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Monitoring commercial eel fisheries in 2003–04

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EXECUTIVE SUMMARY

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This report provides the results from 1) a catch sampling programme on commercial freshwater eels (*Anguilla australis* and *A. dieffenbachii*) in the lower South Island, 2) analysis of eel processors' historic records of species composition and size grades, and 3) a pilot programme to monitor size grades, species composition, and location of catch from all landings in the 2003–04 fishing year from three North Island factories.

A catch sampling programme was carried out in 2003–04 in Southland to determine eel size, sex and species composition from commercial catches. A total of 24 landings were sampled from 12 area strata within the Waiau, Oreti, and Mataura Rivers, including four tributaries. Length and weight were recorded for 2947 longfins (*A. dieffenbachii*) and 24 shortfins (*A. australis*) from landed weights totalling 4.9 t and 0.1 t, respectively (45:1). Longfins were present in all 12 and shortfins in 6 strata, and within these the proportion of longfin was close to 100% in all but one stratum. Length frequency distributions of longfins from coastal strata of mainstem rivers were strongly unimodal (mean size about 50 cm) with few medium sized or large eels. Inland mainstem strata and most tributaries had size distributions skewed to the right with a good representation of medium size eels, and only one tributary had a good representation from all size ranges between 40 and 90 cm. Of the 2947 longfins sampled, 93.9% were classified into one of three categories: immature (49%), male (29%), and female (21%). Of the remaining 6.1% that were unsexed, most were exported live and from size (length and weight) alone were predominantly female. Females outnumbered males in 5 of the 12 strata.

Processors' records were examined for trends over time in size grades and species composition of landed eels. The Mossburn Enterprises data indicate that for the South Island the average size of both longfin and shortfin eels processed has progressively declined over the last 30 years, and is now based on eels in the smallest processed size grade (under 450 g). Over the last few years, the trend of declining size for the three smallest size grades has at least levelled off and is possibly reversing for shortfins. Species composition shows a gradual decline in the proportion of longfins processed by Mossburn Enterprises during the 1990s, but landed tonnages for each species are required to determine if the observed decline is related to a decline in longfin landings. Trends in the Levin Eel Trading longfin and shortfin size data are similar to those for the South Island, showing that the average size of North Island eels processed has progressively declined over time and by the 1980s and 1990s the smallest processed size grade (under 450 g) dominated landings. Other historic size grade and species composition data from North Island processors covers shorter time spans, are less comprehensive, and therefore less informative, but in general support the trends of declining size over time. Species composition data are less informative because there are no data on tonnages and it is not possible to determine if there has been a reduction in longfin landings relative to shortfin landings.

A pilot programme was implemented to monitor size grades, species composition, and catch location from North Island commercial landings in the 2003–04 fishing year. To record location in more detail, the 12 eel statistical areas (ESAs) were divided into 65 subareas (broadly equivalent to catchments). Overall three-quarters of all landed weights of eels in the North Island in 2003–04 (1 Oct 2003–30 April 2004) were shortfin (74%). Only ESAs 8 and 9 provided more longfin than shortfin. The size grade data consist of two to three grades. The proportion of large shortfin eels (over 1000 g) was between 9 and 16%, and about one-third of longfins landed were large eels (over 1000 g or 1200 g). Based on size, more than one-third of all longfins caught in 2003–04 were female, the remainder being either male or female. Differences in size distributions of both species by area are described.

1. INTRODUCTION

This report provides the results of three research initiatives to monitor commercial eel fisheries. 1) a catch sampling programme on commercial freshwater eels (*Anguilla australis* and *A. dieffenbachii*) for selected catchments in the lower South Island, 2) analysis of eel processors' historic records of species composition and size grades, and 3) a pilot programme to monitor size grades, species composition, and location of catch from all landings in the 2003–04 fishing year from three North Island factories.

1.1 The fishery

The commercial freshwater eel fishery developed in the 1960s, with catches peaking in 1975. From 1975 to 1981, reported annual catches averaged about 2000 t, but have since declined, and the average catch over the last 10 years is about 1400 t (Annala et al. 2004) with an export value in 1996 of $9.5 million. Landings consist of both the endemic longfin eel (*Anguilla dieffenbachii*) and the shortfin eel (*A. australis*), which is also found in southeast Australia. Landings from the north of the North Island sometimes include occasional *A. rheinhardtii*, the Australian longfin eel. The South Island eel fishery was introduced into the Quota Management System (QMS) on 1 October 2000 and Total Allowable Commercial Catches (TACC) were set for both species combined for six Quota Management Areas (QMAs). In the North Island, at the time this study was undertaken, a moratorium existed on the allocation of fishing permits, with no restrictions on catch. North Island eels were introduced into the QMS in October 2004.

1.2 Previous research

Although the fishery has been operating since the 1960s, until recently there had been no attempt to assess the sustainability of harvest levels, and stock assessment had been limited to interpretation of annual catch data, knowledge of the biology of the two species, and anecdotal information from processors and fishers on catch rates and trends in landings. In recent years, information from sampling commercial landings (Beentjes & Chisnall 1997, 1998, Beentjes 1999, Speed et al. 2001), catch-per-unit-effort (CPUE) analyses (Beentjes & Bull 2002, Beentjes & Dunn 2003a, b), and studies on recruitment (Jellyman et al. 2000, Boubée et al. 2002) have been available. The sustainability of the fishery under current levels of harvest is, however, unknown (Annala et al. 2004).

Commercial catches of eels from throughout New Zealand previously sampled over four consecutive years between 1995–96 and 1998–99 (Beentjes & Chisnall 1997, 1998, Beentjes 1999) showed that size and sex composition of longfins have been dramatically altered compared to the shortfin. Longfin populations in the more heavily fished mainstem rivers, such as in the lower South Island, had a strongly unimodal size structure with mean size around 50 cm, and were predominantly male (Beentjes & Chisnall 1997, 1998, Beentjes 1999). This suggests that females have been overfished relative to males and this may have implications for future recruitment of longfin eels.

The most comprehensive data sets of eel processors' historic records of species composition and size grades indicated a clear and progressive trend of declining size from the 1970s through to the 1990s, particularly for longfinned eels (Beentjes & Chisnall 1997). There was also a general decline in the proportion of longfinned eels in the landed catches over time. These findings were supported by analyses of catch effort data from throughout New Zealand for 1990–91 to 1998–99, which showed a general decline in CPUE for longfin eels (Beentjes & Bull 2002), and subsequent analyses have reaffirmed these trends (Beentjes & Dunn 2003a, b).

1.3 Current research

Eight years have elapsed since processors' historic records of eel grades processed were examined (Beentjes & Chisnall 1997). We update these records from five of the main eel processors in New Zealand and determine if the trends in declining size and proportion of longfins in the catch have continued into the late 1990s and early 2000s.

The four previous catch sampling programmes have attempted to provide data on size, sex, and growth of eels of both species from as many catchments as possible throughout New Zealand. Results of the first three years of catch sampling showed that for each species the size distribution and sex ratio was similar between the main South Island fisheries or catchments, suggesting that fishing has modified the population structure in a similar way. Therefore, the focus of the 2003–04 sampling programme was to sample key South Island catchments (= fisheries), which should act as broad indicators of the status of eel populations throughout the South Island.

North Island landings were not sampled because of concerns from North Island eel processors about the quality of data that would be obtained. It was thought that the data would not be representative of the many and varied eel populations in the North Island, and the sampled eels would frequently be taken from several amalgamated landings. Instead, a pilot programme was implemented in the North Island to monitor size grades, species composition, and catch location from all North Island landings in the 2003–04 fishing year. The data on area provided with each landing will allow a more detailed breakdown of size and species composition by catchment.

This report was carried out for the Ministry of Fisheries under Project EEL2002/04. The specific objectives of the project were as follows.

1. To examine processors' records for trends in size grades and species composition of landed eels.

2. To determine size, species, and sex from commercial catches from catchments in eel ESAs (ESAs): ESA AV (Otago) and ESA AW (Southland).

2. METHODS

2.1 Catch sampling (South Island)

The catch sampling programme, like those of 1995–96, 1996–97, and 1997–98 (Beentjes & Chisnall 1997, 1998, Beentjes 1999) was based at Mossburn Enterprises Ltd (Invercargill). The sampling strategy was similar to that used in previous years and was aimed at providing data on eel species, size (length and weight), and sex by individual catchment, some of which were broken into area strata. Otoliths were not collected for ageing, however, as in previous sampling programmes.

2.1.1 Areas sampled and stratification

The objectives required 50 landings to be sampled from the South Island from key catchments in Otago and Southland. The rivers initially selected were the Mataura River, Oreti River, Clutha River, and Waitaki River, but towards the end of the season when it was clear that the target of 50 landings would not be reached from these rivers alone, landings from other areas were sampled.

The analyses of Francis (1999) to determine the optimal strategy for sampling eels showed that areal stratification is appropriate and that sampling should be spread over as many landings as possible since between-landing variance in size was greater than within-landing variance. Selected catchments were divided into up to four strata based on fishing practices, physical features (e.g., lakes, falls, confluences, weirs, dams, bridges) and information on species and size distribution (Figure 1). Stratum boundaries are unchanged from those used in the 1995–96, 1996–97, and 1997–98 sampling programmes (Beentjes & Chisnall 1997, 1998, Beentjes 1999). Participating fishers were provided with definitions of all strata boundaries, and requested to keep eels caught within defined strata separate. Eels were delivered by the fisher in holding bags live to the factory at Mossburn Enterprises Ltd.

2.1.2 Sampling procedure

At the factory, total landed weight (species unsorted) was recorded and a sample taken by randomly selecting several of the holding bags or, for smaller landings, the entire catch was sampled. Eels were de-slimed before being processed, with a resultant weight loss estimated at about 3% (Beentjes & Chisnall 1998). Species, length, weight, sex, and maturity were recorded for all individual eels in each sample. Samples usually contained both species and these were sorted as the sample was analysed. The proportion of each species by weight in the total landed weight was calculated as the proportion by weight of that species in the sample. A record was kept of any eels over 4 kg released by fishers (maximum legal size in the South Island is 4 kg).

Sex was assigned by macroscopic examination of gonads using the descriptions from Todd (1974). Eels were recorded as immature (sex indeterminate), male, or female. Male and female gonads were staged from 1 to 4 (see Beentjes 1999). Some larger eels could not be sexed (unsexed category) because they were destined for live export and only their length, species, and weight were recorded.

2.1.3 Length-weight relationship and condition index

The length-weight relationship for longfins for each stratum (area) was determined from the linear regression model $\ln W = b (\ln L) + \ln (a)$, where W is weight (g), L is length (cm), and a and b are the regression coefficients. For each stratum, length was set equal to 45 cm and the resultant weight provided a relative index of condition (45 cm approximates length at MLS (220 g) for longfinned eels). No adjustment was made for the estimated 3% weight loss resulting from the de-sliming process. The standard condition index (K) was also estimated from the model $K = W \times 10^6/L^3$, where W is weight (g) and L is length (mm). There were too few shortfins to estimate growth parameters and K was estimated only for the combined strata.

2.1.4 Calculation of overall means

Overall means for variables such as length and weight were expressed in two ways. Firstly, as the mean of the individual means for each strata (where N is strata) and is termed *strata mean*. Secondly, as the *all eels mean*, calculated without regard to stratification (where N is the total number of eels). These overall means are not always equal due to the weighting effect that sample size can have on the *all eels mean*, i.e., strata that were intensively sampled have a disproportionate effect on, for example, the mean length, whereas when calculating *strata mean*, small or large sample sizes have equal weighting.

2.2 Historic size grade and species composition data

Historical data on size grades and species composition were requested and obtained from the following commercial eel processors in both the North and South Islands: Mossburn Enterprises Ltd (Invercargill), New Zealand Eel Processing Co. Ltd (Te Kauwhata), Levin Eel Trading Co. Ltd (Levin), Thomas Richard & Co. Ltd (Whenuapai), and E.N. Vanderdrift (1987) Ltd (Stratford). In this report, henceforth, these companies are referred to as Mossburn Enterprises, New Zealand Eel Processing, Levin Eel Trading, Thomas Richard, and Vanderdrift. Together these companies process virtually the entire eel landings from New Zealand with the notable exception of Gould Aquafarms, who process mainly shortfin eels from Te Waihora. Apart from Vanderdrift and Levin Eel Trading, data were obtained from all other companies in 1995 (Beentjes & Chisnall 1997) and the expectation was that these records would be updated with size grade and species composition records for the intervening years. Supplementary unpublished data for New Zealand Eel Processing and Wilson Neill Ltd for the 1970s and 1980s were also analysed. The data from each processor were collated and plotted in the most appropriate form to show trends in size grades and species composition over time.

For Thomas Richard, Vanderdrift, and New Zealand Eel Processing, the species composition and size grade data collected for the first 7 months of the 2003–04 fishing years were also plotted with the historic data.

2.3 Size grade, species composition, and catch location data for 2003–04 (Pilot programme)

A pilot programme was implemented in the North Island to monitor size grades, species composition, and catch location from nearly all North Island landings in the 2003–04 fishing year. The programme only included North Island processors because the main South Island eel processor, Mossburn Enterprises, does not sort eels into size grades and species until processing, and thus no information on catch location area could be assigned to individual landings. To determine the most effective way to collect these data the procedures for weighing-in eel landings were discussed with each of the main North Island eel processors: New Zealand Eel Processing, Levin Eel Trading, Thomas Richard, and Vanderdrift. In all factories the catch is sorted into species (shortfin and longfin) and graded by size before weighing. The size grades recorded are processor specific, and are usually determined by market demands, although they have not varied in recent years. The information for each landing is routinely recorded on customised landing record forms by the processor and constitutes the basis of payment to fishers, as well as providing catch data for reporting to the Ministry of Fisheries. Because catch location was not recorded on these landing forms we requested that the respective forms be modified to accommodate an area field. To record location in more detail, the 12 eel ESAs (Figure 2) were divided into 65 subareas (not shown) (broadly equivalent to catchments). For the central North Island the subareas were identical to those used in the trial catch and effort diary scheme carried out in the North Island in 1997–98 to assist with the design of a new reporting form for the eel fishery to replace the Catch Effort Landing Return (CELR) (Beentjes 1998). For the south and north of the North Island, ESAs were subdivided into subareas as part the current programme. Maps showing the subareas were sent to each processor and they were requested to modify their customised landing record forms to include a field for catch location (Appendix 1). ESAs were divided into between 2 and 6 subareas except ESA 4, which has 17 subareas. Where the catch was taken from more than one subarea, provision was made for percentage catch per area to be recorded as Area 9A, 60%; 9B, 30%; 9E, 10%.

Catch that was reported from more than one subarea was prorated across the respective areas in proportion to the catch taken from each area.

Species composition (proportion of each species) and catch by species were analysed and plotted for all processors combined by subarea, ESA, and Quota Management Area (QMA). The QMAs for the

North Island eel fishery are QMA 20 (ESAs 1 and 2), QMA 21 (ESAs 3–6), QMA 22 (ESAs 7 and 10–12), and QMA 23 (ESAs 8 and 9) (Anonymous 2004). Analyses of size grade data were carried out separately for each processor and species because of the different size grades used by the three processors, i.e., Vanderdrift record catch weights of eels less than 1000 g and over 1000 g for shortfin and longfin; New Zealand Eel Processing record weights of longfin 200–500 g, 500–1200 g, and over 1200 g, and weights of shortfin 200–500 g, 500–1000 g, and over 1000 g; Thomas Richard record weights of longfin and shortfin 220–500 g, 500–1000 g, and over 1000 g.

3. RESULTS

3.1 Catch sampling (South Island)

3.1.1 Landings sampled

Between 27 November 2003 and 23 April 2004, 24 landings were sampled from three catchments, the Waiau, Oreti, and Mataura Rivers (Figure 1, Table 1). Within these three rivers, 12 strata were sampled, including four tributaries. Four fishers participated in the programme by providing landing details and/or ensuring that the integrity of catches from designated strata was maintained. The number of landings sampled per stratum varied greatly and was dependent on participating fishers. Sampled landed weights of longfins and shortfins totalled 4.9 t and 0.1 t respectively, and the overall proportion of the landed weights sampled (sum of sample weights/sum of landed weights per species) was 25.8% for longfins and 19.2% for shortfins. The overall ratio of longfin to shortfin landed weights was 45:1. Length and weight were recorded from 2947 longfins and 24 shortfins (Table 1) and the mean number of fish sampled per landing for longfins was 123 (N = 24, range = 55–163) and for shortfins 3 (N = 8, range = 1–8).

Longfins were present in all 12 strata and shortfins in only half the strata (Table 1). In all strata that had shortfin, the proportion of longfins was close to 100%, except the Lowburn where it was 86%.

3.1.2 Length frequency distributions

Length frequency distributions of longfins are given by river and stratum in Figure 3. Mean lengths, standard errors, and ranges are given by stratum in Table 2. The strata mean length (12 strata) was 56.6 cm.

From the classification of length frequency distributions for 1996–97 (Beentjes & Chisnall 1998), longfins generally fell into one of three types.

Type 1: Strongly unimodal with mode between 40 and 60 cm centred around 50 cm, with few medium sized or large eels: includes fish from Waiau (strata 1, 2), Oreti (strata 1 and 2), and Mataura (stratum 1).

Type 2: An underlying mode of similar size to above is clearly evident, but is skewed to the right with a good representation of medium size eels between 60 and 70 cm: includes fish from Waiau (stratum 3), Monowai River (stratum 1), Oreti (Stratum 3), Little Creek (stratum 1), Mataura (stratum 2) and Lowburn (stratum 1).

Type 3: No clear modes evident and good representation from all size ranges between 40 and 90 cm: includes fish from Fox Creek (stratum 1). (Note, there were no eels between 40 and 50 cm).

Length frequency distributions of shortfins are given by river and stratum in Figure 4. Mean lengths, standard errors, and ranges are given by stratum in Table 3. The strata mean length (6 strata) was 75.2 cm.

The mean lengths of shortfins for each stratum were generally greater than those of longfins (Tables 2 and 3), but there were too few eels to comment on the length frequency distributions. Shortfin sample size was small for all strata because of the low proportion of shortfin in landings.

3.1.3 Weight and condition

Mean weight and condition indices are given by stratum for both species (Tables 2 and 3) and regression coefficients only for longfin. The longfin strata mean weight (12 strata) was 521 g and the shortfin strata mean weight (6 strata) was 942 g.

Longfin eels with the lowest mean weight were from lower Waiau (strata 1 and 2), Mataura (stratum 1), and Oreti Rivers (strata 1 and 2), and the highest mean weight was from Fox Creek (see Table 2).

The longfin strata mean condition index (weight at 45 cm) was 217 g (12 strata) and was similar among all strata except Fox Creek where it was considerably lower (169 g). The longfin strata mean K condition index was 2.51 (12 strata) and was also similar among most strata.

3.1.4 Sex and maturity

Of the 2947 longfins sampled, 93.9% were classified into one of three categories: immature, male, and female. Of the remaining 6.1% that were unsexed, most were exported live and from size alone were predominantly the larger females. The *strata mean* proportions of longfins categorised as immature, male, or female were 42%, 28%, and 30%, respectively (Table 4). Similarly, the *all eels mean* proportions of longfins categorised as immature, male, or female were 50%, 29%, and 21%, respectively (Table 4). Females outnumbered males in 5 of the 12 strata (Waiau River all strata, Mataura River stratum 2, Fox Creek) and this was most marked in Fox Creek where 97% of eels were female.

Male longfins were predominantly within the size range 45–65 cm, with modes between about 50 to 55 cm (see Figure 3). Female longfins, however, were generally scattered over a larger size range, from about 44 to 93 cm, with no clear modes. The largest eels, although unsexed, were undoubtedly females, which would extend the female upper size range to 105 cm. In addition, a maximum size limit in the South Island of 4 kg (females equivalent to about 115 cm) resulted in six eels from the sampled landings being released at the point of capture and therefore these eels are not included in our sample data. Longfins in the immature category ranged from about 41 cm to 55 cm length and overlapped the size range of males and smaller females.

As longfin eels grow, their gonads develop from immature where the sex cannot be determined, through four recognised stages (Table 5) (for a description of gonad stages see Beentjes & Chisnall 1998). The sex of longfins was distinguishable in the stage 1 condition at mean lengths of 56 cm for females and 52 cm for males. The stage 4 gonad condition was usually found in both males and females that exhibit morphological signs of migrating, such as enlarged eyes and the shovel-shaped head (Todd 1974, Todd 1980). Most eels of both sexes were stage 1 or 2 (98.5% for males and 75% for females). For longfinned males, only one eel in the stage 4 condition was sampled (52 cm), however, the mean length of 11 eels classified as stage 3 was 64.6 cm indicating that length at migration is greater than this length. The equivalent length for migrating females is likely to be slightly more than the mean length of 87.1 cm recorded for 12 stage 4 females because the largest eels

were either not sexed, due to processor's requirements to live export large eels, and/or eels over 4 kg were not landed.

All 24 shortfin eels sampled were females and, of these, nearly all were stage 1 or 2 (Table 5). Although numbers were low, mean size increased with stage of gonad maturity.

3.2 Historic size grade and species composition data

Data were provided either as a percentage or tonnage for each size grade. To ensure confidentiality for processors, only percentage data are presented here.

3.2.1 Mossburn Enterprises Ltd

Mossburn Enterprises processes the majority of eels in the South Island, most of which are sourced from Otago and Southland. Their data provide the most comprehensive time series of size grade and species composition for the South Island. The same size grades, recorded in imperial units (lbs), have been used since the mid 1970s when records began. For analysis and presentation, pounds were converted to metric units (g) and rounded (Table 6).

