium recruitment (i.e. E in Figure 3) compared with those of nonequilibrium recruitment (i.e. C in Figure 3). However, such differences were small. This was observed for both estimation methods (i.e. data sets II, IV, VII, VIII, XIII, XIV, XVII, and XVIII with nonequilibrium recruitment versus IX, X, XI, XII, XV, XVI, XIX, and XX with equilibrium recruitment, respectively; Tables 3 and 4).

Historical fishing mortalities (i.e. levels A, B, and D) *prior to* sampling tended not to have consistent and significant impacts to REE and REB in the estimation of m and L50 using both logistic models (i.e. data sets I, II, III, IV, IX and X with a low fishing mortality versus V, VII, VI, VIII, XI, and XII with a high fishing mortality; Tables 3 and 4). The REE and REB of m and L50 estimated with the historical fishing mortalities being set at a low level (level B; Figure 4) were similar to those estimated with the historical fishing mortalities being set at a high level (level D; Figure 4). Differences in historical fishing mortality between inshore and offshore tended not to affect the parameterization of either logistic model.

Sampling intensity (i.e. F_{sample} in Table 3) had a large impact to the magnitudes of both REE and REB for the estimation of m using both models. Both REE and REB increased greatly when sampling fishing mortality declined from 0.01 to 0.001 (i.e. data sets II, IV, IX, and X with F_{out} = 0.01 versus XVII, XVIII, XIX, and XX with F_{out} = 0.001; Tables 3 and 4). However, for both models, differences in the REE and REB of the estimated m were small between sampling fishing mortalities of 0.01 and 0.1 (i.e. data sets II, IV, IX, and X with F_{out} = 0.01 versus XIII, XIV, XV, and XVI with F_{out} = 0.1; Tables 3 and 4). For the estimation of L50 using both models, the impacts of sampling intensity to REE were much larger relative to those to REB. REE increased greatly when sampling fish mortality declined from 0.01 to 0.001, but increases in REB were insignificant. For both models, differences in the REE and REB of the estimated L50 was small when sampling mortality increased from 0.01 to 0.1.

The magnitudes of REE and REB for the estimated parameter m were also related to its true value. When sampling intensity was moderate or intensive (i.e. sampling fishing mortality = 0.01 and 0.1; Table 3), REE and REB of the estimated m for the true m = 0.5 were smaller than those for the true m = 1.5 (i.e. data sets I, II, V, VII, IX, XI, XIII, and XV with m = 0.5 versus III, IV, VI, VIII, X, XII, XIV, and XVI with m = 1.5; Tables 3 and 4) and parameter m tended to be consistently under-estimated by both logistic models (Table 4). However, when sampling fishing mortality was small (i.e. = 0.001), parameter m tended to be over-estimated (i.e. data sets XVII, XVIII, XIX, and XX; Tables 3 and 4). No such consistent patterns could be observed in the REE and REB for the estimated L50.

3.2. Modelling length-dependent offshore distribution of redfish

No consistent significant differences in CPUE between day and night were observed during the survey (both t-test and Friedman's test, $P > 0.05$). Thus, day and night data were pooled for further analyses. Mean length at catch for fish sampled inshore was significantly smaller than that for fish sampled from the mid-shelf and outer-shelf (Friedman's test, $P < 0.05$). Such differences were consistent over all sampling years and seasons (Table 5). However, differences in mean length of catch between fish sampled from mid-shelf and outer-shelf were not significant for all sampling years and seasons (Friedman's test, $P > 0.05$). Significant differences in length frequency distributions were observed between inshore and mid-shelf and between inshore and outer-shelf for all sampling years and seasons (Kolmogorov-Smirnov two-sample test, $P < 0.001$). However, differences between the mid-shelf and outer-shelf were not consistently significant. Thus, based on this preliminary analysis of the mean lengths at catch and length frequency distributions, data from mid-shelf and outer-shelf were pooled for the further analysis and were together referred to as "offshore" in this study.

The proportion of redfish at a length inshore tended to decrease with increasing lengths, with the majority of small fish being inshore and the majority of large fish being offshore (Figure 5). This pattern was observed for all sampling years and seasons, a strong indication that redfish off the NSW coast have a length-dependent offshore distribution.

Parameter L50 estimated for different sampling years and seasons ranged from 12.3 cm to 17.4 cm using the original method (Table 6) and from 12.4 cm to 17.4 cm using the transformed method (Table 7). The estimates of L50 using the two methods were almost identical, however, the original method consistently yielded larger estimates of m for each sampling year and season (Tables 6 and 7). Differences in predicting the observed proportion of fish remaining inshore using original and transformed methods were small (Figure 5).

The estimated coefficients of determinant (r^2) using both models were very high for all sampling years and seasons (Tables 6 and 7), suggesting a good fitness of the proposed models to observed changes in the proportion of fish in inshore waters with increasing lengths. The asymptotic coefficient between the estimated m and L50 was small for all sampling years and seasons (Tables 6 and 7). Thus, m was not strongly related to L50 in the parameter estimation, a desirable characteristic in a regression analysis (Ratkowsky 1990).

