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The fishery for freshwater eels (*Anguilla* spp.) in New Zealand

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1. Executive summary

New Zealand has two species of freshwater eel, the shortfinned eel (*Anguilla australis*) and the longfinned eel (*A. dieffenbachii*). The longfin is endemic to New Zealand while the shortfin also occurs in southeast Australia, Tasmania, New Caledonia, and some South Pacific islands. Both species are widespread and frequently co-exist, although the longfin has a preference for flowing waters and penetrates further inland than the shortfin.

The location of the oceanic spawning grounds of each species is unknown, although it has been suggested that these may be northeast of Samoa and east of Tonga for shortfins and longfins respectively. Larvae arrive back in continental waters largely as a result of passive transport on ocean currents. After metamorphosis, the juvenile eels (glass-eels) enter freshwater from August to November.

Although the oceanic phase of the life history is largely unknown, there have been a number of studies of the freshwater phase, especially on age and growth in different habitats, and on the migration periodicity of both juvenile and adult eels. It is difficult to sex immature eels of both species, but at migration the sexes are clearly differentiated by size (females larger than males) and colour. Both species are opportunistic scavengers, with their diet largely reflecting the available food. Growth rates are highly variable but generally slow, with female shortfin and longfin eels typically being 20 and 60 years old respectively at migration.

There is a small but unquantified non-commercial fishery for eels, the most important component being the traditional Maori fishery.

Both species are caught commercially, with shortfins making up about two-thirds of the annual catch. Catches rose from below 100 t in the mid 1960s to a peak of 2434 t in 1975; the past 10 years have been a more stable period with catches averaging 1362 t. The fishery is regarded as fully developed, and no new entrants have been allowed into the fishery since October 1988. As well as this restriction on permits, the fishery is managed by restrictions on size of fish, fishing gear, and effort. Starting in the 1993–94 fishing year, an increased minimum size of 220 g was introduced for all areas of the country except Lake Ellesmere. The fishery in Lake Ellesmere has been managed by a catch quota since 1978, and a minimum size of 140 g was introduced in October 1993 with annual increments of 10 g designed to make it consistent with the remainder of the country in 8 years.

Virtually all eels are caught with fyke nets, with small quantities also being caught with baited traps (hinaki) and fine-meshed set nets. Reporting by the present 22 catchment-based reporting areas (Eel Return Areas) commenced in 1983. Areas producing largest catches over the 1983–84 to 1990–91 fishing years were (in descending order) Waikato, Northland, Southland, Lake Ellesmere, Otago, Hawkes Bay, and Manawatu. Due to changes in the unit

of effort recorded for set net fisheries in the 1989–90 fishing year, meaningful CPUE data are available only up to that time, but these show considerable variation and few trends.

The quality of the FSU/CELR data is not good and data from three sources have been used to obtain the best estimate of annual catch. Because of the lack of biological and biomass data combined with the inherent variability in growth rates and densities, estimation of MCY using analytical methods is not possible. Consequently, the MCY estimate of 1362 t, from the recent MAF Inshore 2 Working Group (Annala 1993) was based on catch history.

During this century, the available habitat for eels has been reduced both quantitatively and qualitatively. For example, vast areas of eel habitat have disappeared with the widespread drainage of wetlands that has accompanied European settlement. There is ongoing concern about the restrictions on upstream access caused by hydrodams and weirs, and there are efforts by both Government and industry to install elver passes and also to transplant elvers above such areas. National Parks and some other reserves remain the only areas of the country where commercial eel fishing is not allowed, although property owners restrict access to some waters, especially in the North Island.

2. Introduction

2.1 Overview

New Zealand has two species of freshwater eel — the shortfinned eel (*Anguilla australis*) and the longfinned eel (*A. dieffenbachii*); the latter is endemic to New Zealand while the former is also found in southeast Australia and Tasmania, New Caledonia, and some South Pacific islands. There have been a number of studies of the biology of the two species and these have been reviewed by Skrzynski (1974), Jellyman & Todd (1982), and McDowall (1990). Both eel species form the basis of an important commercial fishery, which has averaged 1500 t annually over the past 3 years. The fishery was reviewed by Town (1985) who also considered future management options (Town 1986).

This, the first FARD to be published on eels, presents information on the biology and fisheries of both eel species.

2.2 Description of the fishery

The eel fishery is highly fragmented, being carried out in streams, rivers, lakes, and wetlands throughout New Zealand. Except for National Parks and some reserves, virtually all waters accessible to eels will have been commercially fished at some time in the past 25 years. The fishery exploits resident populations of immature eels before their spawning migration to the sea. MAF has responsibility for management and regulation of the commercial and amateur eel fisheries, and the Department of Conservation (DOC) is responsible for the protection of eel species and their habitats.

Modern-day commercial fishing for eels really began in the mid 1960s, with catches remaining below 100 t until 1967 (Table 1). Thereafter catches increased rapidly to reach a peak of 2434 t in 1975. Following a period of variability in catches from 1971 to 1982, the fishery appears to have stabilised over the past 10 years, with an average annual catch over this latter period of 1362 t. Virtually all eels (98%) are caught using fyke nets (baited/unbaited trap nets). In lakes and other areas too deep for fyke nets, baited traps (hinaki) are used. There is also a small fishery in the North Island which uses fine-meshed set nets in tidal areas. Although longfinned eels (longfins) dominate catches in the Taranaki/Wanganui area of the North Island and the west coast and southern districts of the South Island, shortfinned eels (shortfins) provide two-thirds of the national catch.

Fishers are able to fish within the QMA areas specified on their fishing permit. Many well established fishers have established "gentlemen's agreements" on the boundary demarcations with other fishers. Also, most eel fishing in the North Island, and a high proportion in the South Island, is on privately owned land, meaning that fishers usually establish an agreement with the land owner for exclusive access — this obviously benefits the fishers but also means that they are better able to manage the resource by fishing at what they regard as a sustainable level. In theory, eel fishers require the consent of DOC before fishing on Crown land under DOC's jurisdiction, but in practice this seldom happens.

By law, commercial eel fishing is not allowed in various types of reserve. Prohibitions are strictly enforced within National Parks, but enforcement within reserves is variable. Jellyman (1993) reviewed the ability of waterways within National Parks to provide adequate reserve breeding stock and concluded that these waterways provide a barely adequate reserve area for longfins (mainly because hydrodams and weirs reduce recruitment upstream or kill migrant eels during their downstream migration), but an inadequate area for shortfins. A ban on fishing in other reserves would provide substantial assistance to shortfins, but the increased area is still considered insufficient.

Due to the present moratorium on fishing permits, the number of permits has remained reasonably constant over recent years, with about 240 permits currently issued. There are 11 North Island, 10 South Island, and 1 Chatham Island fish processor who processed over 1000 kg of eels during both 1990 and 1991. New Zealand eel products are exported mainly to Holland, Germany, United Kingdom, Belgium, Italy, and France. About 60% of eel product is whole frozen eels, with other chilled or frozen products amounting to about 15%, and live flown eels about 20%. The annual export value is almost $10 million.

In the 1930s there was a campaign to try and eradicate eels from important trout-fishing waters (Cairns 1942b), and bounties for eels were paid by some acclimatisation societies (now Fish and Game Councils) as late as the late 1960s. Until the commercial eel fishery developed, it was generally considered that hydrodams and weirs were acting beneficially by denying or impeding recruitment of juvenile eels to upstream waters. Today, the status of eels is improved to the extent that elver passes are being installed on dams in recognition that eels have intrinsic, cultural, and commercial importance. The regulations concerning eel fishing reflect the changed status of eels. For instance, in the 1970s, regulations were principally concerned with minimising the bycatch of trout in fyke nets. Today, the industry is controlled by specific regulations on netting practices and minimum sizes, and restricted entry, designed to ensure a sustainable fishery.

Most commercially exploited marine fisheries in New Zealand are managed by the Quota Management System (QMS), whereby individual fishers have been allocated a specific quota. Town (1986) suggested that freshwater eels should become a part of the QMS system. However, as a result of a successful application by Maori in 1987 for an injunction prohibiting the issuing of further Individual Transferable Quota (ITQ), it was not possible to manage eels by the conventional issuing of quota until the passing of the recent Treaty of Waitangi (Fisheries Claim) Settlement Act 1992. As a result of this settlement, eels are one of a number of species currently under consideration for introduction to the QMS.

