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A summary of the biology, recreational and commercial landings, and stock assessment of yellow-eyed mullet, *Aldrichetta forsteri* (Cuvier and Valenciennes, 1836) (Mugiloidei: Mugilidae)

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1. EXECUTIVE SUMMARY

The yellow-eyed mullet, *Aldrichetta forsteri*, is widespread in New Zealand waters. It is sometimes a reef-dwelling, pelagic species, but also inhabits estuaries and even fresh water. It feeds on a wide range of food types, from algae and detritus to polychaete worms and fish. It spawns over an extended period during spring and summer, and one study has suggested a second spawning during winter.

The life history of *A. forsteri* includes a pre-settlement, pelagic phase, with entry into sheltered embayments or estuaries in summer, presumably within months of being spawned. The period of confinement to estuarine/riverine habitat is unclear, but adults are known to enter coastal waters to spawn. Within estuarine/riverine systems younger and older fish are separated, with younger preferring less saline conditions.

A. forsteri are taken by Maori, in the recreational fishery, and as a commercial species. The commercial fishery extends back to New Zealand's earliest history but there are no catch records before 1934. The catch history is patchy in some areas, and under-reporting is evident. Since 1982–83, about 5% of the catch is taken with beach seine/drag net, and 95% by setnet/gillnet. Some bycatch is evident but unquantified..

Until the 1960s, highest landings were recorded in Northland. During the 1960s catches in Lake Ellesmere were highest, with fishers targeting to provide for specialised processing. In the 1990s the highest mean annual catch has been in Manukau Harbour.

Effort data are not available from the commercial fishery and this, coupled with uncertainty in the landing figures, precludes estimation of biomass indices using CPUE. No data are available to estimate mortality, and no yield estimates have been produced. Fish have been aged and a length-weight relationship is available, but the latter was estimated for fish whose growth may have been particularly high. Data are available for determining a second length-weight relationship from published results.

Considering the small average size of this species, the recent high increases in catch from one harbour at least, and the absence of information on how localised sub-stocks might be, the critical focus for research in the immediate future is determining stock structure, or at least determining the extent of mixing between different localities. The objective would be to develop a management strategy that avoids any possibility of local depletion.

Various publications from Australian research on this species are available. *A. forsteri* is an important commercial and recreational species in New South Wales, South Australia, Tasmania, and Western Australia.

2. INTRODUCTION

2.1 Overview

This document summarises the currently available biological and fisheries information on yellow-eyed mullet or *aua* of the Maori, *Aldrichetta forsteri* (Cuvier and Valenciennes, 1836). This species is mentioned in a wide range of publications and biological information is available from primary scientific literature published in both Australia and New Zealand. Very little published information is available on the commercial fishery for *A. forsteri*, and the reliability of catch information is unclear. This, coupled with absence of effort data, precludes estimation of biomass indices using CPUE. Yield estimates cannot be calculated.

The species code of *A. forsteri* in research and fisheries databases is YEM.

2.2 Description of the Fishery

The yellow-eyed mullet is one of the most common fishes in coastal waters of New Zealand, where it is widely but erroneously known as herring (Manikiam 1963, McDowall 1990). It is typically a marine, schooling species that also occurs in estuarine and riverine habitats, and was described by Ministry for the Environment (1997) as the most common of 30 fish species occurring in mangrove ecosystems. Maori would have taken this species in historical times, although it is unclear whether it was used primarily for bait or food.

A. forsteri has been referred to as a popular recreational species, both in New Zealand (Thomson 1878, McDowall 1978) and in Australia (Neira *et al.* 1997), and it also has historical commercial importance. The history of the New Zealand commercial fishery is long and varied, and, considering early references to the quality of this species as a food fish by Charles Douglas (*see* McDowall 1980) and others (Thomson 1878, 1879), it is likely that the catch history predates, by a wide margin, the first recorded commercial catch in 1934 (Table 1, Figure 1). Despite the history being long, however, the catch has never been large, and Manikiam (1963) reported total landings of *A. forsteri* between 1920 and 1961 as only 12 614 cwt or 641 t.

The reliability of the yellow-eyed mullet catch history is unclear. Early records are patchy, and there is much variation in landings from individual ports (Table 2). In addition there are potential inaccuracies arising from misidentification and incorrect use of common names. *A. forsteri* was recorded in the Marine Department's Fisheries Reports as *herring*, and when Manikiam (1963) examined them he suggested that there were likely to be inaccuracies in the reporting because of ambiguity arising from the use of the name *mullet*. Although the extent of these inaccuracies is unknown, and the reasons for patchy annual data are unclear, records from some ports are regular and may reflect a more complete record than is apparent from the aggregated data.

The mullet species *A. forsteri* and *Mugil cephalus* play an important role in the fisheries of Australia (Manikiam 1963). Neira *et al.* (1997) ranked *A. forsteri* third in a list of major commercial species taken in Victorian waters between 1990–91 and 1994–95, and reported the average total annual catch in all areas as 284 t.

2.3 Literature Review

Formerly assigned to the American freshwater genus *Agonostomus*, the yellow-eyed mullet is now described as *Aldrichetta forsteri* (Cuvier and Valenciennes, 1836), of the family Mugilidae (mullets), following a strong case based on morphological and ecological differences presented by Whitley (1945), and supported by Thomson (1954). The full list of assignments is relatively long and recorded in detail by Thomson (1954). The family Mugilidae is also represented in New Zealand by the grey mullet, *Mugil cephalus* (Linnaeus).

