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Taihoro Nukurangi

Size, age and species composition of commercial eel catches from South Island market sampling (1997–98)

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Final Research Report for
Ministry of Fisheries Research Project EEL9701
Objective 3

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Report Title:	Size, age and species composition of commercial eel catches from South Island market sampling (1997–98)
Author:	M.P. Beentjes

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This report covers work carried out under Objective 3 for this project: To assess and monitor commercial eel fisheries.

8. Executive summary

This report presents the results of the third consecutive year (1997–98) of market sampling of commercial freshwater eel (shortfinned, *Anguilla australis*; longfinned, *A. dieffenbachii*) landings from throughout the South Island, New Zealand. 104 landings from 11 catchments and 31 strata were sampled and length and weight were recorded for 7869 longfins and 3052 shortfins. The most intensively sampled areas included Te Waihora, Mataura, Clutha, and Oreti Rivers. Longfins were the predominant species in all strata except Te Waihora, Lake Brunner and Waipori Lakes, the proportion usually increasing with distance inland. Longfins were present in 28 and shortfins in 25 of the 31 strata. Length frequency distributions of longfins were generally unimodal with few large eels while shortfin distributions contained a greater proportion of large eels. Overall mean strata length and weight were 55.8 cm and 526 g for longfins and 64.1 cm and 648.7 g for shortfins. Mean size was significantly larger for longfins from less accessible lightly fished areas where females predominated.

Mean age, mean annual weight and mean annual length increments were determined for eels in two weight categories (220–260 g, 450–550 g). Strata mean ages for longfins in these categories were 20.5 y and 24.5 y respectively, and 15.6 y and 17.8 y for shortfins respectively. The corresponding strata mean annual length and weight

increments in these weight categories were 21.7 and 21.8 mm and 12.7 and 16.2 g for longfins, and 28.6 and 34.4 mm and 16.9 and 30.2 g for shortfins. The methods of determining mean age, and mean annual weight and length increments from eels within restricted weight categories has been shown to be both cost effective and practical for comparing growth between areas.

The mean strata proportions 35.0, 35.8, and 29.2% of longfins were categorised as immature or unable to determine, male or female; and shortfins 0.1, 4.3, and 95.6% respectively. They indicate that the shortfin fishery, with the exception if Te Waihora, is almost exclusively based on females while the longfin fishery is based mainly on males (ratio of actual numbers of longfin males to females landed was 2.3:1).

Gonad staging indicated that gonad development was related to weight and length and that at maturity, just prior to migration, longfin males were on average 65 cm, 700 g, and around 23 y; longfin females were 94 cm, 2500 g and 35 y; shortfin males were around 40 cm, < 131 g,
12–21 y; and shortfin females were 82.5 cm, 1100 g and 30 y.

9. Introduction

This report presents the results of the third consecutive year (1997–98) of catch sampling of commercial freshwater eel (shortfinned, *Anguilla australis*; longfinned, *A. dieffenbachii*) landings from throughout the South Island, New Zealand.

The commercial freshwater eel fishery in New Zealand began in the mid 1960s and has been managed largely on the basis of restrictions on permits. Landings peaked in the mid 1970s with the maximum landing of 2434 t recorded in 1975. Landings in recent years average around 1400 t (Annala & Sullivan 1998) with an export value in 1996 of $9.5 million. Stock assessment has been limited to interpretation of annual catch data, and the sustainability of the fishery under current levels of harvest is unknown. The general consensus of the eel industry is that the fishery is showing signs of serial depletion in many areas, with fishers exploiting remote and previously unfished areas. Additionally, despite the absence of quantitative analyses of CPUE, indications are that increasing effort is required to sustain current catch levels. Coupled with this is the widely held view that size of eels available to both commercial and traditional fishers is steadily declining. As part of the Ministry of Fisheries contract in 1995–96 NIWA examined processors' historical records of eel size grades to address the issue of declining size and changes in species composition (Beentjes & Chisnall 1997). The most comprehensive data sets indicated a clear and progressive trend of declining size from the 1970s through to the present, particularly for longfinned eels. North Island data indicated a decline in the proportion of longfinned eels processed over time, but there was no such indication for the South Island.

Freshwater eels have a high priority for introduction into the Quota Management System and the limited stock assessment information presents problems in determining sustainable harvest levels. Given that processors' historical data indicate a decline in size over time, it is important to monitor size and species composition, together with age and growth of the commercially fished eels within priority catchments. Providing stock assessment advice on a catchment basis is desirable in terms of the independence of stocks and the proposed future management. Growth is a key parameter required for stock assessment in each catchment because it is extremely variable and is highly dependent on factors such as water temperature, food supply, and density (Horn 1996). Ideally, growth should be determined for each catchment (fishery) to provide an index of productivity and to allow changes in growth over time to be monitored.

A pilot programme to monitor the size and species composition of commercial eel stocks within the catchments was implemented in the 1995–96 fishing year in both the South and North Islands. The main goal was to initiate a time-series database on size and species composition and to develop a sampling methodology that could be applied in future years. To determine priority areas, the contribution to landings by key areas was determined through a landing survey questionnaire sent to all commercial eel fishers in 1995–96 (Beentjes & Chisnall 1997).

The 1995–96 pilot and 1996–97 programmes sampled 125 and 102 commercial landings respectively, from throughout the South Island. The experience gained from the pilot catch sampling programme in terms of methods used, stratification, and developing relationships with processors and participating fishers, was used in the design and operation of the 1996–97 and 1997–98 programmes. Preliminary results of objective 1 to develop an optimal sampling design for the programme were also implemented where possible in 1997–98.

This research was carried out by NIWA under contract to the Ministry of Fisheries as part of Monitoring of eel fisheries (MFish Project No. EEL9701).

10. Programme objectives

1. To assess and monitor commercial eel fisheries.

Objectives for 1997–98

1. To develop an optimal sampling design for the determination of size frequency of eels caught in commercial eel fisheries and the age of eels at the minimum legal size

2. To monitor the species composition, size structure, and age at the minimum legal size and well above minimum legal size of priority commercial eel fisheries by sampling 100 landings from the Waikato catchment in the fish processing sheds.

3. To monitor the species composition, size structure, and age at the minimum legal size and well above minimum legal size of priority commercial eel fisheries by sampling from 100 landings at the major eel processing shed in the South Island.

4. To determine the most appropriate measures of fishing effort for the collection of commercial catch and effort data.

5. To assess the feasibility of determining the current status of eel stocks in the priority commercial fisheries by analysis of size frequency data.

This report addresses only objective 3 and other objectives are reported elsewhere.

11. Methods

The 1997–98 South Island catch sampling programme was based at Mossburn Enterprises Ltd (Invercargill), as were those of 1995–96 and 1996–97. The sampling strategy was similar to that used in previous years and was aimed at providing data on eel species, size (length and weight), age, and sex by individual catchment or sub-catchment, some of which were broken into area strata.

Areas sampled and stratification

Selecting which catchments and the number of landings to sample was based on: the 1995–96 landing survey questionnaire results (Beentjes & Chisnall 1997); a need to sample a wide geographical area within the South Island covering habitats representative of both species; availability of cooperative eel fishers who fish from these selected catchments and land into Mossburn Enterprises; the contract requirement to sample 100 landings; preliminary results of the optimal sampling design analysis (objective 1).

Preliminary results on optimal sampling (objective 1) tended to support the practise of dividing catchments into strata. Selected catchments and tributaries were divided into up to four strata based on fishing practices, physical features (e.g. lakes, falls, confluences, weirs, dams, bridges etc.) and information on species and size distribution (Figures 1, 2, Table 1). Stratum boundaries are unchanged from those given in 1995–96 and 1996–97 (Beentjes & Chisnall 1997, Beentjes & Chisnall 1998). Participating fishers were provided with definitions of the boundaries of all strata, Allflex cattle ear tags inscribed with the fisher's name, catchment, and stratum number, and written instructions with details of sampling requirements. Fishers were instructed to keep all eels caught within defined strata separate, and label these eel samples with cattle ear tags. Eels were delivered by the fisher in holding bags live to the factory at Mossburn Enterprises Ltd, or picked up by the processor's truck which has six aerated tanks; the latter eels were often transported free-swimming. Tags were either tied directly to holding bags or were attached to a float for free-swimming catches in the truck.

Sampling procedure

At the factory, total landing weight (species unsorted) was recorded and a sample taken by randomly selecting several of the holding bags, or by dip netting 100–200 free-swimming eels from the tanker truck. For smaller landings the entire catch was sampled. Eels were deslimed before being processed, with a resultant weight loss estimated at about 3%. Species, length, weight, sex, and maturity were recorded for all individual eels in the sample. The sample usually contained a mix of the two species and these were sorted as the sample was analysed. The proportion of each species by weight in the total landed weight was calculated from the proportion by weight of that species in the sample. A record was kept of any eels larger than 4 kg which were released by fishers: maximum legal size in the South Island is 4 kg (The Fisheries Area Commercial Fisheries Regulations, 1986)

Otoliths collection and preparation

In 1995–96 and 1996–97 otoliths were collected over the entire size range of eels from each area and this resulted in the collection of up to 150 otoliths per strata. In 1997–98 the contract objective was to determine age at Minimum Legal Size (MLS, 220g) and well above MLS. As a first step the optimal number of otoliths to sample was determined from the 1996–97 ageing data. A target standard error of < 0.9 was nominally set. The results indicated that a sample of 20 otoliths per size class would satisfy this requirement with a margin of error required for broken and unreadable otoliths. Preliminary results from Francis (1998) indicated that sampling of otoliths should also be spread over as many landings as possible since between landing variance of age was greater than within landing variance of age. Data from 1995–96 and 1996–97 were examined to determine the size range that would be required to achieve a sample size of 20 otoliths from a minimum of three landings per size. The results indicated that the weight categories should be set at 200–240 g and 450–550 g. A South Island industry initiative to increase escape tube size from 28 mm to 31 mm in the 1997–98 season meant that the smaller weight category based on MLS had to be increased slightly to 220–260 g.

No attempt was made to determine growth for males and females separately, and the target of 20 otoliths originated from one or both sexes. Generally, otoliths were collected from eels in one stratum per catchment where these were mainstem rivers. This was usually stratum 1, (coastal strata) which often yielded the most landings and both species were often better represented. Otoliths were prepared using the crack-and-burn method (Hu & Todd 1981). Otolith halves were mounted in silicone rubber sealant on microscope slides and observed at X10–50 magnification under a stereo-microscope using transmitted light. Hyaline zones or winter rings were counted and age was expressed as years spent in fresh water, ignoring the central area of oceanic larval growth (Jellyman 1979).

Sex

Eel sex is difficult to determine externally and to in many cases internally, and generally studies have not distinguished between the sexes. Microscopic analysis of gonad tissue in 1995–96 confirmed that assignment of male or female from macroscopic observations was possible. In 1996–97, eels were categorised into four categories: unsexed, immature or unable to determine, male, and female. Gonads were staged as 1 to 4 including the category of immature or unable to determine which showed signs of development but could not be categorised as either male or female (*see* Appendix 1).

Length-weight relationship and condition index

The length-weight relationship for each species for each stratum (area) was determined from ln W=b(ln L) + ln (a), where W=weight (g) and L=length (cm). Weight was calculated from this model by setting length equal to 45 cm to provide an index of condition for each strata. (length of 45 cm was chosen as it approximates length at MLS (220 g) for longfinned eels). No adjustment was made for the estimated 3% weight loss resulting from the desliming process.

Age and annual growth increments analysis

The mean age within each of the two weight categories (220–260 g and 450–550 g) was calculated and these were termed A_{240} and A_{500} respectively. Data from 1995–96 and 1996–97 catch sampling were used to supplement data where sample size was small. Additionally, A_{240} and A_{500} were determined for catchments sampled in previous years but not sampled in 1997–98, by sub-sampling the ageing datasets and selecting ages of eels within the specified weight categories.

Mean annual length and weight increments were derived by dividing the length (minus 50 mm; size at recruitment into fresh water) or weight by age and calculating the mean. Length and weight increments were determined for each weight category. Data from 1995–96 and 1996–97 years catch sampling was also used in the manner described above.

Calculation of overall means

Overall means for variables such as length and weight etc. were expressed in two ways: the first was the mean of the individual means for each strata (where N=no. strata) and is termed *strata mean*; the second is the *all eels mean* calculated without regard to stratification (where N=total no. 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 affect on, for example, the mean length, whereas when calculating *strata mean*, small or large sample sizes have equal weighting. *All eels means* are shown only in tables and are not referred to in the results.

12. Results

Landings

A total of 104 landings were sampled from 11 catchments between 24 November 1997 and 5 March 1998 (Table 1). Sub-division of these catchments resulted in a total of 31 strata being sampled. Eighteen 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. The most intensively sampled catchments were Te Waihora (Lake Ellesmere), Mataura, Clutha, and Oreti Rivers (50 landings). Landing weights of longfins and shortfins totalled 11.2 and 15.5 t respectively, and the overall proportion of the landing weights sampled (sum of sample weights/sum of landing weights per species) was 31.6% for longfins and 8.6% for shortfins. The overall ratio of longfinned to shortfinned eel landing weights was 4:1, (excluding Te Waihora) and about 0.7:1 (including Te Waihora). Length and weight were recorded from 7869 longfins and 3052 shortfins (Table 1) and the mean number of fish sampled per landing for longfins was 87 (N=90, range=2–190, s.e.=4.12) and for shortfins 37 (N=82, range=1–152, s.e.=5.13). Otoliths were extracted, prepared and read for 482 longfin and 206 shortfin eels.

Longfins were the predominant species in all strata sampled except those in Te Waihora, Lake Brunner (Grey River, stratum 2), and Waipori Lakes (Taieri River, stratum 3). The proportion of longfins was greater than 84% in all strata except stratum 2 of Waitaki River where it was 74.1%. The proportion of longfins tended to be higher in inland strata, frequently 100% (Table 1). Longfins were present in 28 and shortfins in 25 of the 31 strata. Longfinned eels were absent only from Te Waihora strata 1, 3 and 4 with only six longfins caught in stratum 2. Shortfinned eels were absent from inland strata of the Waiau, Oreti, Mataura, Taieri and Grey Rivers, and from Lake Wakatipu.

Length frequency distributions

Length frequency distributions of longfins are given by strata in Figures 3–18. Mean lengths, standard errors, and ranges are given by stratum in Table 2. The strata mean length was 55.8 cm (N=28 strata).

Using the classification of length frequency distributions for 1996–97 (*see* 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), Aparima, Oreti, Mataura and Clutha Rivers, Waipori Lakes, and Lake Brunner.

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), Makarewa River, Waituna Creek, Mokoreta, Pomahaka, and Waitaki Rivers. Distributions from Waimakariri were similar but with a larger mode centred around 54 cm.

Type 3: No clear modes evident and good representation from all size ranges between 40 and 90 cm: includes fish from Waikaka Stream, upper Taieri River (stratum 4), Lake Wakatipu, and upper Grey River (stratum 3).

Length frequency distributions of shortfins are given by stratum in Figures 19–34. Mean lengths, standard errors, and ranges are given by stratum in Table 3. The strata mean length was 64.1 cm (N=25 strata).

Mean length of shortfinned eels was generally greater than that of longfinned eels (Tables 2 and 3) and there was considerably more variability in mean length of shortfinned eels both within and between catchments. Shortfin sample size was small for most strata because of the low proportion of shortfin in landings with the exception of lower Mataura River (stratum 1) and Waipori Lakes (Taieri River, stratum 3), Lake Brunner (Grey River, stratum 1) and Te Waihora where > 100 eels were sampled. Length frequency distributions of shortfins from these four areas do not have the pronounced uni-modal shape of longfins although modes are apparent between 47 and 63 cm (centred at about 56 cm), and are strongly skewed to the right with all sizes up to about 100 cm represented (Figures 24, 29, 30 and 32 respectively). The distribution of shortfins in stratum 2 of Te Waihora (Kaitorete Spit to Kaituna Lagoon) is similar in shape, but these eels are slightly smaller with the mode centred at around 51 cm (Figure 32). The distribution of shortfins caught inside stratum 4 (Concession Area where undersize eels are legally harvested during the shortfin male migration period) is strongly unimodal between 33 and 44 cm (centred at 40 cm); these are migrating males (Figure 32). Because so few shortfinned eels were landed from other areas length frequency distributions cannot be interpreted but lengths fall within the ranges of the areas described above.

Weight and condition

Mean weight, regression coefficients and condition indices are given by stratum for longfinned and shortfinned eels (Tables 2 & 3 respectively). The longfin strata mean weight was 526 g (N=28 strata) and the shortfin strata mean weight was 648 g (N=25 strata).

Longfinned eels with the smallest mean weight (where N>100) were from lower Aparima River (stratum 1) and the largest mean weight from the Lake Wakatipu (Table 2). The smallest and largest shortfinned eel mean weights (excluding the Te Waihora Concession Area and where N<100) were from Lake Brunner and Waikaka Stream, respectively (Table 3).

The longfin strata mean condition index was 234 g (N=28) and the strata mean condition index was 201 g (N=25). Longfins with the best condition indices were from inland Waiau River (stratum 3) (244 g) and the poorest were from Lake Wakatipu (197 g). Shortfins with the best condition index were from coastal Waiau River (stratum 1) and Waikaka Steam (238 g for both areas) and the poorest from Te Waihora (stratum 1, 177 g).

Sex and maturity

Of the 7869 longfins sampled 98.4% were classified into three categories: immature or could not be determined, male, and female. Those that were unclassified were destined for live export and were invariably the larger females. The strata mean proportions of longfins that were categorised as immature or could not be determined, male, or female were 35.0%, 35.8%, and 29.2%, respectively (Table 4). Longfins fell predominantly within the size range 43–65 cm with modes between 52 and 56 cm (Figures 3–17). Female longfins, however, were generally scattered over a larger size range, from about 47 to 97 cm with no clear modes. The largest eels, although unclassified, were undoubtedly females which would extend the female upper size range to 110 cm. Eels over 4 kg (equivalent to about 115 cm) must be released by regulation in the South Island so they were not sampled. The incidence of the category 'immature or could not be determined' declines at about the same size that females appear in any number and it is likely that most of these eels will develop into females with immature eels less than 45 cm developing into either male or female.

While the strata mean proportion of longfin males was 35.8%, some areas had virtually no males; these include Waikaka Stream (1.1% male, 95.5% female), Lake Wakatipu (0% male, 88.6% female), and upper Grey River (stratum 3; 2.4% male, 89.4% female) (Table 4). The mean size of longfin eels from these areas was substantially larger than the mean size from other strata reflecting the predominance of larger females (Table 2).

As longfinned eels grow in length, gonads mature and change from immature, where the sex cannot be determined, through to the mature stage 4 condition (Table 5). Longfin sex was clearly distinguishable at mean lengths of about 58 cm for females and 50 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, 1980). For South Island longfinned males, the mean length of 64.6 cm recorded for eels with stage 4 corresponds to length at migration. The equivalent length for migrating females is likely to be slightly larger than the mean length of 86.7 cm recorded for stage 4 females because the largest eels were either not sexed due to processor's requirements to live export large eels, and/or eels > 4 kg were not landed.

Of the 3052 shortfins sampled, only 2 were not sexed. The remaining eels were classified into three categories immature or unable to determine, male, and female. The strata mean proportions of shortfins in these categories were 0.1%, 4.3%, and 95.6% respectively (Table 4). Males landed from the Te Waihora Concession Area accounted for 91.7% (N=603) of all males, the remaining 54 eels came from Te Waihora, Mataura, Taieri and Grey Rivers. There were few immature shortfin males, indicating that shortfin differentiation is occurring at a size less than the smallest shortfin males sampled.