Industry and managers generally agree that the fishery is fully developed with little opportunity for further expansion. In response to widespread concerns about the level of exploitation of eels throughout the country, eels were declared a fully developed fishery in October 1988, and entry into the fishery was restricted. This was followed by the declaring of a moratorium in December 1992. Not issuing new permits was a short-term measure pending a more extensive review of the commercial fishery. The need for this review has been made more urgent by the current upsurge of interest by Maori in becoming more involved in the management of fish and shellfish species they traditionally harvested. Also, the Fisheries Amendment Act 1990 inadvertently created a situation whereby an unrestricted number of fishers could operate on a single permit; this lead to a rapid increase in the number of persons engaged in eel fishing, a situation that MAF was trying to avoid. This anomaly has since been corrected in the Fisheries Amendment Act 1991.

Because catches were declining at an alarming rate, Lake Ellesmere was declared a controlled fishery in December 1978. The initial TAC in 1978 was set at 256 t. At present there are 11 licence holders with the TAC set at 136.5 t. Lake Ellesmere remains the only eel fishery for which a catch quota has been set.

2.3 Literature review

Research on the life histories of eels has been carried out in New Zealand for many years. The wartime years saw investigations of migratory eels (Hobbs 1947) as potential sources of fish oil (Shorland & Russell 1948). The work of Cairns (1941, 1942a, 1942b) was prompted by the desire of the managers of the recreational trout fishery to eradicate eels because of their predation on trout. Subsequently, Burnet (1968) showed that such predation could be beneficial to trout stocks by culling surplus juvenile fish.

The marine larval life has been studied by Castle (1963) and Jellyman (1987), although the actual location of the spawning grounds of both species remains unknown. Only one migratory eel has been caught at sea (Todd 1973). At migration, the gonadosomatic indices of females of both species are low (0.27 and 1.43 for shortfin and longfin respectively; Todd 1980) compared with indices of 22–45 for mature shortfins, and 20–30 for longfins achieved by artificial maturation (Todd 1979). From a review of such data, together with information on offshore hydrology, Jellyman (1987) suggested that the spawning grounds of shortfins could be northeast of Samoa, while spawning grounds for longfins could be east of Tonga. Larvae (leptocephali) will generally be transported passively to New Zealand by the South Equatorial Current, although some detrainment from this current must occur to avoid larvae travelling via the east coast of Australia. The metamorphosed juvenile eels (glass-eels) enter fresh water from August to November.

In contrast to the breeding biology, the freshwater ecology is quite well known. The validity of using otoliths to age New Zealand eels has been established by Jellyman (1979b) and Chisnall & Kalish (1993). Studies on the age and growth of eels have been carried out in small streams (Burnet (1969a), in lakes (Jellyman 1979b, and unpublished data), Chisnall & Hayes 1991, Todd, unpublished results), and in major rivers like the Waikato (Chisnall 1989, Chisnall & Hicks 1993) and Clutha (Harries 1974). Diet has been established from the studies of Cairns (1942a), Burnet (1969c), Ryan (1984, 1986), and Jellyman (1989a); these studies have shown that both species are opportunistic scavengers, and diet largely reflecting food availability.

Migrations to and from the sea are important phases in eel life histories. Upstream migrations of juvenile eels (glass-eels and elvers) have been studied by Jellyman (1977a, 1977b, 1979a) and Jellyman & Ryan (1983), while downstream migrations of adults have been studied by Burnet (1969b) and Todd (1980, 1981a). The relation between environmental factors and eel activity was studied by Jellyman (1991). Todd (1981b) also studied morphometric and gonad changes associated with adult migration, and the artificial maturation of both species (Todd 1979, 1981c). Diseases and parasites of eels are known from the studies of Blair (1984), Hine (1978, 1980), Hine & Boustead (1974), and Jellyman (1989b). The culture of New Zealand eels was reviewed by Jellyman & Coates (1976) and Jones *et al.* (1983).

A review of the commercial fishery was carried out by Town (1985), who also produced a series of management recommendations (Town 1986). A more comprehensive review of the fishery has since been published by Jellyman (1993). To date there have been no published studies involving estimates of mortality and migration rates, and limited data on estimates of abundance and recruitment. Based on his impressions of eel abundance, Cairns (1945) proposed that an annual catch of 5000–10 000 t would be sustainable. Present catch data indicate this to be incorrect by an order of magnitude.

3. Review of the Fishery

3.1 TACCs, catch, landings, and effort data

Catch data are available from various sources. The longest time-series is the MAF Fisheries data compiled from returns of individual fishers. These data are available from 1965, with breakdowns by species (since 1975), and by areas (present areas, Figure 1, are old Catchment Board areas and have been used since 1983). These data are described as MAF Fisheries (before 1982–83), FSU (1982–83 to 1988–89) and CELR (1988–89 to present). Collectively these data are referred to as the MAF Fisheries database. Historically, fisheries data were presented by calendar year, although fishing year (1 October-30 September) is now standard for management purposes. Annual catch data from 1965 to the present are given in Table 1.

As well as the returns from individual fishers, the Licensed Fish Receivers furnish a separate monthly return (LFR returns). Further data come from the export figures collated by the Fishing Industry Board; as at least 90% of all processed eels are thought to be exported, the export data give a reasonable index of catch. Since 1975, separate product categories have been available, meaning that green weight can be estimated from the processed weight.

A number of events have affected both the total fishing effort expended and the completeness of the data supplied by eel fishers. Chronologically the main events are:

1983	Start of the FSU data collection scheme
1984	Part-time fishers excluded from the industry
1984–85	Recommendation that eels enter the QMS, with attendant incentive for fishers to build up good catch histories
1988–89	Change from centralised FSU to regional CELR scheme

During meetings of the MAF Fisheries Inshore 2 Working Group to consider eels, industry representatives expressed concern about the accuracy of CELR and, to a lesser extent, LFR data. To provide a further check, the major processors offered to assist in an audit of their recent catches. These data (Table 1) are considered to be the most accurate estimates of catch for the years 1989–92. Large discrepancies are apparent between the various sets of data; for example, export weight exceeds MAF Fisheries/FSU/CELR landed weight for 14 of the 18 years of record. The FSU/CELR data seem to consistently underestimate actual catch as there is reasonable agreement between the LFR, processors' estimates, and export weights.

The best estimates of annual catch seem to be a combination of MAF data (1965–74), export green weight (1975–82), FSU data (1983–86), LFR data (1987, 1988), and processors' estimates (1989–92). Using these data, the annual catch over the past 10 years (1983–92) has averaged 1362 t, and has shown a steady increase over the past six years.

In addition to problems in assessing total catch, there are also problems in allocating catch to given areas. There appears to have been some confusion by fishers when reporting catch, and catches made in one area but transported to another for processing may have been incorrectly recorded as being caught in the latter area. An additional problem is the confusion between Eel Return Areas and Marine Fishing Return Statistical Areas; for instance, until recently some Lake Ellesmere fishers were wrongly advised to record catch by Statistical Area 22 (the marine area adjacent to Lake Ellesmere) instead of Eel Return Area 21 (Lake Ellesmere). When such information is retrieved, the catches are credited to Eel Return Area 22 (Chatham Islands).

Confusion has also arisen from the use of different areas (QMA areas) for issuing of permits; there appear to have been some regional inconsistencies with the result that permits are generally issued for Quota Management Areas (QMAs) although some have been issued for Eel Return Areas. This again leads to problems in estimating regional catch trends.

Estimated mean annual catch by Eel Return Area for the period 1983–84 to 1991–92 is shown in Figure 2, and Table 2 gives the variability in catch for each area (all data from FSU/CELR records). Areas producing largest catches over the 1983–84 to 1991–92 fishing years were (in descending order) Waikato, Northland, Southland, Lake Ellesmere, Otago, Hawkes Bay, and Manawatu.

Due to a change in the units of effort recorded in the 1989/90 fishing year, meaningful CPUE data are only available from 1983–84 to 1989–90. The CPUE data (Table 3) show considerable variation and few recognisable trends. Between the various areas there is a wide range in mean annual CPUE (3.1–13.1 kg per net-night) although there is an even wider range between years for the same site (e.g., North Canterbury, 4.9–18.0 kg per net-night). Although the Waikato basin has historically been one of the main eel-producing areas of the country, it has a consistently low CPUE (4.1–4.8 kg per net-night). In contrast, CPUE for the Wairarapa is relatively high. There is no significant correlation ($p > 0.05$) between mean annual CPUE and mean annual catch, indicating that areas of high or low catch are not characterised by either consistently high or low CPUE. Over the period of record, the national catch from FSU/CELR returns ranged from 841–1475 t (a 75% variation), whereas CPUE remained relatively constant (5.7–6.8 kg per net-night; a 19% variation). This relative stability of CPUE suggests that stocks were able to sustain those levels of harvest.