The most recent data provided by Mossburn Enterprises were for the fishing years between 1996–97 and 2002–03. These were added to previous data for 1974–75, 1977–78, 1978–79, and 1983–84 to 1995–96 (Beentjes & Chisnall 1997). For each of these years, the proportions of the catch in each size grade were calculated, and for each decade, the mean proportion and standard errors in each size grade were determined. The data are pooled and presented by decade (1970s, 1980s, 1990s, and 2000s).

Longfins

The Mossburn Enterprises size grade data show a clear and progressive trend of declining size from the 1970s through to the 1990s (Figure 5). In the 1970s the predominate size grade was 450–900 g, but changed to the smallest size grade (under 450 g) in the 1980s and has remained so through the 1990s and into the 2000s (15% in 1970s, 43% in 1980s, 52% in 1990s, and 38% in 2000s). The increase in the proportion of the smallest size grade in the 1980s and 1990s was generally accompanied by a progressive decrease in proportions of the larger grades and most of the reduction in size of eels processed took place between the 1970s and 1980s. The size grade data from the 2000s indicates a reversal in the trend of declining size as the relative proportion of the smallest size grade (under 450 g) has decreased and correspondingly, the proportions of some of the larger size grades, particularly the 1800–2270 g, has increased.

Shortfins

Trends in size grades of shortfin eels are similar to those for longfin eels with a clear and progressive decline in size from the 1970s through to the 1990s, although the size grades differ slightly and there were few eels over 2270 g landed (Figure 5). Unlike longfins, however, the proportion of the smallest size grade processed (under 500 g) increased most sharply in the 1990s compared to the 1970s and 1980s. This may be due in part, to the inclusion of Te Waihora eels from 1992–93 onward. Te Waihora is a shortfin fishery that has dispensation to target male migrating eels which would otherwise be smaller than the minimum legal size of 220 g; average weights of shortfin migratory males is about 125 g (40 cm) (Jellyman et al. 1995, Beentjes & Chisnall 1998). Irrespective of this, for the next three size grades, (500–900 g, 900–1360 g, and 1360–1800 g), the greatest differences are between the 1970s/1980s and the 1990s. No eels in the largest size grades for shortfin eels (2270–

3200 g and over 3200 g) were processed in the 1980s and 1990s. There appears to be little change in the proportions of eel size grades processed between the 1990s and 2000s and there are signs that the reversal in the trend of declining size, observed for longfin, may be occurring for shortfin.

Species composition

The proportion of longfin processed by year at Mossburn Enterprises s decrease over time. In the 1970s and early 1980s the species composition was about 90% longfin (Figure 6). From the late 1980s to the late 1990s this declined gradually to about 50% and in recent years about 60% of the catch processed is longfin. However, in 1992–93, Mossburn Enterprises began processing eels from of Te Waihora, a predominantly shortfin eel fishery, and this has probably contributed to the increased proportion of shortfin eels processed in later years. No data were available on landed tonnages to determine if the change in species composition is associated with a decline in catch of longfins over time.

3.2.2 Rainbow Fisheries Ltd

Rainbow Fisheries Ltd was based in Dunedin and processed eels mostly from Otago and Southland throughout the 1980s and 1990s, but have since ceased trading. Data on size grades were provided in 1995 covering 1987–88 to 1993–94 and the results were given by Beentjes & Chisnall (1997). No new data are available and therefore the results will not be presented here but are summarised.

The predominant size grade of longfin eel processed was 450–900 g for all years except 1992–93, although the proportion of eels processed in the smallest size grade (under 450 g) progressively increased each year (12% in 1987–88 to 24% in 1993–94) with the exception of 1992–93 where the proportion was 38%. Commensurate with an increase in the proportions of small eels processed was a decline in the proportions in the larger size grades.

The predominant size grade of shortfin eel processed on average remained around 450–900 g. The data for shortfin eels do not indicate any trends in size of eels processed over time and the proportions processed in the largest size grades are represented equally as strongly in later years.

There were no apparent trends in species composition over time.

3.2.3 Wilson Neill Ltd

Wilson Neill were a Dunedin based export company that operated through the 1970s and 1980s processing eels mostly from Otago and Southland, but have since ceased trading. Data on proportions of eels processed from 1971–72 to 1978–79 (1 April–31 March) were provided to Fisheries research Divisions (Ministry of Agriculture and Fisheries) in 1979 (NIWA, unpublished data). Three size grades were used (imperial units) and these were converted to metric units (see Table 6). Explanatory notes that accompanied the data stated that size grades processed were largely market driven and thus the proportions could be misleading. It is noteworthy that the bulk of longfin eels processed were over 500 g. The proportions in each size grade fluctuated widely among years and there are no clear and consistent trends in these data (Figure 7).

3.2.4 Levin Eel Trading Co. Ltd.

Levin Eel Trading process eels mainly from the central and lower North Island. Their data provide the most comprehensive time series of size grades and species composition of the four North Island processors. The same size grades, recorded in pounds, have been used since the late 1970s when

records began. Pounds were converted to grams and rounded as for Mossburn Enterprises data (see Table 6).

The data span a continuous 25 year period between the 1978–79 and 2002–03 fishing years and were not available for the previous analysis of size grade data (Beentjes & Chisnall 1997). Analysis and presentation of the data are identical to that for Mossburn Enterprises, i.e., for each year, the proportion of each size grade was calculated, and for each decade the mean proportion and standard error in each size grade was determined. The data are pooled and presented by decade (1970s, 1980s, 1990s, and 2000s).

Longfin

The longfin size grade data show a clear and progressive trend of declining size from the 1970s through to the 1990s (Figure 8). The most marked change in relative proportions of size grades processed is generally between the 1970 and 1980s. In the 1970s the predominate size grade was 450–900 g, followed by the largest size grade (over 2270 g), but this decreased to the smallest size grade (under 450 g) in the 1980s and remained so through the 1990s (8% in 1970s, 27% in 1980s, 36% in 1990s, and 30% in 2000s). In the 2000s, however, the 900–1360 g has become the dominant size grade and there was a slight decline in the proportion of the smallest size grade. The complete absence of longfin eels in the 450–900 g size grade in the 2000s is because eels in this grade were incorrectly recorded against eels in the 450 g size grade for the years 1999–2000 to 2003–03 (Mark Kuyten, Levin Eel Trading Co., pers. comm.).

Shortfin

The shortfin size grade data show a clear and progressive trend of declining size from the 1970s through to the 2000s (Figure 8). The most marked change in relative proportions of size grades processed is between the 1970 and 1980s. In the 1970s, the predominate size grade was 450–900 g, but this decreased to the smallest size grade (under 450 g) in the 1980s and has remained so through the 1990s and into the 2000s (21% in 1970s, 54% in 1980s, 55% in 1990s, and 67% in 2000s). The increase in the proportion of the smallest size grade each decade was generally accompanied by a progressive decrease in the larger grades and this trend has continued into the 2000s.

Species composition

The proportion of longfin processed by year at Levin Eel Trading decreased gradually in the mid 1980s. In the late 1970s and early 1980s, the species composition was between 50% and 60% longfin, but in 1984–85 this declined to 24% and thereafter fluctuated between 22% and 35% (Figure 9). The relative landed tonnages (index of catch standardised to shortfin tonnage in 1978–79) of both species are shown in Figure 10. Both shortfin and longfin landings declined sharply between 1978–79 and 1981–82; thereafter longfin catches increased slightly until 1995–96 and then declined to levels of the early 1980s. Shortfin landings displayed a similar but more pronounced trend.

3.2.5 Thomas Richard & Co. Ltd

Thomas Richard is based at Whenuapai and is the largest North Island processor, taking eels mainly from the central and northern North Island. In 1995–96, data were provided for 1985–1990 (the data for the years 1989 and 1990 were provided combined so results were averaged over the two years and presented as 1989–90) (Beentjes & Chisnall 1997). Four size grades were used throughout this period

(150–600 g, 600–900 g, 900–1500 g, and over 1500 g) (Figure 11). For longfin eels the proportion of the smallest size grade (150–600 g) increased from 23 to 93% between 1985 and 1989–90. The proportions of the larger size grades are highly variable over time but indicate that landings of the largest longfins processed (over 1500 g) may have declined over time. There are no apparent trends in shortfin size grades processed over this period.

There were no further size grade data available until 2001–02 because in the interim species were not weighed separately at the time of landing (Figure 11). Further, the current size grades have changed since the 1980s, reflecting market demands, and therefore it is not valid to compare the data between the two periods. The relative proportions of each longfin size grade over the last 3 years are reasonably consistent and show that about half of all longfins landed are over 0.5 kg and about 30% are over 1 kg. The relative proportions of each shortfin size grade over the last 3 years are remarkably consistent and show that half of all shortfins landed are over 0.5 kg and about 16% are over 1 kg. The 2003–04 size grades for both species are for 1 October 2003–30 April 2004 and may change slightly with the addition of data for the remainder of the fishing year.

Species composition was reasonably consistent between 1985 and 1988 (about 60% shortfin and 40% longfin), but changed markedly in 1989–90 when the proportion of longfin eels processed declined to only 10% (Figure 12). The quality of the 1989–90 data is, however, questionable (see above). The proportions of longfin processed in 2001–02, 2002–03, and 2003–04 were 31, 29, and 28% and indicate a possible decline in longfin compared with the 1980s.

3.2.6 New Zealand Eel Processing Co. Ltd

New Zealand Eel Processing is based in Te Kauwhata and is one the three largest North Island processors, taking eels mainly from the central and northern North Island. Size grade data were provided by New Zealand Eel Processing in 1979, 1991 (NIWA unpublished data), 1995 (Beentjes & Chisnall 1997), and most recently in 2004. No distinction was made between species except for the 2004 data, where shortfin and longfin weights were recorded separately. The 1979 data cover four years between 1970 and 1978 (Figure 13) and only two size grades were provided (under 454 g and over 454 g). The 1991 data cover 1982 to 1990 using a slightly larger size grade (under and over 500 g). In 1995, data were provided for the years 1975 to 1985 using the 454 g size grade. In 2004, data were provided for the fishing years 2001–02 and 2002–03 by species and using three size grades. Data collected on size grades and area for 1 October–30 April 2004 were also plotted for comparison (Figure 14).

The 1995 data overlap both the 1979 and 1991 data, and estimates of the proportions of the smallest size grade processed between the years 1982 to 1985 data differ substantially (see Figure 13). I have no explanation for this, but it is likely to be related to how the data were extracted by the processor at different times. The overlapping year between the 1979 and 1995 data (i.e., 1978), however, has a similar estimate. Irrespective of which data set is the more accurate, the trends are the same. If we consider only the 1979 and 1995 data, the proportion of eels processed that were less than 454 g increased markedly between 1970 and 1985 (3% in 1970 and 60% in 1985).

The three size grades recorded for each species in 2001–02, 2002–03, and 2003–04 reflect current market demands (Figure 14). For comparison, the 220–500 g size grade (equivalent to the under 454 g and under 500 g) was plotted for both species combined on Figure 13. Without data it is not possible speculate on what has occurred in the intervening years, but the proportions of eels (both species combined) in the smallest size grade are similar to those in 1985. The size grade data for the most recent years (2001–02, 2002–03, and 2003–04) indicate that both large longfin and shortfin (i.e., eels over 500 g) are reasonably well represented in catches and there are no apparent trends (Figure 14).

Although there were no size grade data recorded by species, data were collected on the overall species composition between 1975 and 1985. Species composition appears to have changed between the

1970s and 1980s when the proportion of longfin eels processed declined from about 25% to 10% (Figure 15). The proportions of longfin processed in the last three years (2001–02, 2002–03, and 2003–04) were 20%, 21% and 16%, and indicate a possible increase in longfin compared with the 1980s. No data were available on landed tonnages to determine if the change in species composition is associated with a decline in catch of longfins over time.

3.2.7 E.N. Vanderdrift (1987) Ltd

E.N. Vanderdrift (1987) Ltd. are based in Stratford and process eels mainly from the Taranaki and Rangitikei-Wanganui areas. No data were available from the previous analysis of size grade data (Beentjes & Chisnall 1997). The data provided are for a single year (2002–03) and there is no species breakdown. Of the two size grades used, 69% of the catch was under 1 kg and 31% over 1 kg.

3.3 Size grade, species composition, and catch location data for 2003–04 (pilot programme)

Three North Island processors (Vanderdrift, New Zealand Eel Processing, and Thomas Richard) provided species, size grade, and catch location data for individual landings between 1 October 2003 and 30 April 2004. Collection of the data is ongoing and further analyses for 2003–04 will require updating with data from the remaining 5 months of the 2003–04 fishing year. No data were received from Levin Eel Trading because they did not process eels during the first half of the 2003–04 fishing year.

3.3.1 Catch and species composition

Total landed tonnages from each processor are combined for presentation for confidentiality and included 73 t (26%) of longfin and 209 t (74%) of shortfin from 963 landings. The proportion of the catch that was shortfin was 84% for New Zealand Eel Processing, 72% for Thomas Richard, and 46% for Vanderdrift. The catch (t) of each species by subarea, ESA, and QMA is shown in Figure 16. Catch was landed from a total of 46 of the 65 subareas (71%) with 0.1% from unspecified locations. The subareas that contribute a relatively high proportion of the catch include 1A, 1D, 4J, and 4L. When expressed by ESA a relatively high proportion of the catch came from these four northerly subareas, particularly 1 and 4, which accounted for 57% of the total catch. All North Island ESAs were represented, except 11 (Wairarapa). Similarly, when the data are expressed by QMA, those containing ESAs 1 and 4 contributed the most catch, with QMAs 20 and 21 providing 82% of the total catch.

The species composition by subarea, ESA, and QMA is shown in Figure 17. Species composition expressed by ESA indicate that shortfin dominate catches in all areas except 8 and 9, where longfin make up 53% and 75% of the catch. In all other ESAs shortfin make up between 65% and 95% of the catch. The species composition by QMA shows a dominance of shortfin in QMAs 20, 21, and 22 (79%, 78%, and 75% shortfin), whereas QMA 23 has a greater proportion of longfin (65% longfin). When the species composition is broken down by subarea there are some areas where the species composition is not consistent with that of the larger ESA. For example, catches from subareas within ESAs 4 are dominated by shortfin, except those from 4N, 4P, and 4Q, which are predominantly longfin. Similarly, catch from subarea 6A is virtually all longfin and 6F exclusively shortfin. Similar disparities in the species composition can also be found among the subareas of ESAs 7 and 8.

3.3.2 Size composition

New Zealand Eel Processing Co. Ltd

Shortfin – shortfin eels processed by New Zealand Eel Processing were sourced from 23 subareas, 7 ESAs (1–7), and 3 QMAs (20–22) (Figure 18). The overall proportions of shortfin in the three size grades were 65%, 27%, and 9% (220–500 g, 500–1000 g, and over 1000 g). ESA 4 had the highest proportion of small eels (220–500 g; 76%) followed by areas 1, 5, and 3 (64%, 60%, and 58%). All seven ESAs yielded eels from all the three size grades, except ESA 6 where no eels over 1000 g were landed – this ESA had the largest proportion of eels in the 500–1000 g size grade (55%). For the six other ESAs, area 2 yielded the largest proportion of eels over 1000 g (19%), and area 4 the least (5%). The shortfin size composition by QMA shows that QMA 22 has the highest proportions of larger eels, and QMA 21 the lowest. When the size composition is broken down by subarea, areas with the largest eels include 1B, 2C, 4Q, 5A, and 7E; those with the smallest include 4I–4M (Figure 18).

Longfin – longfin eels processed by New Zealand Eel Processing were sourced from 22 subareas, 6 ESAs (1–5 and 7), and 3 QMAs (20–22) (Figure 19). The overall proportions of longfin in the three size grades were 52%, 16%, and 32% for the 220–500 g, 500–1200 g, and over 1200 g grades, respectively. ESA 4 had the highest proportion of small eels (220–500 g, 57%) followed by areas 5, and 3 (53%, 50%). All six ESAs yielded eels from the three size grades except 2 which had no small eels (220–500 g) and the largest proportion of eels over 1200 g (500–1000 g size grade (77%). For the five other ESAs, area 1 yielded the largest proportion of eels over 1200 g (45%), and area 4 the least (28%). The longfin size composition by QMA shows that QMAs 20 and 22 have the highest but similar proportions of larger eels and QMA 21 the least. When the size composition is broken down by subarea, areas with the largest eels include 2C and 7E, and to a lesser extent, 1A, 1C, 4M, 4Q, 5A, and 7D; those with the smallest eels include 1D, 4J, 5B and 5C.

E.N. Vanderdrift (1987) Ltd

Shortfin – shortfin eels processed by Vanderdrift were sourced from 14 subareas, 5 ESAs (7–10, and 12), and 2 QMAs (22 and 23) (Figure 20). Overall, 86% of shortfins were under 1 kg. All 5 ESAs yielded eels from both size grades, but area 7 had a relatively high proportion of eels under 1 kg (97%). ESA 9 had the highest proportion of large eels (over 1 kg, 25%). QMA 23 had the highest proportion of larger eels (QMA 23 19%, QMA 22 10%). The subareas with the largest eels include 8C, 9B, 9C, and 9D; those with the smallest include 7F, 8F (no eels over 1 kg), 9A and 9F.

Longfin – longfin eels processed by Vanderdrift were sourced from 17 subareas, 5 ESAs (7–10, and 12), and 2 QMAs (22 and 23) (Figure 21). Overall, 64% of longfins were under 1 kg. All 5 ESAs yielded eels from both size grades, but area 12 had a relatively high proportion of eels under 1 kg (97%). ESA 8 had the highest proportion of large eels (over 1 kg, 45%). QMA 23 had the highest proportion of larger eels (QMA 23 39%, QMA 22 23%). The subareas with the largest eels include 7B, 8A, 8C, 9B, 9C, and 9F; those with the smallest include 9E, 10A and 12A.

Thomas Richard & Co. Ltd

Shortfin – shortfin eels processed by Thomas Richard were sourced from 27 subareas, 7 ESAs (1–7), and 3 QMAs (20–22) (Figure 22). The overall proportions of shortfin in the three size grades were 50%, 34%, and 16% for the 220–500 g, 500–1000 g, and over 1000 g grades, respectively. All seven

ESAs yielded eels from the three size grades although the proportion of eels over 1000 g in area 6 was only 3%. ESA 6 had the highest proportion of small eels (220–500 g, 82%) followed by area 4 (60%), whereas the largest eels came from ESA 2 (65% over 500 g). The shortfin size composition by QMAs shows that QMA 20 has the highest proportion of larger eels and QMA 21 the lowest. When the size composition is broken down by subarea, areas with the largest eels include 2B, 2C, 4B, 4D, 4I, and 4N; those with the smallest include 3B, 4C, 4K, 4L, and 6A.

Longfin – longfin eels processed by Thomas Richard were sourced from 27 subareas, 7 ESAs (1–7), and 3 QMAs (20–22) (Figure 23). The overall proportions of longfin in the three size grades were 56%, 16%, and 28% for the 220–500 g, 500–1000 g, and over 1000 g grades, respectively. All seven ESAs yielded eels from the three size grades. ESA 6 had the highest proportion of small eels (220–500 g, 80%) followed by area 1 (65%), whereas the largest eels came from ESAs 2, 4 and 7. The longfin size composition by QMAs shows that QMA 22 has the highest proportion of larger eels and QMA 20 the lowest. When the size composition is broken down by subarea, areas with the largest eels include 2B, 2C, 4B, 4D, 4J, 4N, 4P, and 4Q, whereas those with the smallest include 1D, 1E, 4C, 4H, 4K, 4L, 5B, and 6A.

4. DISCUSSION

4.1 Catch sampling (South Island)

4.1.1 Landings

The four South Island catch sampling programmes between 1995 and 1999 sampled landings from rivers and lakes throughout the South Island. In contrast, the objective of the 2003–04 catch sampling programme was to restrict sampling to several key South Island catchments, which would act as broad indicators of the status of the eel fishery. In consultation with the Ministry of Fisheries and the commercial eel industry, the rivers initially selected were the Mataura, Oreti, Clutha, and Waitaki Rivers. Attempts to sample the target number of 50 landings from the nominated areas proved to be difficult for a number of reasons. Firstly, numbers of fishers declined markedly after South Island eels were introduced into the QMS in October 2000, and in 2003–04 there were about one-third the number of fishers landing into Mossburn Enterprises than in 1997–98 (Victor Thompson, Mossburn Enterprises, pers comm.). Secondly, February 2004 was unseasonably cold with fewer landings than expected. Towards the end of the season, when it was apparent that the target number of landings would not be achieved from the nominated catchments, landings from smaller creeks and tributaries were sampled.

Landings sampled in 2003–04 included four new strata: Lowburn (tributary of lower Mataura River), Little Creek and Fox Creek, (tributaries of the upper Oreti River), and the Monowai River (tributary of the lower/mid Waiau River). The inclusion of these locations, together with other tributaries such as the Taieri Gorge, the Mokoreta and Pomahaka Rivers, and the Waikaka Stream sampled in previous years, extends our knowledge of the size, sex, and species composition of eels from less heavily fished and less accessible rivers. Larger eels are generally better represented in these areas, and their inclusion provides a broader view of overall population structure. As numbers of fishers have declined, there has also been a reduction in effort in some areas that have historically been fished on an annual basis (Victor Thompson, pers. comm.).

4.1.2 Escape tubes

This programme sampled only commercially sized eels that recruited to the fishery. The national minimum legal size (MLS) of 220 g determines the lower size range of eels landed. Catches are

seldom graded before arriving at the processors, and fishers rely on escape tubes deployed in fyke nets to allow escapement of eels under 220 g. In 1995–96, the minimum legal escape tube diameter was 25 mm, although a code of practice in the South Island encouraged fishers to use 28 mm, which was increased voluntarily to 31 mm in 1997–98. The results from this study indicate that the 31 mm escape tube diameter is reasonably effective since only 3.1% of longfin eels sampled weighed less than the MLS of 220 g.