Unlike longfins, shortfinned males did not exhibit a relationship between gonad maturity and mean length (Table 5). The bulk of the shortfinned males were sampled from Te Waihora Concession Area where the predominant gonad stage was 3 and all eels exhibited the morphological signs of migrating described above. Shortfinned males do not grow large and the results on maturity indicate that they migrate from Te Waihora at a mean length of around 40 cm. Some grading by fishers may occur, so there are probably smaller migrating males in the population than were sampled. Female shortfin eels grow much larger than males and show a clear relationship between gonad maturity and mean length (Table 5). Length at migration approximates mean length of stage 4 females (82.2 cm) since there were no reports of fishers returning shortfins weighing > 4 kg and only one shortfin (131 cm) was exported live and not sexed.

Age and growth

Using data from 1995–96, 1996–97 and mainly 1997–98 longfin mean age and weight within the lower weight category (220–260 g) and upper weight category (450–550 g) are shown for 19 catchments (not the same 19 catchments in each size range) mostly from coastal strata where these were rivers (Table 6). For the lower weight category a total of 259 otoliths were aged from 42 landings, mean ages (A_{240}) ranged from 14.8 y (Waituna Creek) to 30.7 y (Buller River), and the strata mean was 20.5 y. Mean weight ranged from 237.9 to 253.3 g and strata mean weight was 243.5 g. For the upper weight category a total of 283 otoliths were aged from 46 landings, mean ages (A_{500}) ranged from 16.9 y (Waitaki River) to 34.8 y (Buller River), and the strata mean was 24.5 y. Mean weight ranged from 478.9 to 540.0 g and strata mean weight was 495 g.

Longfin mean annual length and weight increments within the two weight categories are given in Table 6. Mean annual length increments ranged from 13.6 mm (Buller River) to 27.9 mm (Waituna Creek) for the lower weight category with a strata mean length increment of 21.7 mm and for the upper weight category 16.2 mm (Buller River) to 31.9 mm (Waitaki River) with a strata mean length increment of 21.8 mm. Mean annual weight increments ranged from 8.3 g (Buller River) to 16.6 g (Waituna River) for the lower weight category with a strata mean increment of 12.7 g and for the upper weight category mean annual weight increments ranged from 16.2 g (Buller River) to 31.9 g (Waitaki River) with a strata mean increment of 23.1 g. There was little difference between annual length increments between the two weight categories but annual weight increments have generally increased markedly.

Similarly for shortfins, using data from 1995–96, 1996–97 and mainly 1997–98 shortfin mean age and weight within the lower weight category (220–260 g) are shown for 11 catchments, and the upper weight category (450–550 g) for 14 catchments, mostly from coastal strata where these were rivers (Table 7). For the lower size range a total of 94 otoliths were aged from 31 landings, mean ages (A_{240}) ranged from 10.5 y (Waitaki River) to 20.8 y (Grey River), and the strata mean was 15.6 y. Mean strata weight ranged from 229.2 to 260 g with a strata mean weight of 244.9 g. For the upper size range a total of 186 otoliths were aged from 85 landings, mean ages (A_{500}) ranged from 14.0 y (Oreti and Pomahaka Rivers) to 25.3 y (Grey River), and the strata mean was 17.8 y. Mean weight ranged from 471.7 to 535.0 g with a strata mean weight of 493 g.

Shortfin mean annual length and weight increments within the two weight categories are given in Table 7. Mean annual length increments ranged from 19.5 mm (Waiau River) to 46.3 mm (Waitaki River) for the lower weight category with a strata mean length increment of 28.6 mm and for the upper weight category 22.7 mm (Hurunui River) to 50.9 mm (Makarewa River) with a strata mean length increment of 34.4 mm. Mean annual weight increments ranged from 11.4 g (Waiau River) to 24.2 g (Waitaki River) for the lower weight category with a strata mean increment of 16.9 g and for the upper weight category mean annual weight increments ranged from 19.7 g (Hurunui River) to 37.4 g (Pomahaka River) with a strata mean increment of 30.2 g There was a slight increase in annual length increments between the two weight categories but annual weight increments have generally increased markedly.

13. Discussion

Landings

Catch sampling in the South Island was based at the major South Island eel processor (Mossburn Enterprises Ltd, Invercargill), where about 65% of all eels landed in the South Island are processed. The cooperation of commercial eel fishers and processors was needed to maintain the integrity of catches from individual strata and, as in 1995–96 and 1996–97, a high level of cooperation was provided ensuring that areal stratification methodology was effective. Sampling of 104 landings in 1997–98 exceeded the MFish contractual requirements to sample 100 South Island landings. The total weight of landings sampled in 1997–98 was 4.8 % of the average annual South Island commercial landings (Annala & Sullivan 1998). Landings sampled in 1997–98 included three new areas; Makarewa River a tributary of the Oreti River, Waikaka Stream a tributary of the Mataura River, and Waituna Creek a small catchment in Southland. The inclusion of these new areas together with other tributaries such as Mokoreta and Pomahaka Rivers extends the sampling programme to include less heavily fished areas which tend to be less accessible. Larger eels are generally better represented in these areas (*see* Figure 10) and their inclusion helps provide a broader view of length distributions and population structure of eels in the South Island than had sampling been confined only to the easily accessed mainstem rivers, the source of most landings. While some catchments from the west coast, Canterbury, Marlborough and Nelson have been sampled in the last three years (see Beentjes & Chisnall 1997, 1998), most landings originate from Otago, Southland and Te Waihora. These four areas contribute around 70% of the South Island landings (Jellyman 1994).

Escape tubes

This programme samples only commercially sized or fishery recruited eels. The national minimum legal size limit of 220 g (excluding Te Waihora) influences the size distribution of eels landed. Catches are seldom effectively manually graded prior to arriving at the processors with the expectation by fishers that escape tubes deployed in fyke nets 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, this was again increased voluntarily to 31 mm in 1997–98. The results from this study indicate that the 31 mm escape tube diameter is effective since only 1.9% and 0.16% (excluding Te Waihora) of longfin and shortfin eels respectively, weighed less than the MLS of 220 g. In 1996–97 5% and 0.36 % (excluding Te Waihora) of longfin eels and shortfins respectively, weighed less than the MLS of 220 g, indicating that the voluntary increase in escape tube diameter from 28 to 31 mm may have contributed to the reduction in numbers of undersized eels landed. Shortfin eels tend to be thinner and weigh less than longfins for a given length, and therefore recruit to the fishery at a slightly greater length of about 46–47 cm compared to longfins which recruit at around 45 cm.

Species composition

Based on the landings sampled at Mossburn Enterprises, longfins were again the predominant commercial species in the South Island, with the exception of Te Waihora, Lake Brunner, (Grey River), and Waipori Lakes which are known shortfin fisheries. Consistent with previous years (1995–96, 1996–97) proportions of shortfins tended to decline from coastal to inland strata and in some cases shortfins were absent, reflecting habitat preference. Species composition can vary considerably between landings, due in part to the fishing practices of each fisher and the number of landings they contribute to the programme. For example, the proportion of longfins in the lower Mataura River was 83.5% in 1995–96 compared with only 68.1% in 1996–97. One fisher who tends to target shortfins, contributed few landings in 1995–96 but a significant number in 1996–97 and accordingly the proportion of shortfinned eels from Mataura stratum 1 had increased in 1996–97. In 1997–98 the same fisher contributed only one landing from this stratum and the proportion of longfins was similar to that of 1995–96 (84%). Thus, the apparent annual fluctuations in the proportion of each species from the same area may in some cases be an artefact of sampling rather than any real change in species composition.

Size

South Island length frequency distributions and mean lengths for both species were similar to 1995–96 and 1996–97 (*see* Beentjes & Chisnall 1997, Beentjes and Chisnall 1998). Most longfinned eel distributions are characteristic of exploited fish populations with relatively few large eels. The bulk of the longfinned eel fishery is based on eels between 45 and 60 cm (220–560 g). This is especially evident in the 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 areas which are seldom fished such as Waikaka Stream, Taieri Gorge, upper Grey River and Lake Wakatipu were comprised mostly of large females.

Shortfins were, on average, larger than longfin eels, length frequency distributions tended not to be unimodal and catches were more evenly spread over a wider size range. This finding indicates that fishing pressure has not impacted on the size structure of shortfin eel populations to the same extent as longfins.

A maximum size limit of 4 kg was introduced in the 1995–96 fishing year for the South Island to protect female longfins. Fishers participating in the catch sampling programme estimated that from the sampled landings, 114 eels over 4 kg (2 of these eels were estimated to weigh 10 kg) were caught and released (77 in 1995–96, 116 in 1996–97). The inclusion of these large eels in landings would not have affected the length frequency and age distributions to any extent.

Sex and maturity

The longfin commercial fishery is dominated by males which are caught 2.3 times as often as females, possibly because females with their greater longevity, are more vulnerable to fishing. There is also a general decline in the proportion of males from the coast to inland strata, although unlike the American eel, *Anguilla rostrata* (Helfman *et al.* 1987), males were not confined to coastal and estuarine areas. The predominance of females from the upper Waikaka Stream, upper Grey River and Taieri Gorge may indicate that tributaries and inland areas are the preferred habitat for large females which tend to displace the smaller males.

There were no longfin males found in the landing from Lake Wakatipu where recruitment has been limited since 1958 when Roxburgh Dam was built. Similarly, no males were found during an eel survey of Lake Wakatipu in 1995 (*see* Beentjes *et al.* 1997) but analysis of age indicated that some recruitment has occurred after the dam was constructed. Given the size range of longfinned eels in Lake Wakatipu we would expect to find some males. The total absence of males may lend support to the conclusions of studies that have shown that sex determination is dependent on the environment and eel populations of low density tend to be largely female while dense populations tend to be predominantly male (*see* Tesch 1977 for review).

Migratory gonad conditions, often associated with morphological changes in migrating eels, indicated that migration in longfins usually takes place for females at a mean size of about 87 cm (94 cm in 1996–97) and 1.8 kg and males at 65 cm (65 cm in 1996–97) and 0.7 kg, but will vary depending on the fishery. Although these sexed fish were not assigned ages, from the age at length regression plots from 1996–97 (Beentjes & Chisnall 1998), age of migrating longfins from the lower Mataura River, for example, would be about 35 years for females and 23 years for males. These estimates agree well with size and age at migration estimates determined by Jellyman and Todd (1982), although the female data are slightly biased toward the small size since longfins > 4 kg were returned to the water and not sampled. Additionally in contrast to 1996–97, some large female eels landed were not sexed due to live export requirements and this may account for the apparent difference of 7 cm in length at migration between years.

In contrast to the longfin fishery which is male dominated, the commercial fishery for shortfins is based almost entirely on females as males migrate at a size that is smaller than the national minimum legal size (220 g). Some males are still landed from Te

Waihora where the MLS in 1997–98 was 180 g, whereas landings from the Concession Area, where no size limit applies, are almost entirely males. The latter were predominantly migratory males as they displayed clear morphological characteristics of migrating eels and had gonads that were maturing, presumably in preparation for migration. The mean length and weight were also similar to those of Te Waihora migrating eels recorded in 1993–95 (Jellyman *et al.* 1995). Shortfinned eel gonads differentiate at a smaller size than longfinned eels and were distinguishable as female at a mean of 49 cm and male at less than 42 cm (and possibly smaller), but these males with the exception of Te Waihora Concession Area are not vulnerable to fishing. The gonad development conditions indicate that female shortfins migrate at a mean length of about 82.2 cm (82.5 cm in 1996–97) and 1.1 kg, and males 41.7 cm (40.8 cm in 1996–97) and 131 g. Comparable age for females of this length from the Mataura River for, example, would be 30 years (Beentjes & Chisnall 1998). The shortfinned migratory males from Te Waihora were aged between 12 and 21 years in 1996–97. These estimates also agree with those of Jellyman & Todd (1982).

Age and growth

The contract in 1997–98 called for ageing to be confined to two size ranges, one at MLS and one well above MLS. Given that growth is highly variable between and even within, catchments (*see* Beentjes and Chisnall 1998, Francis 1998) ageing was generally confined to the coastal strata of the main rivers with the rationale that ages from these strata should be used as relative indices of growth. Overlaps in the ranges of mean age between the two weight categories are consistent with high variability in age at length or weight. The 1997–98 age data was supplemented with ages from previous years to 'top up' sample sizes where they were less than the target sample size of 20. Shortfin eel sample sizes, and particularly the lower weight category, were often less than 20 due to the small quantities of shortfin landed compared to longfin and the size distribution which often did not provide shortfins in the weight category 220–260 g.

From the regression model of age on weight using 1995–96 and 1996–97 data, the overall mean time to reach MLS (220 g) was 17.5 years for longfins and 12.8 years for shortfins (*see* Beentjes & Chisnall 1998). Because of the increase in escape tube diameter used in 1997–98 the target mean weight of the smaller weight category was increased to 240 g resulting in mean weights of 243 g for longfin and 245 g for shortfin. The overall mean time to reach this target weight of 240 g was 20.5 y for longfins and 15.6 y for shortfins; the difference is longer than might be predicted to grow an additional 25 g but may be ascribed to the different statistical techniques used to determine age at a given size. The overall mean time to reach 500 g was 24.5 y for longfins and 17.8 y for shortfins equating to around 4.5 years for longfins to grow from 240 g to 500 g and just over two years for shortfins.

Comparison of regression slopes and annual length or weight increments are generally too variable, and the latter are highly influenced by size to make valid comparisons of productivity between catchments. By restricting the sampling to defined weight categories annual growth increments between different areas are directly comparable in the same way that are mean ages within these categories. Annual length increments were reasonably consistently for both weight categories (220–260 g, 450–550 g) whereas annual weight increased between the small and large weight categories. This reflects the growth characteristic of eels where the relationship between age and length is often linear but weight increases exponentially in relation to length.

The methods of determining mean age, mean annual weight and length increments from eels within defined size categories has been shown to be both cost effective and practical in terms of comparing growth between areas.

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16. Publications

This report has will also be published as a NIWA Technical Report

17. Data storage

All electronic data are archived at NIWA Greta point on the appropriate research databases to the standard and specifications of NIWA fisheries data managers. Otoliths have been catalogued and stored at NIWA Greta Point.

Table 1: Catchments and strata sampled in 1997–98 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 longfinned eel (LFE)

Catchment	Stratum definition	Stratum	Number samples	Longfinned eel Landing wt (kg)	Longfinned eel % wt sampled	Longfinned eel No. eels sampled	Shortfinned eel Landing wt (kg)	Shortfinned eel % wt sampled	Shortfinned eel No. eels sampled	% landing weight LFE
Waiau River	Mouth to Clifden Bridge	1	2	325.9	30.3	252	12.8	40.6	11	96.2
	Clifden Bridge to Mararoa Weir	2	2	212.1	47.6	239	16.5	55.0	14	92.8
	Lake Manpouri to Te Anau control gates	3	2	330.0	48.8	252	–	–	–	100.0
Aparima River	Mouth to Otautau	1	5	709.5	21.9	479	54.8	40.7	31	92.8
	Above Otautau	2	4	640.4	28.1	495	17.5	26.3	9	97.3
Oreti River	Mouth to Branxholme	1	6	446.4	55.5	570	68.3	59.7	55	86.7
	Branxholme to Centre Bush	2	2	114.3	56.8	186	1.1	36.9	1	99.0
	Above Centre Bush	3	2	445.5	21.1	278	–	–	–	100.0
Makarewa River	Entire river (tributary of Oreti River)	1	4	609.9	33.9	492	33.1	28.7	16	94.9
Waituna Creek	Entire creek	1	1	30.6	100.0	83	5.3	100.0	5	85.2
Mataura River	Mouth to Mataura Falls	1	11	477.5	71.6	885	91.2	77.1	117	84.0
	Mataura Falls to Waikaia Junction	2	1	95.5	47.6	97	–	–	–	100.0
Mokoreta River	Entire river (tributary of Mataura River)	1	7	848.2	32.4	646	57.6	34.9	36	93.6
Waikaka Stream	Entire river (tributary of Mataura River)	1	1	295.2	29.7	94	21.2	29.7	4	93.3
Clutha River	Mouth to Balclutha Bridge	1	5	945.5	20.9	571	125.1	15.6	33	88.3
	Balclutha Bridge to Clydevale	2	5	548.2	32.3	426	72.5	55.4	53	88.3
	Clydevale to Beaumont	3	2	131.1	36.6	115	5.1	29.4	2	96.3
Pomahaka River	Entire river (tributary of Clutha River)	1	3	446.5	28.0	221	59.9	48.4	46	88.2

Table 1 – *continued*

Catchment	Stratum definition	Stratum	Number samples	Longfinned eel Landing wt (kg)	% wt sampled	No. eels sampled	Shortfinned eel Landing wt (kg)	% wt sampled	No. eels sampled	% landing weight LFE
Lake Wakatipu	Headwaters of Clutha River	1	1	161.0	43.4	52	–	–	–	100.0
Taieri River	Waipori Lakes	3	6	124.6	60.7	185	756.2	31.9	441	14.1
	Above Taieri Gorge	4	2	1012.3	13.9	218	–	–	–	100.0
Waitaki River	Mouth to 6 km above Waitaki Bridge	1	3	424.1	34.5	237	64.7	28.9	25	86.8
	6 km above Waitaki Bridge to Duntroon	2	3	254.3	39.4	176	89.0	46.7	66	74.1
	Duntroon to Waitaki Dam	3	1	213.4	37.7	115	8.0	37.7	5	96.4
Te Waihora	Kaituna Lagoon to Halswell River	1	1	–	–	–	1467.3	4.7	128	0.0
	Kaitorete Spit to Kaituna Lagoon	2	5	21.6	7.9	6	3591.8	7.8	623	0.6
	Selwyn River to Halswell	3	5	–	–	–	3359.4	6.9	485	0.0
	Concession area for migrating males	4	5	–	–	–	4276.5	1.8	626	0.0
Waimakariri River	Mouth to Bexley Bridge	1	2	261.5	38.5	183	1.1	28.5	1	99.6
Grey River	Lake Brunner and all tributaries that drain into lake	2	4	984.2	7.8	210	1239.2	7.9	219	44.3
	Above junction of Arnold and Grey Rivers	3	1	123.1	100.0	106	–	–	–	100.0
Totals			104	11232.4		7869	15495.2		3052	

Table 2: Catch sampling length, weight, regression coefficents and condition index for longfinned eels. s.e., standard error; –, insufficient data