An ARSS analysis indicated that there were significant differences in the redfish length-dependent offshore distribution patterns modelled by the original model among the sampling seasons for each year ($F_{6,91}$=111.8, P<0.001 for year 1; $F_{6,94}$=264.7, P<0.001 for year 2). Similar ARSS results were obtained using the transformed model to describe the redfish length-dependent offshore distribution ($F_{6,91}$=66.0, P<0.001 for year 1; $F_{6,94}$=171.8, P<0.001 for year 2). An ARSS analysis based on the original model also indicated that yearly differences in length-dependent offshore distributions were not significant for sampling season 1, but significant for the other 3 seasons (Table 8). However, yearly differences were found to be not significant for sampling seasons 1 and 4, but significant for seasons 2 and 3 according to an ARSS analysis based on the transformed model.

4. Discussion

Many fish populations exhibit migration during some phase of their life histories. Migration is usually defined as consistent, directional movement of some component of a population (Hilborn and Walters, 1992). The movement of young fish from nursery grounds to the grounds where adults are found is an example. Such length- or age-specific migrations result in systematic spatial differences in abundances and size composition of fish. Although this has been considered in some studies (e.g. Sparre and Willmann, 1993), because of the difficulty in quantifying the length or age-specific distribution, the impacts of such a migration to stock assessments have not often been considered by fisheries scientists. The approach proposed in this study provides a quantitative way to model the fish length-dependent spatial distribution. Such models can easily be incorporated into models describing the population dynamics of fish and therefore into fish stock assessments (Chen et al., 1996).

Commercial catches of redfish along the NSW coast are almost entirely from waters deeper than 50 meters (Rowling, 1994), indicating that redfish in shallow inshore waters are subject to a very low fishing mortality. However, it is common for redfish to be caught in inshore waters by other inshore fisheries as by-catch (Rowling, 1994). Thus, redfish in these inshore waters are subject to an incidental fishing mortality. The hypothetical fishery simulated here mimics such differences in sources of fishing mortality in inshore and offshore waters. The original method (Equation 1) was found to provide a better estimate of m and the transformed method (Equation 2) tended to yield a better estimate of L50 (Table 4). However, this result should be interpreted with caution because the original model was used in simulating the hypothetical fishery and parameter m in the two models represents different scales of changing rates of the proportion of fish from 1 to 0. Based on the extensive simulations done here, it is evident that the estimation of L50 is very robust with respect to various errors contained in the observed data although both methods tended to underestimate parameter m (Table 4). This result is similar as that observed in a previous study modelling fish maturation data (Chen and Paloheimo, 1994).

Based on the simulation study, a certain level of sampling intensity (i.e. sampling fishing mortality) was necessary to keep the parameter estimation errors low (see Tables 3 and 4). A ten-fold decrease in sampling intensity from sampling fishing mortality 0.1 to 0.01 introduced no significant increases in parameter estimation errors. However, a further 10-fold decrease from 0.01 to 0.001 increased such errors dramatically (see Tables 3 and 4). Thus, there existed a minimum critical value of sampling intensity that should be attained in order to yield small estimation errors for the estimated parameters. If sampling intensity fell below this level, the number of fish sampled in certain lengths might not be large enough to represent their true abundance in the population, and errors in the parameter estimation would increase significantly. This effect is similar to a random subsampling of fish catch in which a certain size of the subsample is required in order to reduce the impacts of error variances due to random subsampling on modelling the dynamics of a fish population (Kimura, 1990; Chen, 1995). In our sampling of redfish along the NSW coast, a large number of fish were caught (Table 1) and sample size should not introduce large errors into modelling of redfish length-dependent offshore distribution.

Annual variation in recruitment tended not to be an important factor in modelling fish length-dependent distribution. No systematic differences in parameter estimation errors were found under the assumptions of equilibrium and nonequilibrium recruitments. This may result from randomness being assumed for the distribution of fish and fishing efforts in the hypothetical fishery. For redfish sampled from an independent survey, the randomness assumption on surveying fishing efforts was likely to be satisfied. However, the distribution of fish might not be random in a defined depth stratum. Because this is difficult to examine, the impacts of possible non-random distribution of fish in a depth stratum on the modelling of length-dependent distributions remain unknown.

However, because of the robustness in estimating L50, we conclude that the estimation of L50 should not be affected. It should be noted that redfish of large sizes are also distributed in slope waters along the NSW coast (Rowling 1994) and this study was conducted based on data sampled in a stratified survey which did not cover the slope waters. However, because there is unlikely to be an overlap in length between redfish in slope waters (large fish) and in inshore waters (small fish; Rowling 1994), the results on modelling redfish length-dependent offshore distribution derived from this study were unlikely biased due to the lack of data on redfish in slope waters.