A. forsteri is mentioned in the literature since the earliest times of New Zealand history (*see* Beaglehole 1962, & Andrews 1986). It was described in detail by Richardson (1848), who erroneously defined its occurrence as New Zealand only. Hector (1872) also presented a description, and it was mentioned by Young & Thomson (1926). A number of localised studies have recorded its presence around New Zealand: Otago (Hutton 1875), the Piako River, Hauraki-Thames (Mair 1903), Fiordland (Cunningham 1951), the Hauraki Gulf (McKenzie 1960), North Otago (Graham 1963), the Wellington district (Howard 1883, McDowall 1964, Jones & Hadfield 1985), Ohiwa Harbour (Paul 1966), the Bay of Plenty (Tong & Elder 1968), Goat Island, Leigh (Russell 1969), Whangateau Harbour, Northland (Grace 1971), Red Mercury Island (Grace 1972), the Ahuriri Estuary, Napier (Kilner & Ackroyd 1978), Karikari Peninsula, Northland (Willan *et al.* 1979), Kaikoura (Francis 1979), the Cavalli Islands, Northland (Nicholson 1979), the Waimakariri River estuary (Knox *et al.* 1978, Eldon & Kelly 1985), the Motu River mouth (Penlington 1988), and Lake Ellesmere (Hughes *et al.* 1974, Hardy 1989). This list is not exhaustive but illustrates the widespread distribution of this species.

Several other localised studies have been more extensive and provide us with valuable information on the general biology of the species. Gorman (1962) examined *A. forsteri* from Lake Ellesmere and presented information on the length-weight relationship, size distribution, and spawning. Manikiam's (1963) thesis is based on *A. forsteri* from the Wellington Harbour and covers a number of aspects, including internal and external morphology, notes on distribution, habitat, and faunal associations, examination of growth and size, determination of age and growth rate, maturity, spawning, and fecundity, feeding, schooling behaviour, and commercial utilisation of the species. Webb's (1973a–e) studies concentrate on fish populations of the Avon-Heathcoate estuary, and cover ecology, breeding and gonad maturity, gut contents, and parasites.

A number of studies have provided information on specific aspects of the biology of *A. forsteri* and its relationship with the environment. Kingsford (1988) and Kingsford & Choat (1985, 1986, 1989) showed the relationship of presettlement and juvenile fish with surface slicks, drift algae, and surface, neustonic waters, and gave insight into the pelagic phase of these early life history stages and the processes by which they may be transported from pelagic to near-shore waters. Jellyman *et al.* (1997) examined the spatio-temporal distribution of fish in the Kakanui River estuary to provide information on the seasonality of abundance and spawning condition of *A. forsteri*.

In South Australia and Western Australia, Potter *et al.* (1993) and Potter & Hyndes (1994) investigated fish communities in open and closed estuarine systems to determine the distribution of species with various life history strategies and the pattern of recruitment of 0+ juveniles, and provided information on habitat preferences for *A. forsteri*. In Western Australia Lenanton *et al.* (1982) investigated surf zone accumulations of detached macrophytes and provided information on the feeding ecology and seasonal pattern of occurrence of 0+ and 1+ cohorts of *A. forsteri*. Edgar & Shaw (1995) investigated the effect of seagrass loss on local fishery production, and determined the importance of seagrass beds as nursery grounds for commercially important fish species in central Victoria. In a number of Australian studies, *A. forsteri* proved to be one of the fish most often taken by gillnet.

A. forsteri have been recorded in the diets of barracouta (*Thyrsites atun*) (Graham 1939), and gannets (*Sula serrator*) (Wodzicki & Moreland 1966, Wingham 1985), and have been described as an important food source for kahawai (*Arripis trutta*) (Baker 1971).

Proximate analyses of *A. forsteri* have been presented by Vlieg (1984, 1988), and lipid content and fatty acid composition by Vlieg & Body (1988). Heavy metal levels were estimated by Tracey & Van den Broek (1987).

The yellow-eyed mullet egg was described by Cassie (1956) and figured by Crossland (1981).

3. REVIEW OF THE FISHERY

3.1 The Commercial Fishery

3.1.1 Catches and landings

A. forsteri have undoubtedly been taken since the earliest days of commercial fishing, although catch records only exist from 1934 (*see* figure 1, Table 1). Its presence in the Otago fish market in the 1870s was recorded by Thomson (1878, 1879), and Charles Douglas wrote in his notes of 1840–1916 that "*The mullet [A. forsteri] is probably the most common fish sold in Westland and they are very good eating and cure well, but the bones are an awful bother*" (McDowall 1980). Phillipps (1921) and Phillips & Hodgkinson (1922) recorded it for sale in Wellington in 1918 and Auckland in the the early 1920s.

There is very little published information on the commercial fishery for *A. forsteri* apart from brief comments about its use as bait (Ayling & Cox 1982). From 1934 to 1972 information from catch records indicate that *A. forsteri* was taken by "other nets", meaning nets other than trawl or Danish seine, which is not very specific. Catch by gear-type data from the Fisheries Statistics Unit (FSU) records between 1982–83 and 1988–89 (Table 3) show a predominant use of setnets and gillnets (about 95.5% of total catch), over beach seine and drag net (about 4.5% of total catch). The very small quantities (presented as "< 0.1 t" in Table 3) recorded for bottom trawl, handline, trotline, bottom longline, and miscellaneous nets, are probably bycatch.

Most of the catch (90%) is taken in the yellow-eyed mullet target fishery (Table 4). Small proportions, ranging from 0.5% to 1.5%, are taken in various target fisheries for other species, including grey mullet (*Mugil cephalus*), kahawai (*Arripis trutta*), and rig (*Mustelus lenticulatus*), with the largest proportions taken as bycatch in the flatfish setnet fishery (about 3%) and garfish (*Hyporhamphus ihi*) beach-seine fishery (about 2%).

The level of error in the catch data due to misidentification is unknown. There is potential for incorrect assignment because of the similarity in common names between grey mullet and yellow-eyed mullet, with the possibility that some fishers refer to both as mullet. A second possible classification error may result from erroneous use of the names *herring* or *sprat*.

Catches by region are shown in Table 2 where the totals generally represent 2 or 3 ports that are geographically close together. Records were sporadic until 1946, although there was a general increase in the number of ports recording catch. By 1950, six or seven ports were regularly recording catch, and sometimes these were large (e.g., more than 50 t in Northland).