Catchment	Stratum	N	Mean length (cm)	s.e.	Range	Mean weight (g)	s.e.	Range	a	b	r^2	Condition index (g)
Waiau River	1	252	51.7	0.53	39–99	393.2	22.11	150–3585	0.0021	3.06	0.96	221
	2	239	52.9	0.51	42–92	423.8	19.18	185–2730	0.0019	3.08	0.94	236
	3	252	58.4	0.75	44–101	645.6	33.87	225–3725	0.0016	3.13	0.97	244
Aparima River	1	479	50.1	0.20	42–87	327.5	5.33	190–1840	0.0038	2.90	0.89	234
	2	495	51.5	0.25	42–102	366.6	10.40	205–3225	0.0015	3.14	0.91	228
Oreti River	1	570	53.4	0.32	35–109	437.6	13.77	90–3810	0.0012	3.20	0.96	231
	2	186	50.9	0.45	44–100	350.9	21.31	220–2995	0.0015	3.12	0.91	221
	3	278	50.9	0.29	42–90	347.5	8.21	215–1825	0.0034	2.93	0.90	234
Makarewa River	1	492	52.5	0.37	40–95	425.1	13.38	200–2775	0.0024	3.03	0.96	243
Waituna Creek	1	83	51.2	0.82	43–94	370.6	24.89	200–1980	0.0056	2.80	0.93	242
Mataura River	1	885	51.7	0.22	43–105	384.5	9.14	215–3535	0.0019	3.08	0.93	235
	2	97	55.6	0.78	45–105	478.6	35.23	250–3420	0.0015	3.14	0.95	228
Mokoreta River	1	646	52.6	0.32	39–100	430.6	13.03	145–3020	0.0009	3.27	0.95	232
Waikaka Stream	1	94	68.9	1.09	49–96	934.1	52.53	290–2955	0.0009	3.25	0.96	213
Clutha River	1	571	50.8	0.23	41–90	349.3	6.98	195–2055	0.0030	2.96	0.93	234
	2	426	53.4	0.35	37–98	418.4	15.20	110–3380	0.0008	3.28	0.94	218
	3	115	52.4	0.89	43–102	418.3	41.69	195–3480	0.0009	3.26	0.97	219
Pomahaka River	1	221	57.1	0.69	42–105	570.1	33.30	190–3705	0.0012	3.20	0.97	232

Table 2 – *continued*

Catchment	Stratum	N	Mean length (cm)	s.e.	Range	Mean weight (g)	s.e.	Range	a	b	r^2	Condition index (g)
Lake Wakatipu	1	52	72.4	2.17	50–100	1345.3	142.10	300–3690	0.0002	3.59	0.98	197
Taieri River	3	185	53.2	0.50	43–110	404.9	19.37	200–3210	0.0025	3.00	0.93	230
	4	218	61.9	0.68	47–95	640.3	26.88	250–2570	0.0009	3.24	0.97	206
Waitaki River	1	237	59.9	0.64	46–101	623.8	26.36	235–3475	0.0012	3.19	0.97	226
	2	176	59.0	0.74	44–102	571.8	32.46	205–3570	0.0015	3.13	0.95	219
	3	115	60.6	1.12	45–103	701.2	52.83	200–3855	0.0008	3.30	0.98	224
Te Waihora	2	6	49.5	2.09	44–57	287.5	39.85	195–455	0.0023	3.00	0.92	209
Waimakariri River	1	183	57.9	0.73	45–103	554.2	31.85	205–3515	0.0015	3.13	0.96	224
Grey River	2	210	51.6	0.56	41–105	368.5	21.56	165–3465	0.0013	3.15	0.95	215
	3	106	70.2	1.38	44–99	1163.1	76.69	190–3255	0.0005	3.40	0.97	218
Strata mean			55.8			526.2						234
All eels mean		7869	53.9	0.10	35–110	454.2	4.23	90–3855	0.0014	3.15	0.96	230

Table 3: Catch sampling length, weight, regression coefficents and condition index for shortfinned eels. s.e., standard error; –, insufficient data

Catchment	Stratum	N	Mean length (cm)	s.e.	Range	Mean weight (g)	s.e.	Range	a	b	r^2	Condition index (g)
Waiau River	1	11	61.1	3.09	46–81	527.7	68.16	250–990	0.0223	2.44	0.93	238
	2	14	65.0	2.08	50–78	667.5	60.32	295–1155	0.0044	2.85	0.97	226
Aparima River	1	31	66.9	1.82	51–86	725.3	66.05	305–1705	0.0012	3.14	0.96	192
	2	9	62.8	2.86	57–84	521.1	85.74	330–1165	0.0016	3.05	0.98	179
Oreti River	1	55	66.9	1.48	47–91	742.1	48.03	275–1770	0.0035	2.90	0.96	217
	2	1	–	–	59	–	–	430	–	–	–	–
Makarewa River	1	16	63.1	2.79	49–81	602.5	76.36	285–1160	0.0045	2.83	0.98	215
Waituna Creek	1	5	75.2	0.94	51–104	1076.0	32.60	305–2110	0.0064	2.74	0.98	220
Mataura River	1	117	63.5	0.94	48–97	612.5	32.59	275–2250	0.0022	3.00	0.97	200
Mokoreta River	1	36	63.5	1.28	50–79	566.5	35.21	270–1045	0.0024	2.99	0.94	210
Waikaka Stream	1	4	85.0	15.48	64–131	1570.0	799.05	565–3955	0.0101	2.64	0.99	238
Clutha River	1	33	64.1	1.89	50–90	608.5	65.51	225–1765	0.0010	3.18	0.98	178
	2	53	69.7	1.22	54–92	759.2	42.82	345–1635	0.0026	2.95	0.95	199
	3	2	71.0	10.00	61–81	730.0	280.00	450–1010	–	–	–	–
Pomahaka River	1	46	63.5	1.74	50–95	630.2	61.46	285–2045	0.0026	2.97	0.98	205
Taieri River	3	441	62.5	0.40	47–94	551.9	12.20	200–1820	0.0016	3.07	0.96	189

Table 3 – *continued*

Catchment	Stratum	N	length (cm)	s.e.	Range	weight (g)	s.e.	Range	a	b	r^2	Condition index (g)
Waitaki River	1	25	69.5	1.65	58–89	758.8	56.90	415–1615	0.0048	2.81	0.90	215
	2	66	65.2	1.15	48–97	634.9	35.71	270–1875	0.0032	2.91	0.95	204
	3	5	62.2	3.97	53–75	596.0	131.12	330–1080	0.0012	3.16	0.95	202
Te Waihora	1	128	59.9	0.85	45–86	539.9	29.77	205–1665	0.0003	3.49	0.98	177
	2	623	55.9	0.44	31–96	453.1	13.32	50–2285	0.0005	3.39	0.97	185
	3	485	58.5	0.36	42–91	481.4	11.52	165–1850	0.0008	3.25	0.96	190
	4	626	39.5	0.11	32–56	116.1	1.32	60–365	0.0008	3.22	0.78	172
Waimakariri River	1	1	–	–	54	–	–	345	–	–	–	–
Grey River	2	219	59.2	0.51	43–85	448.6	13.35	195–1380	0.0014	3.10	0.95	182
Strata mean			64.1			648.7						201
All eels mean		3052	55.9	0.22	31–131	442.6	5.91	50–3955	0.0006	3.31	0.98	180

Table 4: Percentage of longfinned and shortfinned eels in each stratum that were male (M), female (F), or immature or unable to determine (I). –, no data

Catchment	Stratum	Longfinned eels				Shortfinned eels			
		M	F	I	Total	M	F	I	Total
Waiau River	1	47.8	11.6	40.6	249	0.0	100.0	0.0	11
	2	50.9	15.0	34.2	234	0.0	100.0	0.0	14
	3	43.8	30.8	25.4	240	–	–	–	0
Aparima River	1	55.3	4.8	39.9	479	0.0	100.0	0.0	31
	2	52.0	4.3	43.7	492	0.0	100.0	0.0	9
Oreti River	1	49.1	18.2	32.7	566	0.0	100.0	0.0	54
	2	50.0	2.2	47.8	184	0.0	100.0	0.0	1
	3	47.8	5.4	46.8	278	–	–	–	0
Makarewa River	1	41.6	19.5	38.9	488	0.0	100.0	0.0	16
Waituna Creek	1	9.6	18.1	72.3	83	0.0	100.0	0.0	5
Mataura River	1	52.6	2.4	45.0	878	1.7	98.3	0.0	117
	2	39.6	31.3	29.2	96	–	–	–	0
Mokoreta River	1	42.1	17.8	40.1	636	0.0	100.0	0.0	36
Waikaka Stream	1	1.1	95.5	3.4	89	0.0	100.0	0.0	3
Clutha River	1	49.6	9.5	40.9	570	0.0	100.0	0.0	33
	2	49.4	13.1	37.5	421	0.0	100.0	0.0	53
	3	30.1	15.0	54.9	113	0.0	100.0	0.0	2
Pomahaka River	1	46.3	32.2	21.5	214	0.0	100.0	0.0	46
Lake Wakatipu	1	0.0	88.6	11.4	35	–	–	–	0
Taieri River	3	46.2	16.3	37.5	184	0.7	99.3	0.0	441
	4	15.3	65.1	19.5	215	–	–	–	0
Waitaki River	1	31.8	43.2	25.0	236	0.0	100.0	0.0	25
	2	40.5	38.2	21.4	173	0.0	100.0	0.0	66
	3	27.3	42.7	30.0	110	0.0	100.0	0.0	5
Te Waihora	1	–	–	–	0	0.0	100.0	0.0	128
	2	16.7	33.3	50.0	6	7.2	91.3	1.4	623
	3	–	–	–	0	0.2	99.6	0.2	485
	4	–	–	–	0	96.3	3.0	0.6	626
Waimakariri River	1	36.7	37.8	25.6	180	0.0	100.0	0.0	1
Grey River	2	27.3	15.3	57.4	209	1.4	98.6	0.0	219
	3	2.4	89.4	8.2	85	–	–	–	0
Strata mean		35.8	29.2	35.0		4.3	95.6	0.1	
All eels mean		43.8	18.8	37.5	7743	21.5	78.0	0.5	3050

Table 5: Mean length of longfinned and shortfinned eels by by gonad stage. ***See*** **Appendix 1 for gonad descriptions. s.e., standard error**

		Indeterminate sex			Male			Female		
	Gonad stage	N	Mean length (cm)	s.e.	N	Mean length (cm)	s.e.	N	Mean length (cm)	s.e.
Longfins	Immature	2901	48.67	0.06	–	–	–	–	–	–
	1	–	–	–	2463	50.3	0.07	1063	58.4	0.19
	2	–	–	–	779	55.4	0.02	325	72.9	0.36
	3	–	–	–	125	59.8	0.47	52	81.8	0.90
	4	–	–	–	23	64.6	1.40	12	86.7	1.60
	Totals	2901			3390			1452		
Shortfins	Immature	14.0	38.6	1.50	–	–	–	–	–	–
	1	–	–	–	6	41.7	2.01	320	48.9	0.26
	2	–	–	–	58	38.8	0.40	1875	60.2	0.18
	3	–	–	–	511	38.9	0.12	168	77.4	0.64
	4	–	–	–	82	39.3	0.29	16	82.2	2.72
	Totals	14			657			2379		

Table 6: Longfinned eel mean age (A_{240}, A_{500}) and mean annual length and weight increments, for two weight categories, 220–260g and 450–550g. All data was collected in 1997–98 unless otherwise indicated. s.e., standard error; *, 1997–98 data supplemented from 95–96, 96–97; **, data from 95–96, 96–97

Catchment	Stratum	Number of landings sampled	N	Mean weight (g)	Mean length (cm)	Age range	Weight category (g)	Mean age ± s.e.	Mean annual weight increment (g) ± s.e.	Mean annual length increment (mm) ± s.e.
Waiau River	1	1	20	243.3	45.7	18–30	220–260	A_{240} 21.6±1.77	11.6±0.43	19.3±0.67
		2	12	486.7	57.5	21–33	450–550	A_{500} 26.8±0.99	18.4±0.64	19.8±0.64
Aparima River	1	3	30	246.0	46.6	15–24	220–260	A_{240} 19.1±0.43	13.1±0.30	22.1±0.48
		5	18	491.3	55.0	15–35	450–550	A_{500} 25.4±1.28	20.3±1.25	21.6±1.25
	2	1	8	494.4	57.4	21–29	450–550	A_{500} 24.1±1.04	20.7±0.64	21.0±0.78
Oreti River	1	4	22	243.4	46.2	11–23	220–260	A_{240} 18.6±0.55	13.4±0.49	22.6±0.79
		3	24	494.8	56.6	17–33	450–550	A_{500} 22.9±0.91	22.3±0.77	23.3±0.90
Makarewa River	1	2	22	243.4	45.1	12–20	220–260	A_{240} 15.8±0.52	15.8±0.61	26.1±0.93
		3	21	487.4	55.6	16–31	450–550	A_{500} 21.1±0.83	23.8±0.91	24.8±0.91
Waituna Creek	1	1	9	245.6	46.0	13–16	220–260	A_{240} 14.8±0.36	16.6±0.45	27.9±0.70
		1	8	481.3	57.4	17–24	450–550	A_{500} 19.9±0.88	24.4±0.84	26.6±0.87
Mataura River	1	6	26	252.9	46.7	13–24	220–260	A_{240} 17.7±0.56	14.7±0.44	24.2±0.72
		6	22	495.2	56.6	15–36	450–550	A_{500} 21.9±1.28	23.8±1.10	24.9±1.20
Mokoreta River	1	4	20	243.8	45.9	19–34	220–260	A_{240} 26.0±0.88	9.6±0.32	16.0±0.55
		3	20	494.5	56.4	25–42	450–550	A_{500} 32.0±1.08	15.8±0.55	16.4±0.53
Waikaka Stream	1	1	13	509.2	59.2	14–31	450–550	A_{500} 22.2±1.40	24.1±1.73	25.6±1.72
Clutha River	1	2	20	246.8	46.3	13–22	220–260	A_{240} 17.4±0.48	14.3±0.33	24.0±0.62
		3	20	494.0	57.4	15–32	450–550	A_{500} 23.2±1.06	22.3±1.13	23.5±1.10
	2	1	14	245.0	47.0	12–23	220–260	A_{240} 18.9±0.73	13.3±0.66	22.9±1.19
		1	10	504.4	58.5	21–34	450–550	A_{500} 25.6±1.12	19.9±0.57	21.2±0.81
Pomahaka River	1	2	7	237.9	46.3	14–21	220–260	A_{240} 18.7±1.11	13.0±0.87	22.6±1.54
		3	20	484.5	57.4	15–38	450–550	A_{500} 24.6±1.42	21.1±1.33	22.8±1.39

Table 6 – *continued*

Catchment	Stratum	Number of landings sampled	N	Mean weight (g)	Mean length (cm)	Age range	Weight category (g)	Mean age ± s.e.	Mean annual weight increment (g) ± s.e.	Mean annual length increment (mm) ± s.e.
Taieri River	3	1 **	1	235.0	45.0	–	220–260	A_{240} 19.0	14.1±1.70	25.9±4.86
		1 **	1	500.0	57.0	–	450–550	A_{500} 20.0	25.0	26.0
Lake Wakatipu	1	1	5	485.0	57.0	18–28	450–550	A_{500} 21.2±1.93	23.4±1.39	25.1±1.77
Waitaki River	1	4 *	8	243.8	46.1	14–27	220–260	A_{240} 17.3±1.58	14.8±1.07	24.9±1.77
		3	20	500.0	57.7	13–22	450–550	A_{500} 16.9±0.58	30.3±1.05	31.9±1.14
Rangitata River	1	1 **	4	236.3	48.3	15–20	220–260	A_{240} 18.3±1.11	13.2±1.22	24.1±2.03
Rakaia River	1	1 **	1	240.0	48.0	–	220–260	A_{240} 18.0	13.3	23.9
		1 **	5	491.0	60.2	16–22	450–550	A_{500} 19.6±1.29	25.5±1.83	28.6±1.78
Te Waihora	2	1	1	540.0	61.0	–	450–550	A_{500} 19.0	28.4	29.5
Waimakariri River	1	2	5	243.0	46.8	17–34	220–260	A_{240} 26.4±3.17	9.8±1.37	17.0±2.57
		2	22	501.3	57.4	16–45	450–550	A_{500} 29.8±1.54	17.9±1.11	18.7±1.13
Hurunui River	2	1 **	3	243.3	47.0	19–24	220–260	A_{240} 21.0±1.53	11.8±1.19	20.2±1.65
		1 **	9	501.1	57.3	20–28	450–550	A_{500} 25.0±0.80	20.2±0.79	21.1±0.68
Awatere River	1	1 **	9	235.6	45.8	12–21	220–260	A_{240} 17.2±0.92	13.9±0.74	24.3±1.41
Buller River	1	2 **	3	253.3	46.3	28–35	220–260	A_{240} 30.7±2.19	8.3±0.53	13.6±0.79
		2 **	11	480.0	59.5	21–54	450–550	A_{500} 34.8±2.68	14.5±1.05	16.2±0.99
Grey River	2	3	24	240.4	46.4	17–32	220–260	A_{240} 25.9±0.71	9.4±0.28	16.3±0.53
		4	14	478.9	58.1	21–40	450–550	A_{500} 33.2±1.25	14.7±0.68	16.4±0.85
Hokitika River	1	1 **	12	242.5	47.6	20–33	220–260	A_{240} 26.2±1.03	9.3±0.34	16.5±0.58

Table 7: **Shortfinned eel mean age (A_{240}, A_{500}) and mean annual length and weight increments, for two weight categories, 220–260g and 450–550g. All data was collected in 1997–98 unless otherwise indicated. s.e., standard error; *, 1997–98 data supplemented from 95–96, 96–97; **, data from 95–96, 96–97**

Catchment	Stratum	Number of landings sampled	N	Mean weight (g)	Mean length (cm)	Age range	Weight category (g)	Mean age ± s.e.	Mean annual weight increment (g) ± s.e.	Mean annual length increment (mm) ± s.e.
Waiau River	1	1	1	250.0	48.0	–	220–260	A_{240} 22.0	11.4	19.5
		3 *	5	535.0	63.4	17–26	450–550	A_{500} 20.4±1.54	26.7±1.69	29.2±1.97
Aparima River	1	1 **	2	260.0	49.0	14–18	220–260	A_{240} 16.0±2.00	16.5±2.06	27.9±3.49
		1	3	471.7	60.0	19–23	450–550	A_{500} 20.7±1.20	22.9±1.34	26.8±1.95
Oreti River	1	1 **	1	245.0	50.0	–	220–260	A_{240} 17.0	14.4	26.5
		5 *	10	485.0	60.5	10–18	450–550	A_{500} 14.0±0.83	35.7±2.11	40.9±2.58
Makarewa River	1	1	1	485.0	61.0	–	450–550	A_{500} 11.0	44.1	50.9
Waituna Creek	1	1	1	475.0	57.0	–	450–550	A_{500} 16.0	29.7	32.5
Mataura River	1	11 *	11	246.4	49.1	8–19	220–260	A_{240} 12.5±1.04	21.0±1.58	37.8±3.02
		7 **	38	492.9	60.8	8–22	450–550	A_{500} 15.2±0.65	35.0±1.66	39.8±1.90
Mokoreta River	1	2	4	495.0	61.3	22–26	450–550	A_{500} 24.3±0.85	20.5±1.25	23.3±1.18
Clutha River	1	2 *	2	242.5	49.0	10–14	220–260	A_{240} 12.0±2.00	21.0±4.96	37.6±5.43
		2	6	483.3	61.5	11–24	450–550	A_{500} 14.7±1.93	34.7±2.77	40.8±3.57
Pomahaka River	1	1 **	1	260.0	50.0	–	220–260	A_{240} 16.0	16.3	28.1
		2 *	6	474.2	60.5	8–19	450–550	A_{500} 14.0±1.79	37.4±5.65	43.5±6.11
Taieri River	3	2 *	3	255.0	47.7	10–16	220–260	A_{240} 13.7±1.86	19.4±2.82	32.5±4.82
		5 *	27	494.3	62.1	11–33	450–550	A_{500} 15.8±0.96	33.2±1.33	38.5±1.58