4.1.3 Species composition

Longfins were the predominant species in all landings sampled. In previous catch sampling programmes, species composition varied considerably between landings, due in part to the fishing practices of each fisher and the number of landings they contributed to the programme. For example, the proportion of longfins in the lower Mataura River was 83.5% in 1995–96, 68.1% in 1996–97, 84% in 1997–98, and 99.1% in 2003–04. Shortfin catch tends to be higher in flood conditions and/or from discrete areas known to be shortfin fisheries, such as Lake Brunner, Waipori Lakes, and Te Waihora. The very low proportion of shortfin overall in 2003–04 may have resulted from several factors, including targeting practices, environmental conditions, and locations of catch, and is not interpreted as an indication of a decline in abundance of shortfin.

4.1.4 Size

Length frequency distributions and mean lengths for longfin from the Waiau, Oreti, and Mataura Rivers overall were similar to those of 1995–96, 1996–97, and 1997–98 with two points of difference. Firstly, for coastal strata mean size was the smallest of the four years for the Waiau and Mataura Rivers, although these differences were small (e.g., Mataura River stratum 1: 1995–96, 50.7 cm; 1996–97, 50.5 cm; 1997–98, 51.7 cm; and 2003–04, 49.6 cm). Secondly, and more apparent, the mean size of eels from the most inland strata sampled in 2003–04 was the largest of any of the four years for all three rivers (e.g., Mataura River stratum 2: 1995–96, 56.6 cm; 1996–97, 55.6 cm; 1997–98, 55.6 cm; and 2003–04, 60.4 cm). The larger size reflects the higher proportion of females in the catch and possibly an indication that there has been less effort applied to these upper catchments in recent years. Despite these changes it appears that the bulk of the longfin fishery is still based on eels between 45 and 60 cm (220–560 g) taken predominantly from the lower mainstems of southern rivers where length distributions are strongly unimodal with mean lengths around 50 cm. In marked contrast, longfin length frequency distributions from less accessible and less frequently fished Lowburn, Little Creek, and Fox Creek had larger eels overall, and those from Fox Creek were almost 100% female. This is similar to the distributions from such areas as Waikaka Stream and Taieri Gorge, which consisted mostly of large females.

The maximum size limit of 4 kg was introduced to protect female longfins. Fishers participating in the 2003–04 catch sampling programme estimated that, from the sampled landings, 6 eels over 4 kg were caught and released (77 in 1995–96, 116 in 1996–97, 114 in 1997–98). The inclusion of these large eels in landings would not have affected the length frequency distributions to any extent.

4.1.5 Sex and maturity

The South Island longfin commercial fishery between 1995 and 1998 was dominated by males which were at least twice as common in landings as females, possibly because females, with their greater longevity, are more vulnerable to fishing (Beentjes & Chisnall 1997, 1998, Beentjes 1999). The data from the three mainstems sampled in 2003–04 indicate that, although males overall are more common in commercial landings than females, the numerical dominance is less marked than for catch sampling.

between 1995 and 1998, and in the Waiau River and upper Mataura River females outnumbered males. The high percentage of females in Fox Creek is consistent with our understanding of size and sex distributions from less accessible areas, but we have no explanation for the apparent change in sex ratios for the Waiau River and upper Mataura River.

The vast majority of eels of either sex were immature or had stage 1 or 2 gonads. The migratory gonad condition (stage 4), usually associated with morphological changes in migrating eels, indicated that migration in longfin females takes place at least as small as 87 cm and 1.8 kg, and 65 cm and 0.7 kg in males. These estimates agree well with size at migration estimates by Jellyman & Todd (1982), even though our female data are slightly biased toward the small size since longfins over 4 kg were returned to the water and not sampled. Additionally, many large females were not sexed due to live export requirements.

In contrast to the male-dominated longfin fishery, the commercial fishery for shortfins (ouside Te Waihora) is based almost entirely on females as males migrate at a size below the national MLS. The shortfin data are too few to make any comment on size at migration.

4.2 Historical size grade and species composition data

4.2.1 South Island

The Mossburn Enterprise's historical data provide the most comprehensive time series of records on species composition and size grades processed in the South Island, and generally reflect the population structure of commercial eels in the South Island, particularly the southeast region. The main conclusion from analysis of this database is that the average size of both shortfin and longfin eels processed in the South Island has progressively declined over the last 30 years (particularly between the 1970s and 1980s), and is now largely based on eels in the smallest processed size grade (under 450 g) (see Figure 5). Data from 1996–97 to 2002–03, however, indicate a possible reversal in the trend of declining size as the relative proportion of the smallest size grade (under 450 g) has decreased slightly in the 2000s, and correspondingly, the proportion of the 1800–2270 g grade has increased three-fold. There were no longfin eels processed in the two largest size grades in the 2000s, but this may be partly because of the 4 kg maximum size limit introduced in 1995–96. There is no price incentive to land larger eels into Mossburn Enterprises and the three-fold increase in the 1800–2270 g size grade of longfins is not market driven (Victor Thompson, pers. comm.). There are several potential factors that may have contributed to the apparent change is longfin size grades processed in recent years. (1) There has been a substantial reduction (c. 75%) in the number of fishers in the South Island since 1 Oct 2000 when South Island eels were introduced into the QMS; (2) quota has not been caught each year; and (3) attempts to increase exports of eels were limited by poor market demand. Together, these factors have resulted in a substantial reduction in effort in the South Island and many areas that have been previously fished annually have been less frequently fished, effectively allowing eels to attain a larger overall size at capture. I cannot explain, however, why there was no increase in the proportion of the intermediate size grades.

Trends in size grades of shortfin eels processed by Mossburn Enterprises are similar to those for longfin eels. Data for 1996–97 to 2002–03 indicate that for the three smallest size grades that make up the bulk of the landings, there is little difference between the 1990s and the 2000s, indicating that the trend of declining size has at least levelled off and is possibly reversing for shortfins between 500 g and 1360 g. No migrating male shortfin eels from Te Waihora were processed by Mossburn Enterprises over the last 7 years, however, and this may have had some influence on the decrease in the proportion of the smallest size grade.

There was a gradual decline in the proportion of longfins processed by Mossburn Enterprises during the 1990s, although there are signs that over the last 3 years the proportions of longfins may be

increasing, but more years in the time series will be needed to show any trend. Without actual landing tonnages for each species, however, it is not possible to determine if the observed decline in longfin species composition over time is related to a decline in longfin landings.

Other historic size grade and species composition data from South Island processors cover short time spans and are therefore less informative. Nevertheless, the data obtained from Rainbow Fisheries (see Beentjes & Chisnall 1997) support the trend of a reduction in size over time for longfin.

Although data on size of eels processed before the 1970s is lacking, studies before commercial fishing began indicated that longfin populations in Southland were dominated by large females. For instance, the average weight from more than 11 000 eels caught in tributaries of the Oreti River in 1939 was about 1400 g (Cairns 1942), which equates to a length of about 83 cm. Further, longfins from three inland Southland rivers (Waiau tributaries) sampled between 1947 and 1949 (Burnet 1952) were mainly between about 60 and 90 cm, with many eels over 100 cm in length. This contrasts markedly with the size of longfins that are currently processed in the South Island, and provides strong evidence of a major change in the population size structure as a result of commercial fishing.

4.2.2 North Island

The Levin Eel Trading historical data provide the most comprehensive time series of species composition and size grades processed in the North Island and generally reflect the population structure of commercial eels in the central and southern regions of the North Island. The trends in the Levin Eel Trading longfin size data are remarkably similar to those of Mossburn Enterprises for the South Island, showing that the average size of eels processed has progressively declined over time and by the 1980s and 1990s the smallest processed size grade (under 450 g) dominated landings (see Figure 8). The emergence of 900–1360 g as the dominant longfin size grade in the 2000s is considered to be a reflection of market demands for larger eels, as fishers were encouraged to land eels of this size through price incentives (Mark Kuyten, pers. comm.). Further, the incorrect recording of longfin eels in the 450–900 g size grade to the 450 g grade in the 2000s renders both the 450 g and the 450–900 g grades inaccurate for the 2000s. Given this, it is difficult to interpret the relationship between what has been processed and population size structure of eels in the three smallest size grades for the 2000s. However, the continued trend of a reduction in numbers of large eels in the three largest size grades into the 2000s, despite the demand for larger eels, suggests that the population size structure of longfin eels in this region has continued to decline.

The trends in the Levin Eel Trading shortfin size data are also similar to, but are more pronounced than, those of Mossburn Enterprises shortfin for the South Island. These results provide evidence of a long-term and continuing decline in the population size structure of shortfin eels in the central and lower North Island.

The proportion of longfin processed by Levin Eel Trading appears to decline sharply in the early 1980s, but examination of annual landing weights of each species show that this is because landings of shortfin increased relative to longfin (see Figures 9 and 10). Further, apart from the drop in landings of longfin in the early 1980s, longfin landings have been reasonably stable over the last 22 years. Because the tonnage of eels processed by Levin Eel Trading annually has not declined, but the mean size of eels of both species has, landings have increasingly become composed of a greater number of smaller eels.

Other historic size grade and species composition data from North Island processors cover shorter time spans, are less comprehensive, and therefore less informative. In general, however, the trends of declining size over time shown by the Levin Eel Trading data are supported by the longfin data from New Zealand Eel Processing and Thomas Richard. The New Zealand Eel Processing data indicate that the proportion of longfin in the species composition has declined from the 1970s, but there are no data

on tonnages, and it is not possible to determine if there has been a reduction in longfin landings relative to shortfin landings. The Thomas Richard data indicate a possible decline in longfin compared with the 1980s, but the data are too few to be conclusive – certainly there are no clear differences in the quantities of longfins and shortfins landed in the 2000s compared with the 1980s (not presented).

4.2.3 General comments

The similarities between trends in the Mossburn Enterprises and Levin Eel Trading data suggest that the eel populations of both species in the North and South Island have been affected by commercial fishing in a similar way, i.e., size has progressively declined over time. The main difference seems to be that in the South Island there may be a possible reversal of the trend in recent years because effort has declined with the introduction of the QMS. Although the trends in species composition from individual processors are equivocal, estimated North Island catches of shortfin and longfin from catch-effort-landings-returns (CELR) and eel-catch-effort-returns (ECER, after 1 October 2001) show a general decline in longfin landings relative to shortfin landings over the 13 years from 1990–91 to 2002–03 (Beentjes & Dunn 2003b) (Figure 24). Longfin estimated catches declined from about 340 t to 140 t while shortfin fluctuated between 360 t and 600 t, but showed no trend of a decline in landings. These findings indicate that longfin abundance may have declined in the North Island over the last 13 years.

Market demands can have an effect on the size of eels landed and can confound interpretation of trends on size grades. This appears to be the case at Levin Eel Trading where the demand for medium size eels has led to this size grade becoming dominant in recent years. Similarly, market demands can also affect species composition if one species is periodically more desirable than the other.

Data from previous South Island catch sampling programmes indicate that longfin males reach a maximum size of about 65 cm, which equates to a weight of about 700 g (Beentjes 1999). Longfins over this size and weight are predominantly, if not exclusively, females, indicating that the progressive reduction in size is disproportionately affecting females. The shortfin fishery in contrast is virtually 100% females as males migrate before they are vulnerable to capture by fyke net.

4.3 Size grades, species composition, and catch location data for 2003–04 (pilot programme)

This was the first year of a pilot programme to monitor size grades, species composition, and catch location from all North Island landings in a single season (2003–04). Although this provides less information on size and sex distribution from each landing than previous North Island catch sampling programmes (Beentjes & Chisnall 1997, 1998, Chisnall & Kemp 2000), it captures data from all North Island eel landings, rather than a select few, thus providing a more accurate representation of stock structure overall. It also provides very accurate data on species catch and composition by area (ESA or subarea) and the proportion of the population that is composed of large eels — for longfins, this also provides an index of potential female spawners. Finally, because the location of the catch is recorded at the time of landing, it is possible to relate catch, size, and species composition to discrete catchment based areas. The shortcomings of this approach are that size grade data are coarse with only two to three size grades used, grades differ among the processors and/or species, and grades could change depending on market demands. The data also offer limited information on the sex structure of the populations, except for assumptions of sex based on size.

The 281 t of eels included in our analyses for 2003–04 represent about 33% of the total expected North Island landings (averaged 857 t between 1991–92 and 1999–2000 (Annala et al. 2004)).

However, it is likely to be considerably more than this given that there were no landings for Levin Eel Trading in 2003–04, and that landings overall are down compared to previous years as a result of reduced international market demand. The relative catches by ESA are similar to longterm averages (Beentjes & Bull 2002) with ESAs 1 and 4 contributing 57% of the catch. If Levin Eel Trading had processed eels in 2003–04 it is likely that there would have been a higher proportion of catch from the central and lower North Island (QMA 22 and QMA 23). The expression of catch by subarea shows that within a given ESA there is a large variation in the contribution of the various catchments.

Overall 74% of all landed weights of eels in the North Island in 2003–04 were shortfin, which is similar to the long-term proportion of shortfin between 1991and 2003 (68%, estimated catch from CELRs and ECERs) (Beentjes & Dunn 2003b). Only ESAs 8 and 9 provided more longfin than shortfin (see Figure 17), where eels were caught from the many fast flowing streams and rivers on the slopes of Mount Taranaki, known to be good longfin habitat (Peter Mischevsky, Vanderdrift Ltd, pers. comm.). There are some subareas, outside ESAs 8 and 9, however, that had catches dominated by longfin. For example, the western subareas of Statistcal area 4 (4N, 4P, and 4Q) and subarea 6A on the east coast, Bay of Plenty (see Figure 17).

The size grade data provided by three North Island processors provide a breakdown of the proportions of several size grades which can be arbitrarily defined as small, medium, and large (New Zealand eel Processing, Thomas Richard), or small and large (Vanderdrift). The historic data provided by New Zealand Eel Processing and Thomas Richard indicate that the proportions of these grades for both species have been reasonably constant over the last 3 years (see Figures 18, 19, 22, and 23). The proportion of large shortfin eels (over 1000 g) throughout the North Island in 2003–04 was reasonably consistent at between 9 and 16%. One of the main concerns regarding the sustainability of the longfin eel fishery is the potential for recruitment overfishing because of a decline in numbers of large females (Hoyle & Jellyman 2002). About one-third of longfins landed were large eels (over 1000 g or 1200 g) and about one-half were medium or larger (over 500 g). Because longfins above about 700 g weight are predominantly, if not exclusively, females, it follows that less than one-half and more than one-third of all longfins caught in 2003–04 were female, with the remainder being either male or female.

4.3.1 General comments

The collection of size grade data and species composition by location (QMA, ESA, subarea) serves to highlight how eel populations can vary within small geographic areas. For example, although ESA 4 generally had small eels, which were predominantly shortfin, there were several subareas within ESA 4 that had larger eels that were mainly longfins. Thus, the benefit of collecting landing data on a finer scale is that the relative catch contributions, species composition, and size ranges of eels from discrete catchments can be quantified. This could be potentially useful to fisheries managers who may wish to manage fisheries within each QMA using different strategies, such as closed areas, size limits, species or catch restrictions.

5. ACKNOWLEDGMENTS

This research was carried out by NIWA under contract to the Ministry of Fisheries (Project EEL2002/04). We are grateful to the following eel processors for providing catch data: Mossburn Enterprises Ltd. (Invercargill), New Zealand Eel Processing Co. Ltd (Te Kauwhata), Levin Eel Trading Co. Ltd (Levin), Thomas Richard & Co. Ltd (Whenuapai), and E.N. Vanderdrift (1987) Ltd (Stratford). We thank Victor Thompson and Mossburn Enterprises Ltd for their cooperation during the South Island catch sampling programme. We also thank NIWA staff Derck Kater for sampling eels catches, Reyn Naylor for reviewing the manuscript, and Mike Beardsell for editorial comments.

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Table 1: Strata sampled in 2003–04 with associated number of samples, landing weights, percent of the landing weight sampled, numbers of eels measured for length and weight, and the proportion of the total landed weight that was longfin eel (LFE).

				Longfin eel			Shortfin eel			
Catchment	Stratum location	Stratum	Number samples	Landing wt (kg)	% wt sampled	No. eels sampled	Landing wt (kg)	% wt sampled	No. eels sampled	% landing weight LFE
Waiau River	Mouth to Cliffden Bridge	1	1	43.8	83.9	112	2.1	83.9	2	95.4
	Cliffden Bridge to Mararoa Weir	2	2	506.0	17.5	234	0.0	–		100.0
	Lake Manpouri to Te Anau control gates	3	3	698.9	20.7	211	8.6	16.1	1	98.8
Monowai River	Tributary of Waiau River (stratum 2)	1	1	303.0	15.7	83	0.0	–		100.0
Oreti River	Mouth to Branxholme	1	2	416.9	25.0	298	18.6	15.0	4	95.7
	Branxholme to Centre Bush	2	2	447.8	20.7	304	0.0	–		100.0
	Above Centre Bush	3	1	172.0	32.6	126	0.0	–		100.0
Fox Creek	Tributary of Oreti River (stratum 3)	1	1	190.0	30.3	55	0.0	–		100.0
Little Creek	Tributary of Oreti River (stratum 3)	1	1	257.0	21.2	98	0.0	–		100.0
Mataura River	Mouth to Mataura Falls	1	6	648.5	44.8	946	5.8	51.7	5	99.1
	Mataura Falls to Waikaia Junction	2	3	809.4	29.2	405	10.5	40.0	4	98.7
Lowburn	Tributary of Mataura River (stratum 1)	1	1	374.3	12.1	75	62.6	12.1	8	85.7
Totals			24	4867.6		2947	108.2		24	

Table 2: Length, weight, regression coefficents, and condition indices for longfin eels in each stratum. s.e., standard error; –, insufficient data.

		Length (cm)				Weight (g)							Condition	
													Weight (g)	
Catchment	Stratum	N	Mean	s.e.	Range	N	Mean	s.e.	Range	a	b	r^2	at 45 cm	*K* (mean)
Waiau River	1	112	50.8	0.52	42–68	111	334.4	12.7	188–956	0.0020	3.056	0.92	222	2.46
	2	234	52.4	0.50	43–94	230	375.6	15.6	193–2000	0.0032	2.931	0.86	221	2.42
	3	211	61.3	0.80	45–105	208	692.4	32.4	223–3100	0.0013	3.170	0.96	228	2.65
Moūowai River	1	83	55.8	1.33	42–101	83	558.2	59.5	184–2900	0.0007	3.325	0.97	224	2.64
Oreti River	1	298	51.0	0.26	44–87	295	330.4	8.0	196–2100	0.0022	3.025	0.88	219	2.42
	2	304	49.2	0.23	41–92	302	291.5	6.2	180–1800	0.0055	2.788	0.87	222	2.40
	3	126	54.8	0.78	43–94	126	447.4	28.5	213–2400	0.0010	3.232	0.97	213	2.45
Fox Creek	1	55	74.0	1.54	50–97	53	1138.0	88.2	303–3600	0.0002	3.546	0.83	169	2.62
Little Creek	1	98	59.3	0.97	43–87	96	559.1	32.2	189–1600	0.0013	3.157	0.97	215	2.47
Mataura River	1	946	49.6	0.12	41–76	946	305.6	2.7	178–1140	0.0032	2.928	0.84	225	2.46
	2	405	60.4	0.47	45–105	400	621.1	19.4	232–3160	0.0011	3.208	0.95	218	2.56
Lowburn	1	75	60.5	1.13	49–94	71	602.9	43.7	266–2200	0.0016	3.106	0.97	223	2.53
Strata means			56.6				521.4						217	2.51
All eel means		2947	53.8	0.17	41–105	2921	428.0	5.9	178–3600	0.0013	3.15203	0.95	219	2.48

Table 3: Length, weight, and condition index for shortfin eels in each stratum. s.e., standard error; –, insufficient data.

		Length (cm)				Weight (g)			Condition
Catchment	Stratum	N	Mean	s.e.	Range	N	Mean	s.e.	Range	K (mean)
Waiau River	1	2	77.8	4.75	73–82	2	924.9	204.9	720–1130	–
	2									
	3	1	87.5	–	–	1	1444.6	–	–	–
Monowai River	1	0	–	–	–	0	–	–	–	–
Oreti River	1	4	67.8	4.68	60–81	4	681.5	156.5	420–1099	–
	2	0	–	–	–	0	–	–	–	–
	3	0	–	–	–	0	–	–	–	–
Fox Creek	1	0	–	–	–	0	–	–	–	–
Little Creek	1	0	–	–	–	0	–	–	–	–
Mataura River	1	5	66.5	4.14	54–79	5	620.1	151.5	318–1175	–
	2	4	77.2	8.67	60–93	4	1050.2	324.9	426–1850	–
Lowburn	1	8	74.7	2.76	60–87	8	934.0	103.5	448–1401	–
Strata means			75.2				942.5			
All eel means		24	73.0	2.19	54–93	24	866.4	81.4	318–1850	2.08

Table 4: Percentage of longfin and shortfin eels (numbers) in each stratum that were male (M), female (F), or immature (I). –, no data.