Although redfish had size-dependent distributions in all sampling seasons and years, significant seasonal variations were observed for each sampling year in modelling redfish length-dependent offshore distributions. This may indicate seasonality is an important factor in determining the patterns of redfish length-dependent offshore distributions. For fish with life cycles similar to redfish, in order to establish whether a length-dependent offshore distribution is consistent or just temporal, we suggest that the minimum time period required be two years with sampling being conducted in each season. In this case, the distribution patterns can be identified in the first year and be confirmed by data sampled in the second year. It is interesting that between-year differences in modelling length-dependent offshore distribution are much smaller for sampling seasons 1 and 4 compared with those for seasons 2 and 3 (Table 8). More repeats of the survey are required to examine whether such a difference in distribution patterns among different seasons is consistent over a longer time period.

The L50 is a useful parameter. Like age or length at 50% maturity, this parameter can be used directly in fisheries management (Chen et al. 1996). If a length-age relationship can be defined (e.g. the von Bertalanffy growth function), this parameter can be transferred to an estimation of the age at which 50% fish remain in inshore waters. For redfish, this parameter can be set as a length or age when fish entering into the commercial fishing grounds, thus having significant implication in managing this fish stock along the NSW coast.

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Table 1. Sampling dates and catches of redfish in each sampling year and season.

Year	Period	Time day/month/year	Catch (number)
1	1	10/02/93 - 6/04/93	6218
1	2	28/04/93 - 19/06/93	28161
1	3	20/07/93 - 9/09/93	134110
1	4	13/10/93 - 8/12/93	49367
2	1	15/02/94 - 22/04/94	103971
2	2	27/04/94 - 23/06/94	33352
2	3	19/07/94 - 13/10/94	132465
2	4	19/10/94 - 7/12/94	126088

Table 2. Coordinates and depth ranges of the nine grounds selected for sampling. Sampling grounds are defined in Figure 1: North is referred to sampling sites located north of Sydney; Central is referred to sampling sites located between Sydney and Montague Island; and South is referred to sampling sites located south of Montague Island to Gabo Island.

Depth stratum	Sampling ground	Coordinates of sampling ground		Depth range of sampling (m)
Inshore	North	32°57′ 151°47′, 33°05′ 151°41′,	32°57′ 151°49′ 33°05′ 151°43′	25 - 40
Inshore	Central	35°11′ 150°45′, 35°14′ 150°34′,	35°13′ 150°45′ 35°14′ 150°37′	30 - 60
Inshore	South	36°35′ 150°05′, 36°45′ 150°00′,	36°35′ 150°07′ 36°45′ 150°02′	35 - 60
Midshelf	North	33°00′ 152°00′, 33°08′ 151°52′,	33°00′ 152°03′ 33°08′ 151°55′	90 - 125
Midshelf	Central	35°35′ 150°26′, 35°45′ 150°21′,	35°35′ 150°29′ 35°45′ 150°24′	90 - 125
Midshelf	South	36°33′ 150°10′, 36°43′ 150°08′,	36°33′ 150°12′ 36°43′ 150°10′	105 - 120
Outershelf	North	32°52′ 152°18′, 33°00′ 152°10′,	32°55′ 152°21′ 33°02′ 152°13′	125 - 140
Outershelf	Central	34°15′ 151°12′, 34°25′ 151°09′,	34°15′ 151°15′ 34°25′ 151°12′	125 - 160
Outershelf	South	37°12′ 150°17′, 37°22′ 150°16′,	37°12′ 150°20′ 37°22′ 150°18′	125 - 165

Table 3. Parameters used in simulating hypothetical fishery. Fish are assumed to have a length-dependent offshore distribution. Two sets of recruitment (N) data C and E are defined in Figure 3. Fishing mortality rates A, B, and D are defined in Figure 4.

Data	Variation			Parameter					
set	σ_L	σ_f	σ_c	m	L50	F_{in}	F_{out}	N	F_{sample}
I	0.05	0.1	0.1	0.5	15	A	B	C	0.01
II	0.15	0.2	0.2	0.5	15	A	B	C	0.01
III	0.05	0.1	0.1	1.5	15	A	B	C	0.01
IV	0.15	0.2	0.2	1.5	15	A	B	C	0.01
V	0.05	0.1	0.1	0.5	15	A	D	C	0.01
VI	0.05	0.1	0.1	1.5	15	A	D	C	0.01
VII	0.15	0.2	0.2	0.5	15	A	D	C	0.01
VIII	0.15	0.2	0.2	1.5	15	A	D	C	0.01
IX	0.15	0.2	0.2	0.5	15	A	B	E	0.01
X	0.15	0.2	0.2	1.5	15	A	B	E	0.01
XI	0.15	0.2	0.2	0.5	15	A	D	E	0.01
XII	0.15	0.2	0.2	1.5	15	A	D	E	0.01
XIII	0.15	0.2	0.2	0.5	15	A	B	C	0.1
XIV	0.15	0.2	0.2	1.5	15	A	B	C	0.1
XV	0.15	0.2	0.2	0.5	15	A	B	E	0.1
XVI	0.15	0.2	0.2	1.5	15	A	B	E	0.1
XVII	0.15	0.2	0.2	0.5	15	A	B	C	0.001
XVIII	0.15	0.2	0.2	1.5	15	A	B	C	0.001
XIX	0.15	0.2	0.2	0.5	15	A	B	E	0.001
XX	0.15	0.2	0.2	1.5	15	A	B	E	0.001

Table 4. Relative estimation bias (REB) and relative estimation error (REE) for the two parameters, instantaneous rate of length-dependent offshore movement (m) and length at which 50% of fish remaining inshore (L50), in the proposed logistic equations for modelling fish length-dependent offshore distribution for a simulated hypothetical fishery. One hundred simulation runs were conducted for each data set. The two logistic equations are equation 1 (original model) and equation 2 (transformed model) defined in the text.