Table 7 – ***continued***

Catchment	Stratum	Number of landings sampled	N	Mean weight (g)	Mean length (cm)	Age range	Weight category (g)	Mean age ± s.e.	Mean annual weight increment (g) ± s.e.	Mean annual length increment (mm) ± s.e.
Waitaki River	1	3 **	6	229.2	48.7	7–19	220–260	A_{240} 10.5±1.80	24.2±2.86	46.3±5.64
		6 *	12	505.8	62.2	10–35	450–550	A_{500} 17.5±1.82	31.5±2.52	35.5±2.76
Te Waihora	2	3	20	236.8	48.8	9–20	220–260	A_{240} 14.9±0.61	16.5±0.74	30.6±1.44
		3	20	507.5	59.9	10–20	450–550	A_{500} 16.6±0.55	31.2±1.13	33.9±1.33
	3	3	20	245.0	48.5	11–20	220–260	A_{240} 14.9±0.46	16.8±0.57	29.8±0.99
		2	21	495.7	60.1	11–20	450–550	A_{500} 16.4±0.58	31.1±1.33	34.5±1.44
Huruni River	2	2 **	6	494.2	61.8	22–30	450–550	A_{500} 25.3±1.15	19.7±0.91	22.7±1.03
Wairau River	2	1 **	7	242.9	49.7	13–22	220–260	A_{240} 17.4±1.23	14.4±1.19	26.5±1.99
Grey River	2	3	21	241.4	49.3	16–28	220–260	A_{240} 20.8±0.66	11.9±0.42	21.8±0.71
		3	26	497.7	62.4	16–35	450–550	A_{500} 25.3±0.89	20.3±0.74	23.5±0.90

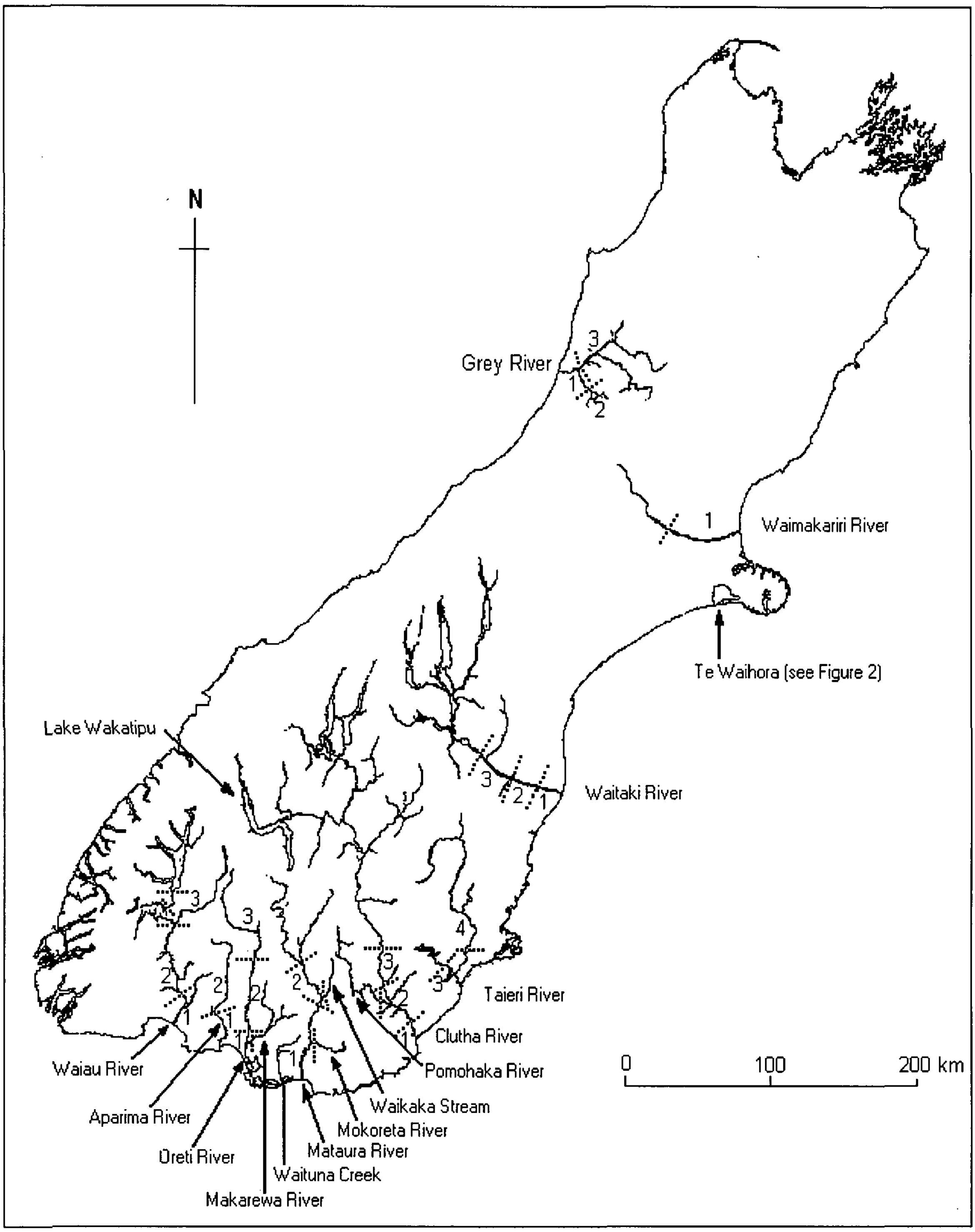


Figure 1: Catchments from where commercial landings were sampled as part of the South Island catch sampling programme in 1997–98. Strata within catchments are indicated by dotted lines and numerals (*see* Table 1 for strata definitions).

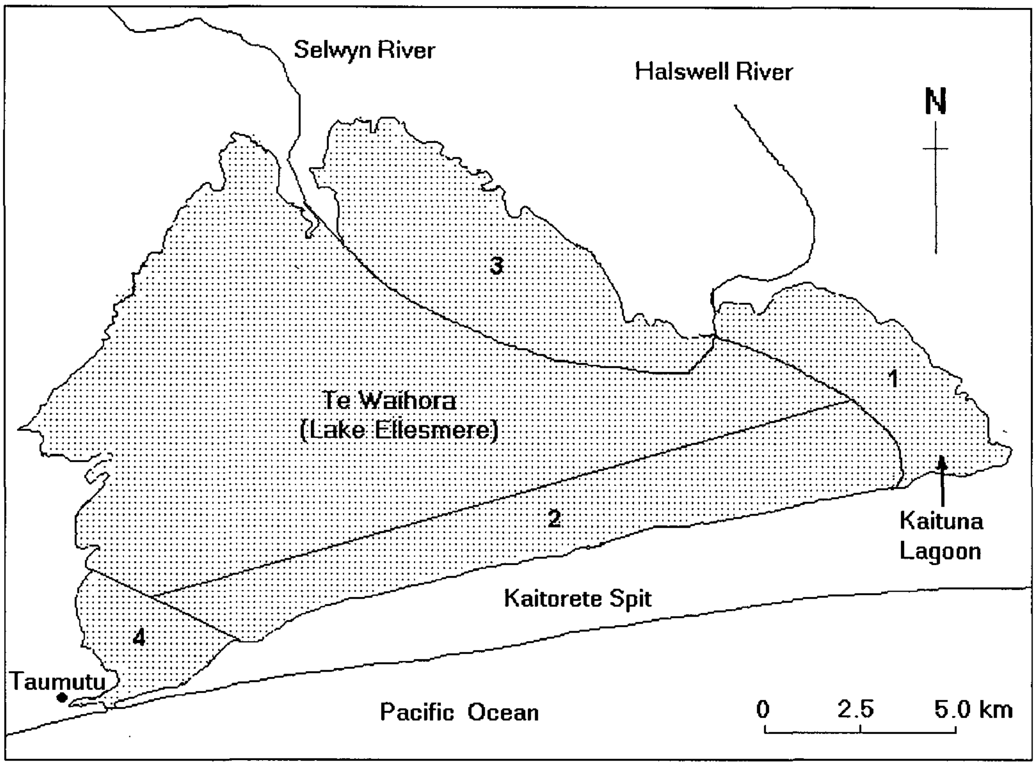
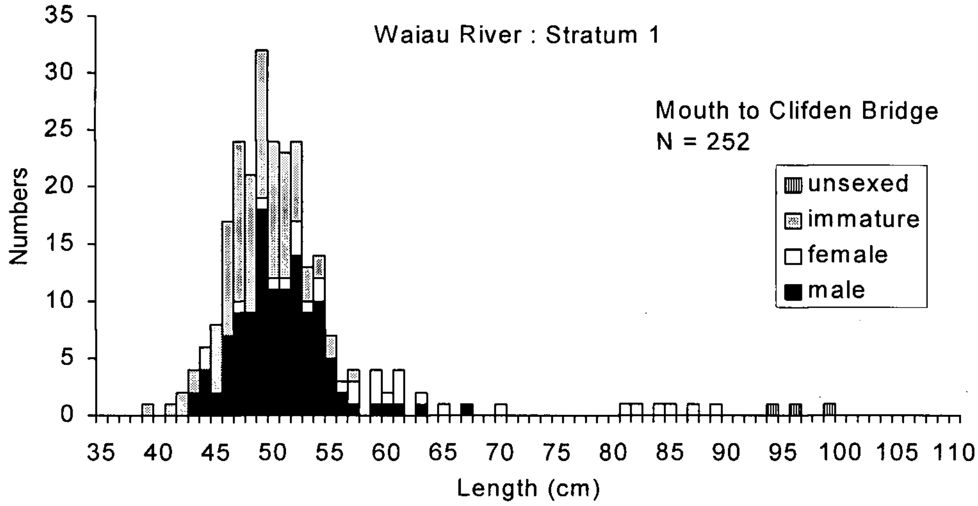
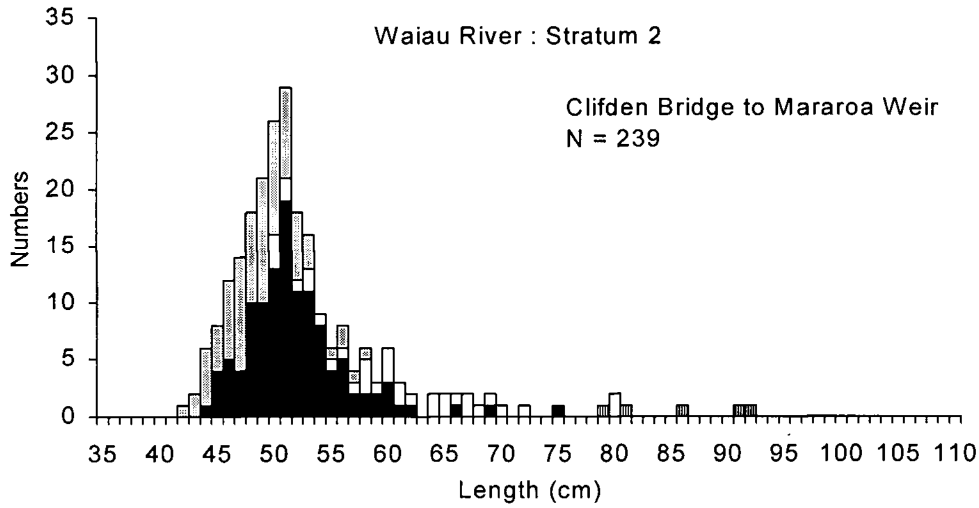


Figure 2: Te Waihora catchment (enlarged from Figure 1) showing strata boundaries used in the South Island catch sampling programme in 1997–98.





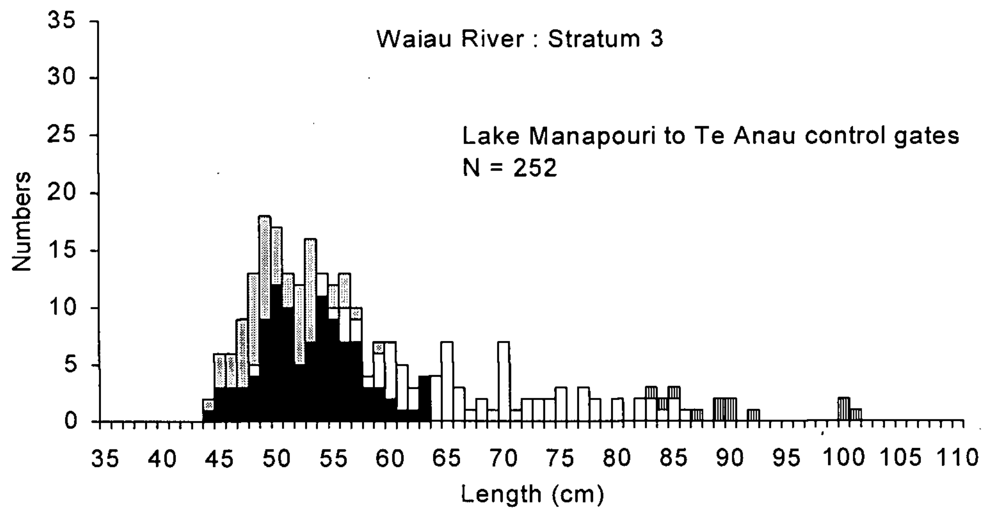


Figure 3: Length frequencies of longfinned eels from strata 1, 2, and 3 of Waiau River.

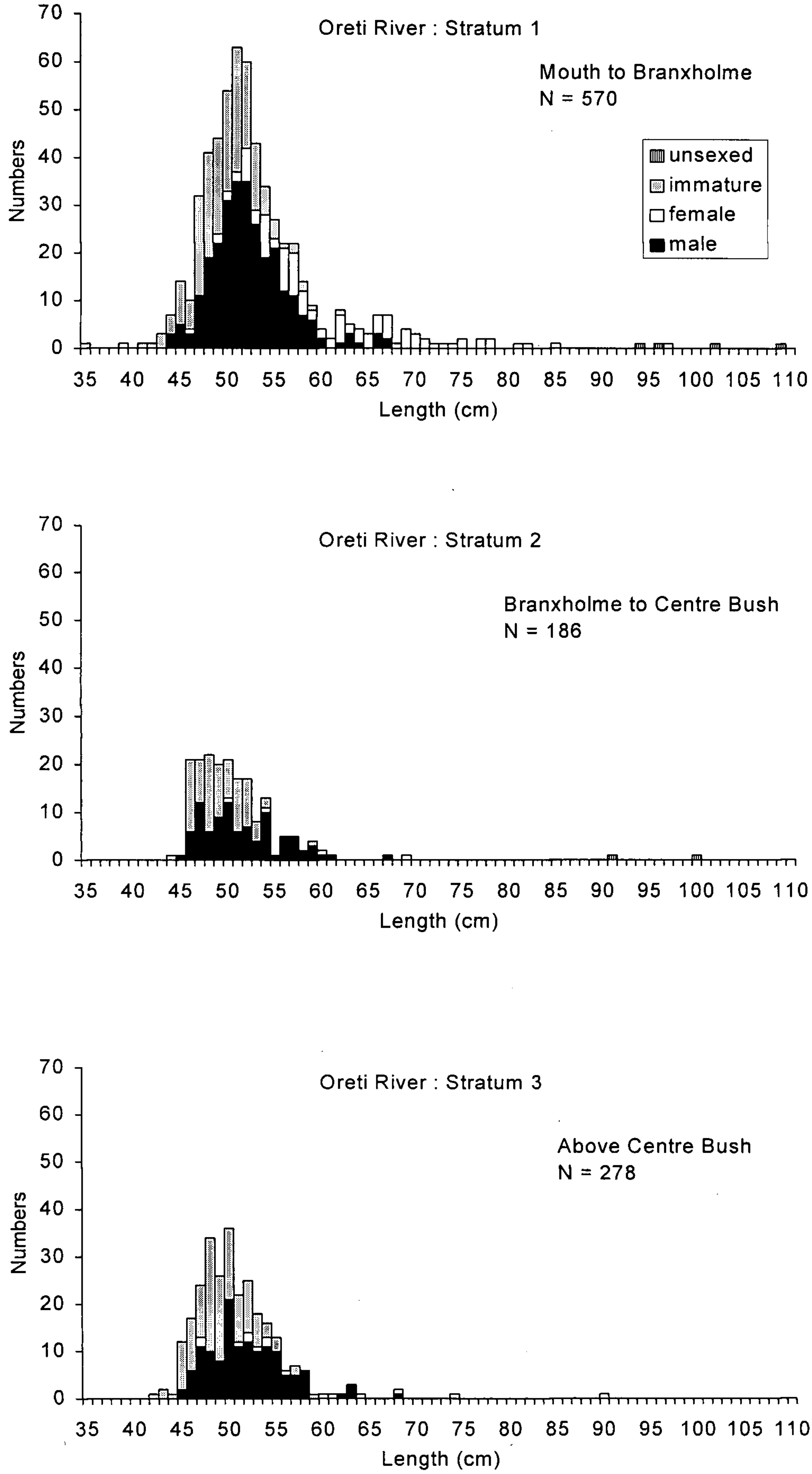


Figure 4: Length frequencies of longfinned eels from strata 1, 2, and 3 of Oreti River.

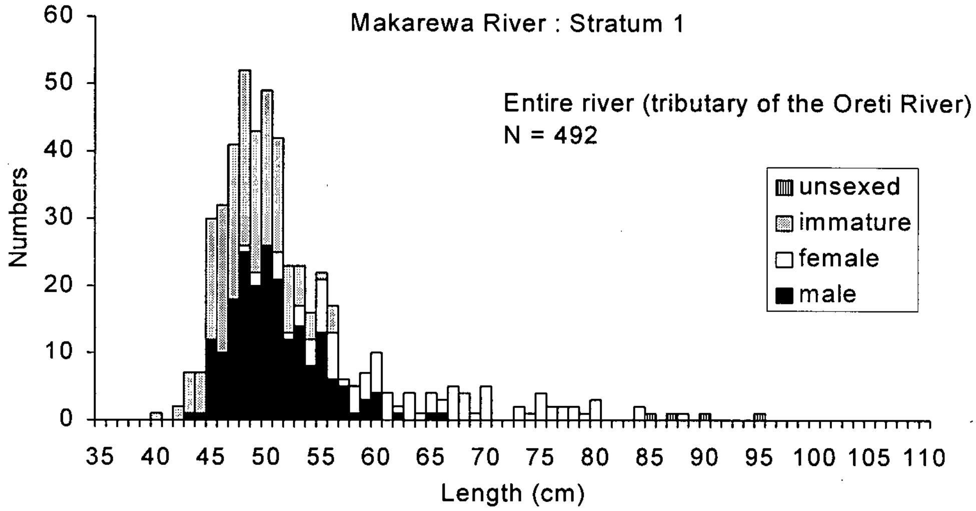
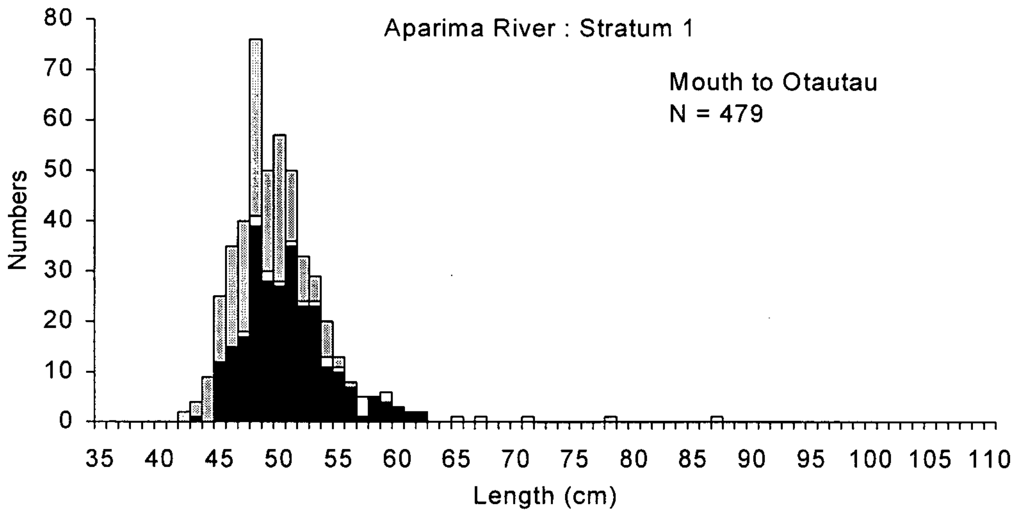


Figure 5: Length frequencies of longfinned eels from stratum 1 of Makarewa River.