3.1.1 Lake Ellesmere fishery

Lake Ellesmere is the only eel fishing area in the country with a catch quota. The initial quota (256 t) was set in 1978 in response to general agreement by industry and managers that the lake was being overfished. At present there are 11 licence holders and a quota of 136.5 t. This quota has remained unchanged over the past six seasons and, until the past season, catches of this size or greater have not been recorded since 1981 (Table 4). The controlled fishery year runs from 1 February to 31 January and migrant eels are included within quotas (i.e., present quotas do not differentiate between migrant and non-migrant eels). The 1 February start allows fishers access to migrants, but should these eels be unavailable due to the lake being open to the sea, then fishers are still able to fill their quota with non-migrant (feeding) eels once these become available again in October-November.

The processors' estimate of annual catch for the past 4 calendar years (mean = 183.8 t), has been substantially greater than the quota. These estimates are conservative — for instance, a total of 37 t of eels of "uncertain origin" were recorded over 3 years from one processor, and only half this quantity has been credited to Lake Ellesmere although it is likely that virtually all these came from the lake. Further, only 5 t of the total catch for 1992 from a major South Island processor was allocated to Lake Ellesmere, although it is probable that this is a substantial underestimate.

A new minimum size of 140 g for eels from Lake Ellesmere came into force on 1 October 1993. This minimum size will increase 10 g/y to bring Lake Ellesmere in line with the new national minimum size of 220 g in 8 years. This 140 g limit will probably result in an immediate reduction in catch. At present, fishers take eels as small as 110 g, and eels of this size will take 1.5 y to reach the new minimum size of 140 g. The average increase in weight of 18 g/y will allow most eels to keep ahead of the minimum size increase of 10 g/y.

The annual migration of shortfin males is of particular importance to fishers, and during the 1992 migratory season (mid February to late March), a number of fishers caught their full annual quota of eels within a few weeks. From 1942 to 1974–80, the average length of male migrants declined by 6 cm (Todd 1980). This decline has apparently continued as a 1993 sample (author's unpublished data) averaged 393 mm, 29 mm shorter than Todd's 1980 average. Data from Todd (1980, and unpublished data) show no change in growth rate from 1974 to 1980.

The new minimum size limit of 140 g (with subsequent 10 g annual increments to 220 g) will have a substantial and increasing impact on the present fishery for shortfin males. A sample of 235 males from the 1993 migration showed that 60% were below the 140 g minimum size, and none exceeded 220 g. During the years 1974–82, only 2.5% of males exceeded 220 g; using the weight-frequency data of these years as a template for examining the length data of Hobbs (1947), it seems likely that historically, about 30% of males would have exceeded 220 g.

Unless there is a corresponding increase in the average size of males over the next few years (which would be contrary to the current trend), then the migrant male fishery will cease in 5–6 years. This will result in additional pressure being put on the female eels (i.e., any eels currently larger than about 220 g). Biologically, escapement of females must be regarded as more important than escapement of males, and the exclusion of the male eels from the fishery is an unfortunate consequence of the new minimum size limit.

3.2 Other information

Relative to most marine fisheries, the eel fishery requires low capital investment, with permitted fishers needing a supply of fyke nets, a small boat, and transport. Being land-based, the fishery is not subject to the same weather constraints as are marine fisheries, although there are very definite seasonal limitations on the availability of eels.

Eel fishers and processors claim that over the 22 years that the eel fishery has been well developed, the quality of the eels has increased markedly. Twenty years ago it was often difficult to sell New Zealand eels as they were regarded as being of low quality due to poor condition and low oil content. Today processors report that New Zealand eels are held in high regard, and often demand prices equivalent to Baltic sea eels — traditionally the best quality wild eels in Europe. While there has not been any specific research to confirm these observations, it would be interesting to see whether the growth rates and average condition of eels has increased as a result of exploitation.

A recent development has been the initiative of industry in transplanting elvers to waters where access is impeded. Thus a special permit to transfer up to 0.52 t of elvers from below Karapiro Dam to sites upstream was approved by MAF Fisheries in 1992; a similar special permit application has been received for 1993–96 for these same waterways (D. Allen, MAF Fisheries, pers. comm.). The technique has considerable potential for enhancing eel stocks in major waterways throughout the country, especially as there are indications that growth rates are largely density dependent (Chisnall & Hicks 1993).

The bycatch of other freshwater fish during eel fishing is an ongoing concern to fishery managers. Several other species, including the relatively rare giant kokopu (*Galaxias argenteus*) and shortjawed kokopu (*G. postvectis*), are liable to be caught in fyke nets. Ducks, and particularly shags, get caught in poorly set fyke nets. A further concern is the potential for eel-fishers to inadvertently spread undesirable fish like the brown bullhead catfish (*Ictalurus nebulosus*) and koi carp (*Cyprinus carpio*). Both species are present in the lower Waikato River and could be spread from there; juvenile catfish can survive being out of water for short periods and could be transported unnoticed between catchments in fyke nets. Koi have adhesive eggs which are transported to new areas via attachment to water weeds, boats, fyke nets, etc.

The spread of the undesirable introduced aquatic alga "water net" (*Hydrodictyon reticulatum*) is a new threat to lowland eel habitats. This prolific plant has the capacity to completely choke a water system, making it unsuitable for commercial fishing, recreation, and even much aquatic life. Fortunately, its inability to tolerate cooler water means that it is unlikely to become well established in any but the warmer waters in the north of the North Island. Nevertheless, eel fishers must be particularly careful in cleaning fragments from nets to avoid spreading the plant more widely. Similarly the problem "oxygen weeds", *Egeria* and *Lagarosiphon*, can also be inadvertently spread from fragments in nets. Ideally, fyke nets should be thoroughly dried before they are used in a different catchment.

3.3 Recreational, traditional, and Maori fisheries

There is a small but unquantified non-commercial eel fishery. The most important component of this is the traditional fishery operated by Maori who have strong traditional and historic ties to eels and their harvest. A traditional Maori eel harvest is carried out annually at Lake Forsyth (Todd 1978a), one of two exclusive Maori eel reserves (the other is Lake Horowhenua).

Eels often form an important part of the food at hui, tangi, etc, and Maori can be granted an exemption from the amateur fishing regulations to capture eels for such occasions. However, there is little published information on the extent of the traditional catch of eels by Maori. Certainly there are a number of descriptions of the extensive and highly developed fishery that operated during the period of European colonisation (e.g., Downes 1918), but much of the understanding on the extent of harvest will be verbal rather than written. In locations like Lake Ellesmere (Waihora), Maori are understood to have operated a fishery that may have caught as much as 100 t annually (T. Lynch, MAF Policy, pers. comm.).

Maori have requested an increased involvement in management of the eel resource. Maori have a number of concerns about the status of eels stocks and the management of the commercial eel fishery. Primary concerns are the high level of commercial fishing, the reduced availability of large eels, the need for recognition by fishery managers of areas of traditional importance, loss and degradation of eel habitat, and the need for Maori to have increased opportunity to participate in the eel fishery and management decisions.

4. Research

4.1 Stock structure

Unlike marine fisheries where it is possible to identify separate breeding stocks within a particular species, both species of eel are of a single but highly fragmented stock. Until their seaward migration, adult eels undergo limited movements within a catchment, meaning that each catchment effectively contains a separate fishery stock. While longfins are endemic to New Zealand, biochemical evidence suggests that New Zealand and Australian shortfins are part of a single biological stock (Jellyman 1987).

4.2 Resource surveys

Many resource surveys of New Zealand lakes and rivers have incorporated eels as one of the fish species recorded without them being the prime focus of the study.

For example, surveys have been carried out in coastal lakes and lagoons (Cunningham *et al.* 1953, Eldon & Greager 1983, Eldon & Kelly 1985, Taylor 1988), large rivers (Davis *et al.* 1983, Strickland 1985, Hanchet & Hayes 1989), and high country rivers (Woods 1964). Specific and longer term studies on eel populations have been carried out by Todd (unpublished data), Jellyman (unpublished results) and Chisnall (1989). The studies by Chisnall in the Waikato catchment are designed to provide a database for monitoring the changes in size and abundance over time. Similarly, the studies on unexploited eel stocks in Lake Pounui (Jellyman, unpublished results) were designed to complement and contrast with those of Todd (1980, unpublished data) for the heavily exploited Lake Ellesmere.

4.3 Other studies

The distribution of both species is broadly known (McDowall 1990), with shortfins preferring the coastal lagoons, lakes and swamps, and slower flowing lower reaches of rivers. In contrast, longfins inhabit faster flowing waters, and penetrate further inland to high country lakes. Within these broad patterns, there is considerable overlap in the distribution of both species. In reviewing habitat criteria associated with the distribution of eels in south Westland, Taylor (1988) noted that longfins were widespread but appeared to show no particular preference for certain water types, while shortfins preferred swampy locations. Being nocturnal in habit, both species of eel are very dependent upon cover; Burnet (1952) noted that the abundance of longfins was directly related to the amount of cover available.