		Longfins					Shortfins				
		Percent sex			Numbers		Percent sex			Numbers	
Catchment	Stratum	Male	Female	Immature	Unsexed	Total	Male	Female	Immature	Unsexed	Total
Waiau River	1	8.1	24.3	67.6	1	112	0.0	100	0.0	0	2
	2	12.4	25.3	62.2	17	234	0.0	100	0.0	0	
	3	28.9	42.8	28.3	38.0	211	0.0	100	0.0	0	1
Monowai River	1	33.8	23.0	43.2	9.0	83	0.0	100	0.0	0	
Oreti River	1	41.0	24.5	34.5	8.0	298	0.0	100	0.0	0	4
	2	28.6	7.4	64.0	7.0	304	0.0	100	0.0	0	
	3	32.0	18.9	49.2	4.0	126	0.0	100	0.0	0	
Fox Creek	1	3.3	96.7	0.0	25.0	55	0.0	100	0.0	0	
Little Creek	1	49.4	19.5	31.0	11.0	98	0.0	100	0.0	0	
Mataura River	1	28.1	8.9	63.0	17.0	946	0.0	100	0.0	0	5
	2	34.5	40.4	25.1	34.0	405	0.0	100	0.0	0	4
Lowburn	1	37.9	28.8	33.3	9.0	75	0.0	100	0.0	0	8
Strata means		28	30	42			0	100	0		
All eels means		29.3	21.2	49.4	180	2947	0.0	100	0.0	0	24

Table 5: Mean length of eels grouped by gonad stage.

	Indeterminate sex		Male		Female	
Gonad stage	Mean length (cm)	N	Mean length (cm)	N	Mean length (cm)	N
Longfin						
Immature	48.6	1638	–	–	–	–
1	–	–	52.0	697	55.7	317
2	–	–	59.4	103	64.1	184
3	–	–	64.8	11	73.1	63
4	–	–	52.5	1	87.1	12
Totals		1638		812		576
Shortfin						
Immature	–	0	–	–	–	–
1	–	0	–	0	67.9	12
2	–	0	–	0	76.0	10
3	–	0	–	0	90.0	2
4	–	0	–	0	–	0
Totals		0		0		24

Table 6: Longfin eel size grades used by Mossburn Enterprises and the conversions from imperial to metric unit. Shortfin size grades are identical except for the < 1 lb and 1–2 lb grades where they have used < 500 g and 500–900 g, respectively.

		Size grade
(lbs)	(g)	Rounded (g)
< 1	< 454	< 450
1–2	454–908	450–900
2–3	909–1362	901–1360
3–4	1363–1816	1361–1800
4–5	1817–2270	1801–2270
5–7	2271–3178	2271–3200
> 7	> 3178	> 3200

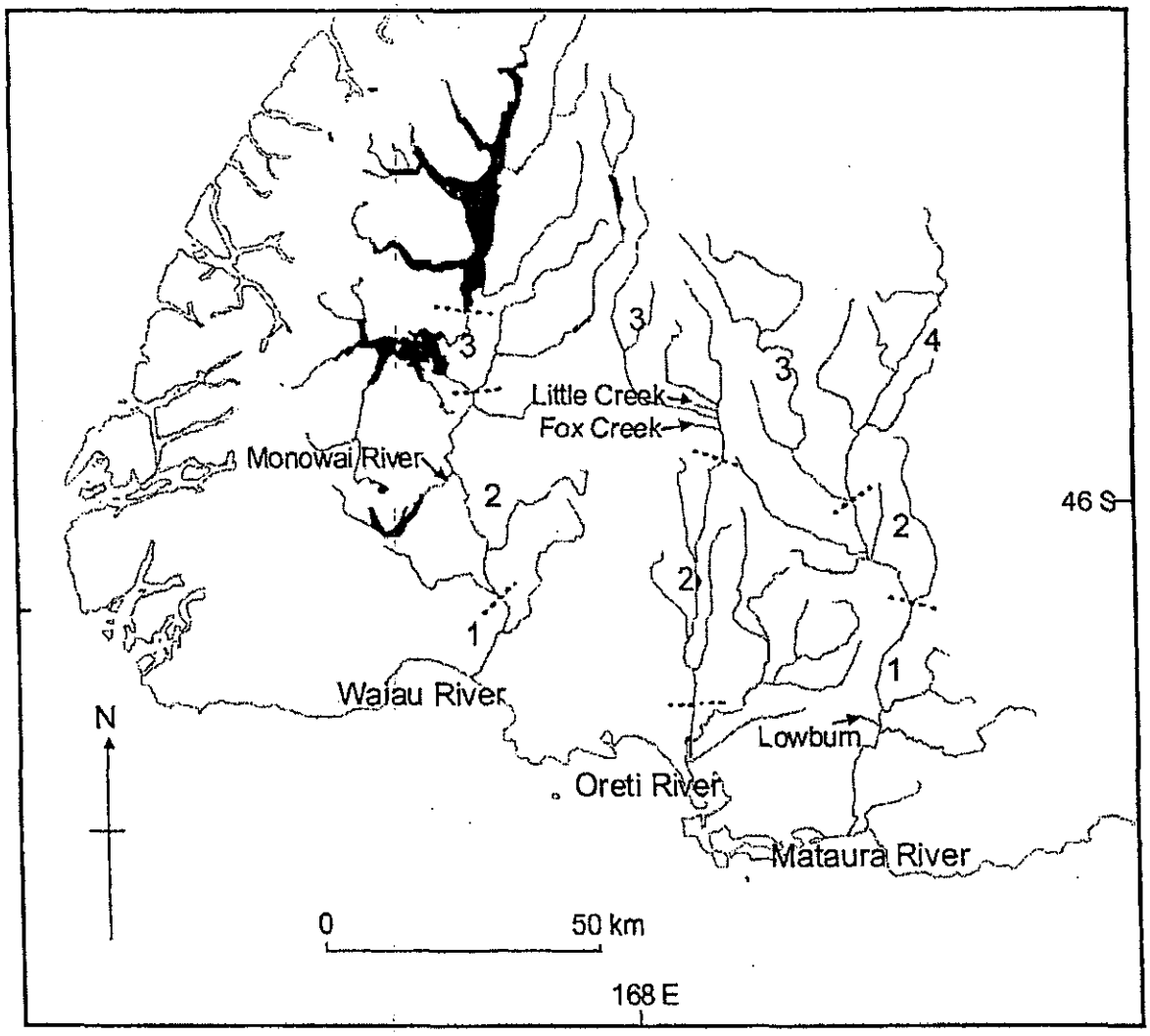


Figure 1: Map of lower South Island showing rivers and strata sampled.

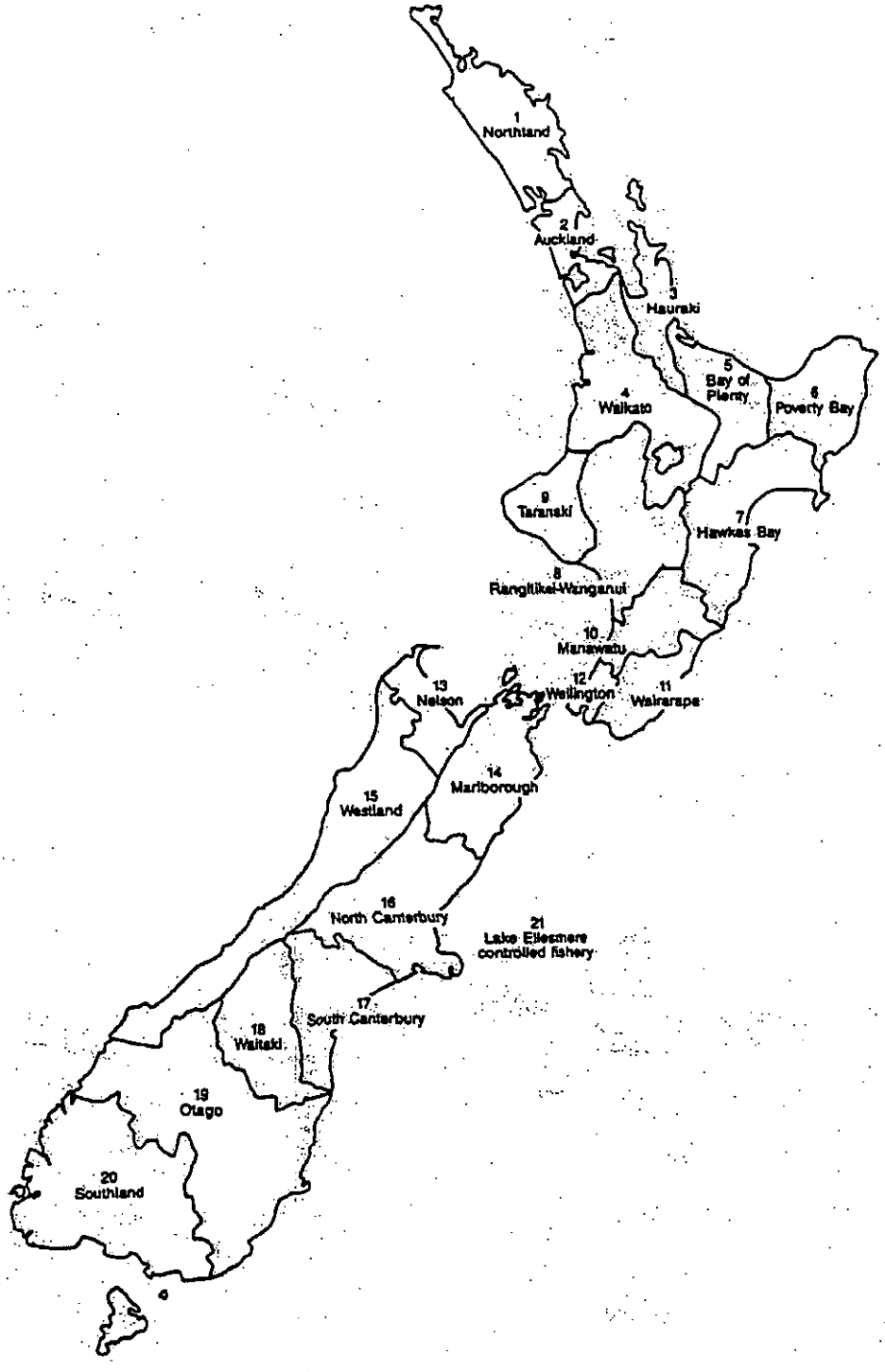


Figure 2. Eel Return Areas (ERAs).

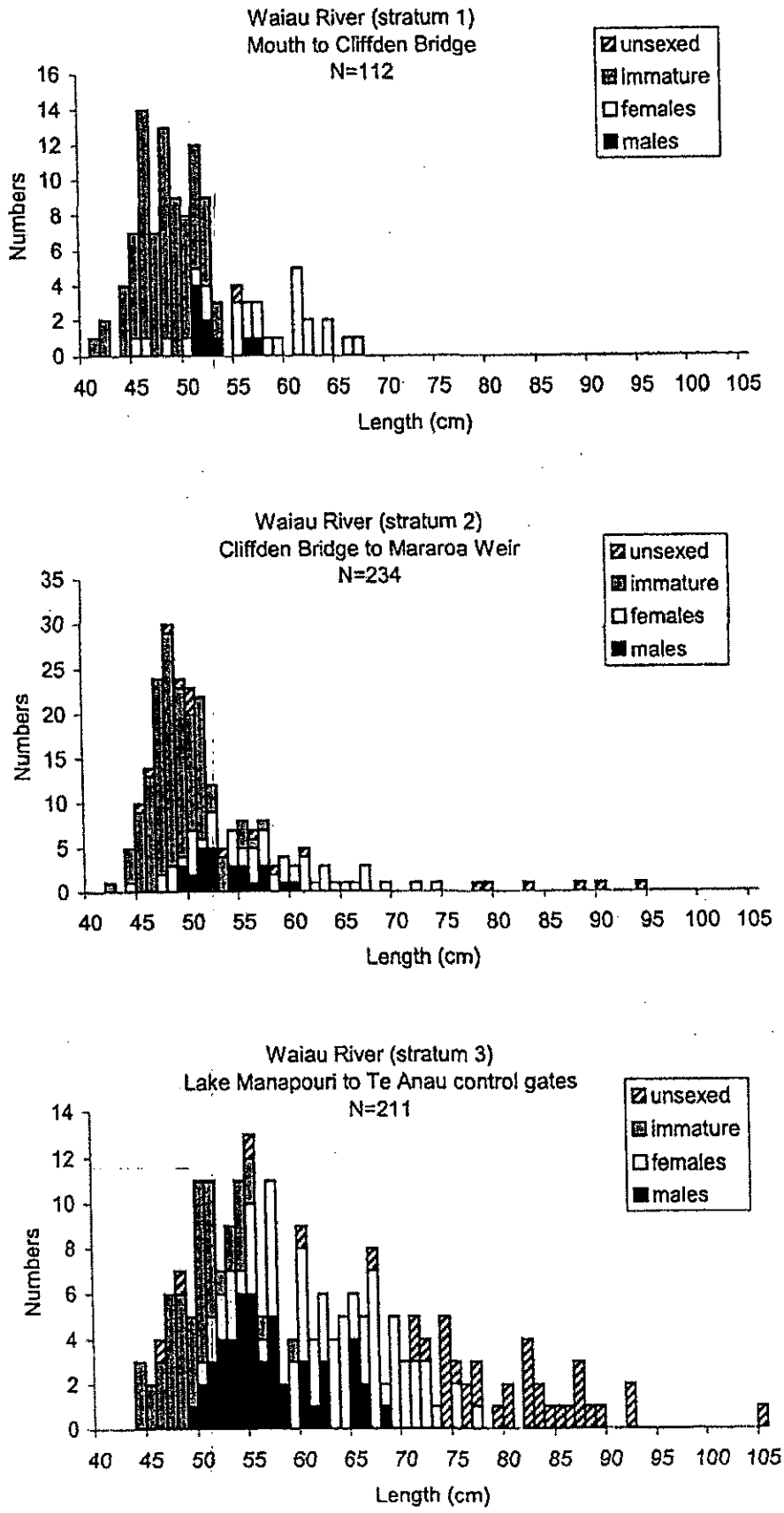


Figure 3: Length frequency distributions of longfin eels.