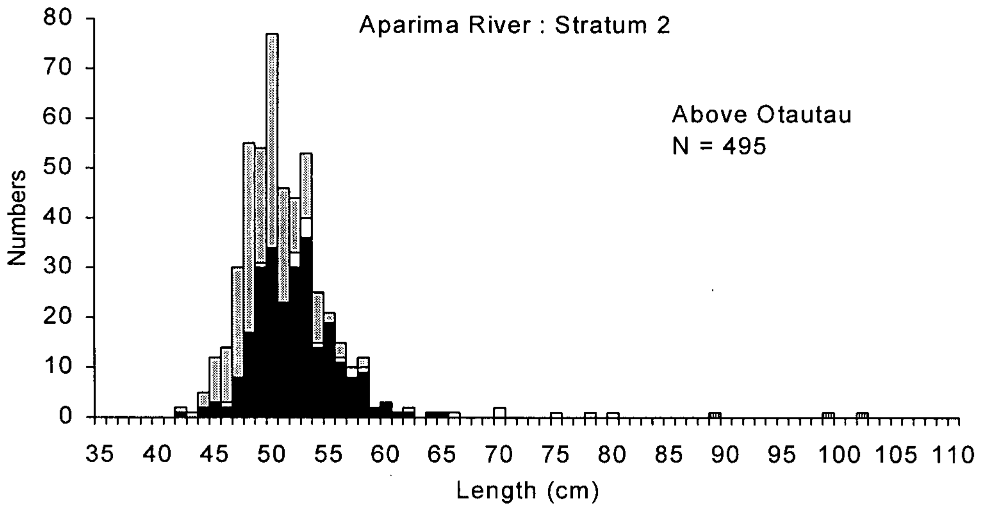


Figure 6: Length frequencies of longfinned eels from strata 1 and 2 of Aparima River

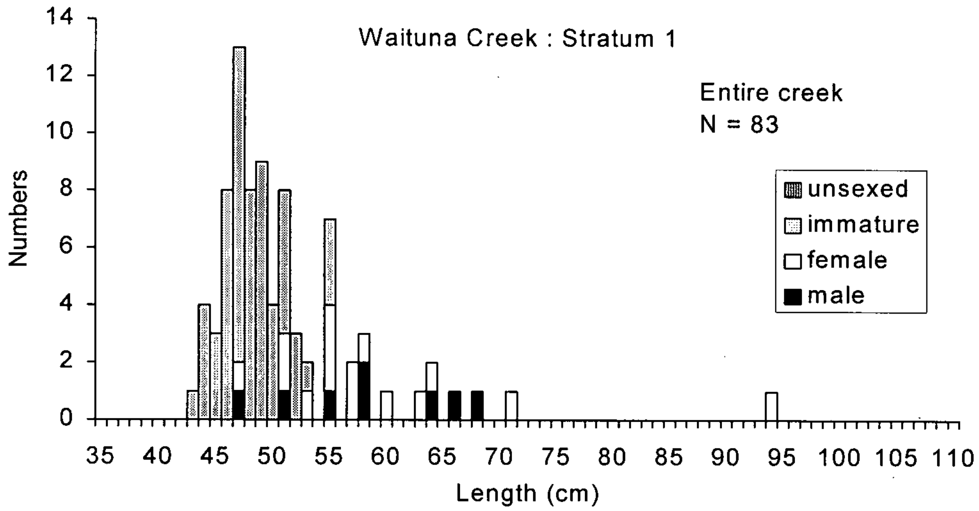


Figure 7: Length frequencies of longfinned eels from stratum 1 of Waituna Creek.

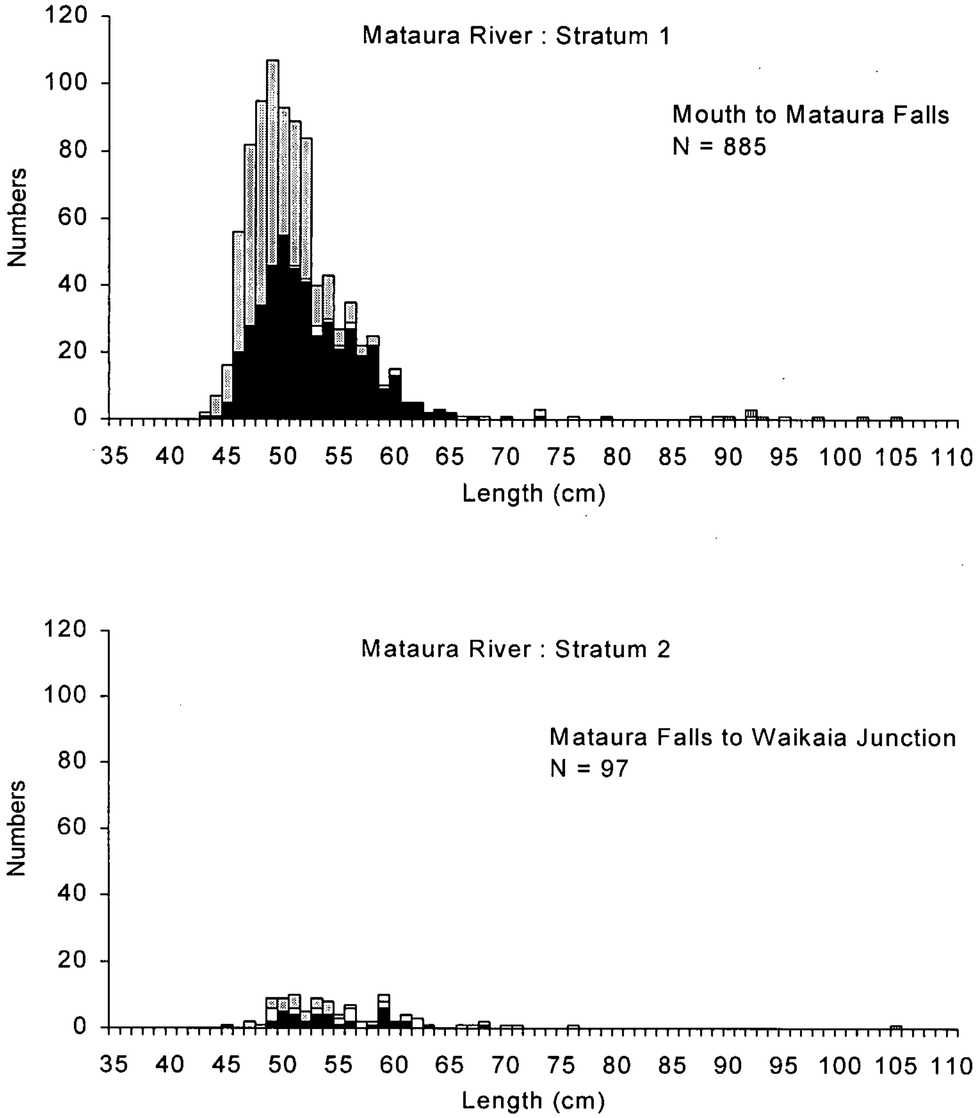


Figure 8: Length frequencies of longfinned eels from strata 1 and 2 of Mataura River.

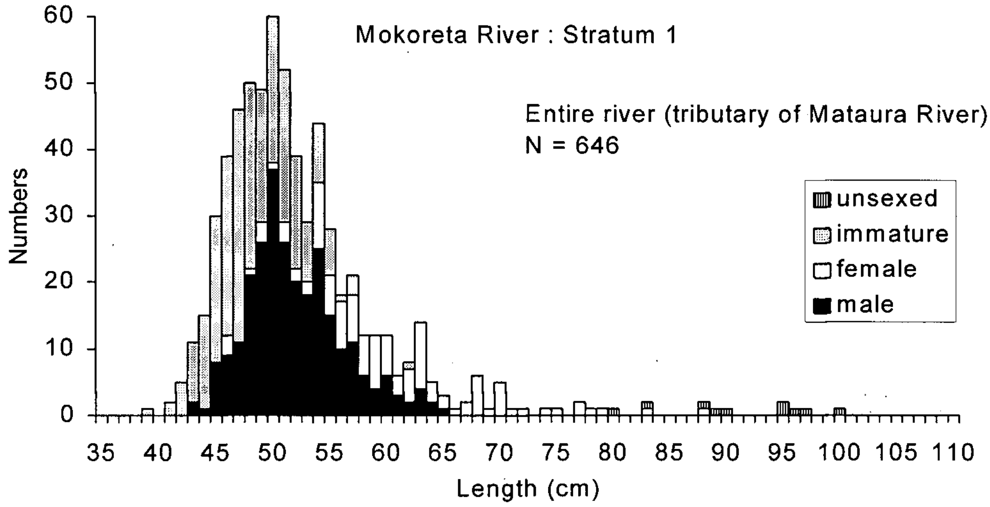


Figure 9: Length frequencies of longfinned eels from stratum 1 of Mokoreta River.

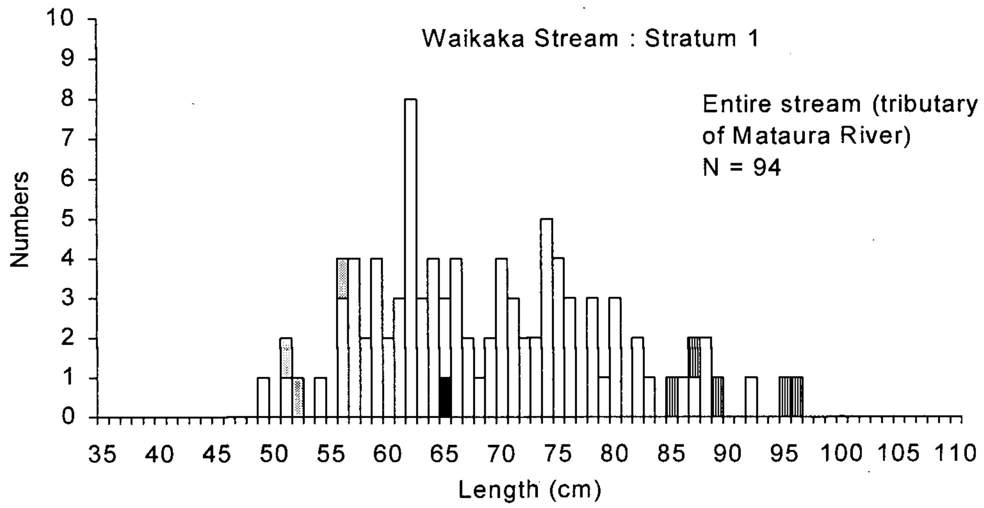


Figure 10: Length frequencies of longfinned eels from stratum 1 of Waikaka Stream.

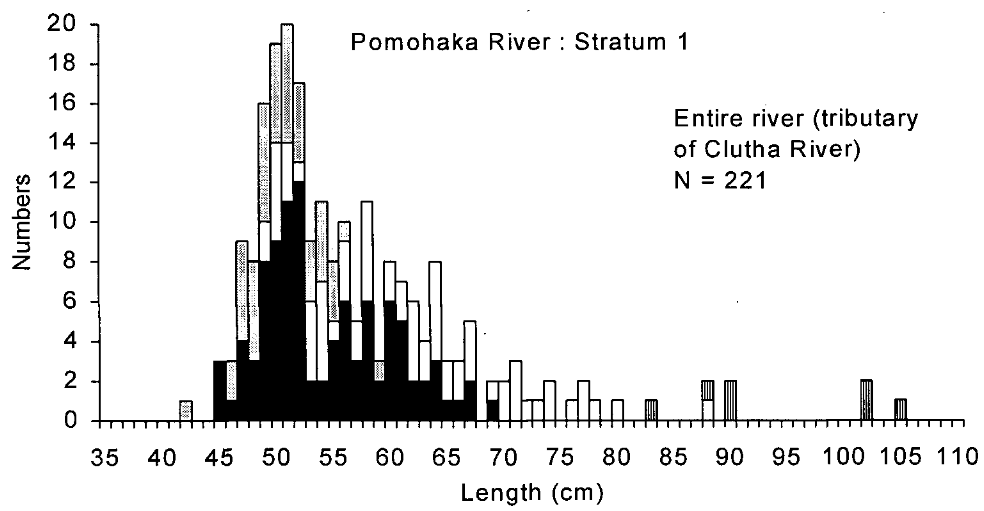
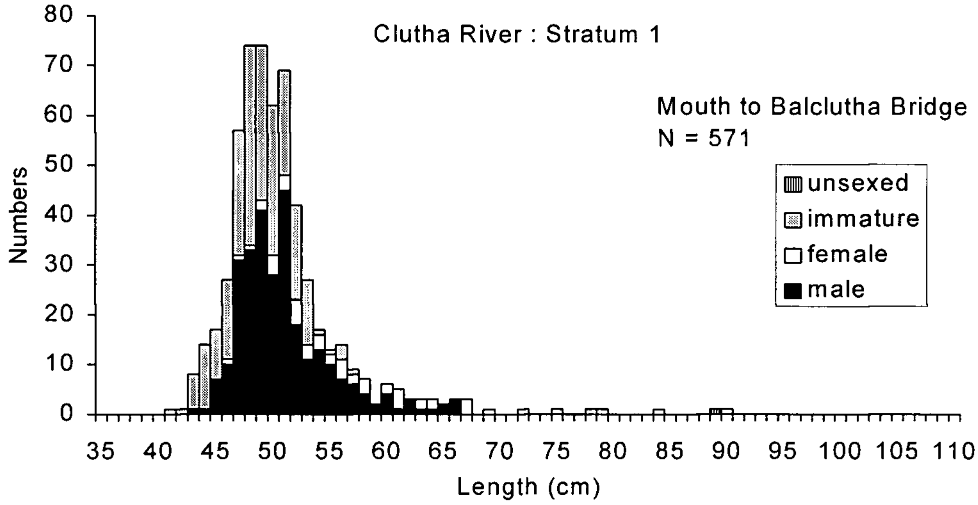
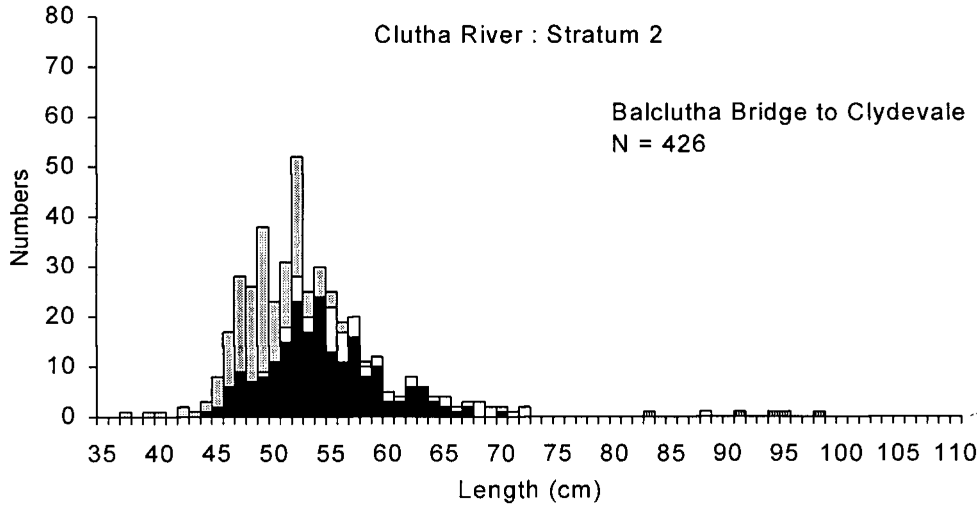


Figure 11: Length frequencies of longfinned eels from stratum 1 of Pomohaka River.





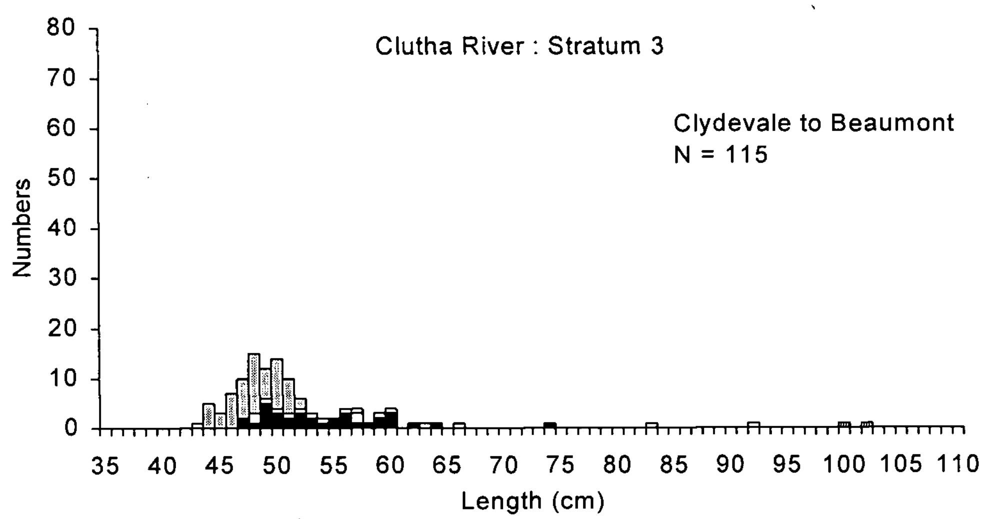


Figure 12: Length frequencies of longfinned eels from strata 1, 2, and 3 of Clutha River.

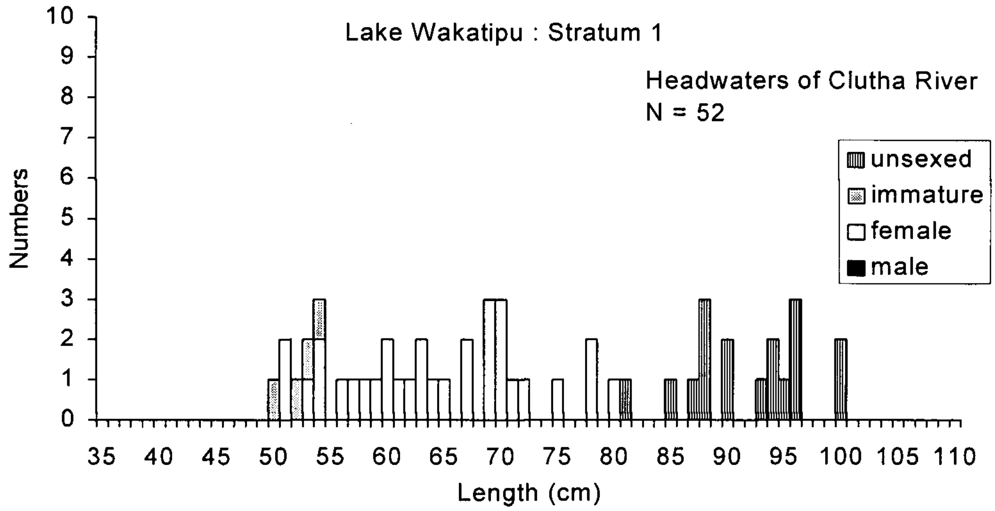
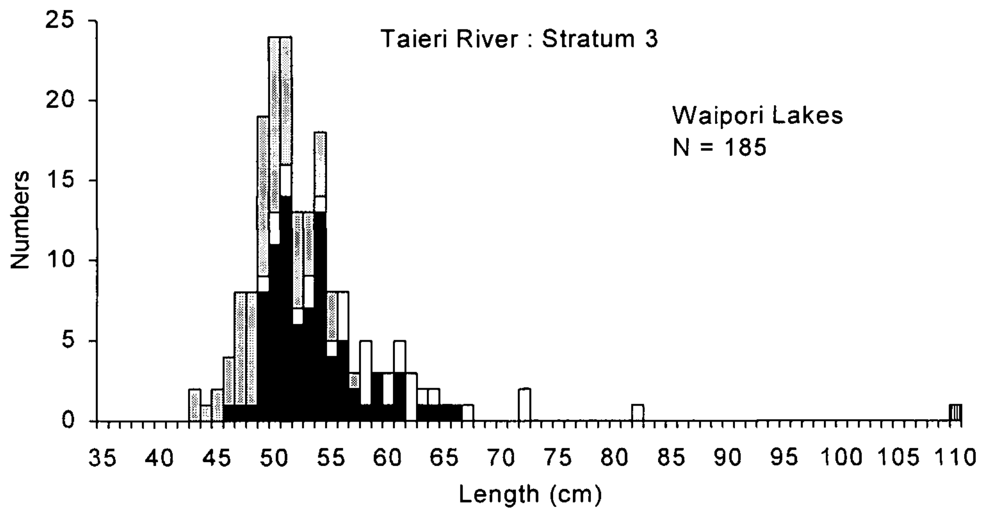


Figure 13: Length frequencies of longfinned eels from stratum 1 of Lake Wakatipu.