Before 1960 most of the recorded catch of *A. forsteri* was taken in Northland (*see* Table 2). After 1960 there was a marked increase in the catch recorded from Lake Ellesmere (which contributes most of the catch recorded for Kaikoura-Banks Peninsula in Table 2). Regular records were also available from Napier (most of the Hawkes Bay catch), beginning in 1941, and Manukau Harbour (representing most catch records for the category "West Coast"). Apart from Lake Ellesmere, records for the South Island were sporadic.

The increased take at Lake Ellesmere in the early 1960s, coincides with the development of a kippering process by a Christchurch company, a "*venture that has proved so successful that the Company concerned is willing to accept as much mullet as can be produced from the lake*" (Gorman 1962). The influence of this fishery persisted until at least 1968 (*see* Table 2), but is not evident in the records after 1970 (Table 5, QMA 3). There is no record of the date on which this fishery ceased.

Catches by QMA (*see* Table 5, Figure 2 were low from 1974 to 1979, perhaps as a result of under-reporting, but they then began to rise. This rise lags for a little at the changeover to the new recording system (FSU), but continues rising to reach a peak of almost 100 t in 1986–87. Most of this increase is a result of an apparent increase in landings in QMA 9, with a much lower but significant increase in QMA 1. The subsequent variations can be accounted for in much the same way, although QMAs 3 and 7 show occasional high landings.

No explanation is available for the peak in 1986–87 or the second in 1992–93, except that it is clear from Figure 3 that annual landings in Manukau Harbour increased dramatically after 1972 (*see* Table 2, Ack.). Large landings are also evident from

Kaipara Harbour and the Hauraki Gulf. These increased landings around Auckland suggest an increased marketability of *A. forsteri* in the 1990s.

Two pieces of evidence indicate the possibility of under-reporting in the catch records. The first is the difference between the licensed fish receivers (LFRR) totals and the QMA total, presented as "Other" in Table 5. In some years this represents a high proportion of the total landings (e.g., 46% in 1988–89), and adds a level of uncertainty to the catch history. Unfortunately, under-reporting cannot be estimated for other years using this method because the licensed fish receivers' (LFRR) landings totals that are used as the New Zealand total during the period from 1986–87 to 1995–96 are not available in other years.

Irregularities in annual reported catches by port of landing (*see* Table 2) may also be a result of under-reporting, but under-reporting may not explain all the irregularities. It is clear that some level of targeting occurs in QMAs 1 and 9, and the records from these areas are quite regular since the inception of the fishery. Irregular catches are more evident from areas where there is no record of an active target fishery. These irregularities may be the result of *A. forsteri* being taken as occasional bycatch.

A seasonal pattern is evident in the aggregated landings data shown in Figure 4 which can also be seen in the catch data for each QMA, with annual peaks around July and August indicating a winter fishery (Figure 5).

3.1.2 Effort

There is no information on fishing effort.

3.1.3 Management

A. forsteri is currently managed outside the Quota Management System. The species may be targeted for commercial purposes only under the authority of a fishing permit which lists it as a target species. Under the moratorium introduced in 1992, no new fishing permits for non-quota species (other than tuna) may be issued. In addition to this effort limitation, competitive catch limits of 100 and 50 t are set in QMAs 3 and 5 respectively. *A. forsteri* may be taken by commercial fishers as an inevitable consequence of the lawful taking of other species.

The recreational catch in the northern region has no daily bag limit, but a minimum set-net mesh size of 25 mm is defined by regulation.

3.2 Traditional Maori Fishing

The importance of *A. forsteri* to Maori is difficult to determine. While it is undoubtedly true that this species was taken in historical times, it is unclear what the level of catch might have been. Information on the specific use to which *A. forsteri* were put might provide some idea of the level of utilisation in the absence of any numerical data. One instance of a catch of *A. forsteri* being taken by Maori was recorded by Mair (1903) at a village some 3 miles up the Piako River, but it was mixed with other species and the description does not include how the catch was used. In the Waitangi Tribunal report (1988b), Wiremu Paraone refers to both *herring* and *mullet* when describing the plentiful abundance of Parengarenga Harbour in the 1960s and before. However, *A. forsteri* is not mentioned in the lists of fish taken that are presented in other sections of the Tribunal's report. The only specific mention of yellow-eyed mullet use by Maori is in the Resources subsection of the Modern Fisheries section, where it is included in a list following the statement that "*a number of non-pelagic reef dwelling fish species are exploited at low levels*".

Although there is some reference to *A. forsteri* being taken as a food fish in the recent literature (Waitangi Tribunal 1988a), not all historical records (Taylor 1855, Poata 1919, Best 1929) or evidence from archeological sites (Waitangi Tribunal 1988a, Leach & Boocock 1993) support this view. Beattie (*circa* 1920) includes yellow-eyed mullet in an extremely comprehensive list of food items obtained from South Island Maori in 1920, and Morris Te Whiti Love's evidence to the Tribunal concerning Lake Ellesmere (Waitangi Tribunal 1988a), refers to *aua* as a component of the food resource known "*throughout Aotearoa*" as *waihora*. It is likely that *aua* were often used as bait, and Phillipps (1934) makes direct reference to this, but does not indicate how important this activity may have been. Generally, however, uncertainty and the lack of quantitative information precludes any estimation of the amount of fish taken in the traditional Maori fishery.

3.3 Recreational Fishery

A. forsteri has been documented since early times as a popular recreational species (Thomson 1878, McDowall 1978). In Australia, Neira *et al.* (1997) refer to it as an important recreational species in Victorian waters, particularly with shoreline anglers, and estimate the total annual recreational catch in Victoria as 8–14 t.

In New Zealand, catches of *A. forsteri* have been recorded in most Fishstocks during recreational fishing surveys, with estimated numbers highest in QMA 1. Estimated numbers of fish and harvest tonnages for yellow-eyed mullet from surveys carried out in different years in Ministry of Fisheries regions are presented in parts (i) and (ii) of Table 6. These surveys are: South in 1991–92 (Teirney & Kilner, unpublished data), Central in 1992–93 (Kilner & Coddington, unpublished data), North in 1993–94 (Bradford 1996), and national in 1996 (Bradford 1998). Harvest estimates are dependent on sample sizes being large enough to estimate a coefficient of variation (c.v.), which is not possible in a number of the cases presented. The value of the c.v. is incorporated into estimates of survey harvest tonnage, which are therefore presented as a range reflecting the uncertainty in the estimate.