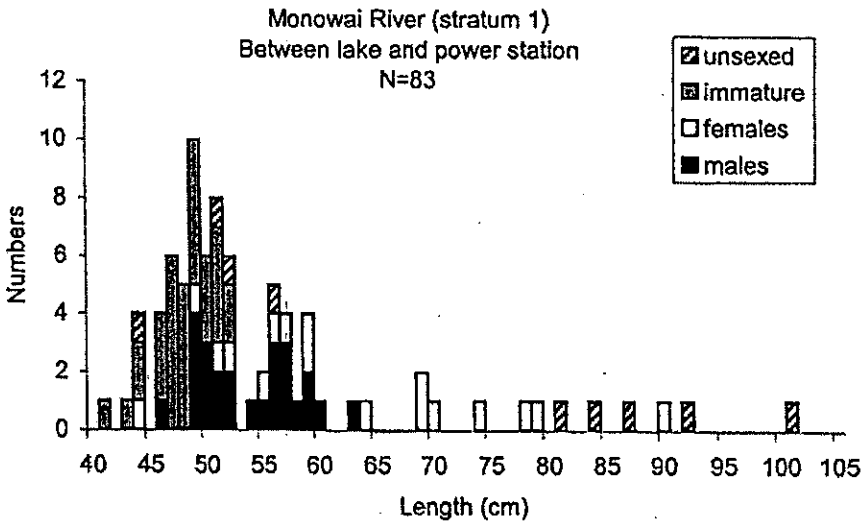


Figure 3 -- *continued*

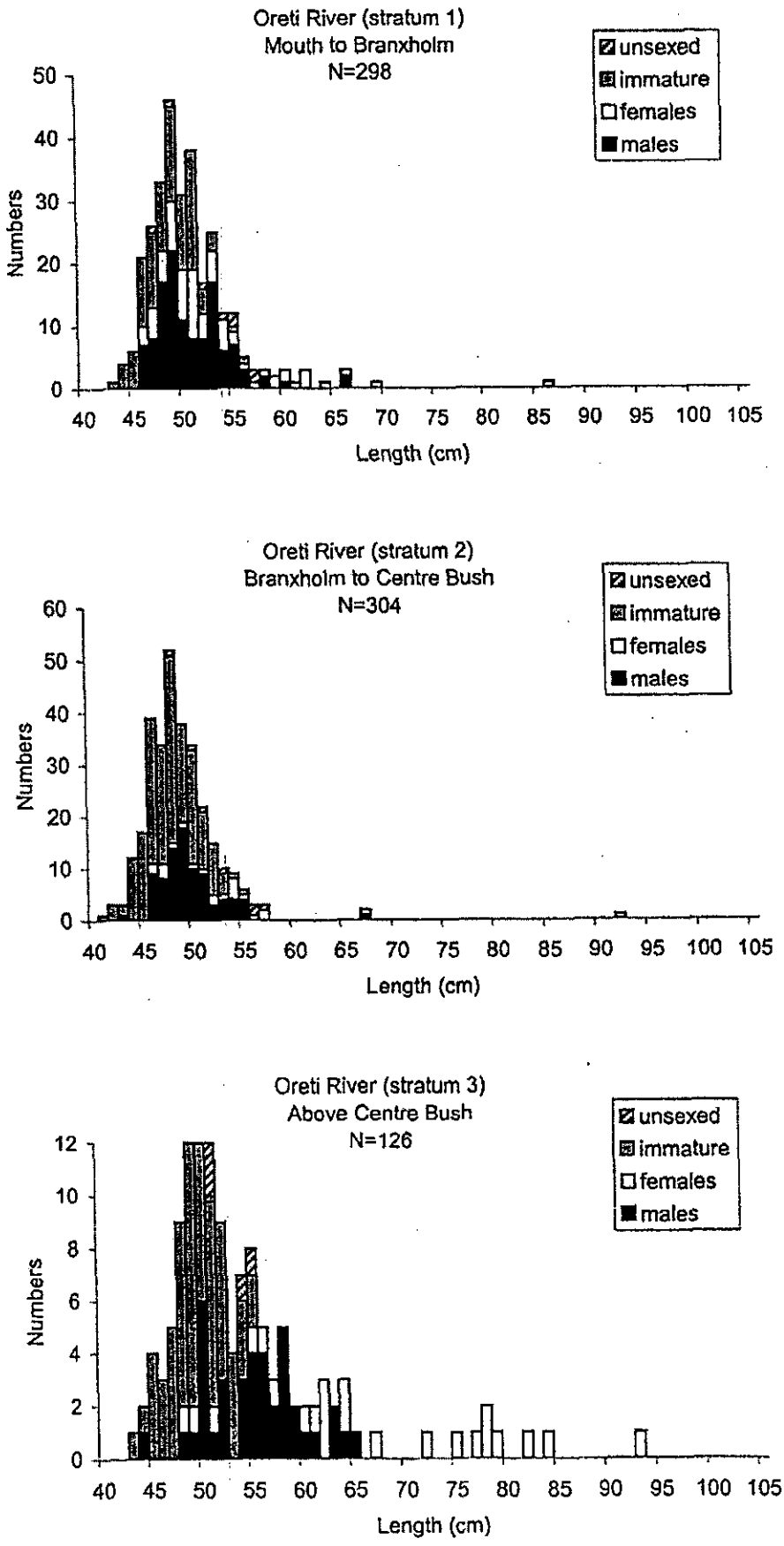


Figure 3 – *continued*

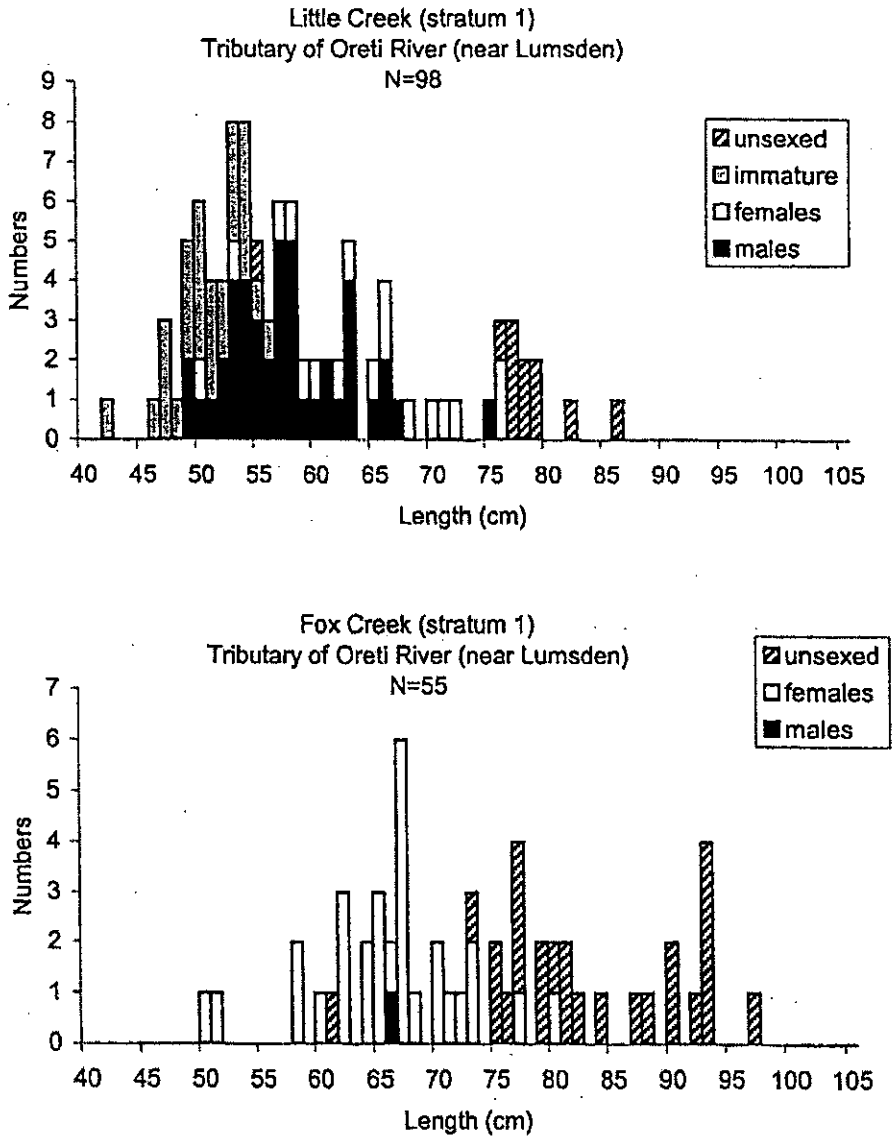


Figure 3 – ***continued***

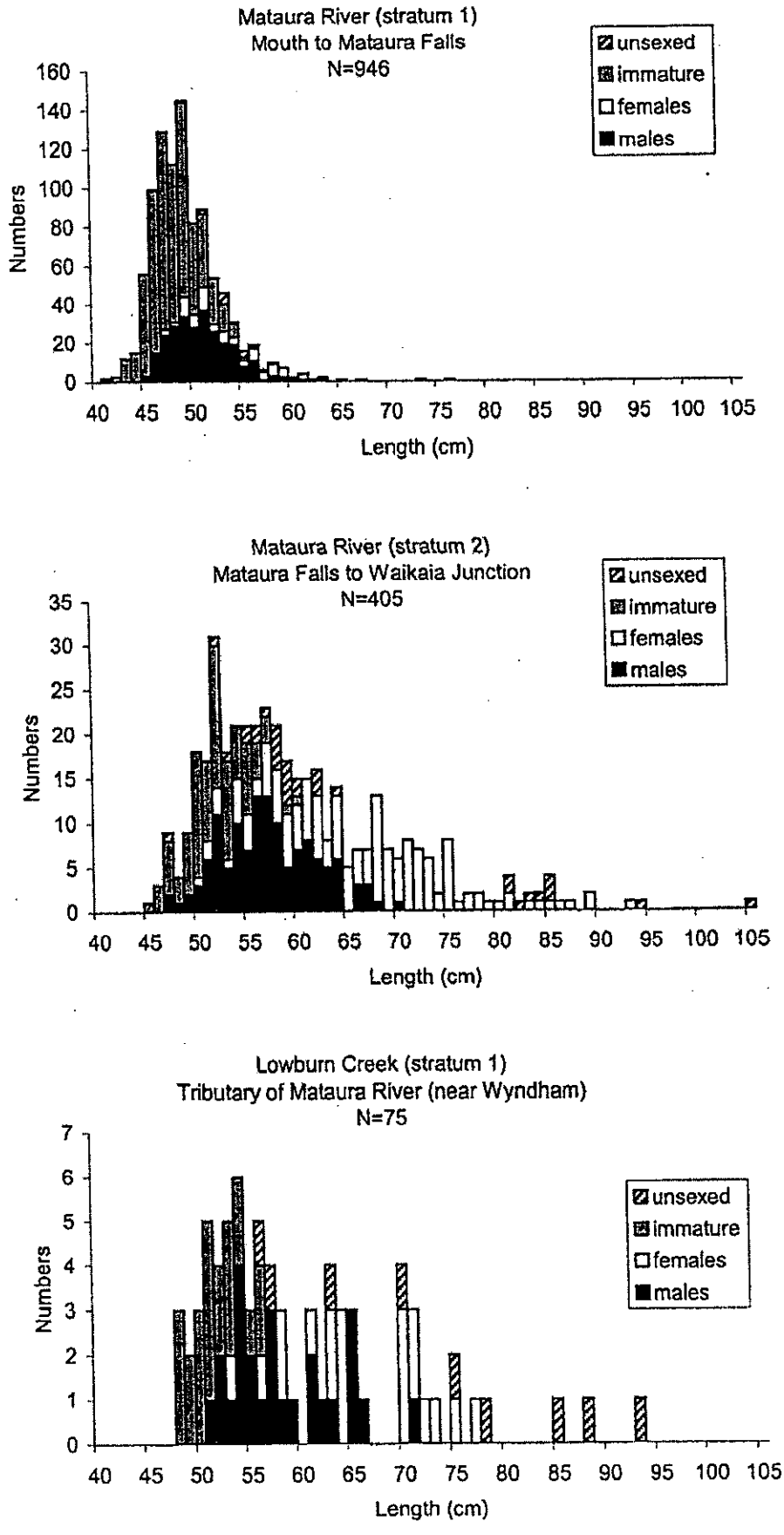


Figure 3 – ***continued***

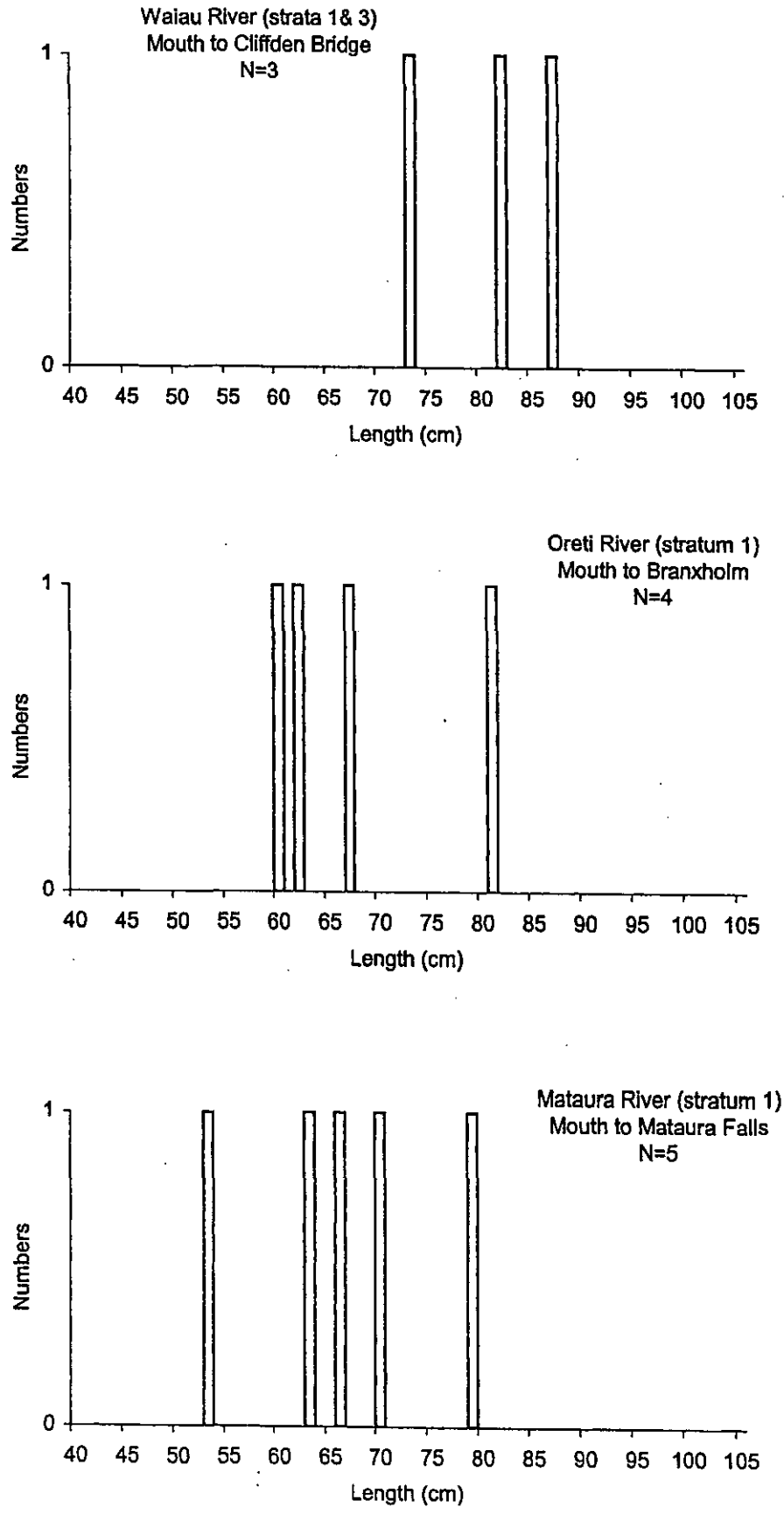


Figure 4: Length frequency distributions of female shortfin eels.

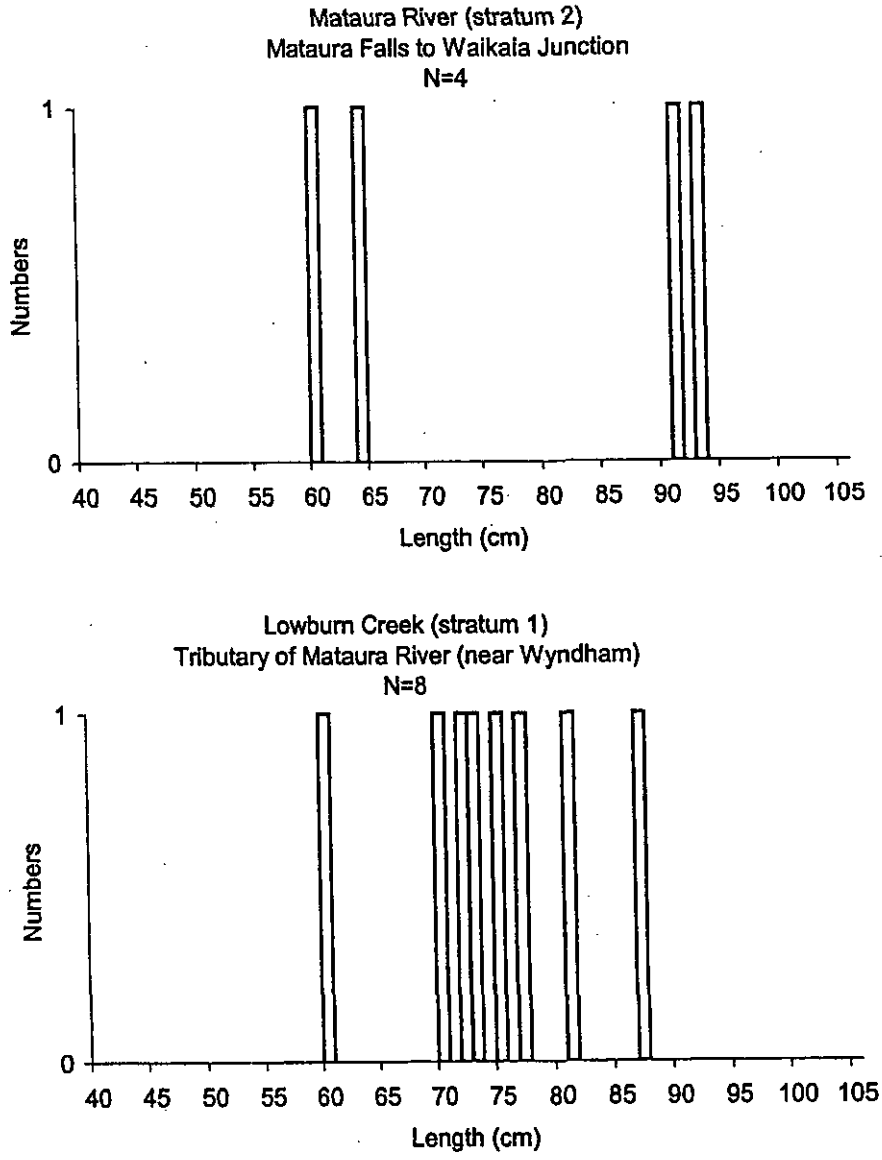


Figure 4 – *continued*

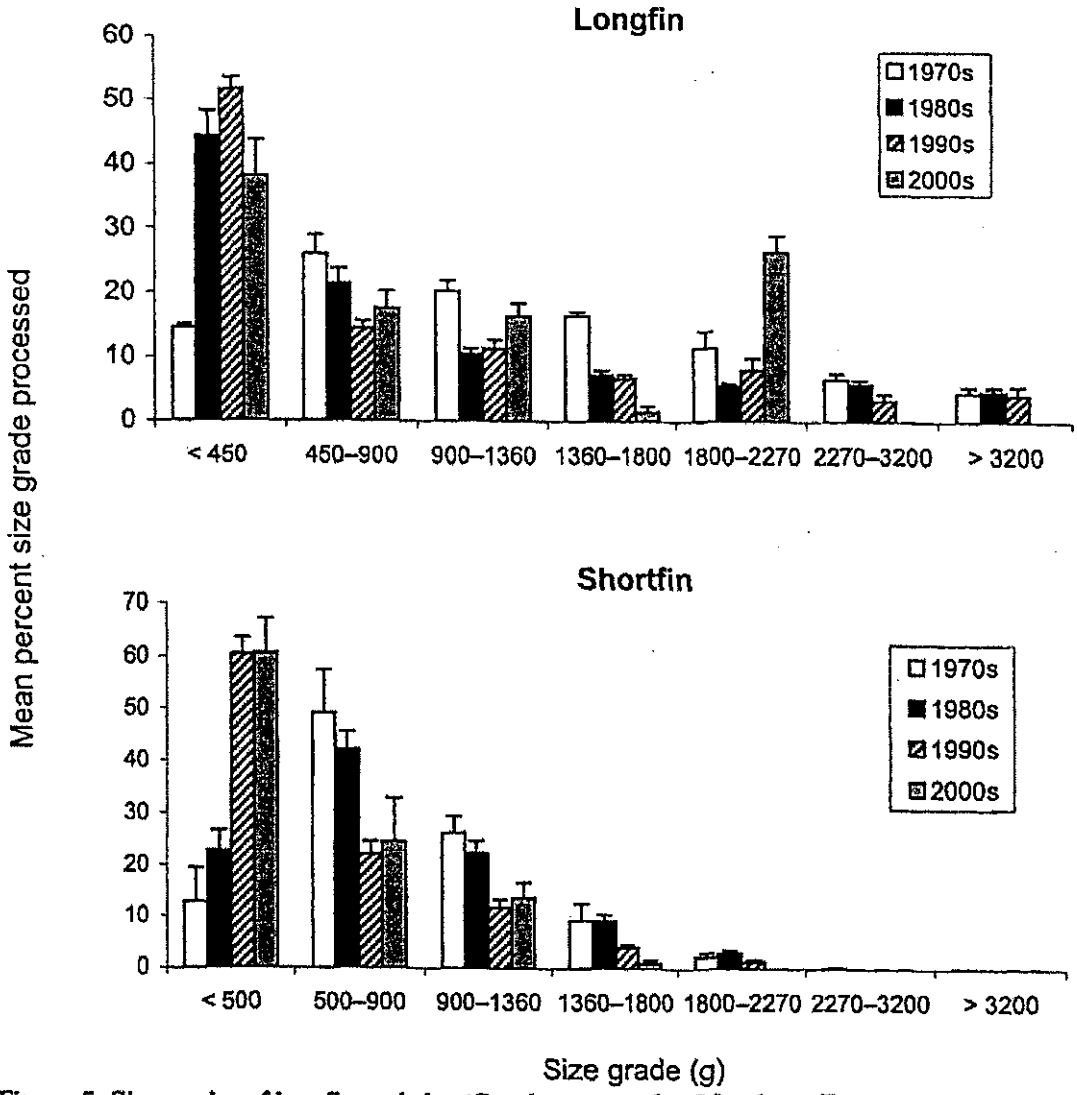


Figure 5: Size grades of longfin and shortfineels processed at Mossburn Enterprises (Invercargill) in the 1970s, 1980s, 1990s, and 2000s. 1970s years: 1974–75, 1977–78 and 1978–79; 1980s years: 1983–84 to 1988–89; 1990s years: 1989–90 to 1998–99: 2000s years: 1999–2000 to 2002–03. Error bars represent standard errors.

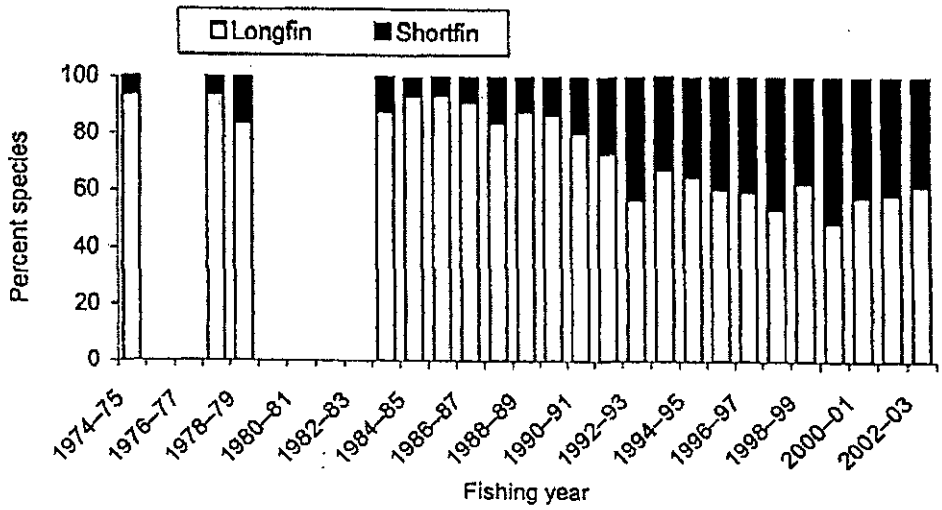


Figure 6: Proportion of longfin and shortfin eels processed at Mossburn Enterprises Ltd (Invercargill) from 1974–75 to 2002–03 fishing years.

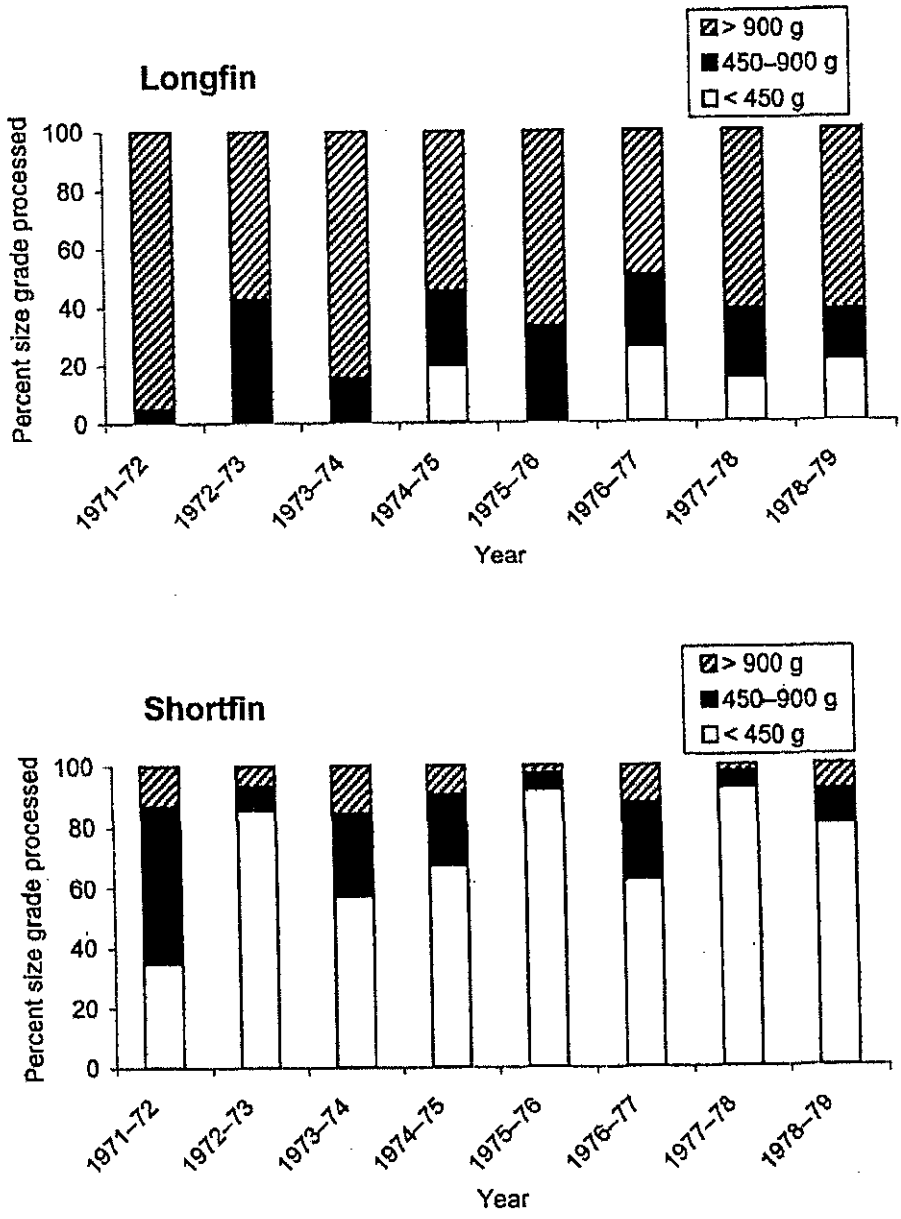


Figure 7: Size grades of longfin and shortfin eels processed by Wilson Neill Ltd 1971–72 to 1978–79 (1 April–31 March).