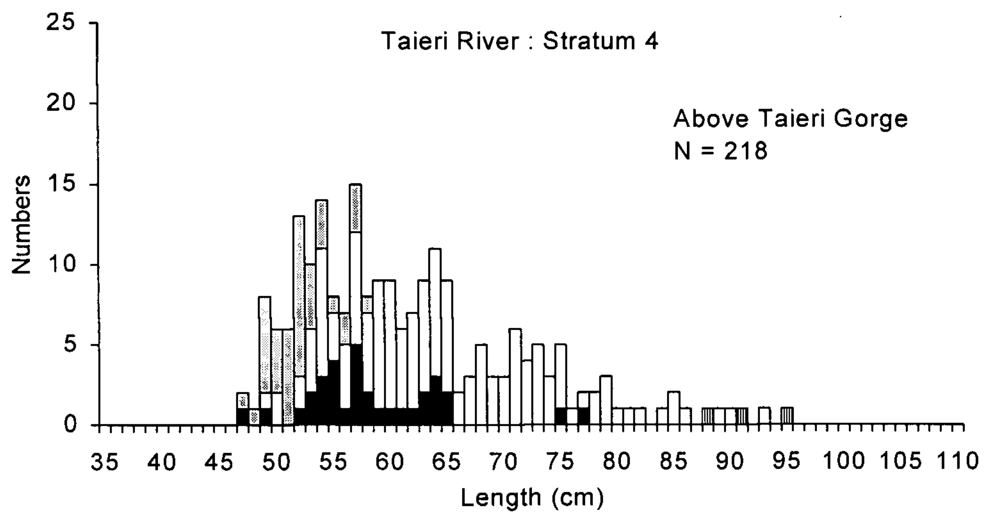


Figure 14: Length frequencies of longfinned eels from strata 3 and 4 of Taieri River.

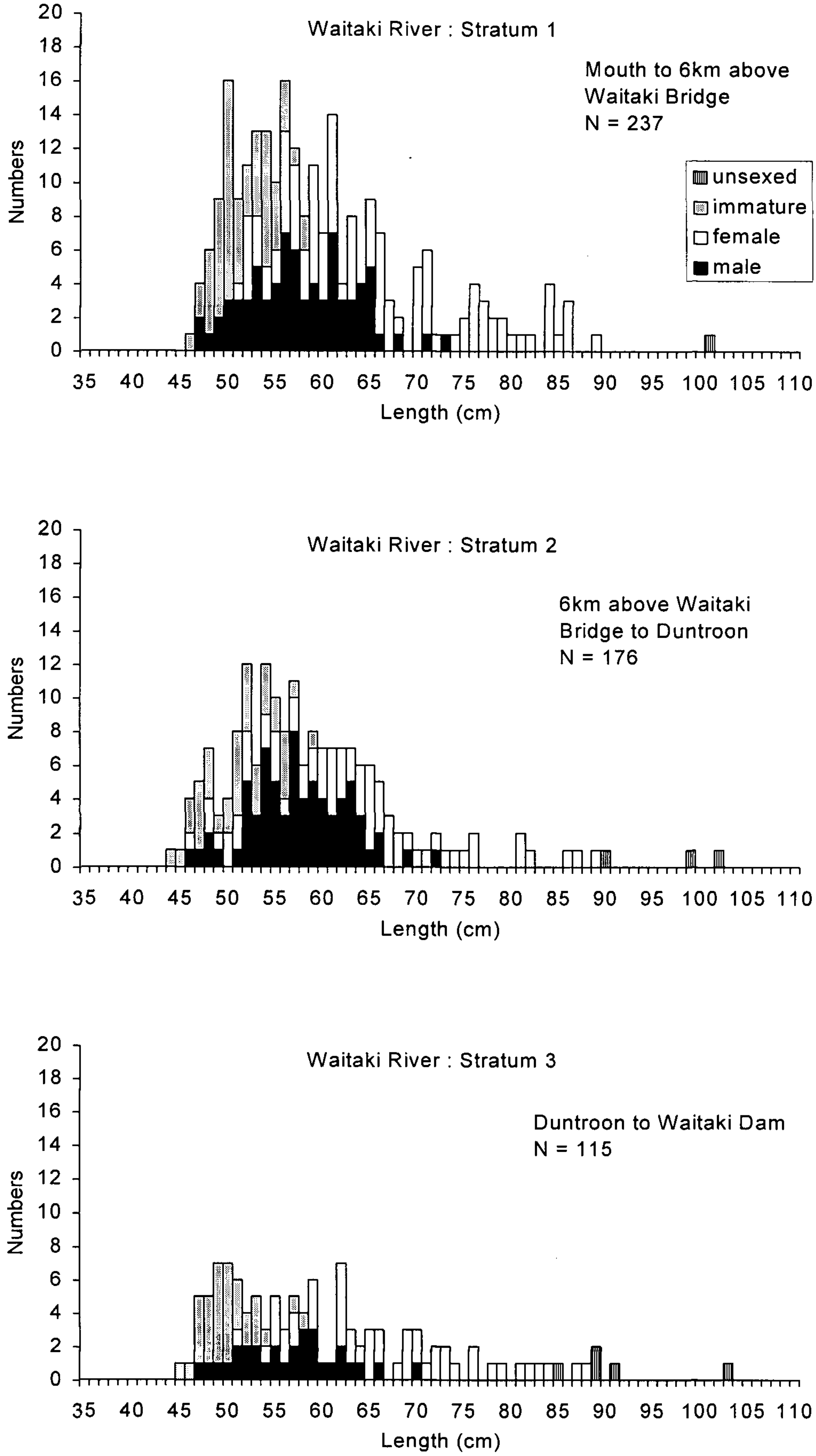


Figure 15: Length frequencies of longfinned eels from strata 1, 2, and 3 of Waitaki River.

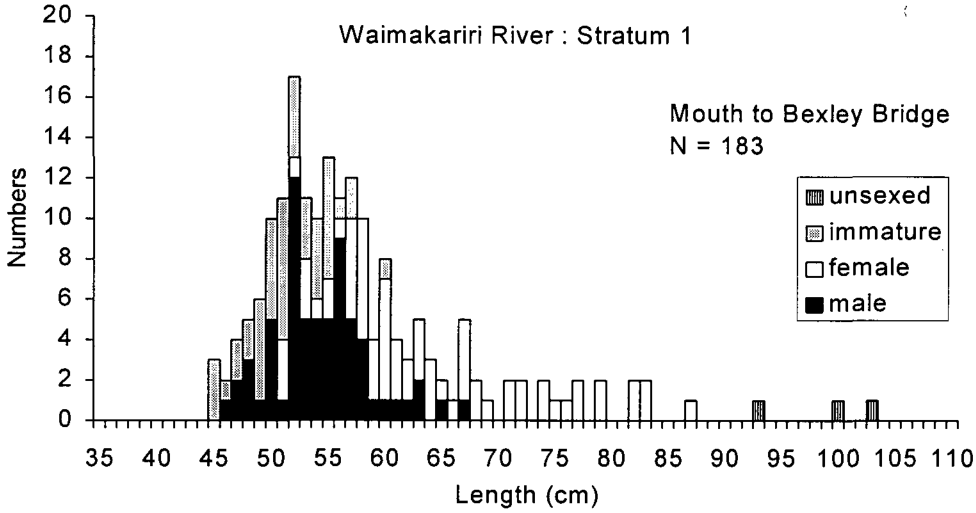
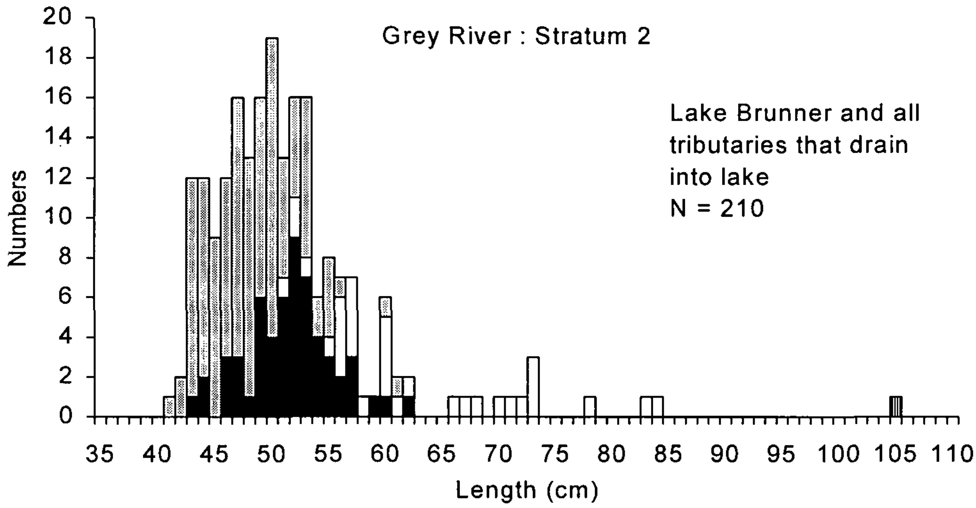


Figure 16: Length frequencies of longfinned eels from stratum 1 of Waimakariri River.



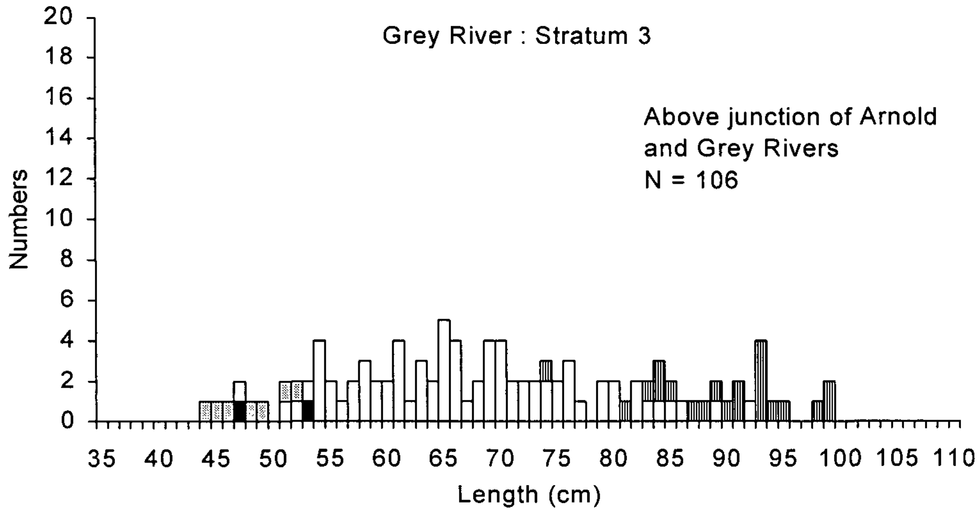


Figure 17: Length frequencies of longfinned eels from strata 2 and 3 of Grey River.

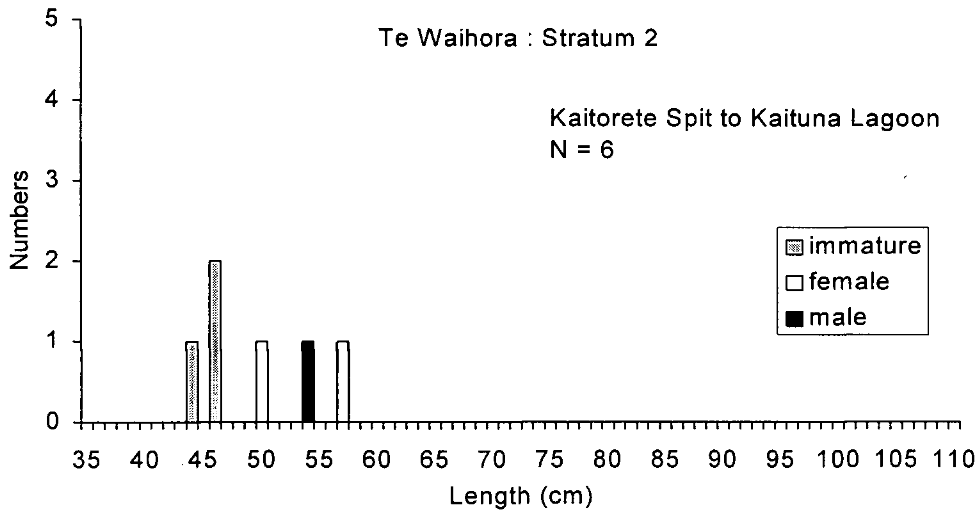


Figure 18: Length frequencies of longfinned eels from stratum 2 of Te Waihora.

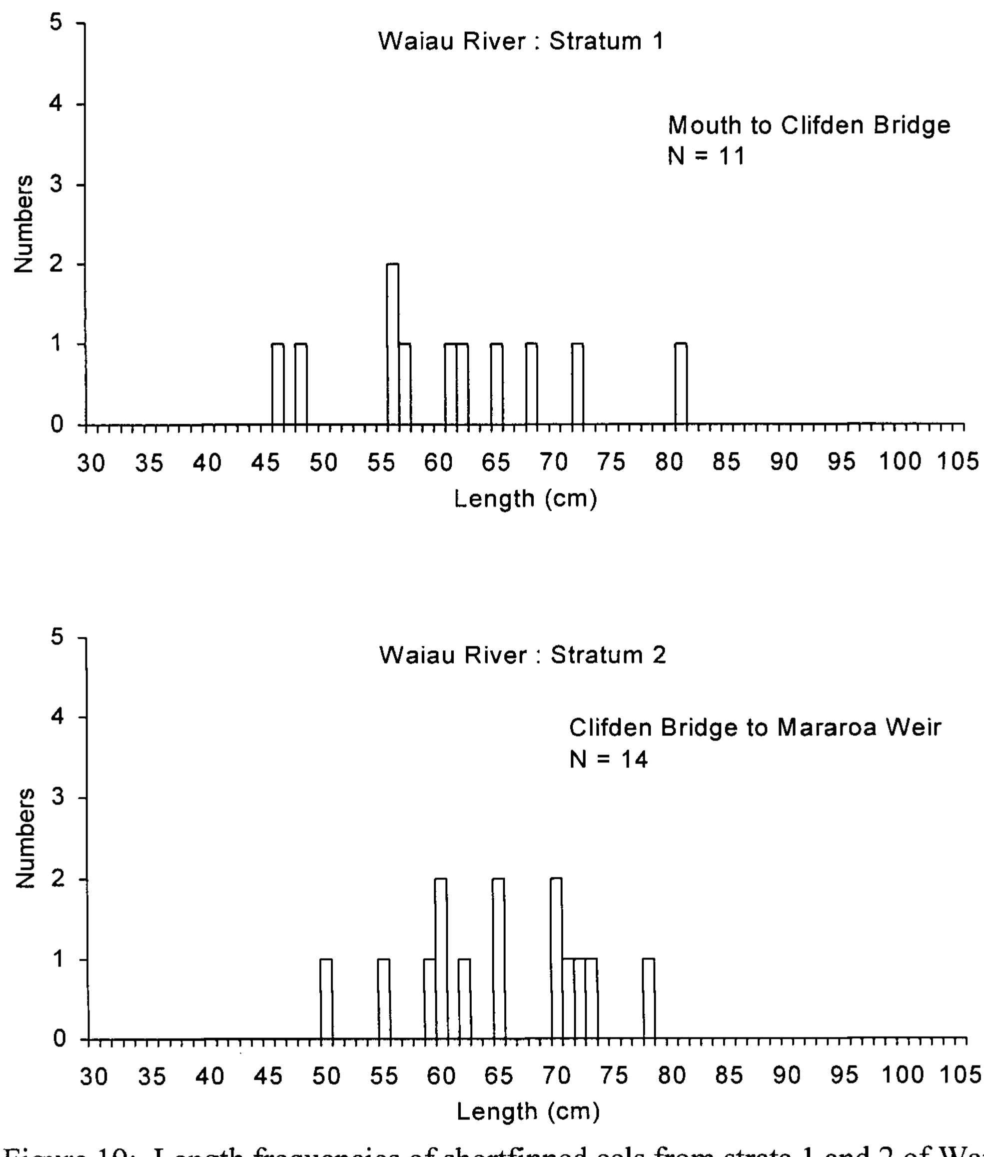
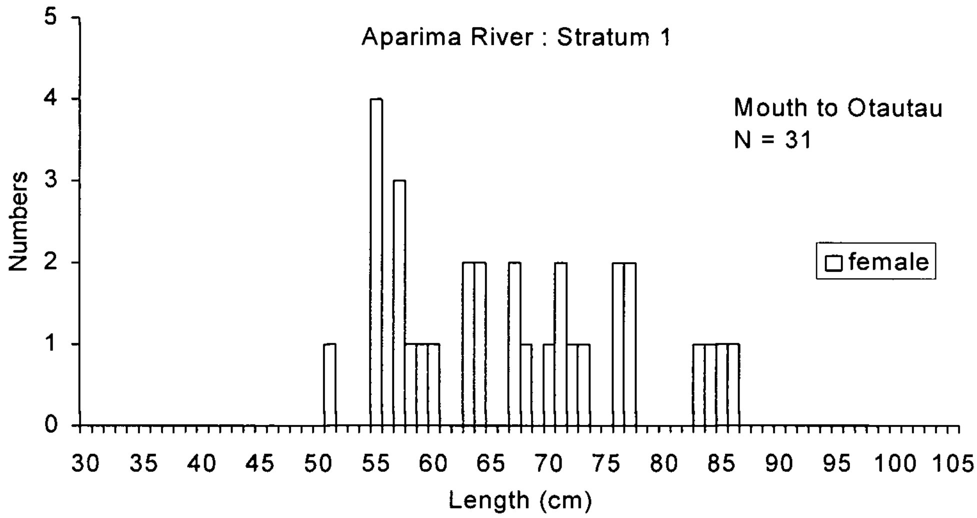


Figure 19: Length frequencies of shortfinned eels from strata 1 and 2 of Waiau River.