There have been a number of studies on the growth rates of both eel species; Burnet (1969a) and Jellyman (unpublished results) used growth rates determined from tag recaptures to supplement rates determined from otoliths. The validity of using otoliths has been confirmed by Jellyman (1979), and Chisnall (pers. comm.), with the latter using tetracycline injections to confirm the annual zonation of otolith banding.

A summary of length-at-age data for the more significant ageing studies is given by species in Table 5. Several factors are apparent. Firstly, a wide range of different habitat types has been sampled, from coastal streams to high country lakes. Secondly, growth rates are highly variable between locations and even within a single location (although the latter observation is not apparent from the data given). Thirdly, growth rates in the wild are generally slow. However, growth rates from experimental culture (Jones *et al.* 1983) indicate that New Zealand eels have the potential to grow at rates equivalent to those for other cultured eel species. Fourthly, eels can live to considerable ages; to date the maximum ages recorded are 60 and 106 years for shortfins and longfins, respectively.

Such variable growth would cause problems in trying to model eel populations on a national basis. Also, growth rates in most of these studies were linear, e.g., Chisnall & Hayes (1991), Jellyman (unpublished results), so that fitting a von Bertalanffy curve would be inappropriate. Natural mortality rates have been estimated for two unexploited stocks (Jellyman, unpublished data); in accord with slow growth and considerable longevity, natural mortality estimates (M) were low at 0.038 and 0.036 for unexploited stocks of shortfins and longfins in Lake Pounui, and 0.041 for longfins in Lake Rotoiti. These values are generally similar to the 0.05 assumed by Sullivan (1992). [Note: using the "rule-of-thumb" method of estimating natural mortality by dividing $\log_e 100$ by the maximum observed age gives values of M = 0.08 for shortfins and M = 0.04 for longfins.]

There has been no systematic study of the distribution of both sexes of eel throughout a complete waterway in New Zealand. Some observations on the sex ratios in the Clutha and Taieri Rivers were made by Harries (1974): he concluded that while the Clutha showed reasonable conformity to the classical distribution of the proportion of males declining with progress upstream, the distribution pattern in the Taieri did not. Other estimates of sex ratios come from the trapping of migratory eels (e.g., Hobbs 1947, Burnet 1969b). Such assessments need to recognise the distinct seasonality of migration of both sexes of both species. As in other species of *Anguilla*, it is not known which factor(s) trigger the onset of sexual maturation. Both age and size at migration are variable (Table 6), but it is likely that within a range of size, attainment of a certain level of condition is required to initiate maturation.

4.4 Biomass estimates

Biomass estimates, obtained by quantitative electric fishing, are available only for a number of small-scale studies (Table 7). In addition to these data, the National Institute of Water and Atmospheric Research (NIWA) Freshwater Fish Distribution Database contains further records from quantitative sampling of streams and small rivers. Compared with Europe (Tesch 1977), the biomass of eels in New Zealand waters is high, probably because we have a fairly sparse freshwater fish fauna.

4.5 Yield estimates

4.5.1 Estimation of MCY

Given the limited biological information available and lack of biomass estimates over wide areas, MCY cannot be estimated using analytical methods. Therefore, MCY was estimated using the equation $MCY = cY_{av}$ (Annala 1993). Based on the estimates of natural mortality, the natural variability factor, c, was set at 1.0. The best estimate of annual catch was used to estimate Y_{av}, with the period 1983–92 chosen, being a period of relative stability. Thus MCY = 1.0 * 1362 = 1362 t. Ideally, the time period used for calculating Y_{av} should be a minimum of one generation for the species, which for eels would exceed 50 years.

4.5.2 Estimation of CAY

Given the lack of current biomass estimates, estimation of CAY was not possible.

4.5.3 Other yield estimates

Todd (1978b) gave peak annual yields from the Lake Ellesmere fishery of 36 kg/ha, which is comparable to the highest yields achieved in European fisheries (Tesch 1977). Unfortunately, the MAF Fisheries database cannot be used to estimate yields for other waters as these are not discrete areas like Lake Ellesmere but accumulations of several catchments.

4.6 Models

Todd (1978b) used a stock production model to estimate the maximum sustainable yield of eels from Lake Ellesmere. The estimate of 370 t proved too high, and initial quotas of 250–300 t have since been reduced to the present 136.5 t.

Sullivan (1992) used a yield-per-recruit analysis to evaluate the likely effects of new size limits on the eel fishery; the results varied between sites and species. For example, for shortfin eels from Lake Ellesmere he concluded it was likely that an increased size limit could result in small gains in yield although this depended on the proportion of male migrants that would be below the minimum size. For shortfins in Lake Pounui, an increase in minimum size would result in a reduced yield-per-recruit at all levels of fishing mortality, but increased yield for longfins.

5. Management implications

There are a number of future decisions that will affect the future of the both the non-commercial (traditional) and commercial eel fisheries. To date, eels have not been included within the QMS, although they are one of a number of species currently under consideration for inclusion.

While it is desirable to maintain small management areas to maximise fishing and conservation efficiency, this may be impractical. As there is already a great deal of uncertainty about the accuracy of area catch data, any sub-division of areas would only compound this problem. Accordingly, the report from the 1993 Fishery Assessment Plenary (Annala 1993) suggested that for the purposes of permitting and any future allocation of quota, the present 22 Eel Return Areas should be reduced to 8; 3 North Island, 3 South Island (excluding Lake Ellesmere), Lake Ellesmere, and the Chatham Islands. For consistency with previous years, reporting of catch should continue to be by the present 22 areas.

The estimated MCY of 1362 t is over 200 t less than the 1991 and 1992 calendar year catches, and is also less than the catch for 14 of the past 22 years. The recently announced increases in minimum sizes may mean that in heavily fished areas, like the lower Waikato River, it might be difficult to catch sufficient eels of legal size to reach the MCY.

Given the variability in growth rates and densities between eel populations plus the gaps in biological information, it seems likely that future yield estimates will continue to be derived from catch data rather than estimated from biological and biomass data. Important factors in monitoring the well-being of populations will be trends in size frequencies, growth rates, and CPUE. Future research for management should concentrate on these areas.

With the exception of reserves, virtually all waterways containing eels are fished commercially to some degree. This accessibility of eels, plus the fact that they are vulnerable to capture over a long time as a consequence of their (generally) slow growth, means that the fishery is easy to over-exploit. Certainly, there is evidence that commercial fishing has led to a marked decline in size of eels in some areas (Jellyman 1993). Future monitoring of the sizes of eels in selected catchments would provide valuable information about size composition of stocks and exploitation rates.

Conditions at sea may be the single most important factor influencing recruitment of glass-eels, but having sufficient escapement of migratory eels also is a significant factor. The best way of ensuring adequate escapement is to set aside reserve areas (*see* Section 3.2). However, most of the present reserve areas are inland so that migratory eels moving downstream are vulnerable to capture. To combat this, and to allow for a greater escapement from exploited areas, Jellyman (1993) proposed that upper size limits should be established for females of both species. He considered that a maximum harvestable size of 4 kg would be appropriate for longfin females as it would allow 50% escapement, and a 1 kg limit for shortfins would allow 25% to escape. In addition to any such reserves and upper size limits, the impact of hydrostations on downstream migrating adult eels should be reviewed to see whether passage can be assisted.

Although there is some hearsay evidence that glass-eel migrations in New Zealand have declined over the past 50 years, there are no data to confirm this. Also, as most of the development of the commercial eel fishery has occurred within a single generation time of a female eel, the full impact of commercial harvest may not yet be apparent. Attempting to monitor the strength of each year's recruitment in selected waters would be difficult and expensive. Instead, NIWA fishery scientists have proposed that automatic counters be incorporated into elver passes as the passes are installed on dams and weirs throughout the country. The counters will provide an index of elver numbers (primarily age classes 0+ and 1+) moving past the dams. Counters have been installed at Matahina and Patea dams, although there are currently some concerns about the efficiency with which the passes operate.

6. References

Annala, J.H. (Comp.) 1993: Report from the Fishery Assessment Plenary, May, 1993: stock assessment and yield estimates. Unpublished report held in MAF Fisheries Greta Point Library, Wellington. 241 p.

Blair, D. 1984: A checklist and bibliography of parasites of New Zealand freshwater fish. *Mauri Ora 11*: 5–50.

Burnet, A.M.R. 1952: Studies on the ecology of the New Zealand long-finned eel, *Anguilla dieffenbachii* Gray. *Australian Journal of Marine and Freshwater Research 3*: 32–63.

Burnet, A.M.R. 1959: Some observations on natural fluctuations of trout population numbers. *N.Z. Journal of Science 2*: 410–421.