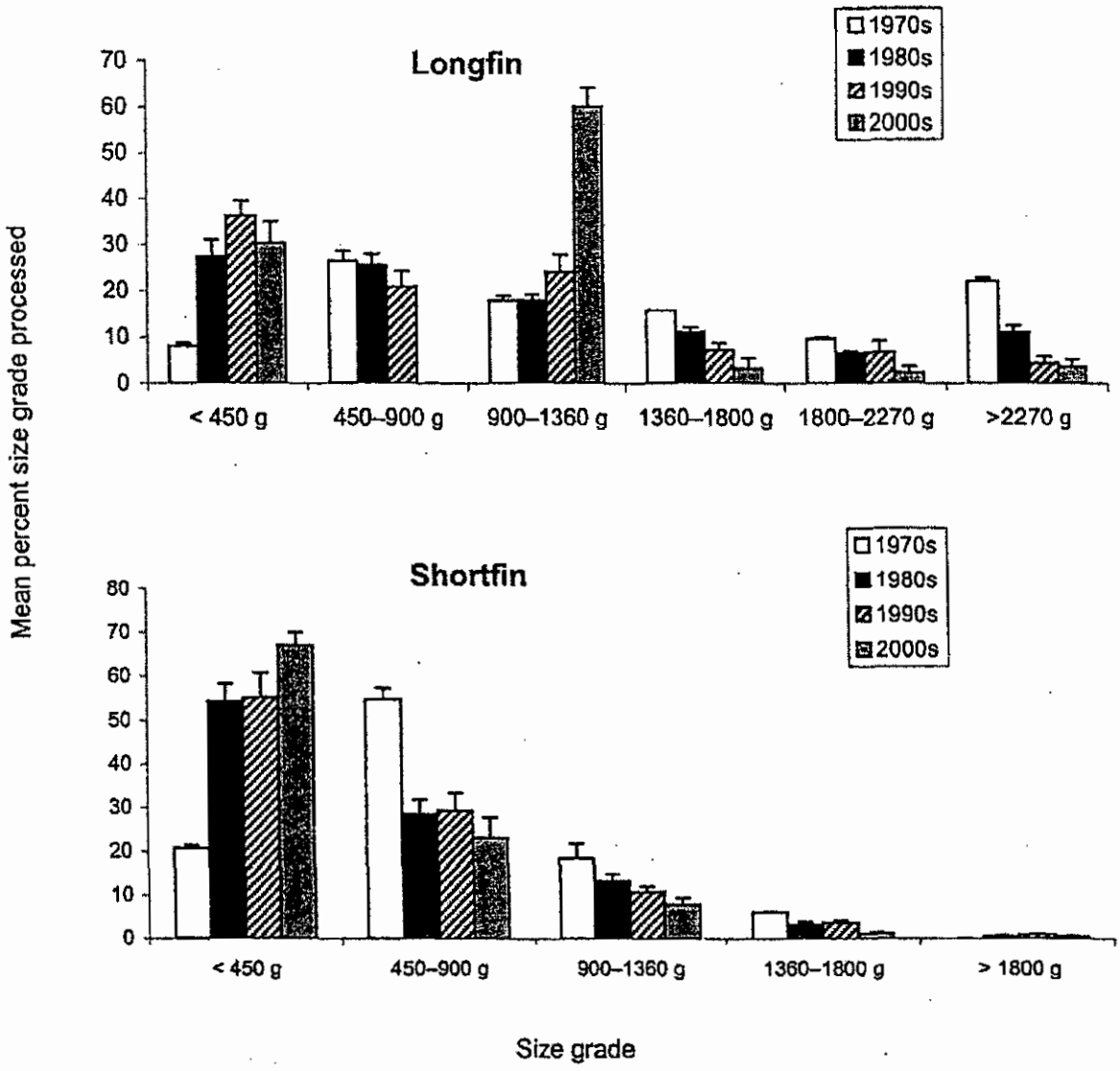


Figure 8: Size grades of longfin and shortfin eels processed at Levin Eel Trading Co. Ltd. In the 1970s, 1980s, 1990s, and 2000s. 1970s years: 1978–79 and 1979–80; 1980s years: 1980–81 to 1989–90; 1990s years 1990–91 to 1999–2000; 2000s years: 2000–01 to 2002–03. Error bars represent standard errors.

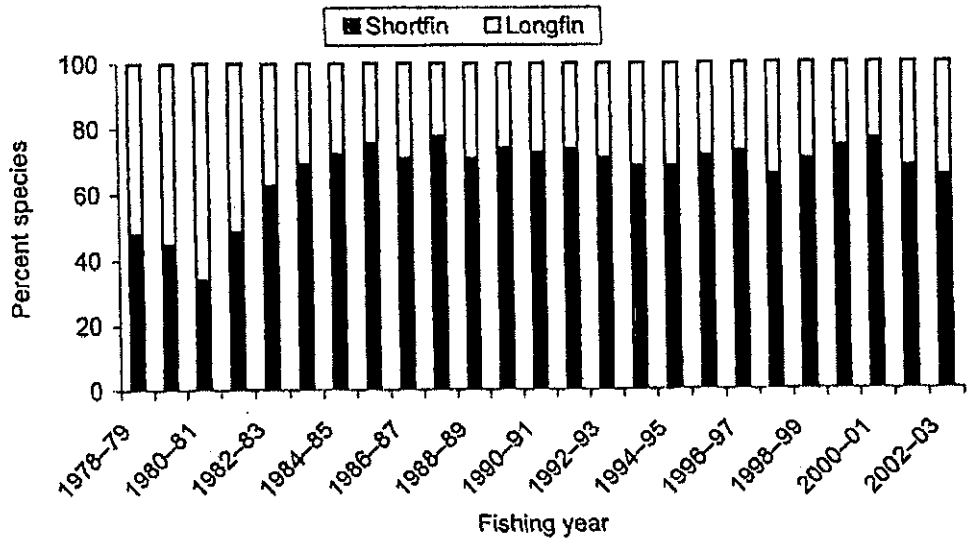


Figure 9: proportion of longfin and shortfin eels processed at Levin Eel Trading Co. Ltd. from 1978–79 to 2003–03.

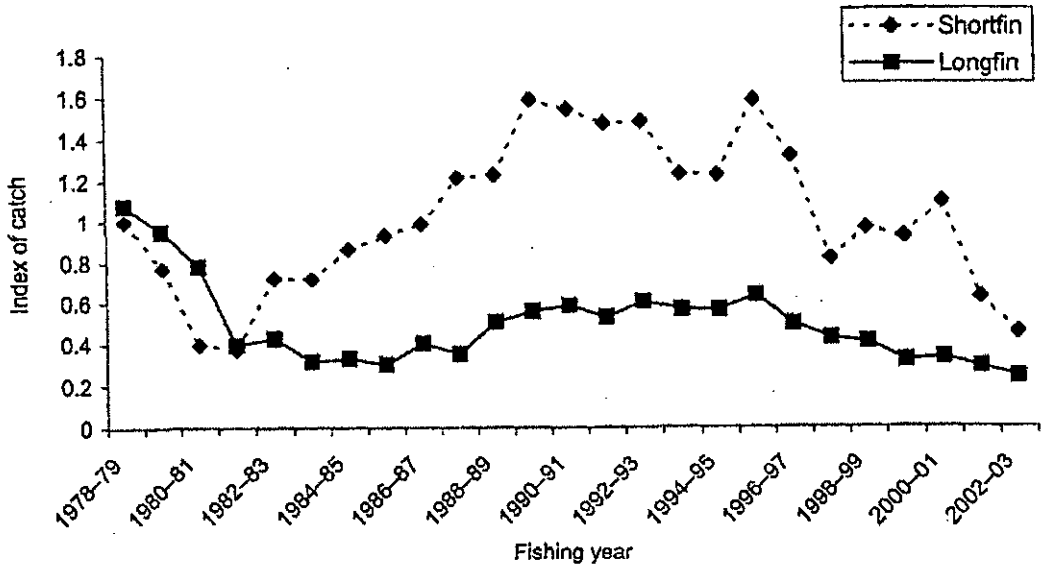


Figure 10: Index of catch for longfin and shortfin eels processed at Levin Eel Trading Co. Ltd between 1978–79 and 2002–03. Data are standardised to catch of shortfin in 1978–79.

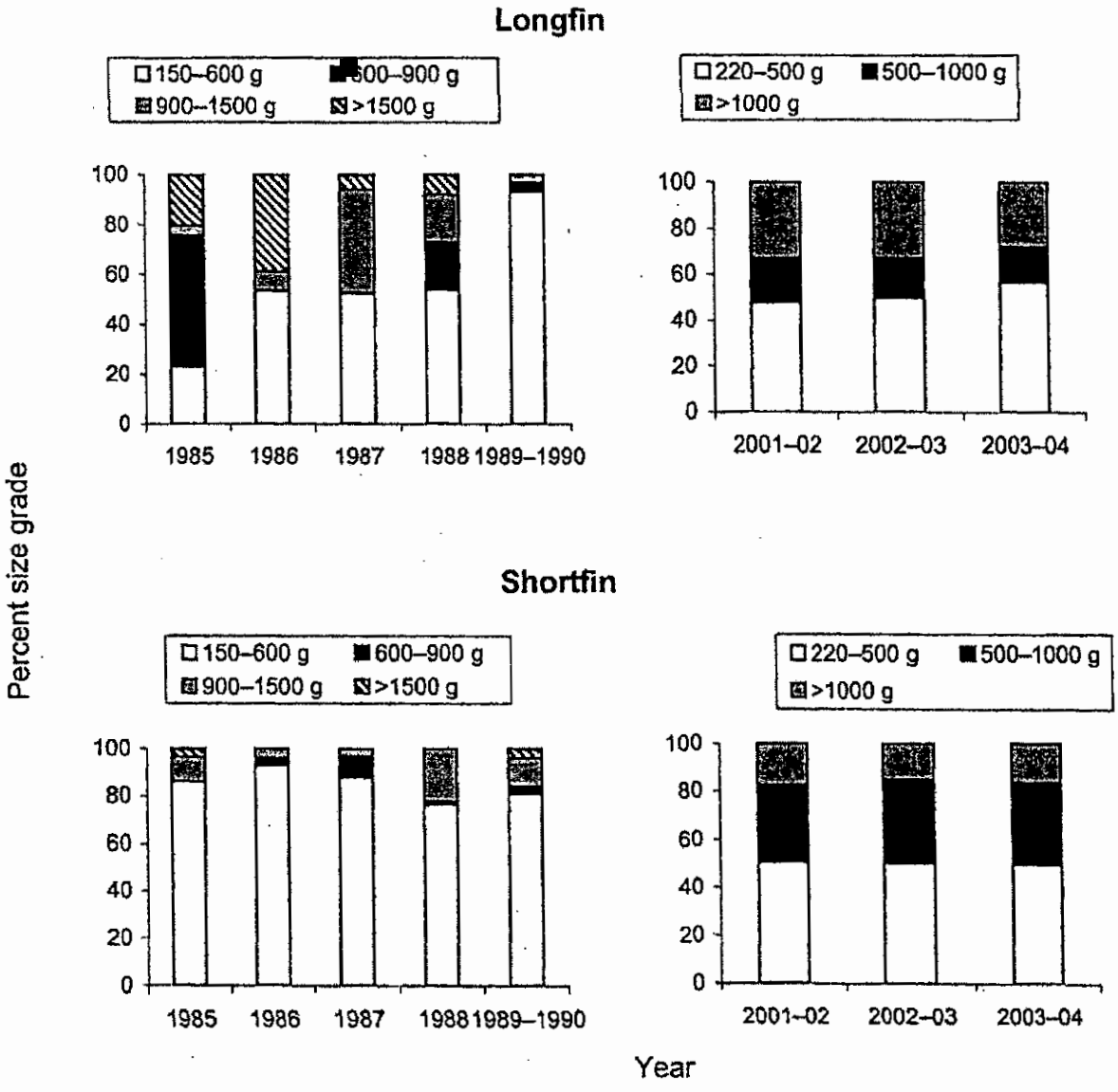


Figure 11: Size grades of longfin and shortfin eels processed by Thomas Richard & Co. Ltd. Graphs on the left are for 1985 to 1989–90, and those on the right from 2001–02 to 2003–04 (2003–04 from 1 Oct 2003–30 April 2004). Note the different size grades between these periods.

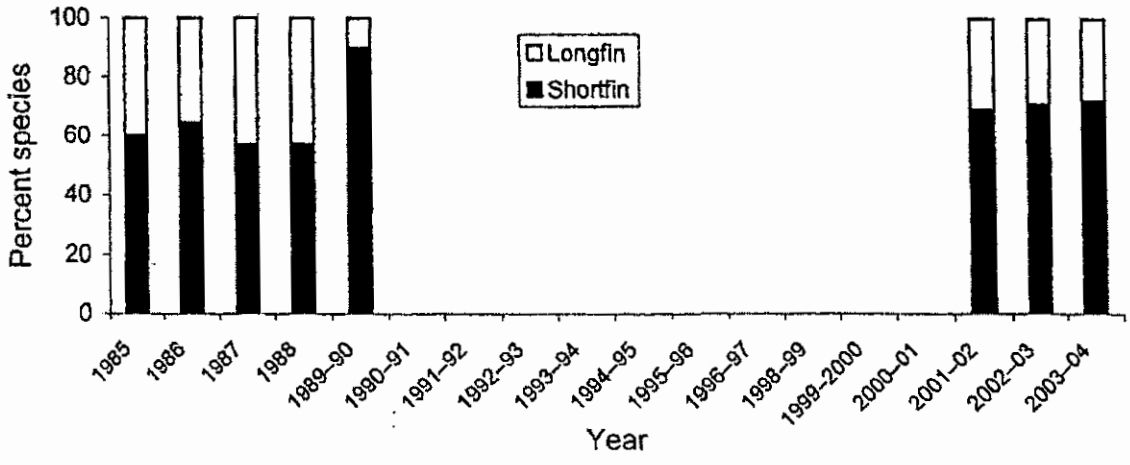


Figure 12: Proportion of longfin and shortfin eel processed by Thomas Richard & Co. Ltd for 1985 to 1989–90 and 2001–02 to 2003–04. (2003–04 from 1 Oct 2003–30 April 2004).

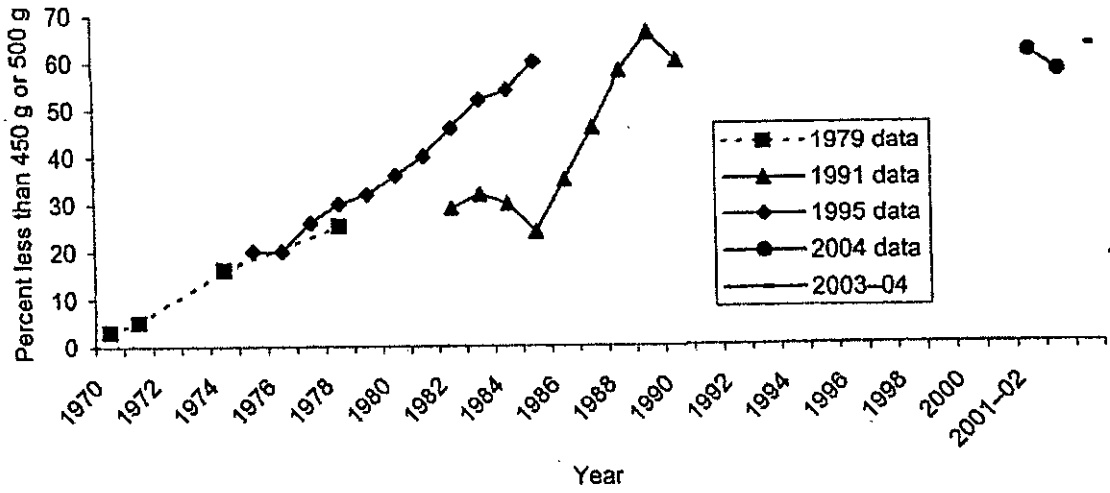


Figure 13: Proportion of eels (shortfin and longfin combined) less than 454 g (1979 and 1995 data) and less than 500 g (1991, 2004 and 2003–04 data) processed at New Zealand Eel Processing Co. Ltd. 2003–04 from 1 Oct 2004–30 Apr 2004.

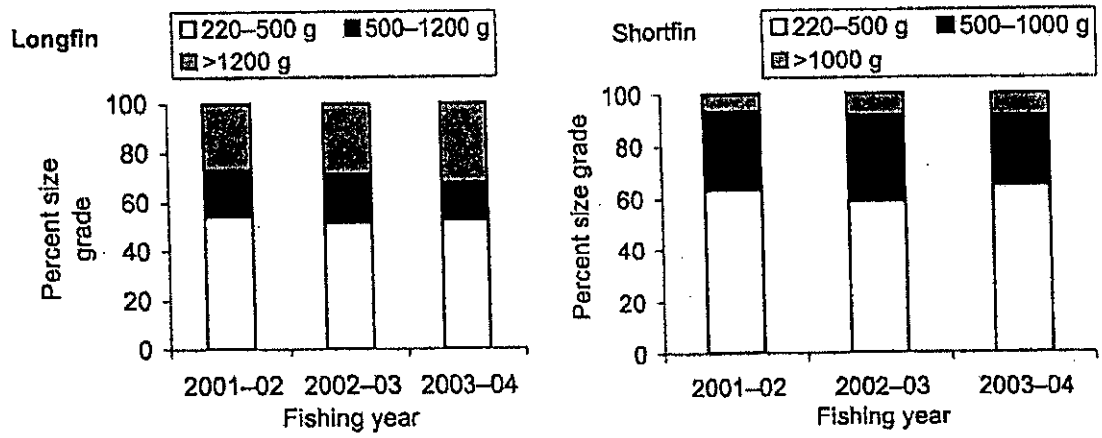


Figure 14: Proportion of longfin and shortfin eels in three size grades processed at New Zealand Eel Processing Co. Ltd. from 2001–02 to 2003–04 (1 Oct 2003–30 Apr 2004).

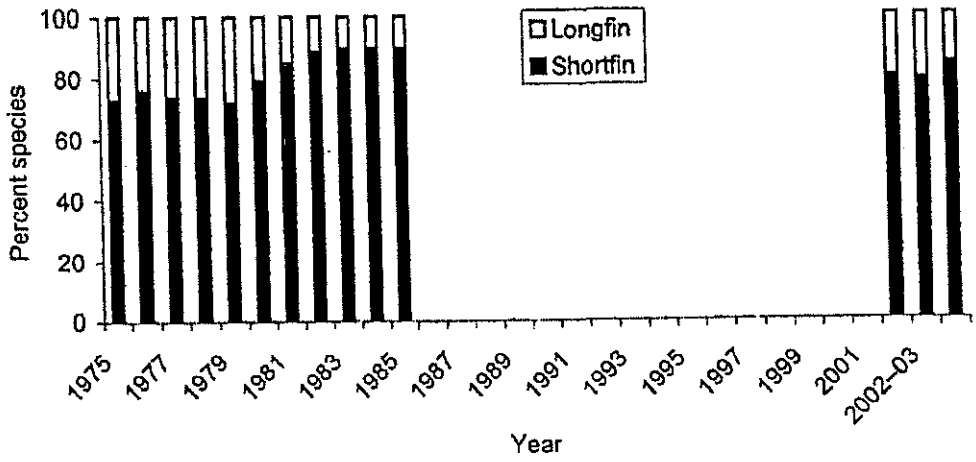


Figure 15: Proportion of longfin and shortfin eel processed at at New Zealand Eel Processing Co. Ltd. (Te Kauwhata) from 1975 to 1985, and 2001–02 to 2003–04 (1 Oct 2003–30 Apr 2004).

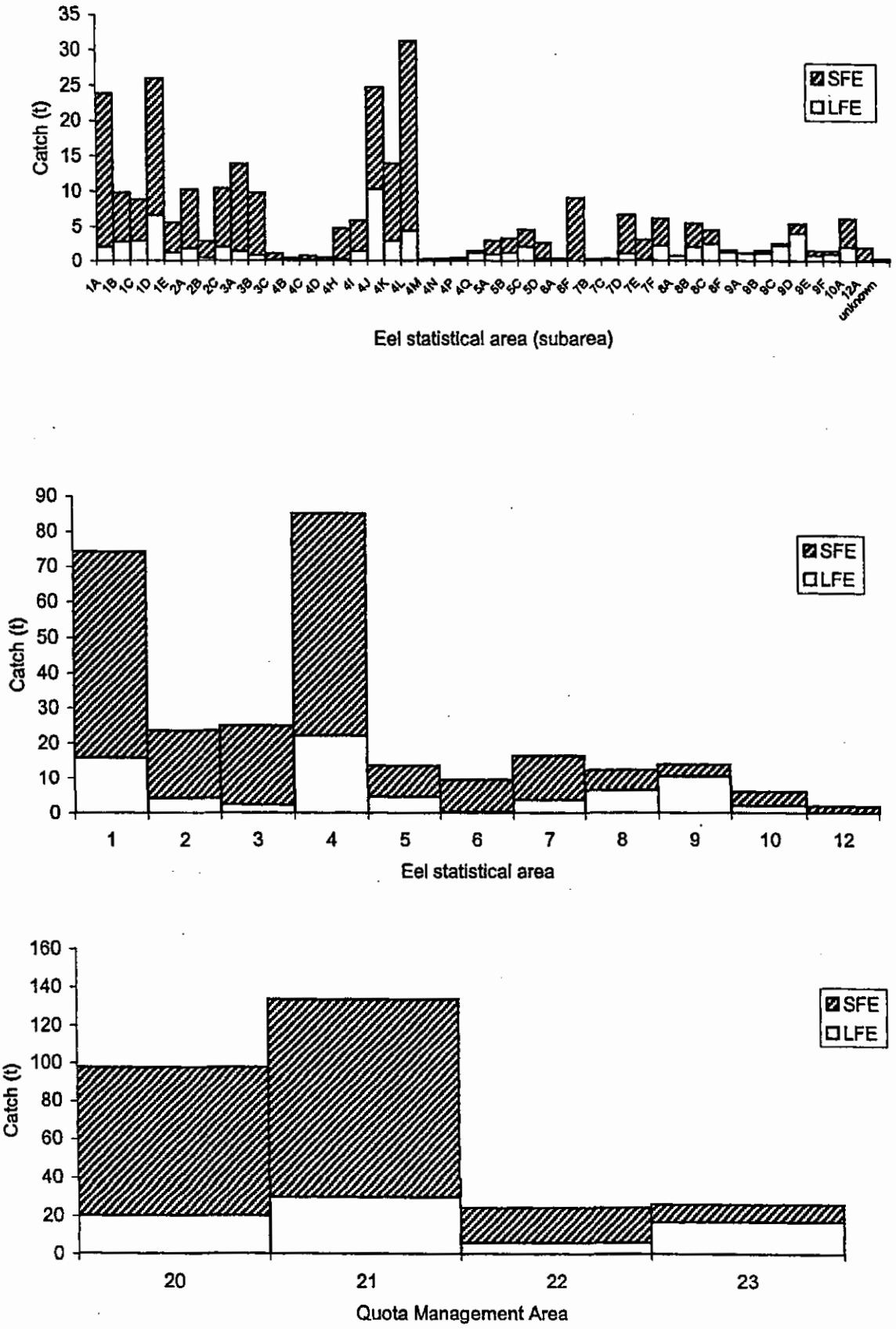


Figure 16: Catch of shortfin (SFE) and longfin (LFE) eels by three North Island eel processors (Thomas Richard, Vanderdrift, New Zealand Eel) from 1 October 2003 to 30 April 2004. Data are from processors' landing records and include 73 t of longfin and 209 t of shortfin from 963 landings. Overall proportion of shortfin was 74%.