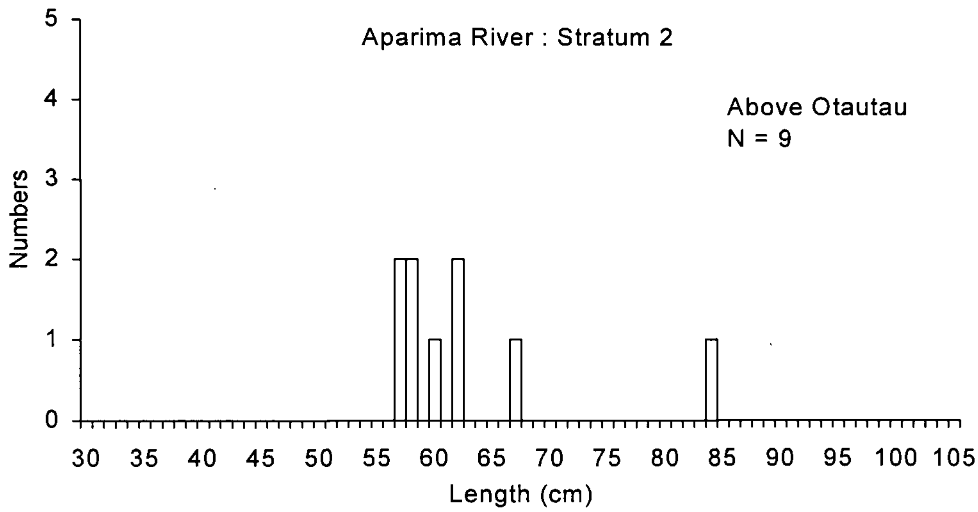


Figure 20: Length frequencies of shortfinned eels from strata 1 and 2 of Aparima River.

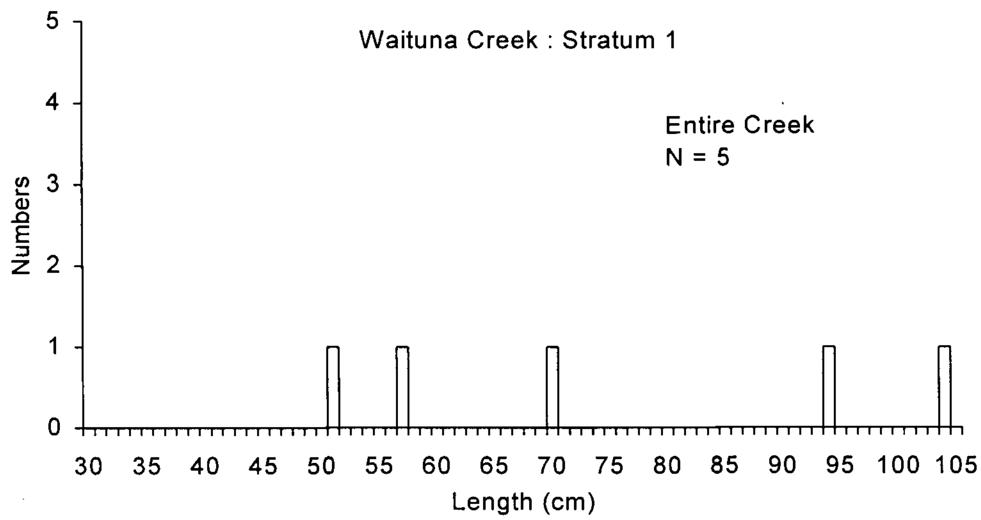
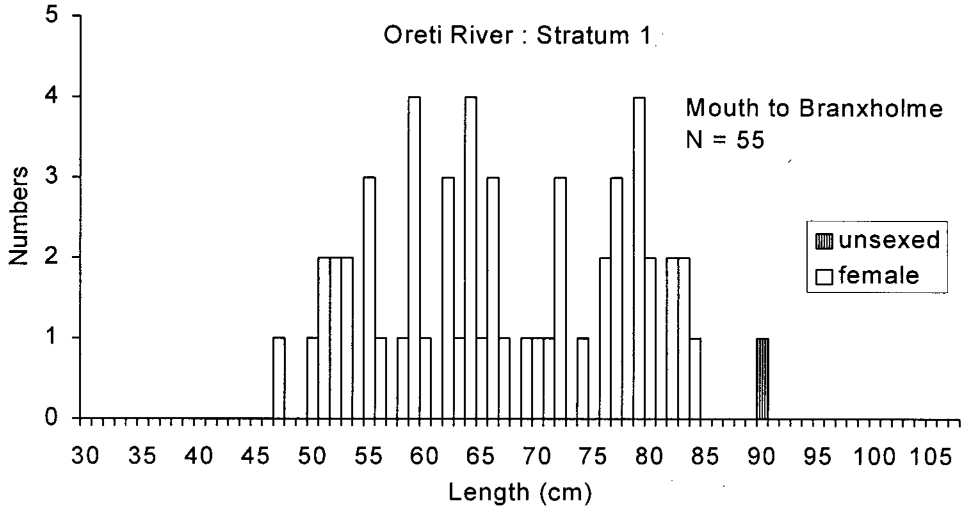


Figure 21: Length frequencies of shortfinned eels from stratum 1 of Waituna Creek.



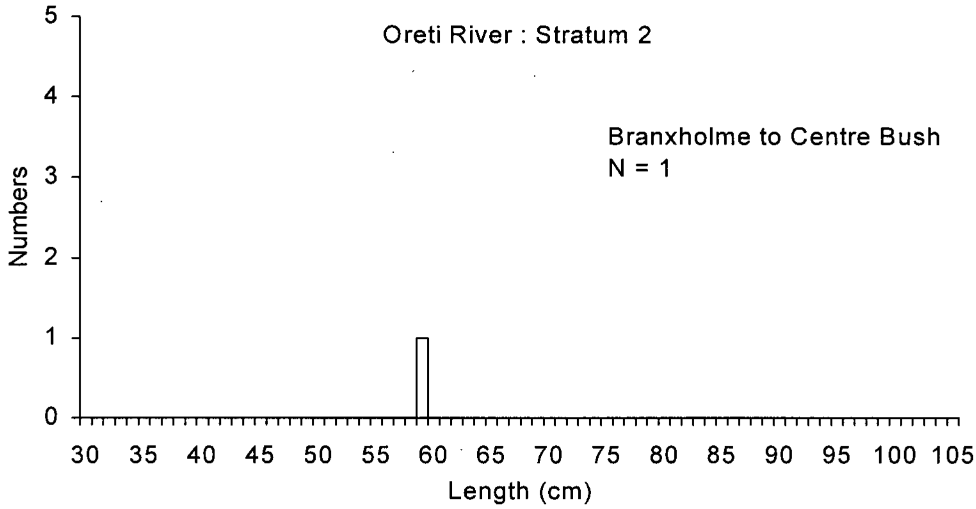


Figure 22: Length frequencies of shortfinned eels from strata 1 and 2 of Oreti River.

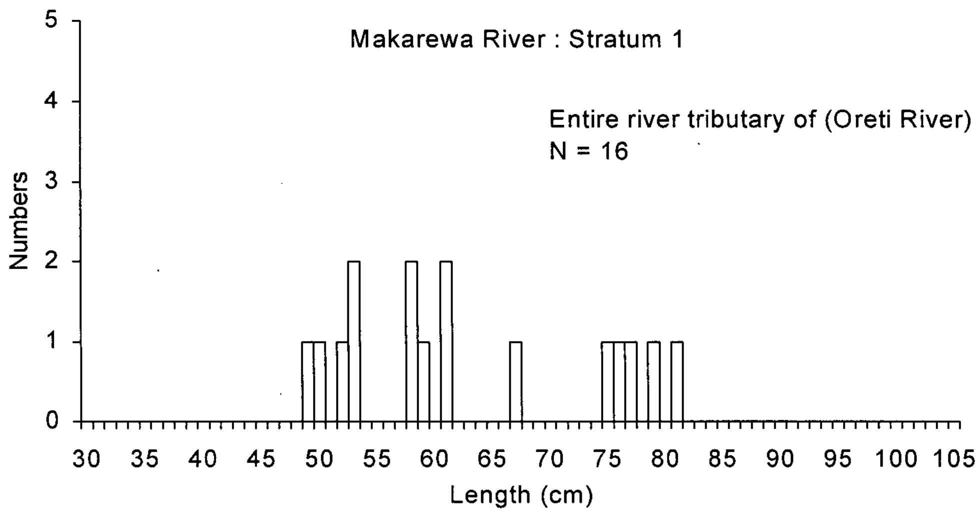


Figure 23: Length frequencies of shortfinned eels from stratum 1 of Makarewa River.

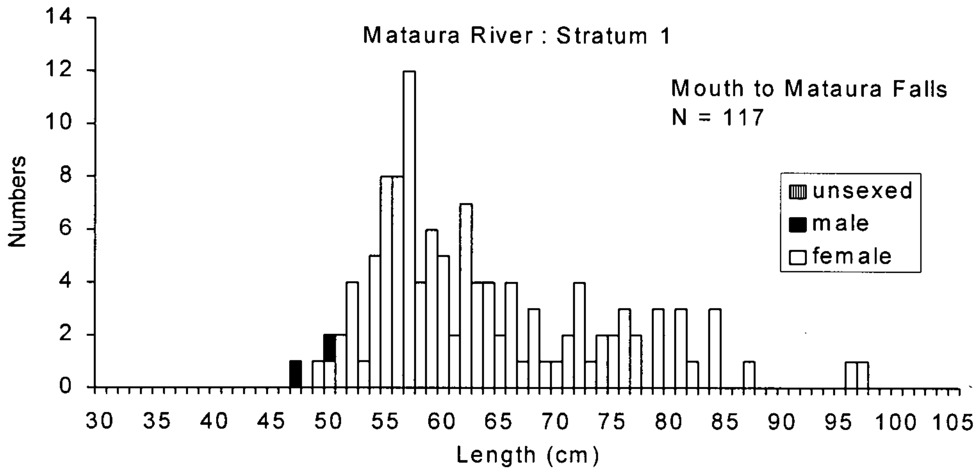


Figure 24: Length frequencies of shortfinned eels from stratum 1 of Mataura River.

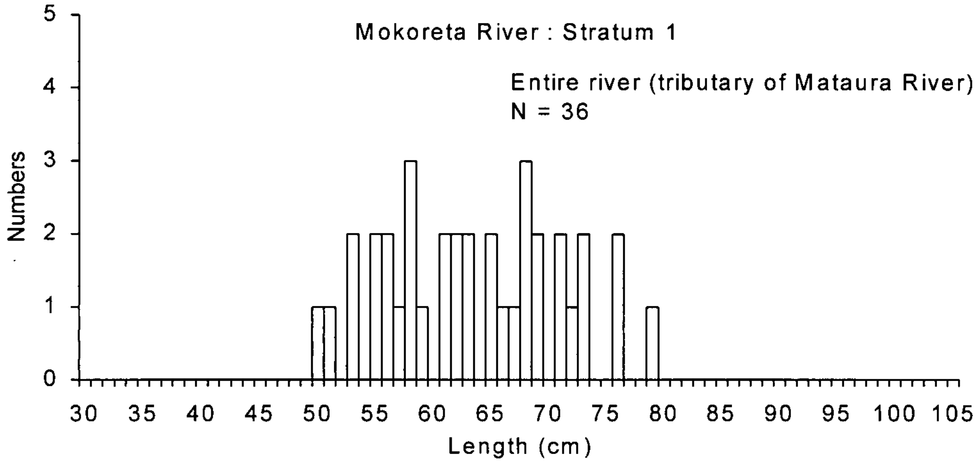


Figure 25: Length frequencies of shortfinned eels from stratum 1 of Mokoreta River.

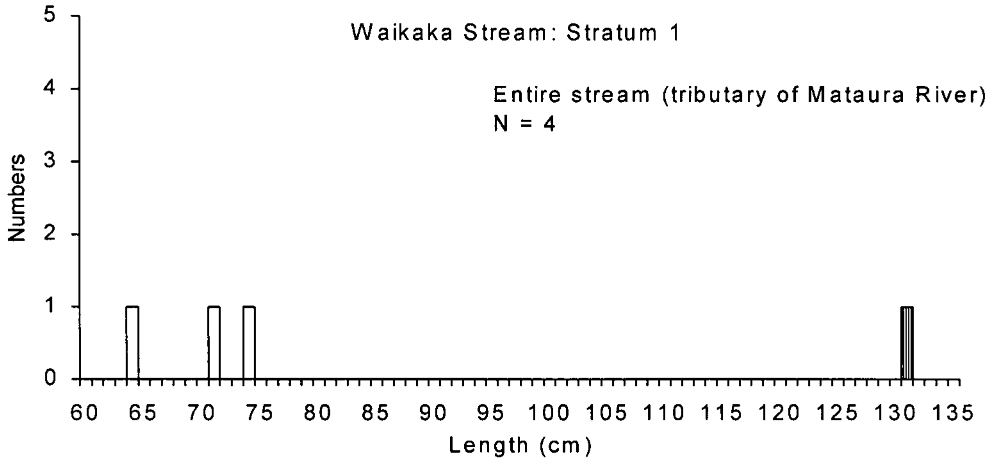
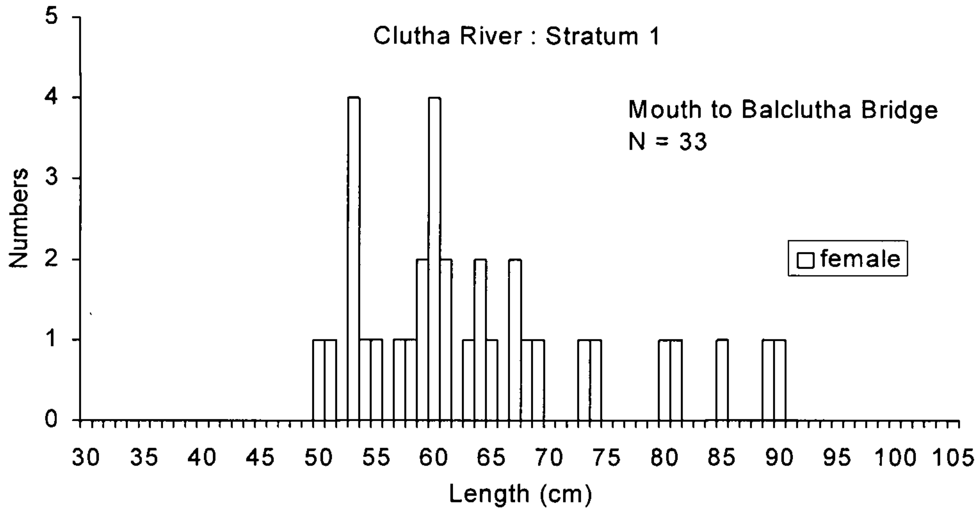
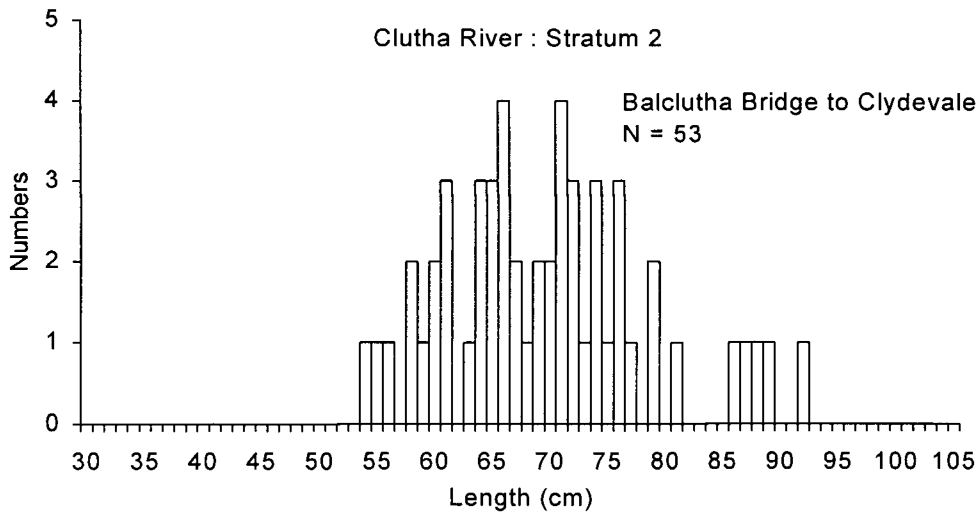


Figure 26: Length frequencies of shortfinned eels from stratum 1 of Waikaka Stream. Note the change of scale on the length axis.





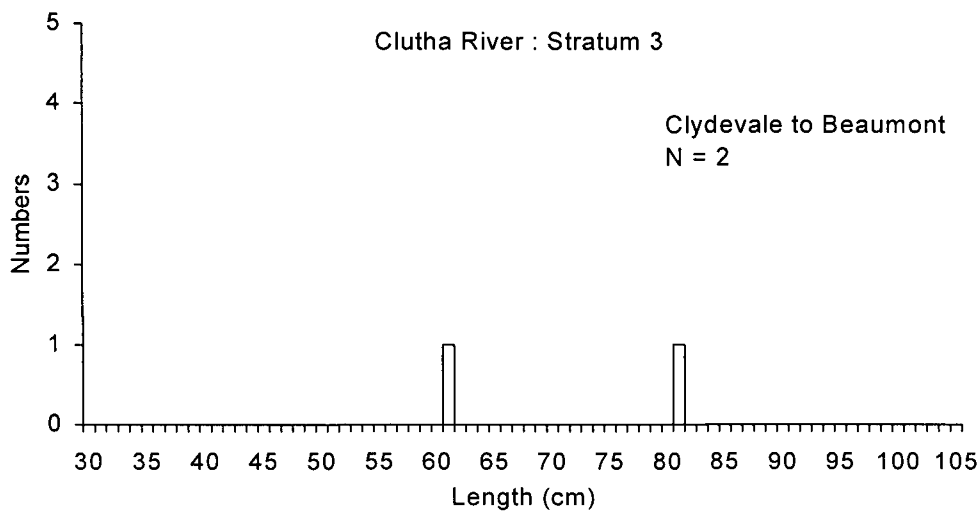


Figure 27: Length frequencies of shortfinned eels from strata 1, 2, and 3 of Clutha River.

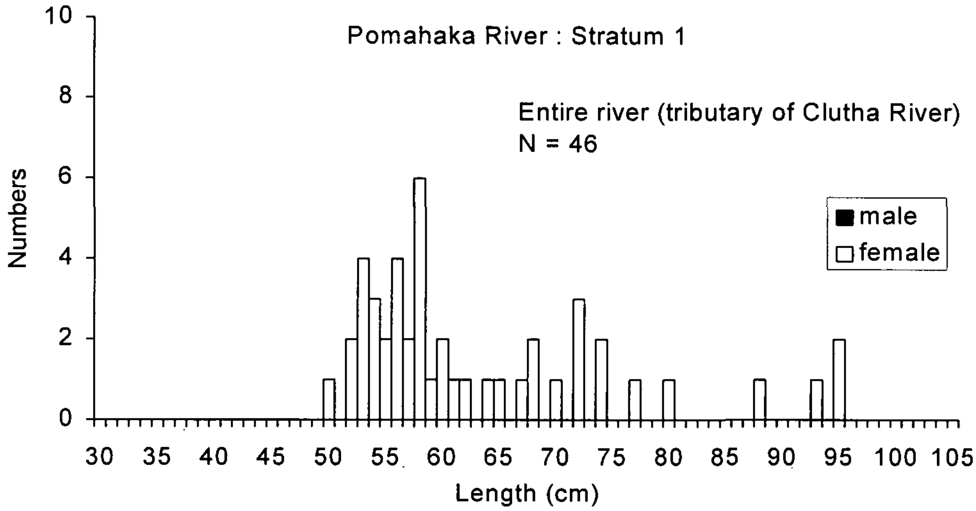


Figure 28: Length frequencies of shortfinned eels from stratum 1 of Pomohaka River.