The survey data have a number of sources of uncertainty. The level of misidentification arising from similarity in the common names grey mullet and yellow-eyed mullet, and erroneous use of the names *herring* or *sprat*, is unknown. The level of assignment to the general mullet category "MUU" is also unknown. Estimates of the number of fish and harvest tonnage are presented for MUU in part (iii) of Table 6.

4. RESEARCH

Information on *A. forsteri* is available from research in New Zealand and Australia. Australian work has shown variations in the biology of the species between western and eastern Australian waters, and further comparison with New Zealand results indicates some similarity in the biology of *A. forsteri* between eastern Australia and New Zealand (Manikiam 1963).

4.1 Distribution

The distribution of *A. forsteri* is restricted to New Zealand, Norfolk Island, and Australia. In New Zealand its distribution extends from North Cape to Stewart Island (McDowall 1978), and in Australia it ranges from the Murchison River in Western Australia, across South Australia and around Tasmania to the Hawkesbury River in New South Wales (Thomson 1954).

A. forsteri is found in a variety of habitats in a distribution that seems to be related to life history stage, but is ill-defined for some phases. Spawning in New Zealand occurs in coastal waters, and 0+ presettlement juveniles follow a pelagic phase within the ichthyoplankton, during which they have been found up to 18 km from shore (Kingsford & Choat 1989). In mugilids, the end of this phase is represented by the eventual association with a reef, although the importance of this association has not been described for *A. forsteri*.

Potter *et al.* (1993) have shown that in Western Australia, *A. forsteri* of 20–50 mm TL enter estuaries and remain there for the winter. Thomson (1957a) has also shown that *A. forsteri* are spawned in winter in Western Australia, suggesting that the juveniles entering estuaries for the winter are about 9 months old. By contrast, most research on the reproduction of *A. forsteri* in New Zealand indicates spawning during summer, leaving a much shorter period if they too are to enter sheltered embayments and estuaries for the winter. However, no information is available on the age of their recruitment into estuarine systems in New Zealand.

Typical habitats of *A. forsteri* are coastal waters, harbours, and estuaries, and they also enter brackish and even fresh waters. Manikiam (1963) suggests that the species shows no preferred choice between sand and gravel bottom or tidal mudflat. He observed that juveniles swim close to the shore and often school close to the surface. Generally adults are not seen at the surface, although Manikiam (1963) coaxed fish of up to 300 mm fork length (FL) there using groundbait, but stated that fish larger than this were "*rarely, if ever, encountered at the surface*".

Various studies and observations indicate that *A. forsteri* enters streams and rivers but seldom moves far from the influence of seawater (McDowall 1964, 1980). In Western Australia Potter *et al.* (1983) found a difference in preference between large and small *A. forsteri* for estuarine basin or river habitat, and Potter & Hyndes (1994) found an apparent preference in juveniles for reduced salinity or features associated with a riverine habitat.

The habitat types of *A. forsteri* are wide ranging and include a number of variations within the coastal zone. Manikiam (1963) interpreted a list of species published by Graham (1956) that include *A. forsteri* in their diets as evidence for *A. forsteri* inhabiting rocky coastline, seafloor, and more intermediate depths. Grace (1971) and Russell (1969) showed that presettlement juveniles have a definite preference for a surface, neustonic habitat when inhabiting the coastal zone.

4.2 Stock Structure

It is unknown whether biologically distinct stocks of *A. forsteri* occur in New Zealand, and it is unknown how localised fine scale distribution patterns might be. Some aspects of its biology are complex, particularly details of changes in distribution with life history stage (Thomson 1957a, Kingsford & Choat 1989), and little can be drawn about stock structure from this information. Although the pelagic phase of the juveniles presents an opportunity for various localities to be seeded from a broad reproductive resource, no information is available on whether this is the case, or whether settling juveniles return to particular localities.

According to Manikiam (1963), two subspecies have been suggested in Australia by G.P. Whitley, based on counts of scales and gill-rakers, but this conclusion is not generally supported and Manikiam (1963) suggested that the differences result from clinal variation.

Determining the level of localisation in substocks may require information characterising the extent of movement, and tagging studies are often used to meet such an objective. This species is very fragile, however, and the only tagging study known to date, where *A. forsteri* were tagged opportunistically with operculum tags (*see* Thomson 1957a) during a tagging programme on sea mullet (*Mugil dobula*) in Western Australia (Thomson 1951), produced a return rate of 1.1%. This rate is pitifully low and gives an indication of the number of fish that would have to be tagged to ensure enough returns for a definitive result. Too few recaptures were made to indicate any patterns of movement, either within estuaries or outside.

4.3 Fish Size

There have been a number of localised studies on *A. forsteri* in New Zealand. Graham (1938) examined *A. forsteri* at the Portobello Marine Laboratory, possibly sampled from the Dunedin fish market, and recorded its maximum length as 508 mm total length (TL), estimating the average length (TL) as 280 mm. Gorman (1962) worked at Lake Ellesmere and recorded a maximum length of 395 mm FL for a fish of 850 gr. He expanded his original work by sampling fish from Lyttelton Harbour where he recorded maximum length as 250 mm FL, and concluded that the larger size of Lake

Ellesmere fish was due to a faster growth rate resulting from a lower level of interspecific competition. Manikiam's (1963) samples were from Wellington Harbour and he recorded a maximum length of 350 mm FL; the smallest fish was 31 mm FL.

In Western Australia, Thomson's (1957a) age and growth study showed that "*age for age, female fish are larger than males.*"

4.4 Length-weight relationships

Information on the length–weight relationship in *A. forsteri* is disappointing. Gorman (1962) studied fish from Lake Ellesmere and presented a form of

$$W=2.39*10^{-4}(L^{3.2})$$

where W and L are weight and length. The validity of this relationship is probably limited, however, considering his conclusions about the higher growth rate in the lake referred to in Section 4.3 above.