Data	Original model				Transformed model			
	REB(%)		REE(%)		REB(%)		REE(%)	
set	m	L50	m	L50	m	L50	m	L50
I	3.4	-0.3	18.97	2.83	-7.2	0.2	16.73	2.24
II	-25.2	-3.9	28.28	6.97	-37.0	-1.8	37.95	5.11
III	-61.5	-2.4	61.86	3.47	-63.0	-1.1	63.21	2.15
IV	-71	-4.7	71.27	7.47	-74.6	-2.6	74.77	5.71
V	9.3	-0.7	35.78	2.94	-0.8	-0.1	21.91	2.25
VI	-60.6	-2.8	61.61	3.85	-63.2	-1.4	63.46	2.34
VII	-26.4	-1.9	28.98	7.23	-36.3	-0.2	37.42	5.75
VIII	-71.7	-3.5	71.89	7.13	-75.3	-1.6	75.34	5.33
IX	-18.9	-0.4	26.83	5.35	-34.8	-0.1	36.88	4.76
X	-61.9	1.5	63.39	4.49	-71.0	1.4	71.24	4.03
XI	-18.3	1.2	41.47	5.84	-36.0	0.7	37.95	5.14
XII	-57.9	2.5	93.69	5.38	-65.2	2.4	96.59	4.96
XIII	-30.8	-3.9	32.25	7.37	-53.3	-0.8	53.29	5.17
XIV	-73	-4.3	73.06	6.97	-78.7	-0.9	78.71	4.30
XV	-30	0.9	30.98	4.71	-54.1	0.8	54.41	4.39
XVI	-67.2	1.4	67.26	4.13	-78.0	1.2	78.00	3.79
XVII	1271	-5.2	2118.5	14.64	1521	-4.9	2447	14.54
XVIII	307	-5.3	610.3	14.84	390	-5.0	736	14.71
XIX	2001	3.0	3131.1	16.21	3015	2.4	4723	14.98
XX	586	1.3	937.1	12.02	896	1.2	1351	11.98

Table 5. Mean length at catch (cm) for redfish sampled from the three locations during a two-year quarterly survey. Sampling grounds are the same as those defined in Table 1. N/A refers to no length being calculated due to the lack of redfish in survey catch.

Sampling grounds	Sampling Year	Sampling Time	Sampling depth Inshore	Midshelf	Outershelf
North	1	1	10.5	18.4	17.6
North	1	2	9.6	20.6	17.9
North	1	3	8.3	17.8	17.9
North	1	4	8.2	17.0	18.4
North	2	1	9.6	17.6	18.9
North	2	2	7.1	16.0	17.6
North	2	3	8.1	17.3	19.2
North	2	4	N/A	17.7	17.5
Central	1	1	14.0	16.4	18.9
Central	1	2	14.4	18.3	18.2
Central	1	3	14.1	17.9	18.7
Central	1	4	14.2	16.8	16.5
Central	2	1	11.5	16.6	19.8
Central	2	2	13.9	15.1	16.4
Central	2	3	12.2	15.2	17.4
Central	2	4	13.3	16.2	15.6
South	1	1	13.3	20.9	N/A
South	1	2	12.4	14.5	20.4
South	1	3	10.3	14.4	17.0
South	1	4	10.8	20.2	19.5
South	2	1	12.8	17.2	N/A
South	2	2	11.2	18.4	18.1
South	2	3	11.0	14.5	19.0
South	2	4	11.3	16.8	18.1

Table 6. Estimation of parameters in a logistic function (i.e. equation 1) modelling changes in the proportion of fish in inshore with increasing lengths. Data from the three sampling locations were combined for each depth stratum. m = instantaneous length-dependent offshore movement rate. L50 = length at which 50% of fish remain in inshore. SE = standard error. r^2 = coefficient of determinant calculated as (TSS-RSS)/TSS in the nonlinear least squares estimation, where TSS = corrected total sum of squares and RSS = residual sum of squares. Corr = asymptotic correlation coefficient between the estimated m and L50.