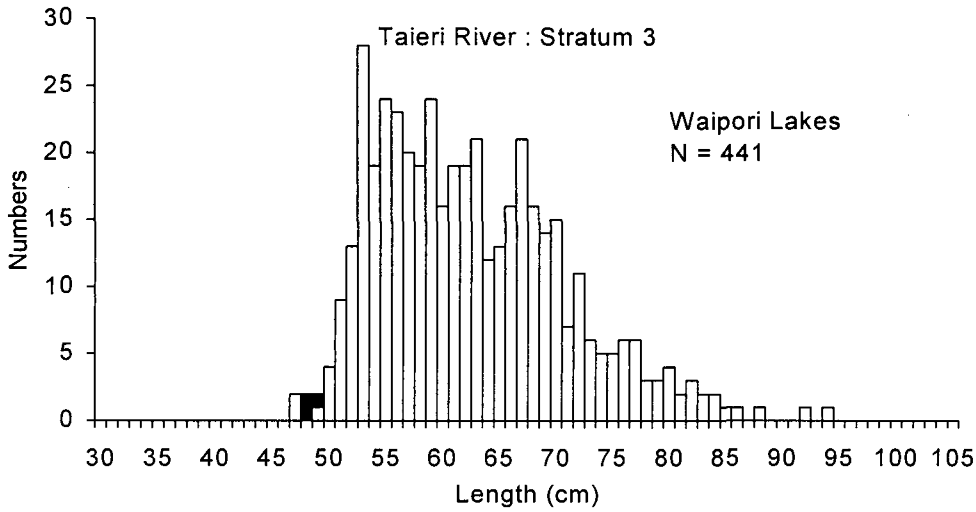


Figure 29: Length frequencies of shortfinned eels from stratum 3 of Taieri River.

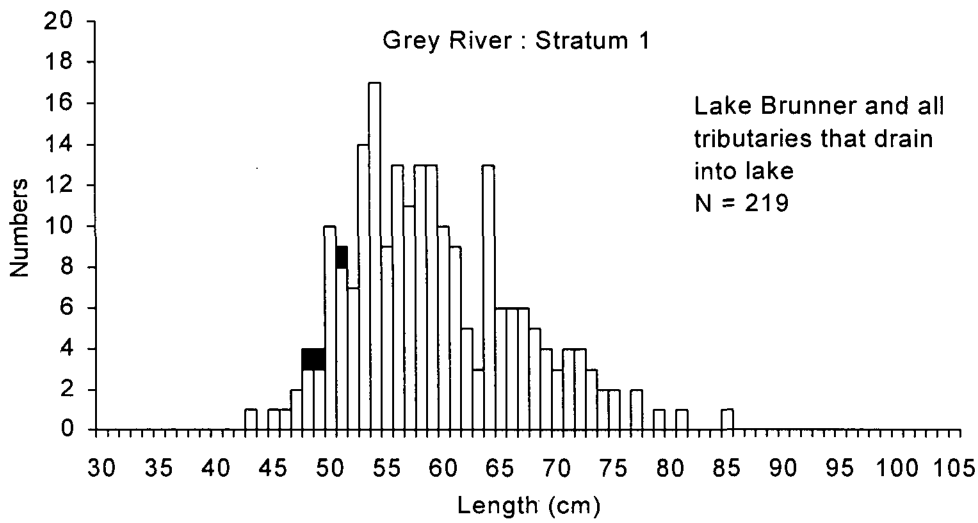
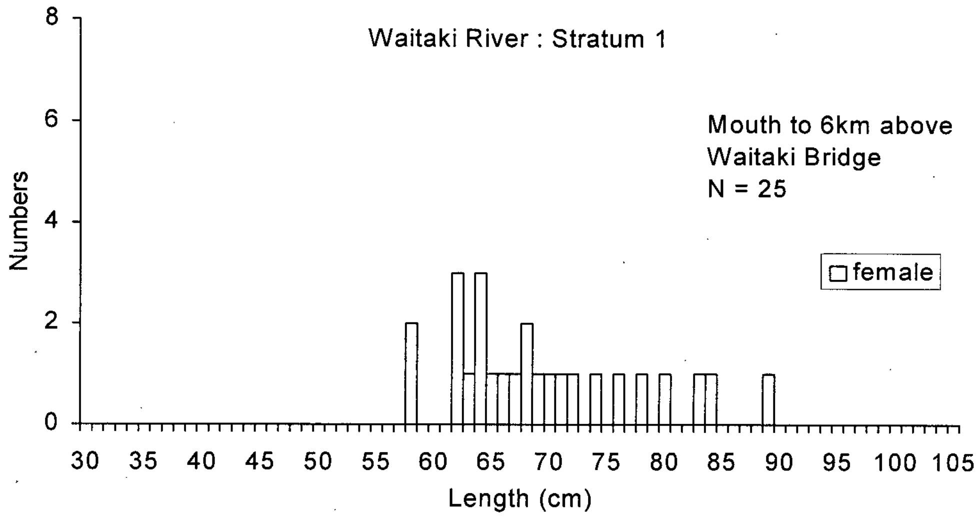
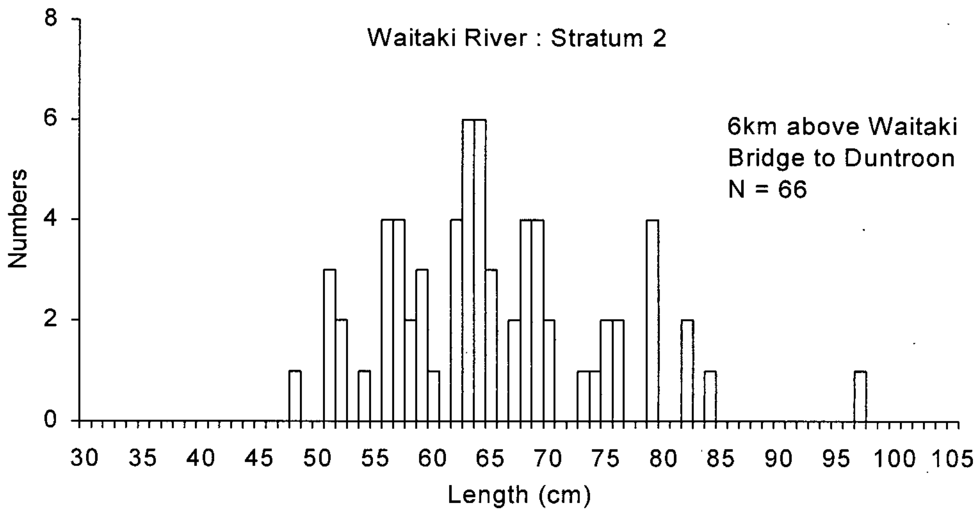


Figure 30: Length frequencies of shortfinned eels from stratum 1 of Grey River.





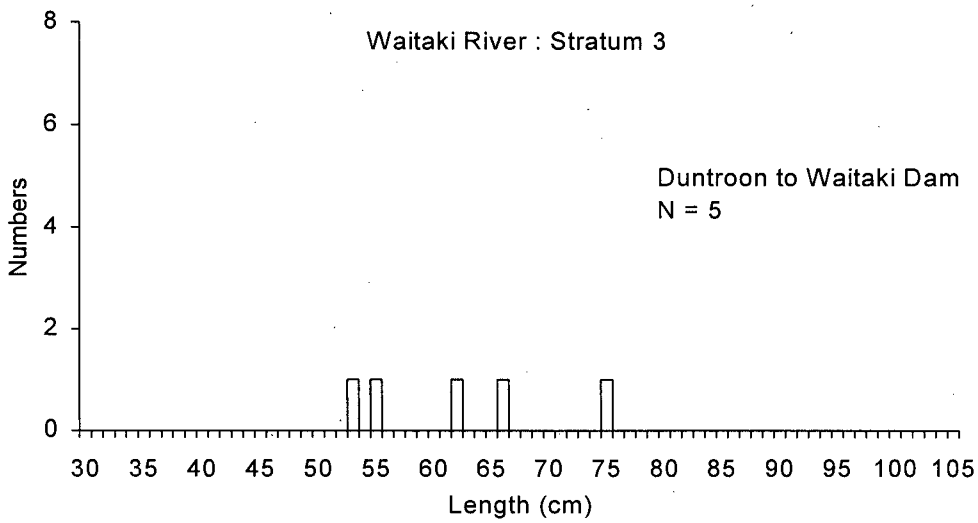


Figure 31: Length frequencies of shortfinned eels from strata 1, 2, and 3 of Waitaki River.

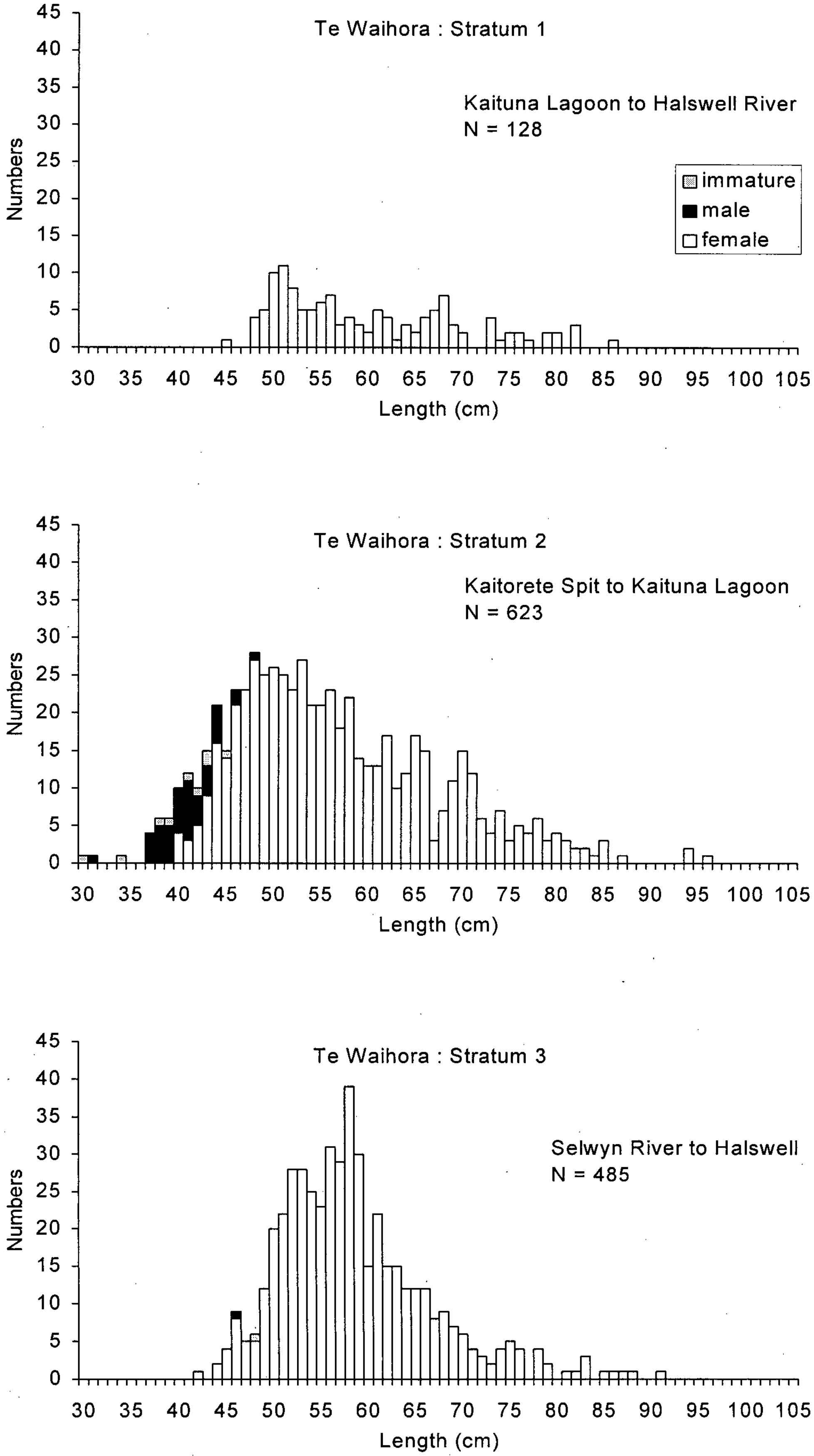


Figure 32: Length frequencies of shortfinned eels from strata 1, 2, and 3 of Te Waihora.

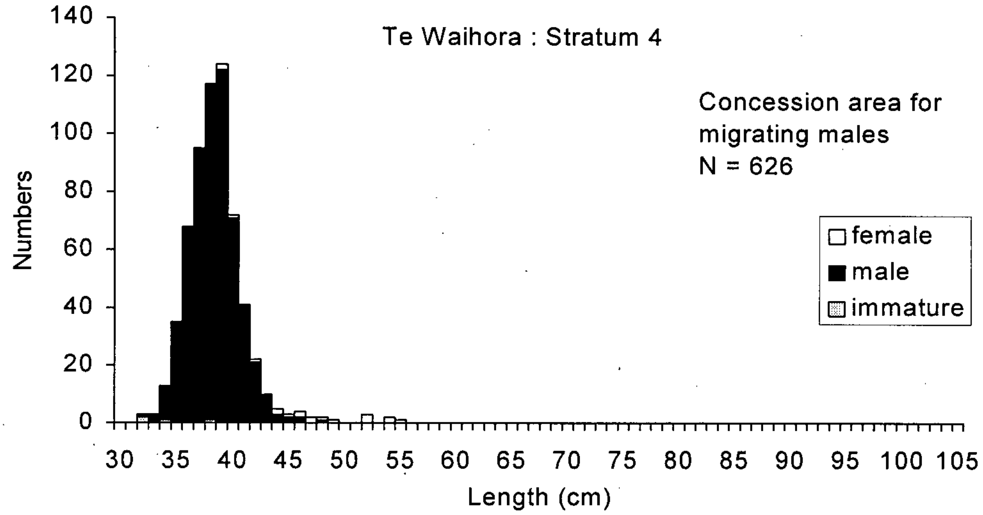


Figure 33: Length frequencies of shortfinned eels from stratum 4 of Te Waihora. Note the change of scale on the numbers axis.

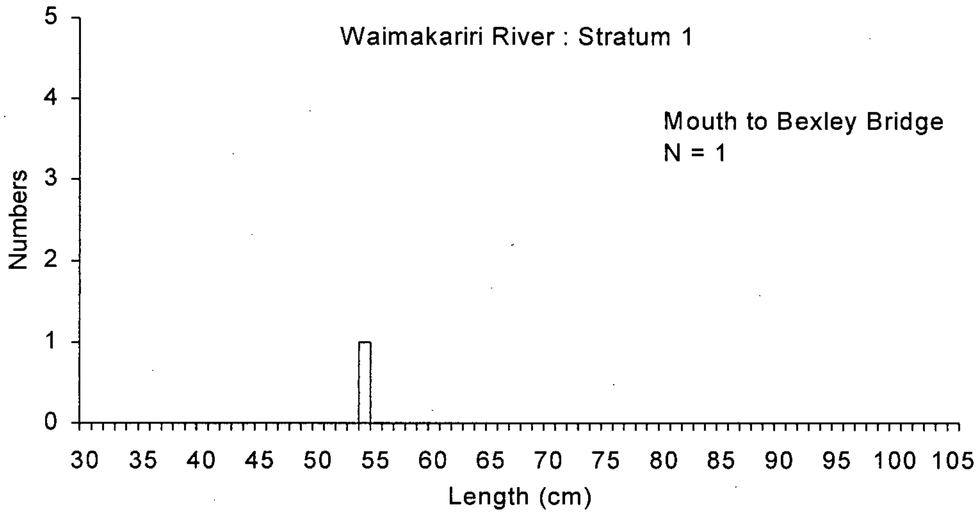


Figure 34: Length frequencies of shortfinned eels from stratum 1 of Waimakariri River.

Appendix 1: Gonad staging descriptions for longfinned and shortfinned eels.

Both species

Immature or could not determined

These gonads can appear as a very thin almost transparent thread like organ and cannot be differentiated into male or female for either species (usually where size < 200 g). Commonly gonads in this category were developing in size with irregular segmentation but could not be clearly distinguished as male or female and were designated as stage 1 since gonads were of similar size to male and female stage 1. Note that in 1996–97 eels in this category were staged from 1–3 where sex was not clear but gonads were clearly developing in size relative to male and female staged eels (Beentjes & Chisnall 1998).

Longfins

Males:

Stage 1	Regularly lobar Syrski organ developed even at very small sizes. Stage 1 organ is typically very narrow (2–3 mm), and often quite unrelated to fish length. Typified by flesh pink colouration.
Stage 2	The lobar organ is usually slightly larger than stage 1 (2–4 mm), but more dense in appearance, very obviously lobar and often ranges in colour from dark pink to yellow.
Stage 3	As for stage 2 but further developed in size and density.
Stage 4	Very large lobed organ, up to 12 mm or more in width, always dark red in colour and with well developed vein network. Usually found in migrants and in longfins up to about 1300 g.

Notes on longfinned males:

By far the majority of longfins less than about 350 g will be either stage 1 males or will be indeterminate as a result of having insufficiently lobed structure to the gonad strip. Regular lobe-type form is the key diagnostic feature, irrespective of colouration. Sometimes gonads in stage 2–3 sizes will appear male in density and form but will be incompletely lobed. These are assumed to be anomalous forms and still regarded as male. Some male fish have a number of external morphological features that assist in confirmation of sex, but must not be used as primary method of diagnosis: A russet colouration, particularly about the underbelly; very tough belly skin in larger, more mature males; often a squared off, or truncated looking tail; generally appear to have smaller relative head-size and fatter bodies than females of the same length.

Appendix 1 – ***continued***

Females:

Stage 1	Characterised by a thin (2–5 mm) ribbon, quite translucent and often broken in places, but not regularly segmented or lobar.
Stage 2	Ribbon usually (but not necessarily) wider than stage 1 (approx 4–10 mm), and displaying creamy pigmentation.
Stage 3	Ribbon is wider than stage 2 (up to 20 mm perhaps) and is substantially folded or pleated. Completely opaque, cream or white.
Stage 4	Very large, well developed gonad with substantial vein network, fully coloured bright white. Slightly granular texture in many stage 4 gonads, but not necessarily diagnostic. Usually found in migrants or near migrants.

Shortfins

Males:

Shortfinned males are small and therefore the development of the gonads is less conspicuous than females and most migrate before they recruit to the commercial fishery. Te Waihora is an exception since fishers are granted a dispensation to catch sub-legal males from Ellesmere during the migration period of shortfinned males.

Stage 1	Classic lobar organ of Syrski. Pale opaque lobes < 2 mm wide.
Stage 2–4	Dark red , very lobar organs. Whether classed as stage 2, 3 or 4 depends on the relative size and depth of colouration. Nearly all males sampled were Te Waihora eels exhibiting the migrant morphological condition.

Females:

Stage 1	Frilled ribbon 2–5 mm wide and translucent. Usually in small fish < 300g.
Stage 2	Frilled ribbon 4–10 mm wide and pale, creamy colour. The most common stage in females.
Stage 3	Frilled ribbon up to 15 mm wide. Usually with vein network. Completely opaque.
Stage 4	Larger, heavy version of stage 3. Very white, and slightly granular structure. Usually only observed in migrants.