Burnet, A.M.R. 1968: A study of the relationships between brown trout and eels in a New Zealand stream. [N.Z. Marine Department] *Fisheries Technical Report 26*. 49 p.

Burnet, A.M.R. 1969a: The growth of New Zealand eels in three Canterbury streams. *N.Z. Journal of Marine and Freshwater Research 3*: 376–384.

Burnet, A.M.R. 1969b: Migrating eels in a Canterbury river, New Zealand. *N.Z. Journal of Marine and Freshwater Research 3*: 230–244.

Burnet, A.M.R. 1969c: A study of the inter-relation between eels and trout, the invertebrate fauna and the feeding habits of the fish. [New Zealand Marine Department] *Fisheries Technical Report 36*. 23 p.

Cairns, D. 1941: Life-history of the two species of New Zealand fresh-water eel. Part I. Taxonomy, age and growth, migration, and distribution. *N.Z. Journal of Science and Technology 23*: 53–72.

Cairns, D. 1942a Life-history of the two species of fresh-water eel in New Zealand. II. Food and inter-relationships with trout. *N.Z. Journal of Science and Technology 23*: 132–148.

Cairns, D. 1942b: Life-history of the two species of fresh-water eel in New Zealand. III. Development of sex. Campaign of eel destruction. *N.Z. Journal of Science and Technology 23*: 173–178.

Cairns, D. 1945 Utilization of eels. *N.Z. Science Review 2*: 3–4, 12.

Castle, P.H.J. 1963: *Anguillid leptocephali* in the southwest Pacific. *Zoology Publications from Victoria University of Wellington 33*. 14 p.

Chisnall, B.L. 1989: Age, growth, and condition of freshwater eels (*Anguilla* spp.) in backwaters of the lower Waikato River, New Zealand. *N.Z. Journal of Marine and Freshwater Research 23*: 459–465.

Chisnall, B.L. & Hayes, J.W. 1991: Age and growth of shortfinned eels (*Anguilla australis*) in the lower Waikato basin, North Island, New Zealand. *N.Z. Journal of Marine and Freshwater Research 25*: 71–80.

Chisnall, B.L. & Hicks, B.J. 1993: Age and growth of longfinned eels (*Anguilla dieffenbachii*) in pastoral and forested streams in the Waikato River basin, and in two hydro-electric lakes in the North Island, New Zealand. *N.Z. Journal of Marine and Freshwater Research 27*: 317–332.

Chisnall, B.L. & Kalish, J.M. 1993: Age validation and movement of freshwater eels (*Anguilla dieffenbachii* and *A. australis*) in a New Zealand pastoral stream. *N.Z. Journal of Marine and Freshwater Research 27*: 333–338.

Cunningham, B.T., Moar, N.T., Torrie, A.W., & Parr, P.J. 1953: A survey of the western coastal dune lakes of the North Island, New Zealand. *Australian Journal of Marine and Freshwater Research 4*: 343–386.

Davis, S.F., Eldon, G.A. Glova, G.J., & Sagar, P.M. 1983: Fish populations of the lower Rakaia River. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report 33*: 109 p.

Downes, T.W. 1918: Notes on eels and eel-weirs (tuna and pa-tuna). *Transactions and Proceedings of the New Zealand Institute 50*: 296–316.

Eldon, G.A. & Greager, A.J. 1983: Fishes of the Rakaia Lagoon. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report 30*. 65 p.

Eldon, G.A. & Kelly, G.R. 1985: Fishes of the Waimakariri estuary. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report 56*: 59 p.

Glova, G.J. 1988: Fish density variations in the braided Ashley River, New Zealand. *N.Z. Journal of Marine and Freshwater Research 22*: 9–15.

Glova, G.J., Bonnett, M.L., & Docherty, C.R. 1985: Comparison of fish populations in riffles of three braided rivers of Canterbury, New Zealand. *N.Z. Journal of Marine and Freshwater Research 19*: 157–165.

Hanchet, S.M. & Hayes, J.W. 1989: Fish and fisheries values of the Maokau River and tributaries draining the Mokau coalfield. *N.Z. Freshwater Fisheries Report* 110. 79 p.

Harries, D.H.A. 1974: Sex, growth and distribution of the longfinned eel, *Anguilla dieffenbachii*. M. Sc. thesis, University of Otago, Dunedin. 125 p.

Hine, P.M. 1978: Distribution of some parasites of freshwater eels in New Zealand. *N.Z. Journal of Marine and Freshwater Research 12*: 179–187.

Hine, P.M. 1980: Distribution of helminths in the digestive tracts of New Zealand freshwater eels. 1. Distribution of digeneans. *N.Z. Journal of Marine and Freshwater Research 14*: 329–338.

Hine, P.M. & Boustead, N.C. 1974: A guide to disease in eel farms. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Research Division Occasional Publication 6.* 28 p.

Hobbs, D.F. 1947: Migrating eels in Lake Ellesmere. *Transactions and Proceedings of the Royal Society of New Zealand 77*: 228–232.

Hopkins, C.L. 1971: Production of fish in two small streams in the North Island of New Zealand. *N.Z. Journal of Marine and Freshwater Research 5*: 280–290.

Jellyman, D.J. 1977a: Summer upstream migration of juvenile freshwater eels in New Zealand. *N.Z. Journal of Marine and Freshwater Research 11*: 61–71.

Jellyman, D.J. 1977b: Invasion of a New Zealand freshwater stream by glass-eels of two *Anguilla* spp. *N.Z. Journal of Marine and Freshwater Research 11*: 193–209.

Jellyman, D.J. 1979a: Upstream migration of glass-eels (*Anguilla* spp.) in the Waikato River. *N.Z. Journal of Marine and Freshwater Research 13*: 13–22.

Jellyman, D.J. 1979b: Scale development and age determination in New Zealand freshwater eels (*Anguilla* spp.). *N.Z. Journal of Marine and Freshwater Research 13*: 23–30.

Jellyman, D.J. 1987: A review of the marine life history of the Australasian species of *Anguilla.* pp. 276-285 *In:* Dadswell, M.J., Klauda, R.J., Moffitt, C.M., Saunders, R.L., Rulifson, R.A., & Cooper, J.E. (Eds.), "Common Strategies of Anadromous and Catadromous Fishes." *American Fisheries Society Symposium 1.* 561 p.

Jellyman, D.J. 1989a: Diet of two species of freshwater eel (*Anguilla* spp.) in Lake Pounui, New Zealand. *N.Z. Journal of Marine and Freshwater Research 23:* 1–10.

Jellyman, D.J. 1989b: Occurrence of the nematode *Hedruris spinigera* in the stomachs of freshwater eels. *N.Z. Journal of Zoology 16*: 185–189.

Jellyman, D.J. 1991: Factors affecting the activity of two species of eel (*Anguilla* spp.) in a small New Zealand lake. *Journal of Fish Biology 39*: 7–14.

Jellyman, D.J. 1993: A review of the fishery for freshwater eels in New Zealand. *N.Z. Freshwater Research Report 10.* 51 p.

Jellyman, D.J., & Coates, G.D. 1976: The farming of freshwater eels in New Zealand. Indo-Pacific Fisheries Council, 17th session. FAO Symposium on the Development and Utilisation of Inland Fishery Resources. Colombo, Sri Lanka. 6 p.

Jellyman, D.J., & Ryan, C.M. 1983 Seasonal migration of elvers (*Anguilla* spp.) into Lake Pounui, New Zealand, 1974-1978. *N.Z. Journal of Marine and Freshwater Research 17*: 1–15.

Jellyman, D.J., & Todd, P.R. 1982: New Zealand freshwater eels: their biology and fishery. *Fisheries Research Division Information Leaflet 11.* 19 p.

Jones, J.B., Astill, M., & Kerei, E. 1983: The pond culture of *Anguilla australis* in New Zealand — with special reference to techniques and management of the experimental farm at Te Kaha, Bay of Plenty. *Rivista Italiana di Piscicoltura e Ittiopatologia 18(3):* 85–88, 91–94, 97–98, 101–104, and *18(4)*: 138–140, 143–144, 147–149, 151–154, 157.

McDowall, R.M. 1990: *New Zealand Freshwater Fishes. A Natural History and Guide.* Heinemann Reed, Auckland. 553 p.

Mitchell, C.P., & Chisnall, B.L. 1992: Problems facing migratory native fish populations in the upper Rangitikei River system. *N.Z. Freshwater Fisheries Miscellaneous Report* 119. 21 p.

Ryan, P.A. 1984: Diet and seasonal activity of the shortfinned eel, *Anguilla australis*, in Lake Ellesmere, Canterbury, New Zealand. *Environmental Biology of Fishes 11*: 229–234.