Manikiam (1963) analysed length and weight data for fish from Wellington Harbour, but presented his results in graphical form only. His length-weight relationship is transcribed in Figure 6. Although it is probably possible to lift the data from the graph and estimate a length–weight relationship, it has not been done here.

4.5 Age and Growth

Manikiam (1963) also presented his results on age and growth in graphical form only. No other information is available for *A. forsteri* in New Zealand waters. Manikiam's (1963) age-length relationship and growth curve are transcribed in Figures 7 and 8 respectively.

Bradstock (1985) suggested a maximum age of age 6 years but failed to support his claim with any source or methodology. The oldest fish that Manikiam (1963) aged (using scales) was 7 years. However, the length of this fish (350 mm FL) was much less than the 508 mm TL maximum size recorded by Graham (1938), and somewhat less than the 395 mm FL recorded by Gorman (1962).

In Western Australia, Thomson (1957a) carried out age and growth studies on *A. forsteri*, using scales from the mid-flank region, and showed that females have a higher growth rate than males that becomes apparent from the third year. He observed that "*few females and still fewer males seem to live more than 5 or 6 years,*" and recorded a maximum age of 7 years.

4.6 Natural Mortality

Natural mortality (M) was estimated from the equation M = $\log_e 100$/maximum age, where maximum age is the age to which 1% of the population survives in an unexploited stock. Using 7 years for the maximum age results in an estimate of M = 0.66. The maximum age used here is for *A. forsteri* taken by Manikiam (1963) in Wellington Harbour in 1963.

4.7 Reproduction

Manikiam (1963) used gross observations of the ovary and microscopic measurements of egg diameters to show that yellow-eyed mullet from Wellington Harbour first spawn at the end of the third year, when their length is between 178 and 250 mm FL. Using similar methods, Webb (1973b) found that size at first maturity was 220–240 mm TL for both sexes in the Avon-Heathcoate Estuary. In Western Australia, Thomson (1957a) defined a similar age at first maturity and found initial signs of ripening gonads in fish of 180 mm FL. However, he found that all spent males were 220 mm FL or greater, and all spent females 245 mm FL or greater. From these observations, and considering the offset in length records arising from the two measurement methods used in New Zealand (Manikiam (1963) used a factor of 1.073 to convert from FL to TL), it seems reasonable to accept a mean size at first maturity of about 220 mm FL for New Zealand fish. This is less than that proposed for Western Australian *A. forsteri*, but would coincide with some proportion of the 2+ group.

The ova of *A. forsteri* are pelagic (Manikiam 1963) and attain an average diameter of 0.48 mm that remains uniform with fish length. Development begins in July and maturity occurs by late December (Manikiam 1963, Graham 1939). Manikiam (1963) postulated a single annual spawning event for Wellington Harbour fish which extends from late December to mid-March. Webb's (1973b) Avon-Heathcoate work, however, produced different results, indicating a biennial spawning in females, with peaks in winter and summer, while males matured mostly between October and December. Gorman (1962) supported the summer spawning with records of gravid females from Lake Ellesmere in February and March. Crossland's (1982) records of *A. forsteri* eggs from the Hauraki Gulf in December 1976, and East Northland in October and December 1977, seem to support a spring–summer spawning, but is difficult to interpret considering that sampling was largely restricted to the months that eggs were found.

Webb (1973b) described cohorts occurring at what seemed to be less than yearly intervals. Webb described *A. forsteri* spawning within the estuary, whereas most other studies referenced in this report suggest spawning taking place in open coastal waters.

Using systematic sampling of the gonads from 1353 *A. forsteri* throughout the year, Thomson (1957a) showed that spawning in Western Australia occurs during winter, from May to October. However, he obtained a different result in eastern Australia where he used a much less extensive sampling programme, taking fish from various sites between Victoria and Tasmania from December to March. In this second study, he found that most gonads were at an advanced stage of maturity. These results illustrate a similar, summer spawning period for New Zealand and eastern Australia, and a winter spawning for Western Australia.

At least two estimates of fecundity have been produced for *A. forsteri* by gravimetric methods. Manikiam (1963) pesented ova counts from Wellington Harbour specimens ranging from 117 000 for a fish of 211 mm FL, to 680 000 for a fish of 350 mm FL. In Western Australia, Thomson (1957a) showed a range from 125 000 eggs for a 245 mm FL fish, to 630 000 eggs for a 391 mm FL fish.

4.8 Sex Ratios

Some information is available on sex ratios, but there is uncertainty in interpreting the results. Webb (1973a) showed variations in sex ratios throughout the year for his Avon-Heathcoate study, with peaks of about 8:1 females predominant in January-February and June and lower female predominance (between 2.5:1 and 4.9:1) during the rest of the year. He suggested that this supported his conclusion of two spawning peaks in summer and winter. Thomson (1957a) showed a variation in estimated sex ratios for Western Australia between 1.2 and 1.7 females per male, with the latter value occurring when small samples were ignored. He also discussed certain variations based on the sample site, concluding a predominance of females in all but 3 of the 42 samples. Considering the difference in growth rate and size between the sexes shown by Thomson (1957a), the differences in sex ratios in the samples of both studies could be a result of a difference in gear selectivity.

4.9 Feeding

Generally, *A. forsteri* is described as omnivorous with a tendency to prefer algae in its diet (McDowall 1978, Edgar & Shaw 1995). Manikiam (1963) collected 322 specimens in the size range 31–310 mm from Wellington and district (Shelly Bay, Evans Bay, Horokiwi Stream, and Makara Estuary). He listed 18 groups of organisms from gut contents and regrouped them into the following major categories:

algae	32.2%
crustaceans	29.7%
diatoms	7.7%
detritus	7.0%
sandgrains	6.8%
molluscs	6.8%
insect larvae	6.1%
other	3.7%

Most algae were filamentous greens, such as *Enteromorpha* sp., *Cladophora* sp., and *Chaetomorpha* sp., and strands of *Ulva* sp. were also present. Copepods were the predominant planktonic crustacean group, with crustacean larvae (including decapods), malacostracans (mainly decapods), amphipods, and ostracods present in decreasing order of importance. Diatoms are often found associated with algal filaments and are likely to be ingested by *A. forsteri* from this source. Molluscs consisted of *Potmopyrgus* sp. and a small unidentified violet bivalve. Insect larvae comprised trichopteran larvae including *Deleatidium* nymphs, and dipteran larvae including Chironomidae. "*Other*" included polychaete worms (*Nereis amblyodonta*), hydroids (mainly *Obelia* species), and fish eggs. Empty stomachs accounted for 11% of the 322 stomachs examined.