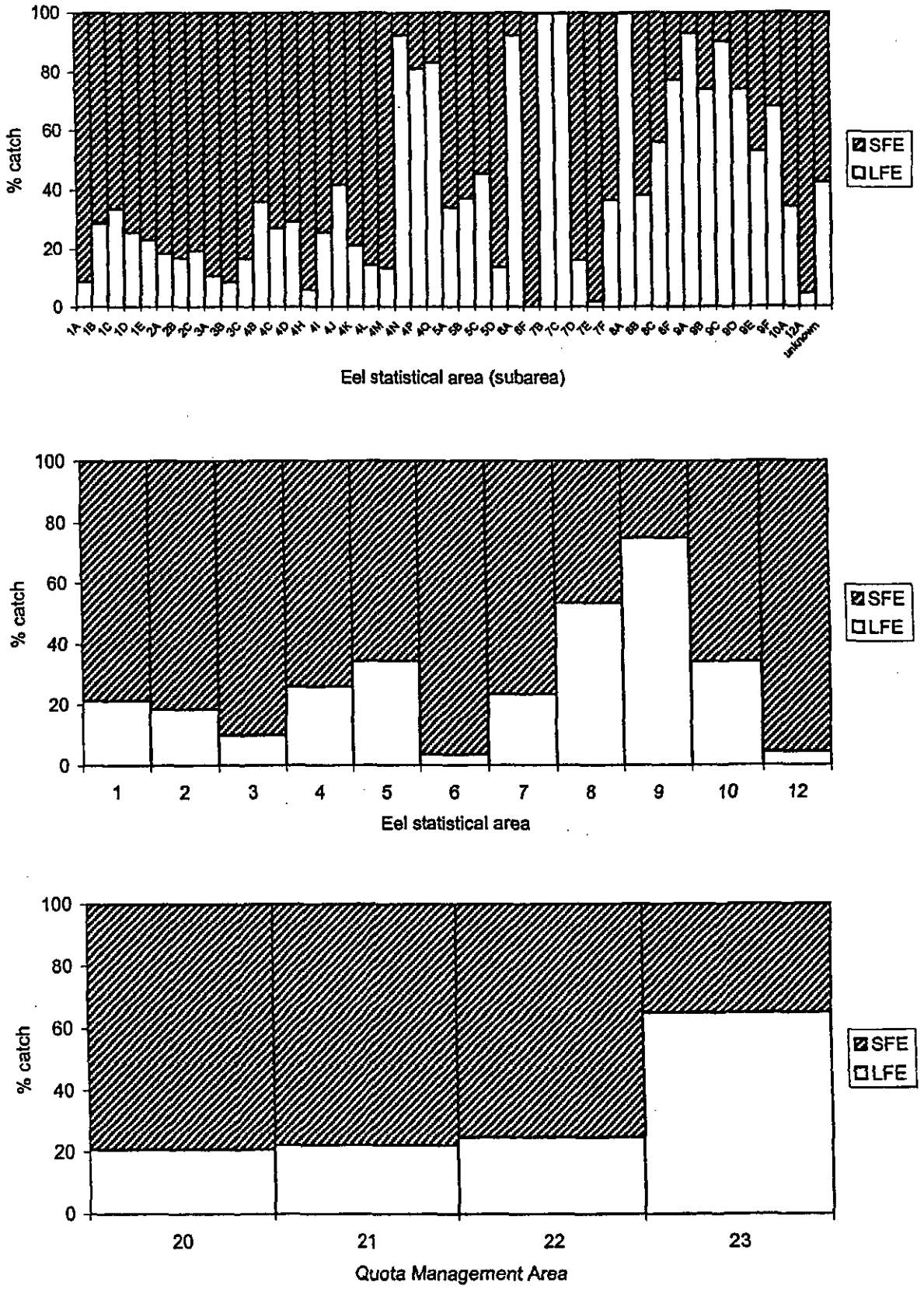


Figure 17: Species composition of shortfin (SFE) and longfin (LFE) eels from three North Island eel processors (Thomas Richard, Vanderdrift, New Zealand Eel) from 1 October 2003 to 30 April 2004. Data are from processors' landing records and include 73 t of longfin and 209 t of shortfin from 963 landings. Overall proportion of shortfin was 74%.

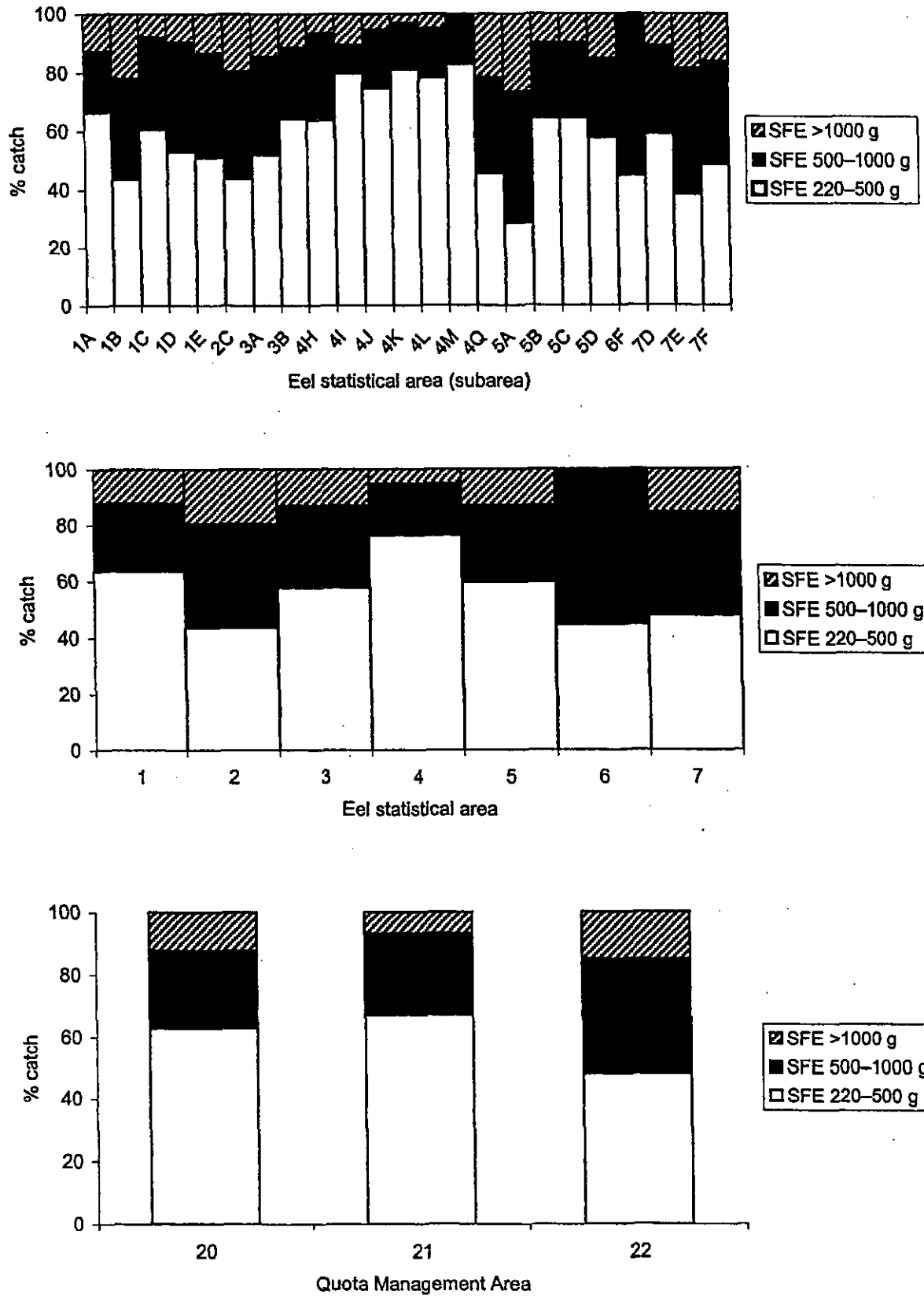


Figure 18: Proportion of shortfin (SFE) catch in three size grades, by area, processed by New Zealand Eel Processing Co. Ltd from 1 October 2003 to 30 April 2004. Data are from processor's landing records. Overall proportions of SFE in size grades were 220–500 g, 64.7%; 500–1000 g, 26.7%; over 1000 g, 8.6%.

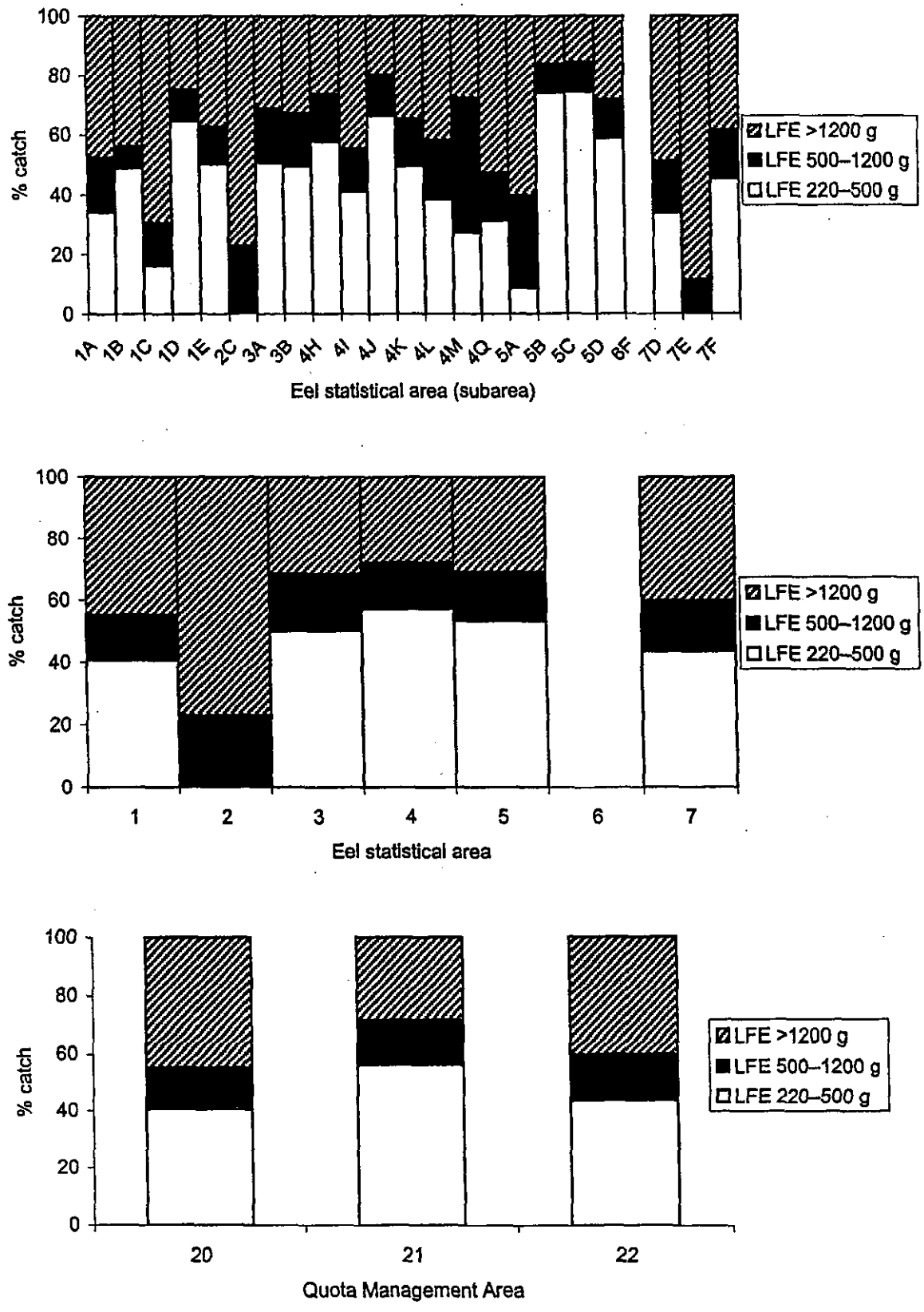


Figure 19: Proportion of longfin (LFE) catch in three size grades, by area, processed by New Zealand Eel Processing Co. Ltd from 1 October 2003 to 30 April 2004. Data are from processor's landing records. Overall proportions of LFE in size grades were 220–500 g, 52.4%; 500–1200 g, 15.5%; over 1200 g, 32.0%.

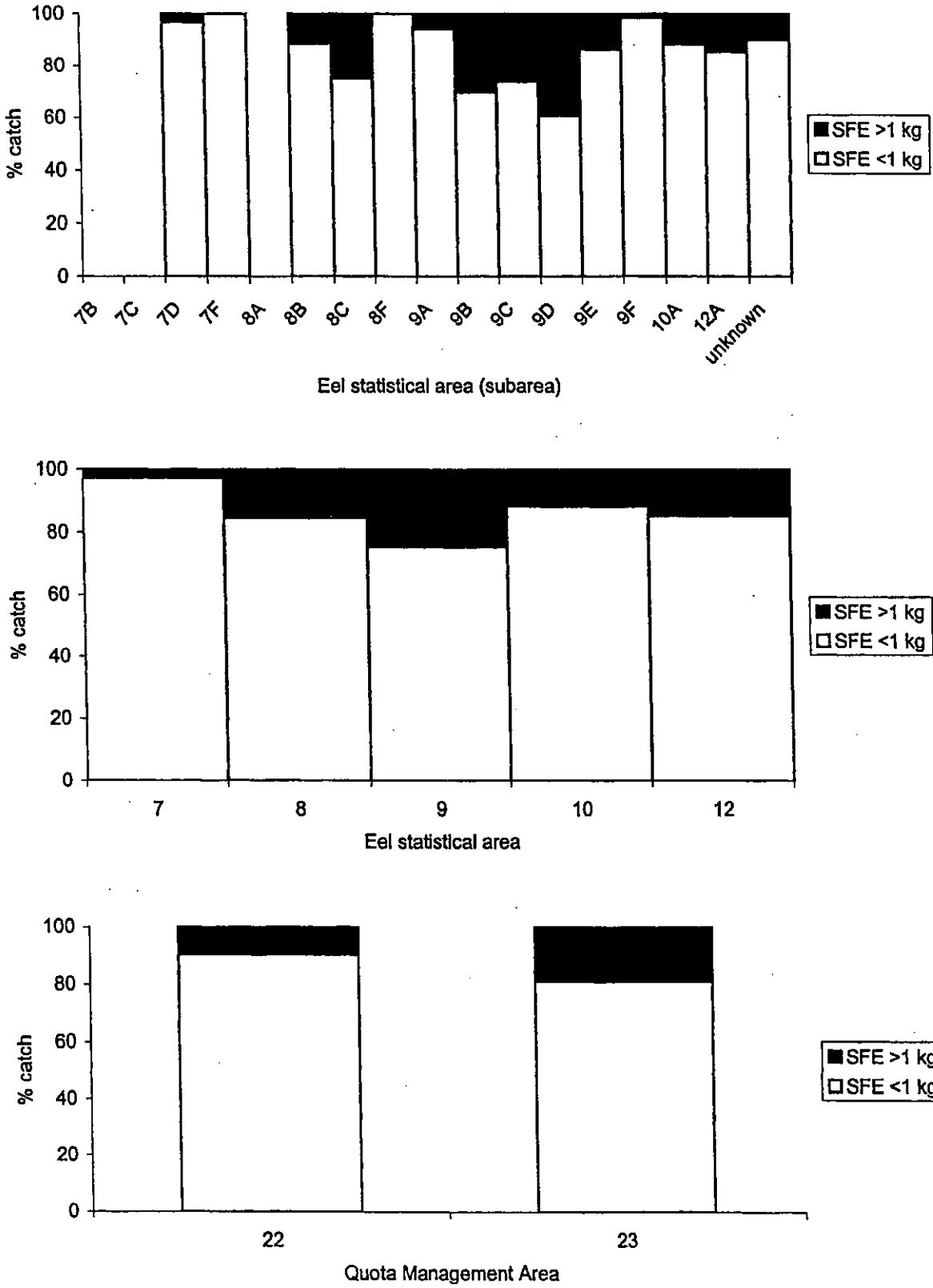


Figure 20: Proportion of shortfin (SFE) catch over and under 1 kg, by area, from Vanderdrift Ltd from 1 October 2003 to 30 April 2004. Data are from processor's landing records. Overall proportion of shortfin over 1 kg was 14%.

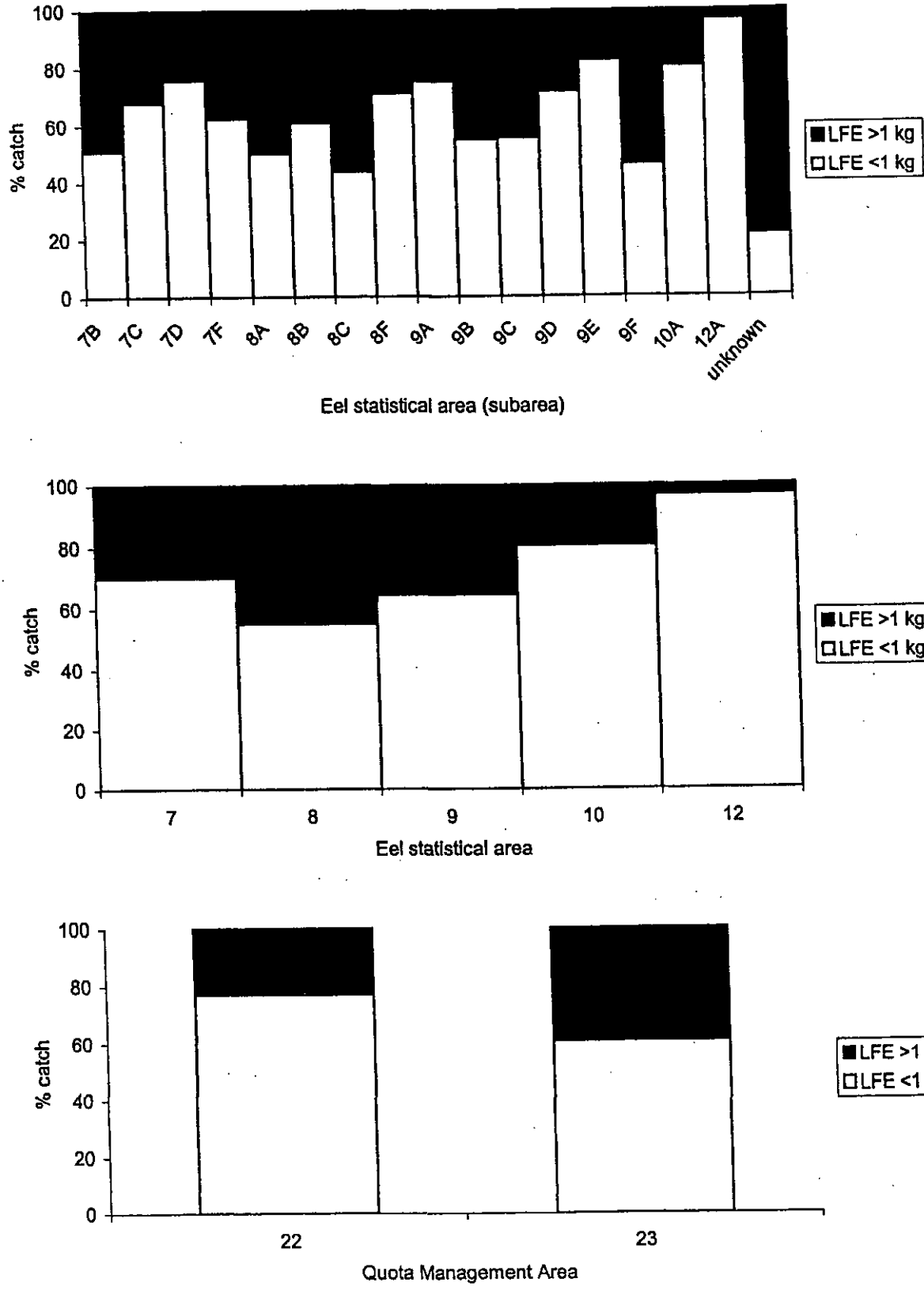


Figure 21: Proportion of longfin (LFE) catch over and under 1 kg, by area, from Vanderdrift Ltd from 1 October 2003 to 30 April 2004. Data are from processor's landing records. Overall proportion of longfin over 1 kg was 36%.