Ryan, P.A. 1986: Seasonal and size-related changes in the food of the shortfinned eel, *Anguilla australis*, in Lake Ellesmere, Canterbury, New Zealand. *Environmental Biology of Fishes 15*: 47–58.

Shorland, F.B. & Russell, J. 1948: Observations on the oil content of New Zealand fresh water eels. *N.Z. Journal of Science and Technology 29*: 164–200.

Skrzynski, W. 1974: Review of biological knowledge on New Zealand freshwater eels (*Anguilla* spp.). [N.Z. Ministry of Agriculture and Fisheries] *Fisheries Technical Report 109*. 37 p.

Strickland, R.R. 1985: Distribution and habitats of fishes in the Mohaka River. *N.Z. Ministry of Agriculture and Fisheries, Fisheries Environmental Report 55*. 86 p.

Sullivan, K.J. 1992: Yield-per-recruit analysis in New Zealand eel fisheries. Unpublished report held in MAF Fisheries Greta Point Library, Wellington. 13 p.

Taylor, M.J. 1988: Features of freshwater fish habitat in South Westland, and the effect of forestry practices. *N.Z. Freshwater Fisheries Report 97*. 89 p.

Tesch, F.-W. 1977: *The eel. Biology and management of anguillid eels*. Chapman & Hall Ltd, London. 434 p.

Todd, P.R. 1973: First record of the freshwater eel *Anguilla dieffenbachii* Gray to be caught at sea. *Journal of Fish Biology 5*: 231–232.

Todd, P.R. 1978a: Wairewa Maoris stick by old eeling methods. *Catch 5*: 24.

Todd, P.R. 1978b: A review of the Lake Ellesmere eel fishery. Ministry of Agriculture and Fisheries, Internal Report. 32 p.

Todd, P.R. 1979: The hormone-induced maturation of New Zealand freshwater eels. *Rapports et Proces-Verbaux des Reunions 174*: 91–97.

Todd, P.R. 1980: Size and age of migrating New Zealand freshwater eels (*Anguilla* spp.). *N.Z. Journal of Marine and Freshwater Research 14*: 283–293.

Todd, P.R. 1981a: Timing and periodicity of migrating New Zealand freshwater eels (*Anguilla* spp.). *N.Z. Journal of Marine and Freshwater Research 15*: 225–235.

Todd. P.R. 1981b: Morphometric changes, gonad histology, and fecundity estimates in migrating New Zealand freshwater eels (*Anguilla* spp.). *N.Z. Journal of Marine and Freshwater Research 15*: 155–170.

Todd, P.R. 1981c: The hormone-induced maturation in male New Zealand freshwater eels (*Anguilla* spp.). *N.Z. Journal of Marine and Freshwater Research 15*: 237–246.

Town, J.C. 1985: Commercial freshwater eel fishery. [N.Z. Ministry of Agriculture and Fisheries] *Fisheries Management Plan Series 12*. 24 p.

Town, J.C. 1986: Commercial freshwater eel fishery: future management. [N.Z. Ministry of Agriculture and Fisheries] *Fisheries Management Plan Series 23*. 26 p.

Waitangi Tribunal. 1992: The Ngai Tahu sea fisheries report. Waitangi Tribunal Report. 409 p.

Woods, C.S. 1964: Fisheries aspects of the Tongariro power development project. [N.Z. Marine Department] *Fisheries Technical Report 10*. 214 p.

Table 1: Comparison of eel catch data (t) from various sources, i.e., MAF database (MAF Fisheries, FSU, and CELR data), LFR, processors estimates and converted export data, and best estimate of annual catch. – = no data

					Reported catch
Calendar year	MAF database	LFR	Processors estimate	Exports green weight	Best estimate of annual catch
1965	30	–	–	–	30
1966	50	–	–	–	50
1967	140	–	–	–	140
1968	320	–	–	–	320
1969	450	–	–	–	450
1970	880	–	–	–	880
1971	1 450	–	–	–	1 450
1972	2 077	–	–	–	2 077
1973	1 310	–	–	–	1 310
1974	860	–	–	–	860
1975	1 185	–	–	2 434	2 434
1976	1 501	-	–	1 750	1 750
1977	906	–	–	1 697	1 697
1978	1 583	–	–	2 314	2 314
1979	1 640	–	–	2 124	2 124
1980	1 395	–	–	1 873	1 873
1981	1 043	–	–	1 686	1 686
1982	872	–	–	1 274	1 274
1983	1 206	–	–	941	1 206
1984	1 401	–	–	951	1 401
1985	1 505	–	–	1 011	1 505
1986	1 166	–	–	1 094	1 166
1987	1 044	1 114	–	1 065	1 114
1988	989	1 281	–	1 067	1 281
1989	894	1 315	1 348	1 312	1 348
1990	984	1 412	1 390	1 455	1 390
1991	1 272	1 523	1 598	1 516	1 598
1992	1 370	1 557	1 617	1 592	1 617

Table 2: Mean annual eel catch (t) by area for the 1983–84 to 1991–92 fishing years. (SD = standard deviation; CV = coefficient of variation.) Eel return areas are shown in Figure 1

Eel Return Area	Mean	SD	CV	Eel Return Area	Mean	SD	CV
01 Northland	149	40	0.27	12 Wellington	1	2	2.00
02 Auckland	72	38	0.53	13 Nelson	10	8	0.80
03 Hauraki	39	16	0.41	14 Marlborough	31	14	0.45
04 Waikato	162	64	0.40	15 Westland	43	19	0.44
05 Bay of Plenty	22	12	0.55	16 North Canterbury	39	16	0.41
06 Poverty Bay	5	7	1.40	17 South Canterbury	28	23	0.82
07 Hawkes Bay	83	31	0.37	18 Waitaki	9	9	1.00
08 Rangitikei-Wanganui	47	35	0.74	19 Otago	89	34	0.38
09 Taranaki	33	12	0.21	20 Southland	114	41	0.36
10 Manawatu	62	13	0.21	21 Lake Ellesmere	112	28	0.25
11 Wairarapa	34	15	0.44	22 Chatham Islands	15	13	0.87

Table 3: Fyke net catches (t) of eels and catch-per-unit-effort (CPUE) (kg per net-night) for each Eel Return Area, for the fishing years 1983–84 to 1988–89. % SF/LF/Unid = average % of shortfin, longfin, or unidentified eels, 1983–84 to 1988–89

	1983–84		1984–85		1985–86		1986–87		1987–88		1988–89		Mean		Species		
Eel return area	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	Catch	CPUE	% SF	% LF	% Unid.
01 Northland	151.1	6.6	200.2	6.2	198.7	6.3	160.1	4.7	130.9	5.5	75.7	4.8	152.9	5.7	68.8	27.9	3.3
02 Auckland	61.9	4.7	71.4	8.7	51.2	8.8	26.3	9.2	29.2	5.8	79.2	7.4	53.2	7.0	63.8	36.0	0.2
03 Hauraki	67.2	4.8	57.6	6.5	53.3	7.3	24.4	8.5	26.6	6.4	32.1	6.7	43.5	6.2	74.7	24.0	1.3
04 Waikato	252.3	4.1	249.1	4.4	197.2	4.2	96.1	4.1	91.6	4.8	77.4	4.4	160.6	4.3	71.9	24.9	3.2
05 Bay of Plenty	18.1	6.0	33.9	4.2	32.8	3.1	11.6	3.0	10.0	3.1	7.2	2.9	18.9	3.6	60.4	26.8	12.8
06 Poverty Bay	15.2	2.2	9.0	5.4	0.2	1.7	0.1	3.5	4.1	11.4	<0.1	7.2	4.8	3.1	31.5	68.5	0.0
07 Hawkes Bay	84.2	9.1	95.8	11.1	86.2	15.6	61.2	9.2	68.2	13.9	26.4	7.7	70.3	11.0	80.5	15.9	3.6
08 Rangitikei-Wanganui	18.3	9.5	22.8	10.1	28.1	6.8	14.9	6.0	27.9	16.2	28.0	8.4	23.3	8.7	23.1	61.5	15.4
09 Taranaki	33.1	8.0	27.1	8.3	55.4	10.2	43.9	9.4	42.0	7.4	12.8	5.1	35.7	8.3	7.5	80.4	12.1
10 Manawatu	83.8	12.9	72.3	9.9	65.0	12.6	59.5	7.1	49.8	8.3	71.7	9.8	67.0	9.9	73.8	17.4	8.8
11 Wairarapa	29.0	17.6	29.6	11.2	44.5	12.5	58.9	12.7	54.7	11.4	23.0	22.4	40.0	13.1	32.6	67.4	0.0
12 Wellington	3.4	5.3	0.3	–	5.7	8.3	0.0	–	0.0	–	0.0	–	1.6	7.1	2.1	97.9	0.0
North Island total	818.0	–	869.1	–	818.3	–	557.0	–	535.0	–	433.5	–	671.7	–	63.6	32.0	4.4
13 Nelson	2.5	32.3	8.6	8.0	10.4	7.4	11.7	5.9	3.8	3.5	16.1	6.0	8.9	6.4	69.1	28.4	2.5
14 Marlborough	19.7	19.0	52.7	8.0	43.6	9.1	40.4	10.0	29.8	9.9	13.6	7.2	33.3	9.4	41.3	47.9	10.8
15 Westland	18.0	10.0	38.3	10.1	45.9	11.2	24.3	5.3	31.6	4.9	40.6	6.5	33.1	7.4	41.8	57.5	0.7
16 North Canterbury	32.6	4.9	26.2	7.5	29.4	8.2	31.1	7.9	30.1	18.0	73.9	15.7	37.2	9.3	71.9	27.2	0.9
17 South Canterbury	72.3	5.3	59.6	4.0	14.8	7.2	8.8	8.1	16.9	4.5	9.1	3.1	30.3	4.7	84.4	13.6	2.0
18 Waitaki	3.5	5.0	3.1	19.3	1.5	11.4	0.0	–	5.0	8.4	8.9	6.5	3.7	7.4	44.1	40.5	15.4
19 Otago	144.7	5.0	130.8	6.7	71.4	6.8	91.3	5.9	111.5	5.3	75.0	5.8	104.1	6.1	8.4	77.4	14.2
20 Southland	88.3	9.8	171.9	7.8	98.5	6.5	174.8	7.4	102.4	7.0	70.9	7.3	117.8	7.5	12.9	86.9	0.2
21 Lake Ellesmere	117.6	4.1	98.4	3.7	82.0	3.8	114.1	4.8	100.0	8.0	99.9	7.1	102.0	4.8	97.2	1.1	1.7
South Island total	499.2	–	589.6	–	397.5	–	496.5	–	431.1	–	408.0	–	470.4	–	44.8	50.5	4.7
22 Chatham Islands	13.9	5.2	17.0	11.1	0.0	–	0.0	–	12.3	7.5	0.0	–	7.2	7.4	88.9	11.1	0.0
New Zealand total	1331.1	5.7	1475.7	6.1	1215.8	6.3	1053.5	6.1	978.4	6.8	841.5	6.7	1149.3	6.5	56.1	39.4	4.5
Total effort (net-nights)	223 038		232 805		184 194		162 891		138 503		113 508		175 823				