Webb (1973c) presented lists of food items from two samples of *A. forsteri* that differed by size. His first sample was of 1868 individuals that were larger than 150 mm, and the second was 496 individuals that were smaller than 150 mm. His summary is as follows:

fish	✔	✔
insect larvae		✔
crustaceans	✔	✔
molluscs	✔	✔
polychaetes	✔	✔
coelenterates	✔	
algae	✔	✔
unidentified eggs	✔	✔
starch waste	✔	
detritus & mud	✔	✔

Generally the groups he identified from each sample were the same as Manikiam (1963) had recorded, although the species composition differed a little. The main difference between the two studies is the presence of fish species, which were not found by Manikiam (1963): Webb (1973c) identified *Galaxias maculatus attenuatus* and *Anguilla australis*.

McMillan (1961) examined fishes of the Rangitata River mouth, Canterbury, and found that *A. forsteri* include silveries (*Retropinna anisodon*) in their diet. An interesting observation by Webb (1973c) was that *A. forsteri* were often filled to capacity with mud during winter; mugilids are generally considered detritus feeders (McDowall 1978).

At Western Port in Victoria, Edgar & Shaw (1995) examined production and trophic ecology of shallow-water fish species and found that although the number of omnivorous species was low, several omnivores were abundant, including *A. forsteri* which was the dominant species in gillnet catches. They attributed the success of *A. forsteri* to its broad dietary range, and, perhaps more importantly in its competition with other omnivores, its "*targeting the more productive invertebrates low on the food chain (i.e. grazing and detritivorous molluscs and peracarid crustaceans) rather than the carnivorous crabs and shrimps selected by other fish species of a similar body size*".

Edwards (1977) also studied trophic relationships in Victoria, this time on a coastal fish community at Port Phillip Bay. The subjects were from a sewage farm discharge zone where the nearshore area was characterised by typically euryhaline species including *A. forsteri*. Diet was identified as being mainly epibenthic crustacea and polychaetes, with the note that dense populations of bivalve molluscs (*Notospisula* *trigonella* and *Macoma* sp.) that are present there were not significant in the fishes' diets.

4.10 Movement and Behaviour

Much of the information available on the movements of yellow-eyed mullet is closely linked with distribution and has been discussed elsewhere in this report. Generally, adults leave the harbour, apparently to spawn in coastal waters, during August–December (Bradstock 1985). The fry enter a pelagic phase (Kingsford & Choat 1989) and are eventually transported back to near-shore waters by some onshore water movement possibly related to internal waves (Kingsford & Choat 1986). The pelagic phase is short and fry migrate into the harbour during summer (Bradstock 1985).

However, there is one aspect of movement which is poorly understood. Nothing is available on how localised substocks of *A. forsteri* might be. The settlement of post-pelagic phase individuals close to their area of spawning could have important implications for the management of this species.

Some information on schooling behaviour is available. Both Phillipps (1929) and Morgans (1966) recorded very low numbers of *Sprattus antipodum* and *Sardinops neopilchardus* associated with *A. forsteri* in schools, but Phillipps (1929) described a more common association where *A. forsteri* are observed schooling at the surface while *S. neopilchardus* lie below them, close to the bottom.

5. STOCK ASSESSMENT

5.1 *Biomass Estimates*

No independent biomass estimates are available for *A. forsteri* in New Zealand waters. The absence of effort data precludes the use of CPUE as an index of biomass.

5.2 Estimation of Maximum Constant Yield (MCY)

Because there are no estimates of absolute biomass or mortality, estimation of MCY is not possible. There is no stable period of fishing effort where $MCY = cY_{av}$ (Annala *et al.* 1998) can be applied. Here, c is a factor of natural variability and Y_{av} is the average catch over an appropriate period.

5.3 Estimation of Current Annual Yield (CAY)

No estimates of current biomass are available for any stock and it is not possible to estimate CAY.

5.4 Factors Modifying Yield Estimates

Uncertainty in the catch history and the absence of effort data, estimates of mortality, and indices population size, preclude the possibility of estimating yield.

6. MANAGEMENT IMPLICATIONS

Yellow-eyed mullet may be at risk of depletion in some areas. The importance of this arises from the current nature of the commercial fishery. Generally, the fishery is highly localised and recent catches show patterns where landings in some areas, particularly the Manukau Harbour (*see* Figure 3), are high. These patterns of catch, for a species that may follow a life history pattern within relatively fine scale localities, carry a high risk of local depletion, in some areas at least.

Yellow-eyed mullet are predominately taken in shallow coastal habitats using fine-mesh nets. Consequently, the fishery has the potential to impact on other coastal fin-fish species, particularly those inhabiting shallow water during their juvenile phase. No information is available on the quantity and species composition of juvenile fish discarded from yellow-eyed mullet catches. This is an area where future research on the species could be directed.

Generally, catches are taken within harbours and estuarine systems that are easy to identify (*see* Figure 3). This natural division should be taken into account when boundaries for Fishstocks are being set.

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8. REFERENCES

Annala, J.H., Sullivan, K.J., O'Brien, C.J., & Iball, S.D. 1998: Report from the Fishery Assessment Plenary, May 1998: stock assessments and yield estimates. 409 p. (Unpublished report held in NIWA library, Wellington.)

Andrews, J.R.H. 1986: The Southern Ark. Zoological discovery in New Zealand 1769–1900. Century Hutchinson New Zealand Ltd., Auckland. 237 p.