Year	Season	m	SE(m)	L50	SE(L50)	r^2	Corr
1	1	1.99	0.262	15.6	0.08	0.97	-0.40
1	2	0.82	0.097	17.7	0.20	0.95	-0.37
1	3	0.55	0.046	13.6	0.12	0.95	0.19
1	4	1.22	0.077	14.6	0.05	0.99	-0.26
2	1	1.31	0.064	15.5	0.05	0.99	-0.38
2	2	0.57	0.061	12.3	0.18	0.91	-0.52
2	3	1.81	0.043	12.6	0.02	1.00	-0.18
2	4	1.21	0.105	14.3	0.09	0.97	-0.26

Table 7. Estimation of parameters in a logistic function (i.e. equation 2) modelling changes in the proportion of fish in inshore with increasing lengths. Data from the three sampling locations were combined for each depth stratum. Proportional data were arcsin-square-root transformed.

Year	Season	m	SE(m)	L50	SE(L50)	r^2	Corr
1	1	0.78	0.086	15.8	0.18	0.94	-0.59
1	2	0.48	0.048	17.4	0.26	0.92	-0.50
1	3	0.37	0.030	13.5	0.16	0.93	0.22
1	4	0.76	0.061	14.7	0.10	0.97	-0.27
2	1	0.84	0.047	15.5	0.08	0.99	-0.48
2	2	0.44	0.048	12.4	0.22	0.90	-0.55
2	3	1.11	0.045	12.5	0.04	0.99	-0.17
2	4	0.74	0.056	14.4	0.11	0.96	-0.32

Table 8. An analysis of residual sum of squares (ARSS) for testing differences in redfish length-dependent offshore distribution patterns modelled by the two proposed logistic functions between sampling years for each sampling season.

	Original model		Transformed model	
Season	F	P	F	P
1	$F_{2,43}=2.1$	>0.05	$F_{2,43}=0.55$	>0.05
2	$F_{2,47}=330.9$	<0.001	$F_{2,47}=180.5$	<0.001
3	$F_{2,49}=150.6$	<0.001	$F_{2,49}=125.9$	<0.001
4	$F_{2,46}=4.5$	=0.02	$F_{2,46}=1.9$	>0.05

Captions of figures

Figure 1. Map of the coast of New South Wales, Australia between Crowdy Head and Gabo Island showing the location of the survey ground. ● = inshore, ■ = midshelf, and ▼ = outershlef.

Figure 2. Numbering of cohorts in the hypothetical fishery. Numbers in cells represent numbering of cohorts that still have individuals alive in the fishery when sampling took place.

Figure 3. Two sets of recruitments used in simulating the hypothetical fishery.

Figure 4. Inshore and offshore historical fishing mortalities for the simulated fishery.

Figure 5. Observed and predicted proportions of redfish inshore of different lengths for different sampling years and seasons in the catch sampled from the independent survey.