Table 4: Annual eel catch (t) in Lake Ellesmere, 1973–1992 calendar years. The seasonal quota (t) set for the fishery is also shown. * = excluding migrants; + = including migrants; – = no data

Calendar year	Reported catch	Estimate from processors data	Seasonal quota
1973	251.0	–	–
1974	256.0	–	–
1975	566.0	–	–
1976	847.0	–	–
1977	441.0	–	–
1978	524.0	–	256.0 *
1979	359.0	–	250.0 *
1980	299.0	–	300.0 *
1981	208.0	–	300.0 +
1982	109.0	–	200.0 +
1983	107.5	–	150.0 +
1984	89.6	–	150.0 +
1985	99.4	–	150.0 +
1986	81.6	–	136.5 +
1987	103.1	–	136.5 +
1988	103.7	–	136.5 +
1989	104.5	186.1	136.5 +
1990	89.3	169.5	136.5 +
1991	129.4	179.7	136.5 +
1992	167.6	199.9	136.5 +

Data for 1973–84 from Town (1985).

Note: the Fisheries Authority has set a 1 February–31 January quota year for Lake Ellesmere; the "Seasonal quota" is for this period.

Table 5: Variation in mean length-at-age (cm) for eels from various locations throughout New Zealand. – = no data

Age	Location																	
(yrs)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Shortfinned eels																		
5	10	10	–	38	21	–	32	24	20	22	24	30	24	–	52	–	–	–
10	18	43	–	55	28	–	38	36	34	45	32	35	31	–	105	–	–	–
15	20	60	–	68	36	–	44	48	48	69	39	40	39	–	–	–	–	–
20	30	70	–	79	43	–	50	59	62	–	47	45	46	–	–	–	–	–
25	40	–	–	–	51	–	56	71	76	–	55	51	55	–	–	–	–	–
30	43	–	–	–	58	–	62	–	–	–	63	56	–	–	–	–	–	–
35	–	–	–	–	66	–	68	–	–	–	71	61	–	–	–	–	–	–
40	–	–	–	–	73	–	74	–	–	–	79	67	–	–	–	–	–	–
45	–	–	–	–	81	–	–	–	–	–	–	–	–	–	–	–	–	–
50	–	–	–	–	88	–	–	–	–	–	–	–	–	–	–	–	–	–
Longfinned eels																		
5	10	–	15	–	22	29	–	–	–	–	–	–	25	32	–	27	22	–
10	18	–	25	–	32	33	–	–	–	–	–	–	33	37	–	40	30	–
15	24	–	36	–	41	38	–	–	–	–	–	–	39	43	–	53	37	–
20	30	–	48	–	51	42	–	–	–	–	–	–	46	48	–	66	45	52
25	36	–	58	–	61	47	–	–	–	–	–	–	–	–	–	80	53	57
30	41	–	65	–	70	51	–	–	–	–	–	–	–	–	–	93	60	62
35	45	–	76	–	80	56	–	–	–	–	–	–	–	–	–	106	68	67
40	50	–	82	–	89	60	–	–	–	–	–	–	–	–	–	119	75	72
45	51	–	90	–	99	64	–	–	–	–	–	–	–	–	–	–	83	–
50	52	–	98	–	100	69	–	–	–	–	–	–	–	–	–	–	91	–

Locations

1	=	South Branch, Waimakariri River	Burnet (1969a)
2	=	Doyleston Drain, Canterbury	Burnet (1969a)
3	=	Main Drain, Canterbury	Burnet (1969a)
4	=	Pukepuke Lagoon, Foxton	Jellyman (1979b)
5	=	Lake Pounui, Wairarapa	Jellyman (unpublished data)
6	=	Lake Rotoiti, Nelson	Jellyman (unpublished data)
7	=	Lake Ellesmere, Canterbury	Todd (unpublished data)
8	=	Lake Whangape, Waikato	Chisnall & Hayes (1991)
9	=	Lake Waahi, Waikato	Chisnall & Hayes (1991)
10	=	Lake Waikare, Waikato	Chisnall & Hayes (1991)
11	=	Pastoral Stream, Waikato	Chisnall & Hayes (1991)
12	=	Whangamarino Swamp, Waikato	Chisnall & Hayes (1991)
13	=	Waikato River, backwater	Chisnall (1989)
14	=	Waikato River, mainstem	Chisnall (1989)
15	=	Lake Aniwhenua	Mitchell & Chisnall (1992)
16	=	McGregors Drain, Taieri River	Harries (1974)
17	=	Lee Stream Taieri River	Harries (1974)
18	=	Clutha River	Harries (1974)

Table 6: Variation in mean length (cm) and age (years) (in bold) of migrating eels from throughout New Zealand. – = no data

Location	Shortfinned eels		Longfinned eels		
	Male	Female	Male	Female	
Various	40	80	60	90	Cairns (1941)
Lake Ellesmere					
1942	48	68	64.5	119	Hobbs (1947)
1972	44	72	–	–	Todd (1980)
1974–80	43 (**14**)	78 (**24**)	67	116 (**49**)	Todd (1980)
South Branch (Waimakariri)	43	64	59	121	Burnet (1969)
Makara Stream	36.5	74	62	106	Todd (1980)
Lake Onoke	45	76	–	–	
Lake Pounui	41.5 (**22**)	74 (**41**)	61 (**34**)	124.5 (**56**)	Jellyman (unpubl. data)
Range of means					
length	40-48	64-80	59–67	90–124	
age	**14–22**	**24–41**	–	**49–56**	

Table 7: Biomass estimates of eels from various New Zealand studies. NW = reach with no willow (*Salix* sp.) cover; MW = reach with moderate willow cover; DW = reach with dense willow cover