Ayling, A.M. & Cox, G.J. 1982: Collins guide to the sea fishes of New Zealand. Collins, Auckland. 343 p.

Baker, A.N. 1971: Food and feeding of kahawai (Teleostei: Arripididae). *N.Z. Journal of Marine and Freshwater Research 5(2)*: 291–299.

Beaglehole, J.C. (Ed.) 1962: The Endeavour Journal of Joseph Banks 1768–1771. The Trustees of the Public Library of New South Wales in Association with Angus and Robertson. 2 Vols, 476 and 406 p.

Beattie, H.J. *circa* 1920: Oral traditionary lore gathered from the Maoris and half-castes of Murihiku etc. Manuscript, Hocken Library, ms 181.

Best, E. 1929: Fishing methods and devices of the Maori. *Dominion Museum Bulletin No. 12.* 264 p.

Bradford, E. 1996: Marine recreational fishing survey in the Ministry of Fisheries North Region, 1993–94. *New Zealand Fisheries Data Report No. 80.* 24 p.

Bradford, E. 1998: Harvest estimates from the 1996 national recreational fishing surveys. New Zealand Fisheries Assessment Research Document.

Bradstock, M. 1985: Between the tides. New Zealand shore and estuary life. Reed Methuen, Auckland. 158 p.

Cassie, R.M. 1956: Early development of the snapper, *Chrysophrys auratus* Forster. *Transactions of the Royal Society of N.Z. 83*: 705–713.

Crossland, J. 1982: Distribution and abundance of fish eggs and larvae from the spring and summer plankton of north–east New Zealand, 1976–78. *Fisheries Research Bulletin No. 24.* 59 p.

Crossland, J. 1981: Fish eggs and larvae of the Hauraki Gulf, New Zealand. *Fisheries Research Bulletin No. 23.* 61 p.

Cunningham, B.T. 1951: A preliminary report on fisheries. *In* Poole, A.L. (Ed.), Preliminary reports of the New Zealand–American Fiordland expedition. Investigations in Fiordland, New Zealand, in 1949. pp. 73–76. *N.Z. Department of Scientific and Industrial Research, Bulletin 103.*

Edgar, G.J. & Shaw, C. 1995: The production and trophic ecology of shallow-water fish assemblages in southern Australia. II Diets of fishes and trophic relationships between fishes and benthos at Western Port, Victoria. *Journal of Experimental Marine Biology and Ecology 194*: 83–106.

Edwards, R.C.C. 1977: Trophic and energetic relationships of a coastal fish community in Port Phillip Bay. *Australian Marine Sciences Bulletin No. 6.* 8.

Eldon, G.A. & Kelly, G.R. 1985: Fishes of the Waimakariri River estuary. *Fisheries Environmental Report No. 56.* 59 p.

Francis, M.P. 1979: Checklist of the marine fishes of Kaikoura, New Zealand. *Mauri Ora 7*: 63–71.

Gorman, T.B.S. 1962: Yellow-eyed mullet Aldrichetta forsteri Cuvier and Valenciennes in Lake Ellesmere. *Fisheries Technical Report No. 7.* 20 p.

Grace, R.V. 1971: A checklist of fishes from the entrance to the Whangateau Harbour, Northland, New Zealand. *Tane 17*: 129–136.

Grace, R.V. 1972: A preliminary checklist of marine fishes of Red Mercury Island, north-eastern New Zealand. *Tane 18*: 91–93.

Graham, D.H. 1938: Fishes of Otago Harbour and adjacent seas, with additions to previous records. *Transactions and Proceedings of the Royal Society of N.Z. 68(3)*: 399–419.

Graham, D.H. 1939: Breeding habits of the fishes of Otago Harbour and adjacent seas. *Transactions and Proceedings of the Royal Society of N.Z. 69(3)*: 361–72.

Graham, D.H. 1956: A treasury of New Zealand fishes. Reed, Wellington. 424 p.

Graham, J. 1963: The North Otago shelf fauna. Part III – Chordata, sub–phylum Gnathostomata. *Transactions of the Royal Society of N.Z., Zoology 3*: 165–70.

Hardy, C.J. 1989: Fish habitats, fish, and fisheries of the Ellesmere catchment. *N.Z. Fisheries Freshwater Report No. 104.* 152 p.

Hector, J. 1872: Notes on the edible fishes. In Hutton, F.W., and Hector, J. Fishes of New Zealand. pp. 97–133. Colonial Museum and Geological Survey Dept., Wellington.

Howard, [Mr] [1883: Catch of Dajus forsteri and Retropinna osmeroides in the Hutt River.] *Transactions and Proceedings of the N.Z. Institute 15.* 527.

Hughes, H.R., McColl, R.H.S., & Rawlence, D.J. 1974: Lake Ellesmere, Canterbury, New Zealand. A review of the lake and its catchment. *New Zealand DSIR Information Series No. 99.* 27 p.

Hutton, F.W. 1875: Fauna of Otago. *In* Hutton, F.W. & Ulrich, G.H.F., Report on the geology and gold fields of Otago, Appendix C to Part 1, Geology of Otago. pp. 128–139. Provincial Council of Otago, Dunedin.

Jellyman, D.J., Glova, G.J., Sagar, P.M., & Sykes, J.R.E. 1997: Spatio-temporal distribution of fish in the Kakanui River estuary, South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 31*: 103–118.

Jones, J.B. & Hadfield, J.D. 1985: Fishes from Porirua and Pauatahanui Inlets: occurrence in gill nets. *N.Z. Journal of Marine and Freshwater Research 19(4)*: 477–484.

Kilner, A.R. & Akroyd, J.M. 1978: Fish and invertebrate macrofauna of Ahuriri Estuary, Napier. Fisheries Technical Report No. 153. 79 p.

King, M.R. 1985: Fish and shellfish landings by domestic fishermen, 1974–82. *Fisheries Research Division Occasional Publication: Data Series No. 20.* 122 p.

Kingsford, M.J. 1988: The early life history of fish in coastal waters of northern New Zealand: a review. *N.Z. Journal of Marine and Freshwater Research 22(3)*: 463–479.