Figure 1

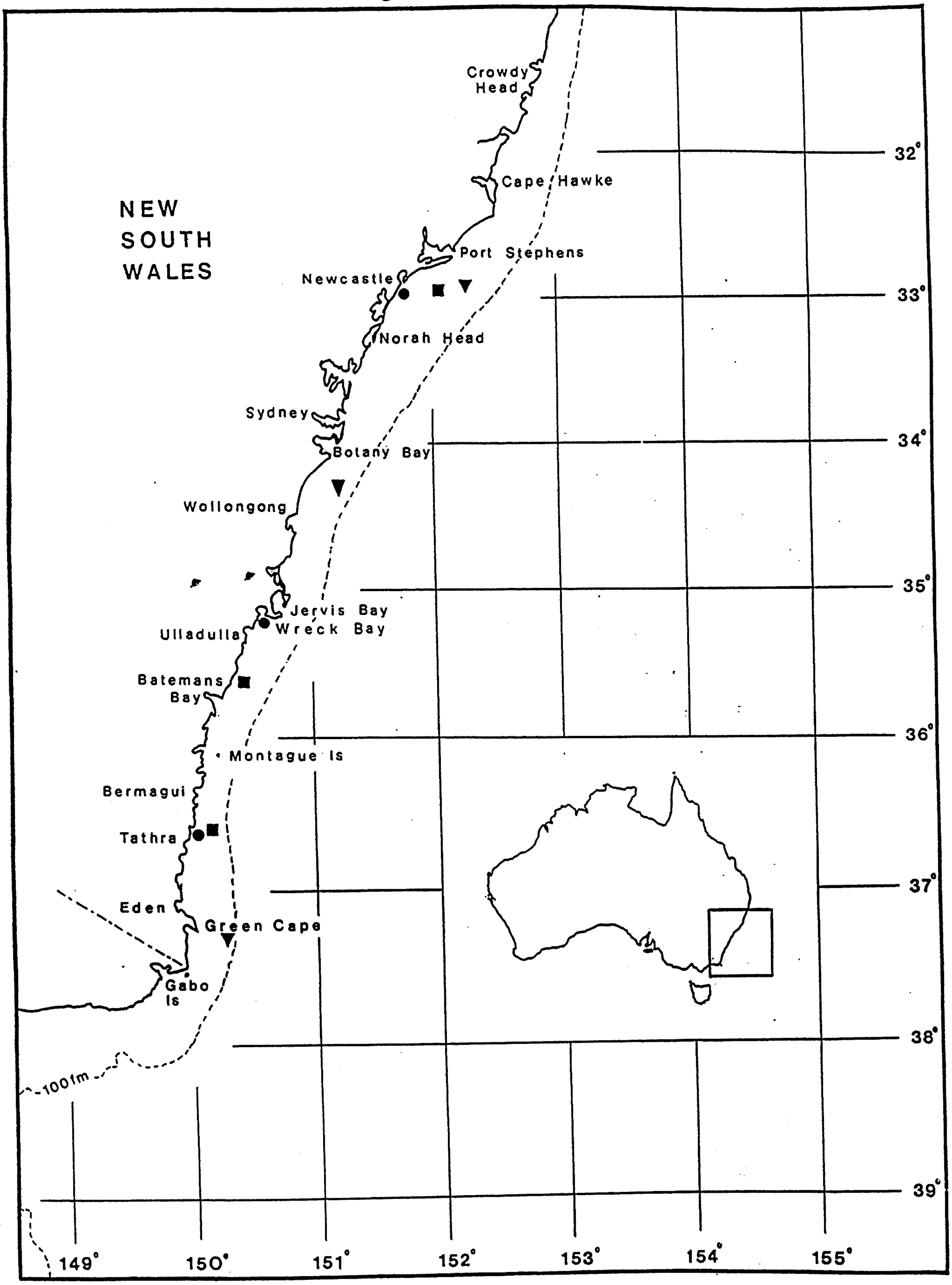

NEW SOUTH WALES
Crowdy Head
Cape Hawke
Port Stephens
Newcastle
Norah Head
Sydney
Botany Bay
Wollongong
Jervis Bay
Wreck Bay
Ulladulla
Batemans Bay
Montague Is
Bermagui
Tathra
Eden
Green Cape
Gabo Is
100fm
32°
33°
34°
35°
36°
37°
38°
39°
149°
150°
151°
152°
153°
154°
155°

Figure 2

Year \ Age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1																			
2	2	1																		
3	3	2	1																	
4	4	3	2	1																
5	5	4	3	2	1															
6	6	5	4	3	2	1														
7	7	6	5	4	3	2	1													
8	8	7	6	5	4	3	2	1												
9	9	8	7	6	5	4	3	2	1											