Waterway		Area studied (ha)	kg/ha	Author
Wainuiomata River (Wellington)		0.9	320	Burnet (1952)
Doyleston Drain (Canterbury)		0.1	130	Burnet (1952)
Hanmer Road Drain (Canterbury)		0.3	66	Burnet (1959)
Hinau Stream (Wairarapa)		0.2	138	Hopkins (1971)
Hinaki Stream (Wairarapa)		0.2	809	Hopkins (1971)
South Branch (Canterbury)		–	249	Burnet (1969a)
Main Drain (Canterbury)		–	135	Burnet (1969a)
Ashley River riffles (Canterbury)		0.8	55	Glova (1988)
Ashley River pools (Canterbury)		0.1	435	Glova (1988)
Ashley River runs (Canterbury)		0.3	20	Glova (1988)
Ashley River riffles (Canterbury)		0.3	104	Glova *et al.* (1985)
Hurunui River riffles (Canterbury)		1.1	9	Glova *et al.* (1985)
Rakaia river riffles (Canterbury)		5.3	13	Glova *et al.* (1985)
Shag River (Otago)	NW	0.05	21	Glova & Sagar (unpublished results)
	MW	0.03	20	Glova & Sagar (unpublished results)
	DW	0.02	133	Glova & Sagar (unpublished results)
Wakapuaka River (Nelson)	NW	0.04	71	Glova & Sagar (unpublished results)
	MW	0.02	267	Glova & Sagar (unpublished results)
Tiritea Stream (Manawatu)	NW	0.01	23	Glova & Sagar (unpublished results)
	MW	0.01	24	Glova & Sagar (unpublished results)

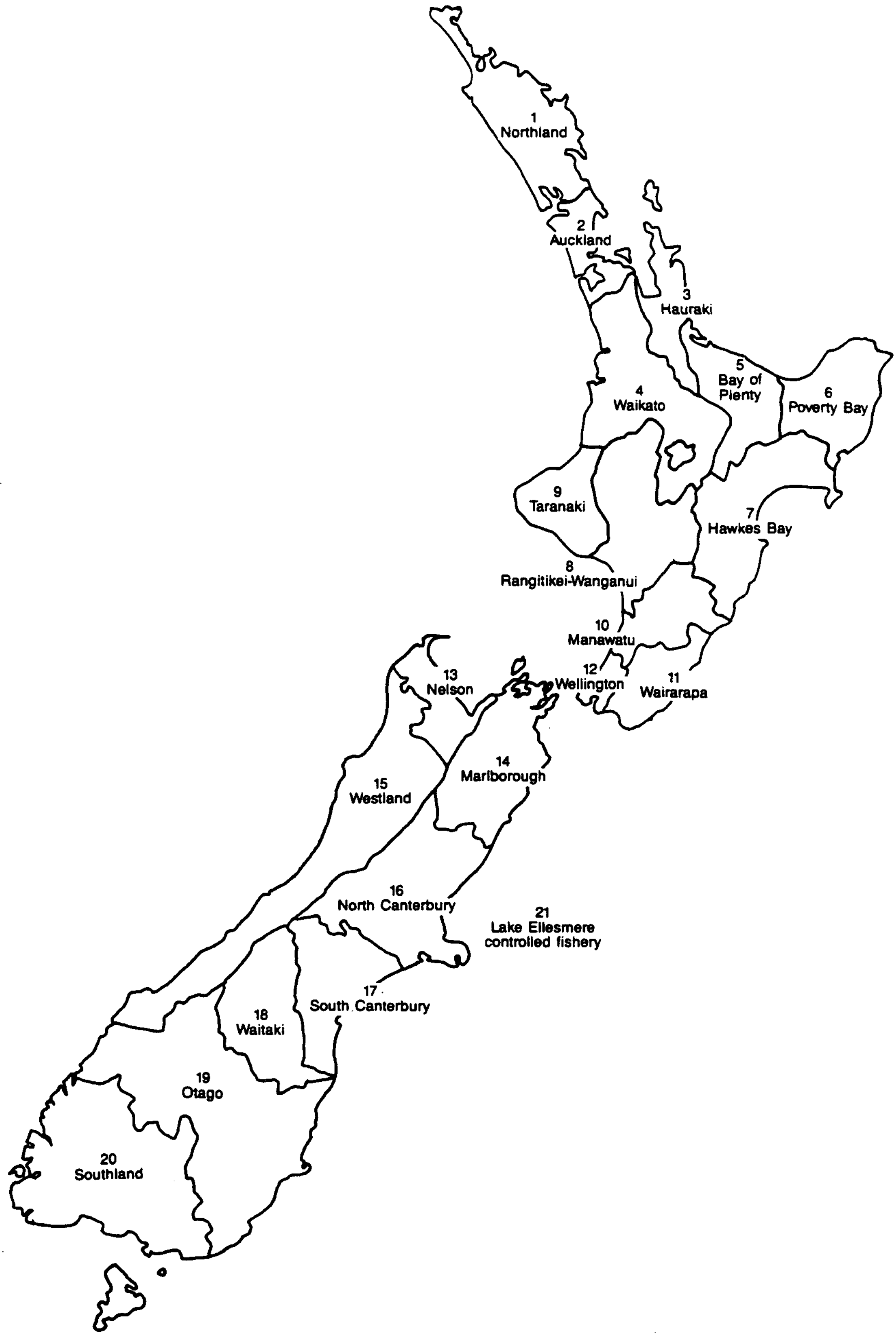

FIGURE 1. Present Eel Return Areas.

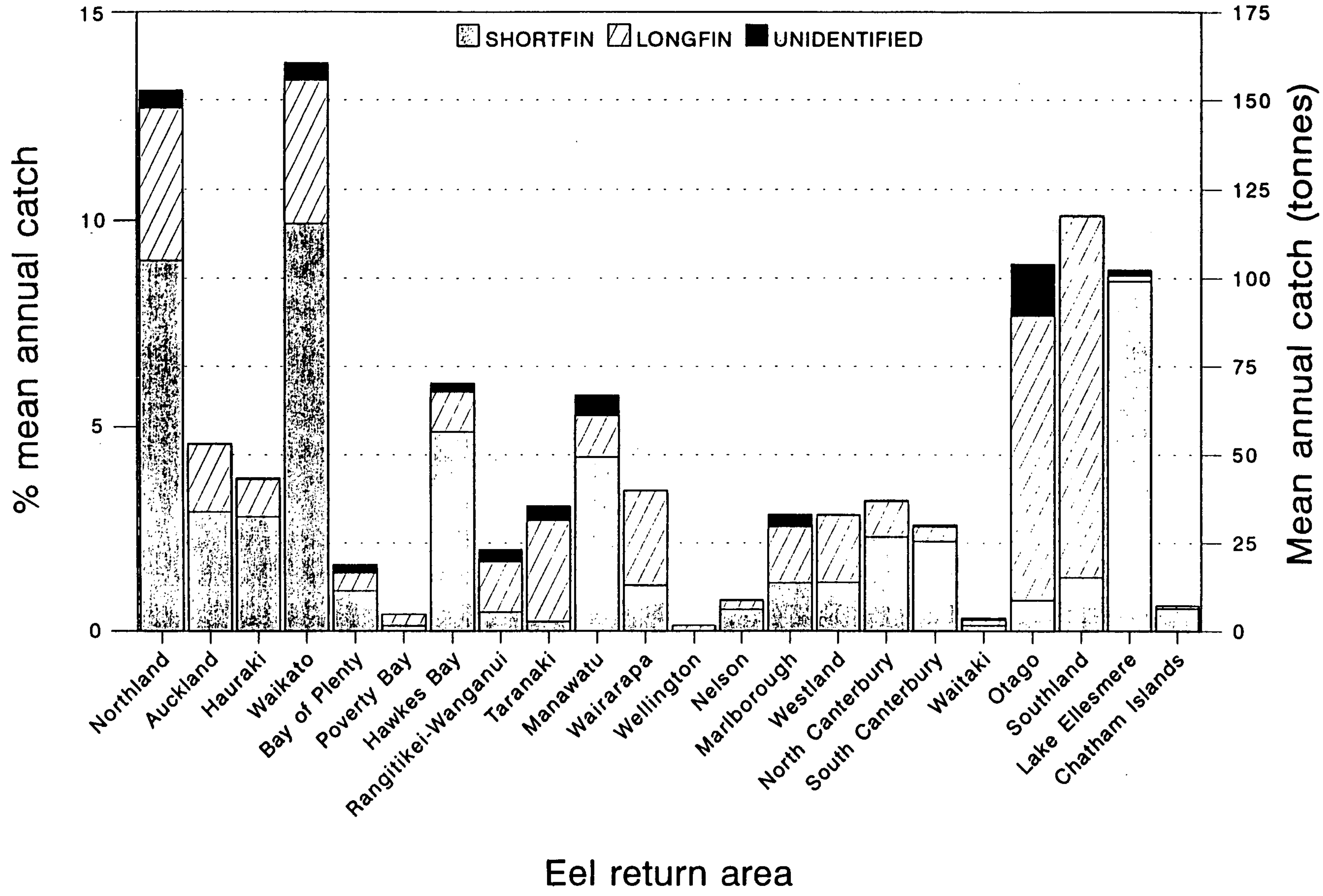

FIGURE 2. Mean catch by species for Eel Return Areas for fishing years 1983/84-1991/92