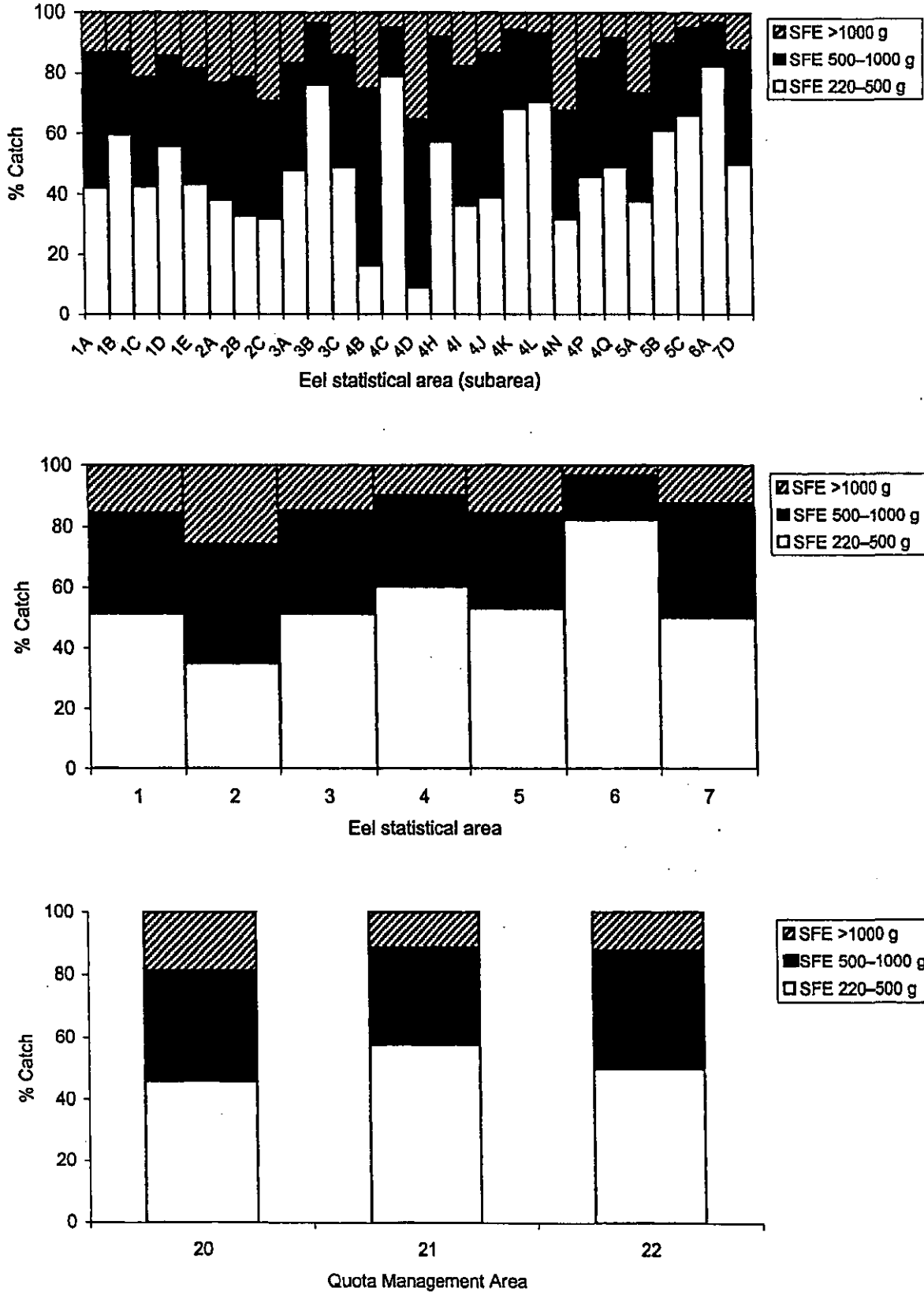
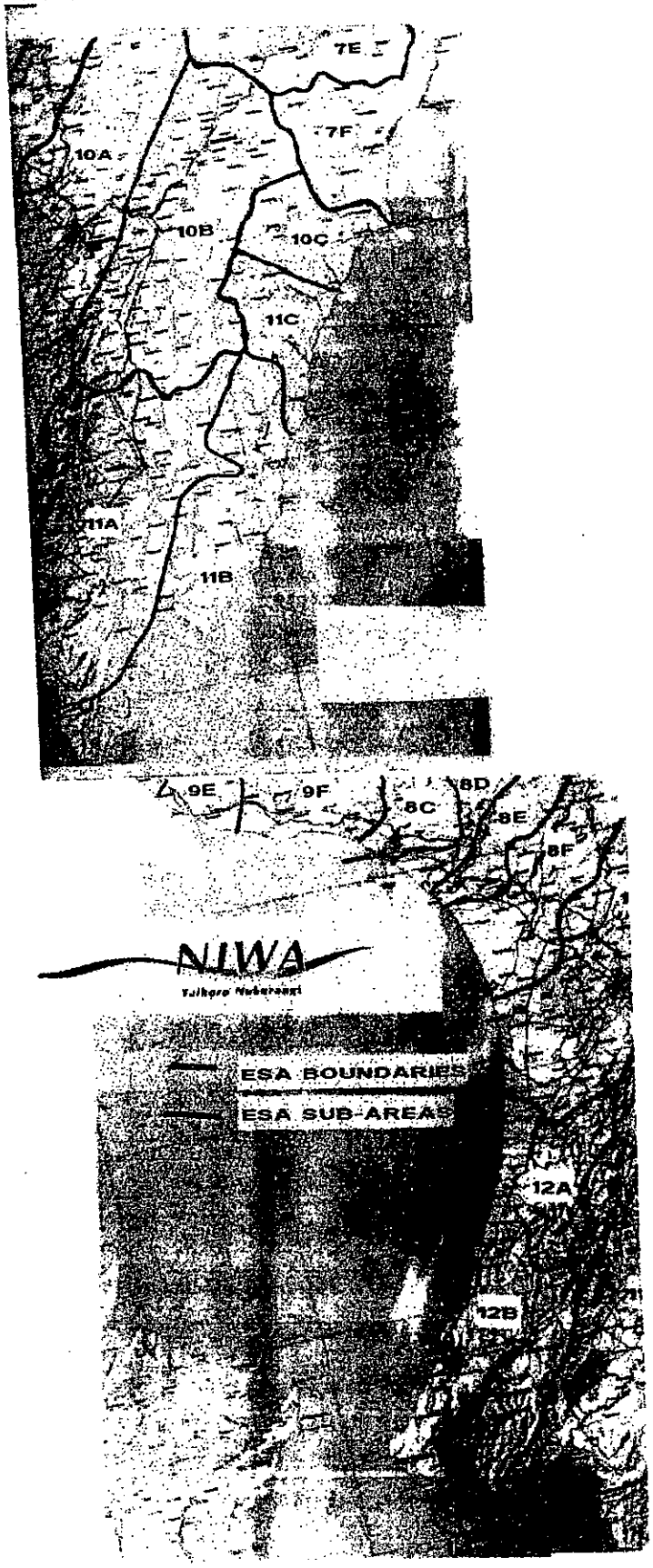
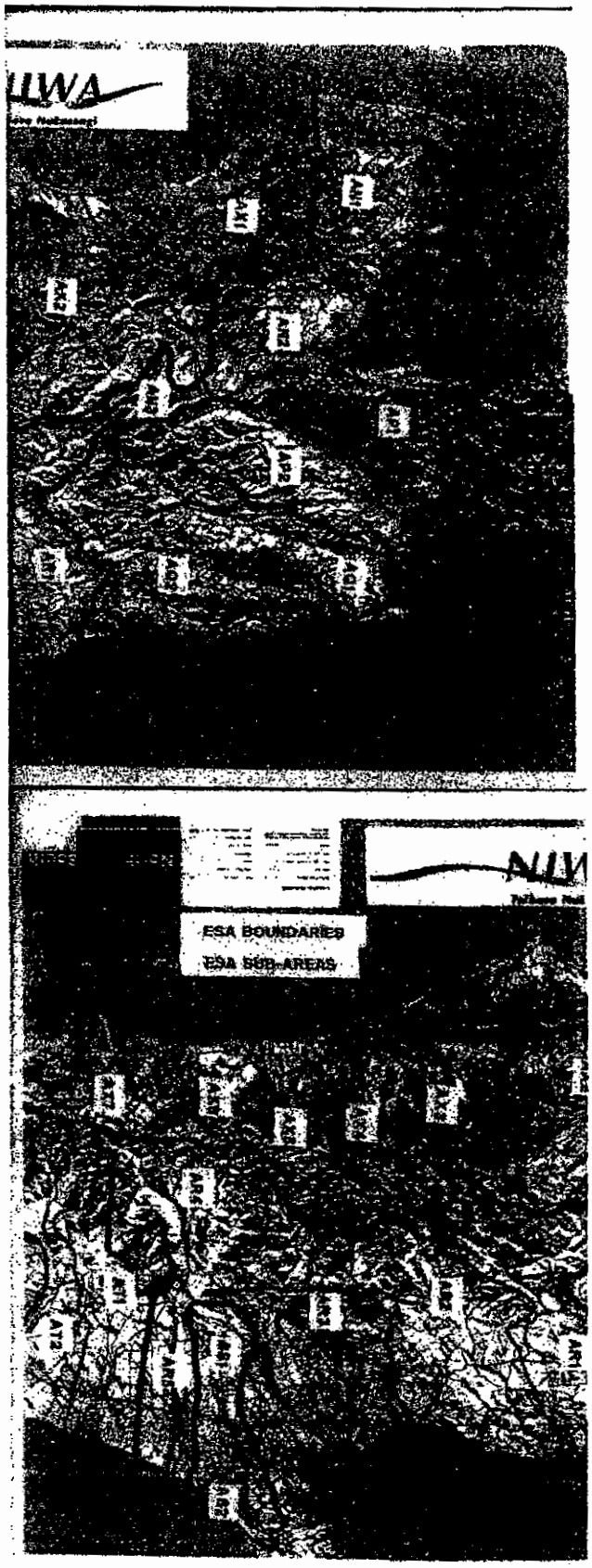


Figure 22: Proportion of shortfin (SFE) catch in three size grades, by area, processed by Thomas Richards Ltd from 1 October 2003 to 30 April 2004. Data are from processor's landing records. Overall proportions of shortfin in size grades were 220–500 g, 49.7%; 500–1000 g, 34.1%; over 1000 g, 16.2%.

Appendix 1 – *continued*



Appendix 1 – *continued*



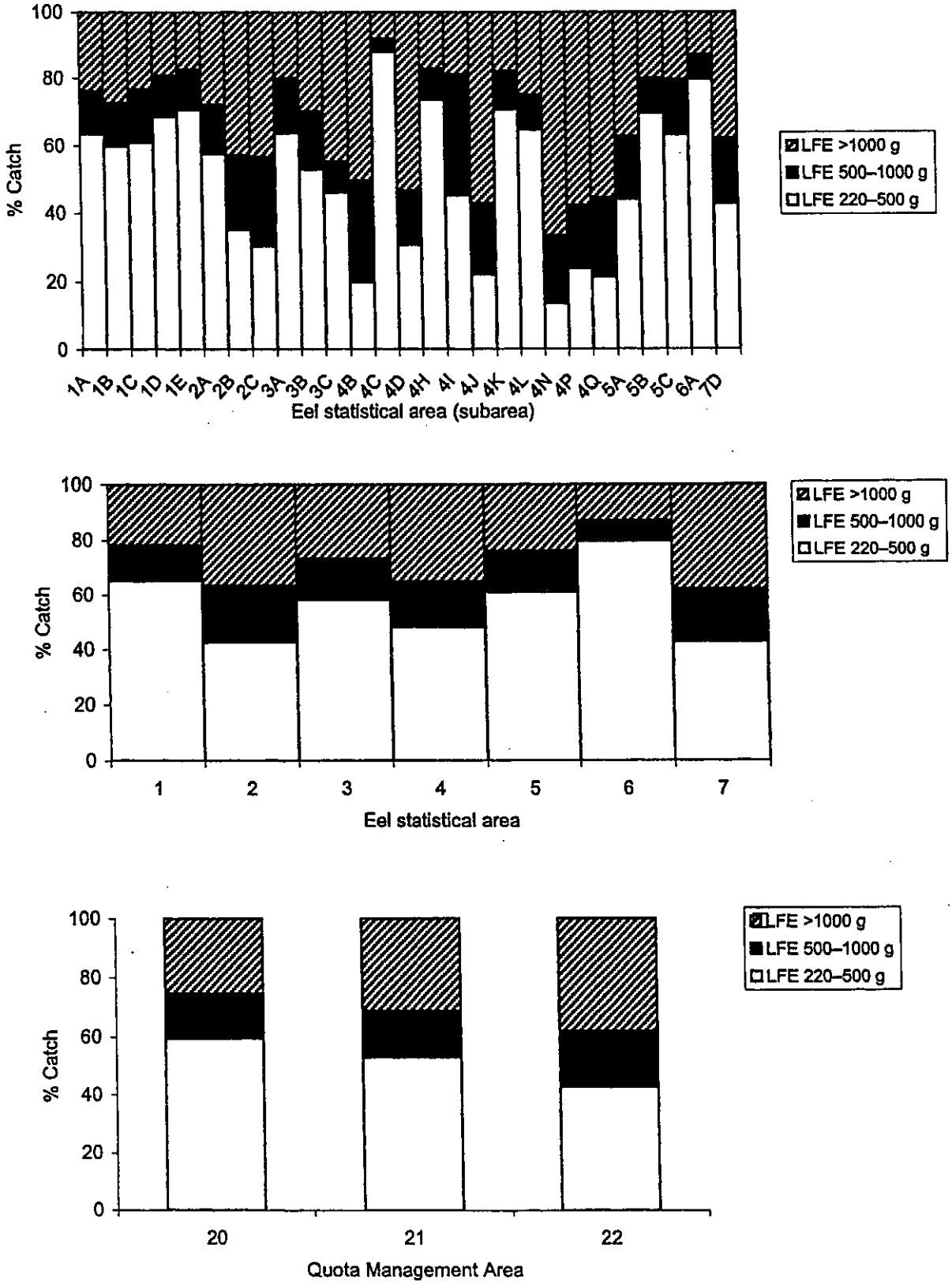


Figure 23: Proportion of longfin (LFE) catch in three size grades, by area, processed by Thomas Richards Ltd from 1 October 2003 to 30 April 2004. Data are from processor's landing records. Overall proportions of longfin in size grades were 220–500 g, 56.4%; 500–1000 g, 15.7%; over 1000 g, 27.9%.

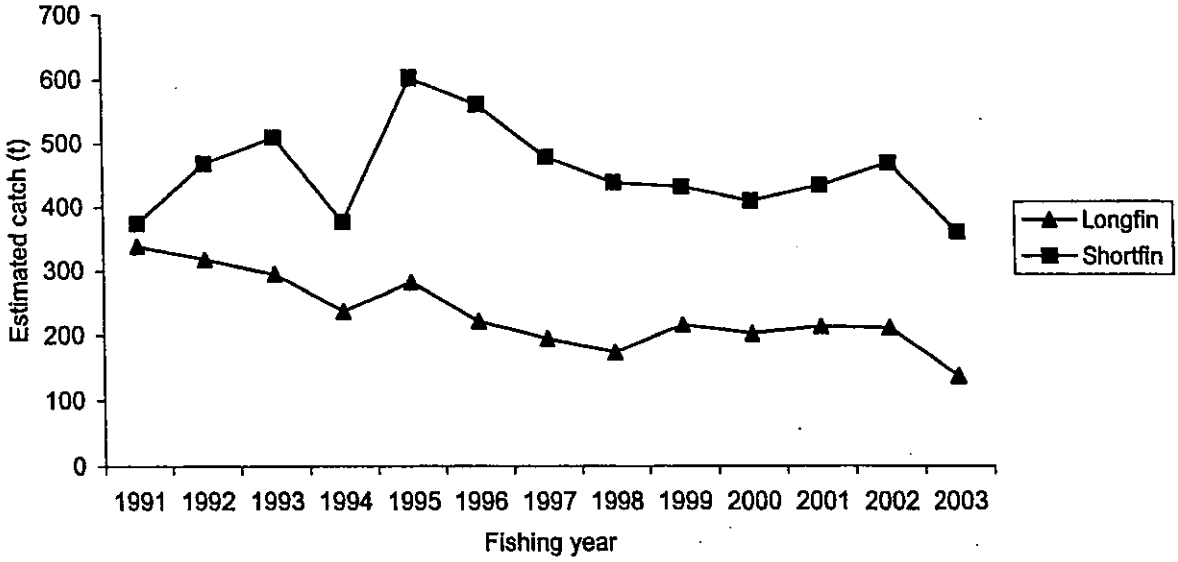
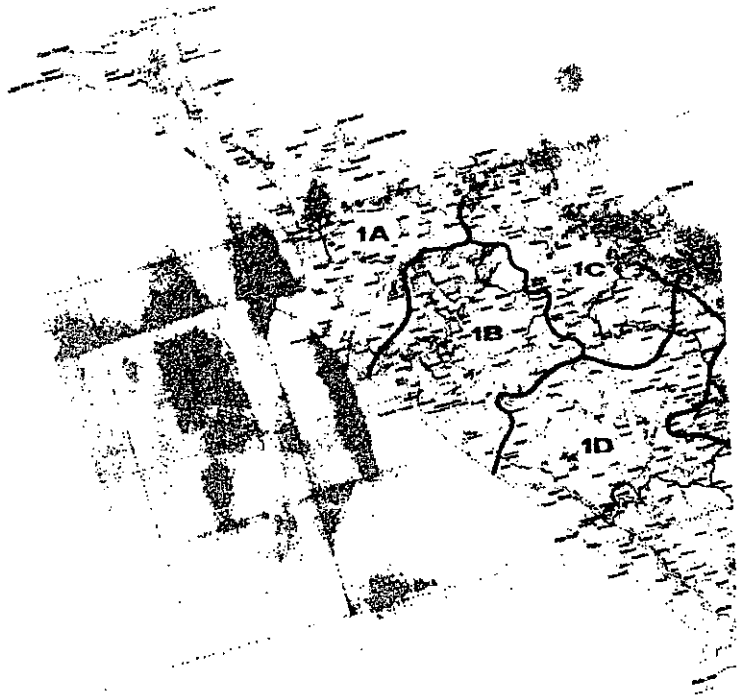
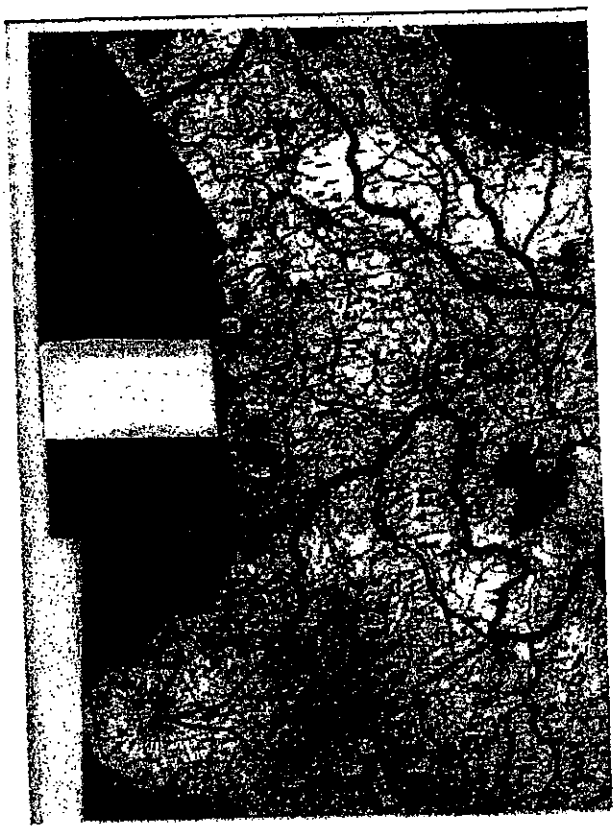


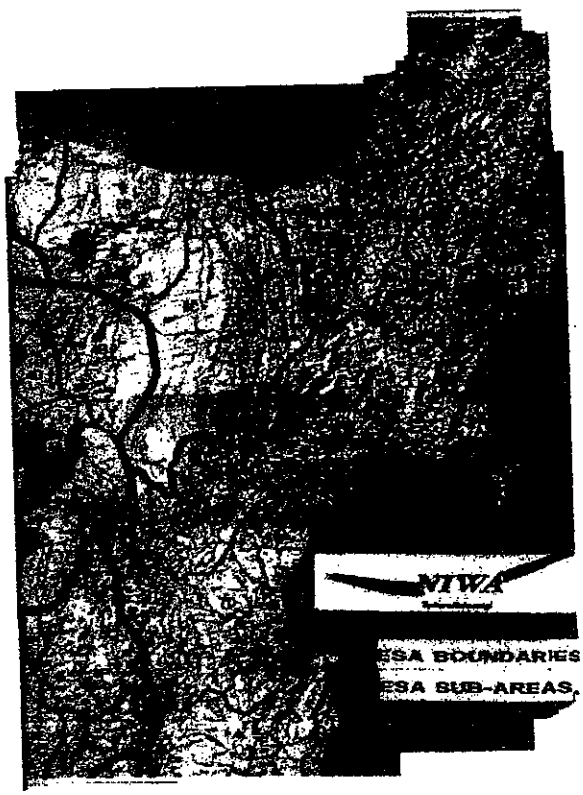
Figure 24: Estimated North Island catch of longfin and shortfin eels, 1991 to 2003 from CELRs and ECEF 1991 represents 1990–91 fishing year. (Data from Beentjes & Dunn 2003b).

Appendix 1: Eel statistical area (ESA) and subarea boundaries for reporting species and size grade of commercial landings. Reproduced by permission of Land Information New Zealand.



Appendix 1 – *continued*





Appendix 1 – *continued*