10	10	9	8	7	6	5	4	3	2	1										
11	11	10	9	8	7	6	5	4	3	2	1									
12	12	11	10	9	8	7	6	5	4	3	2	1								
13	13	12	11	10	9	8	7	6	5	4	3	2	1							
14	14	13	12	11	10	9	8	7	6	5	4	3	2	1						
15	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1					
16	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1				
17	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1			
18	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1		
19	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	
20	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

Figure 3

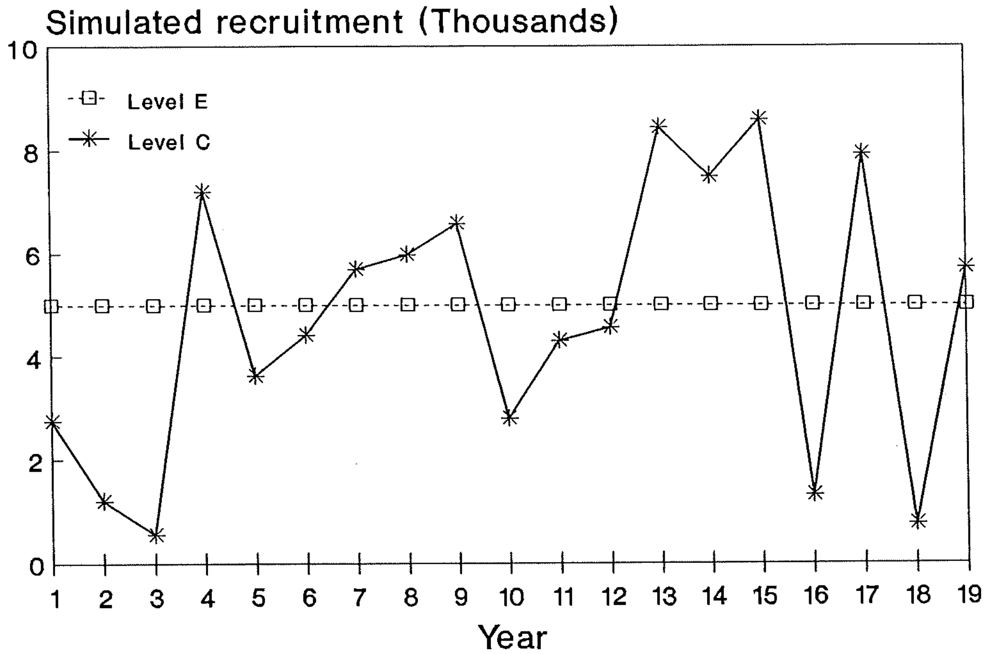
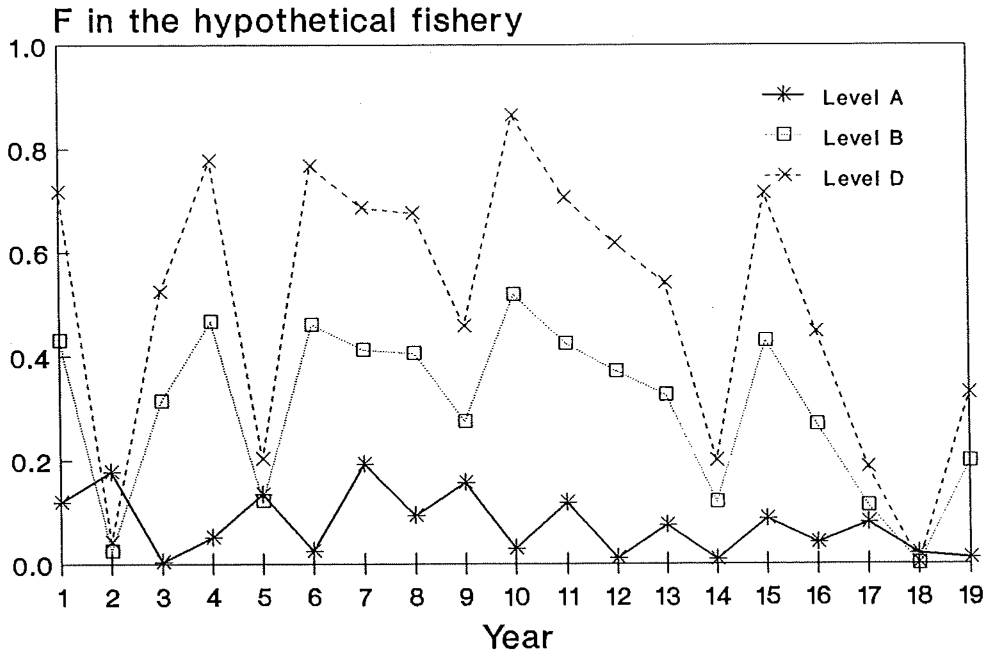

Simulated recruitment (Thousands)
10
8
6
4
2
0
Level E
Level C
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Year

Figure 4


F in the hypothetical fishery
1.0
0.8
0.6
0.4
0.2
0.0
Level A
Level B
Level D
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Year

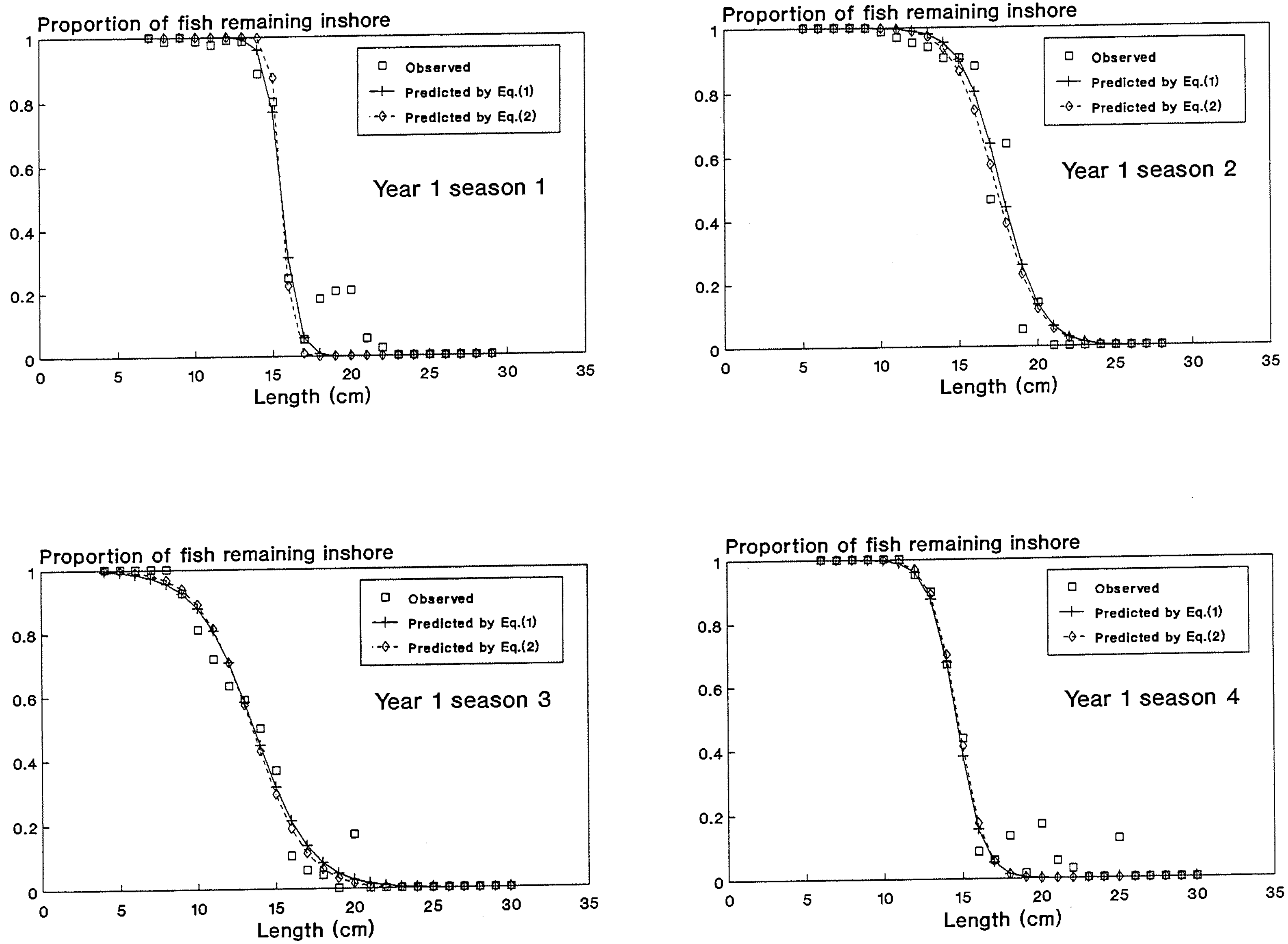


Figure 5, page 1

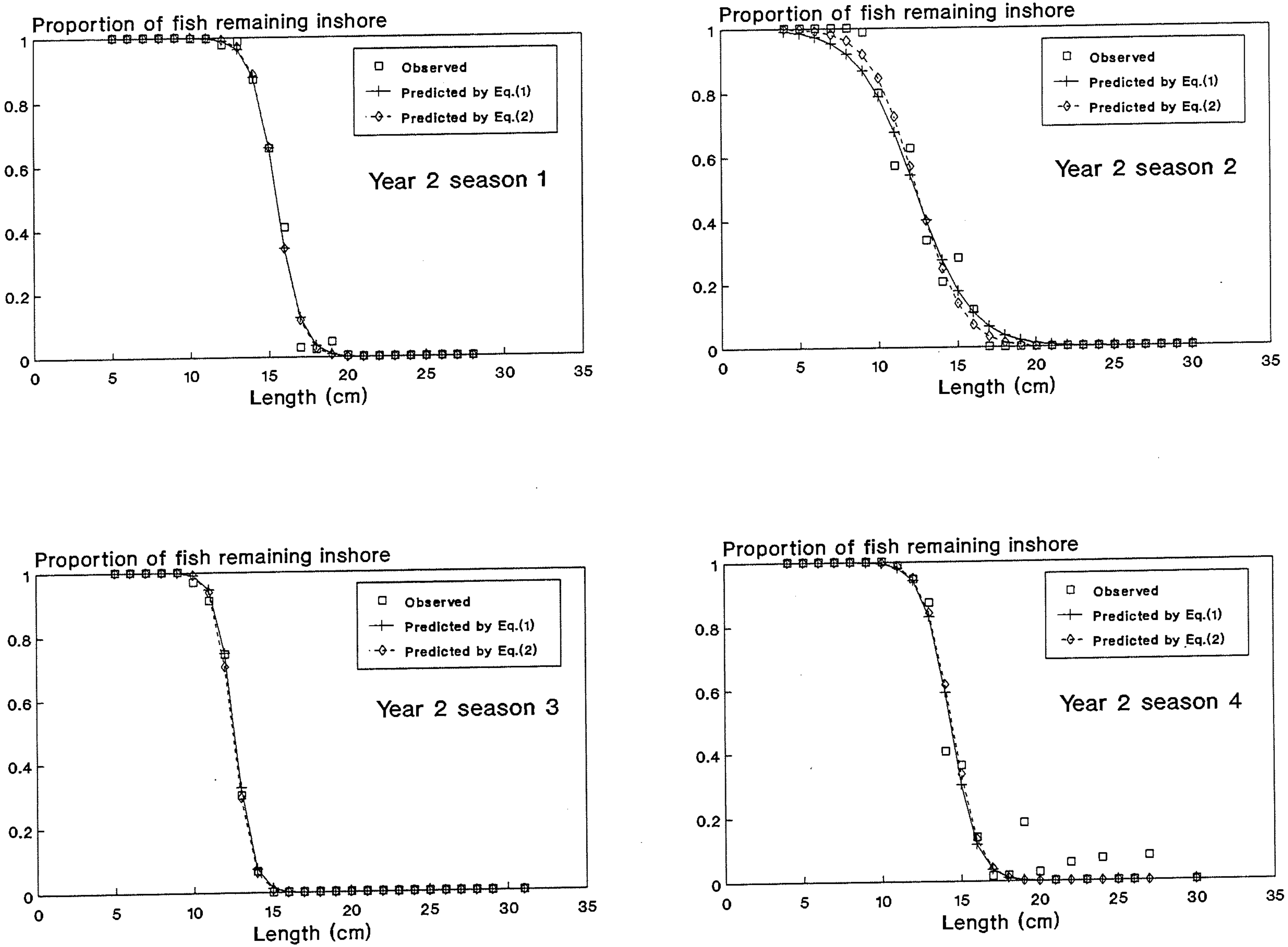


Figure 5, page 2.