Kingsford, M.J. & Choat, J.H. 1985: The fauna associated with drift algae captured with a plankton-mesh purse seine net. *Limnology and Oceanography 30(3)*: 618–630.

Kingsford, M.J. & Choat, J.H. 1986: Influence of surface slicks on the distribution and onshore movements of small fish. *Marine Biology 91(2)*: 161–171.

Kingsford, M.J. & Choat, J.H. 1989: Horizontal distribution patterns of presettlement reef fish: are they influenced by the proximity of reefs? *Marine Biology 101(3)*: 285–297.

Knox, G.A., Bolton, L.A., & Hackwell, K. 1978: The ecology of the benthic macro flora and fauna of Brooklands Lagoon, Waimakariri River estuary. *Department of Zoology, University of Canterbury, Estuarine Research Unit Report No. 16.* 125 p.

Leach, B.F. & Boocock, A.S. 1993: Prehistorical fish catches in New Zealand. *Tempus Reparatum Bar International Series 584.* 38 pp.

Lenanton, R.C.J., Robertson, A.I., & Hansen, J.A. 1982: Nearshore accumulations of detached macrophytes as nursery areas for fish. *Marine Ecology—Progress Series,* *9*: 51–57.

Mair, G. 1903: Notes on fish found in the Piako River. *Transactions and Proceedings of the N.Z. Institute 35*: 319–320.

Manikiam, J.S. 1963: Studies on the yellow-eye mullet. Unpublished MSc thesis, Victoria University of Wellington.

McDowall, R.M. 1964: Studies on the biology of the red-finned bully Gobiomorphus huttoni (Ogilby). Part I - Habitat and species inter-relationships. *Transactions of the Royal Society of N.Z. Zoology 4*: 175–182.

McDowall, R.M. 1978: New Zealand freshwater fishes. A guide and natural history. Heinemann Educational Books (N.Z.) Ltd, Auckland. 230 p.

McDowall, R.M. 1980: Charles Douglas, explorer: his notes on freshwater fishes. *Journal of the Royal Society of New Zealand 10(4)*: 311–324.

McDowall, R.M. 1990: New Zealand freshwater fishes. A natural history and guide. Heinemann Reed, Auckland. 553 p.

McKenzie, M.K. 1960: Fish of the Hauraki Gulf. *Proceedings of the N.Z. Ecological Society 7*: 45–49.

McMillan, H.M. 1961: An addition to the knowledge of the fish, Retropinna anisodon Stokell (Retropinnidae). *Transactions of the Royal Society of N.Z., Zoology 1(10)*: 139–144.

Ministry for the Environment 1997: The state of New Zealand's environment 1997. The Ministry for the Environment, Wellington, New Zealand.

Morgans, J.F.C. 1966: Possibilities raised by a study of the size distribution in a sample of a shoal of sprats, Sprattus antipodum (Hector). *Transactions of the Royal Society of N.Z., Zoology 8(13)*: 141–147.

Neira, F.J., Coutin, P.C., and Elliot-Tippet, D. 1997: Commercial catches of selected scale fish species from Victorian waters, 1978–1995. *Marine and Freshwater Resources Institute Report No. 2.* 78 p.

Nicholson, J. 1979: A checklist of fishes from the Cavalli Islands, Northland, New Zealand. *Tane 25*: 133–139.

Paul, L.J. 1966: Observations on past and present distributions of mollusc beds in Ohiwa Harbour, Bay of Plenty. *N.Z. Journal of Science 9*: 30–40.

Penlington, B.P. 1988: The kahawai fishery at the Motu River mouth. *N.Z. Fisheries Freshwater Report No. 103.* 27 p.

Phillipps, W.J. 1921: Notes on the edible fishes of New Zealand. With a record of fishes exposed for sale in Wellington during 1918. *N.Z. Journal of Science and Technology 4*: 114–125.

Phillipps, W.J. 1929: Notes on the pilchard (Sardinia neopilchardus) in Queen Charlotte Sound. *N.Z. Journal of Science and Technology 10*: 343–345.

Phillipps, W.J. 1934: Maori bait-trap for catching small fish. *N.Z. Journal of Science and Technology 16*: 165–166.

Phillipps, W.J. & Hodgkinson, E.R. 1922: Further notes on the edible fishes of New Zealand. *N.Z. Journal of Science and Technology 5*: 91–97.

Poata, T.R. 1919: The Maori as a fisherman and his methods. Scott and Sons, Opotiki. 27 p. (Reprinted 1929 by Te Aroha News Printing and Publishing Co. 32 p.)

Potter, K.C. & Hyndes, G.A. 1994: Composition of the fish fauna of a permanently open estuary on the southern coast of Australia, and comparisons with a nearby seasonally closed estuary. *Marine Biology 121(2)*: 199–209.

Potter, K.C., Hyndes, G.A., & Baronie, F.M. 1993: The fish fauna of a seasonally closed Australian estuary. Is the prevalence of estuarine spawning species high? *Marine Biology 116(1)*: 19–30.

Potter, K.C., Loneragan, N.R., Lenanton, R.C.J., Chrystal, P.J., & Grant, C.J. 1983: Abundance, distribution and age structure of fish populations in a Western Australian estuary. *Journal of Zoology 200(1)*: 21–50.

Richardson, J. 1844–1848 [1848]: Ichthyology of the voyage of H.M.S. Erebus and Terror. In Richardson, J., and Gray, J.E. (Eds.), The Zoology of the Voyage of H.M.S. Erebus and Terror, under the command of Captain Sir James Clark Ross, R.N., F.R.S., during the years 1839–1843. Vol. 2(2), 139 pp. Edward Newman, London.

Russell, B.C. 1969: A checklist of the fishes of Goat Island, North Auckland, New Zealand, with an analysis of habitats and associations. *Tane 15*: 105–113.

Taylor, R. 1855: Te Ika a Maui or New Zealand and its inhabitants. Reprint by Wertheim and MacIntosh, London, 1974.

Thomson, P. 1878: The Dunedin fish supply. *Transactions and Proceedings of the N.Z. Institute 10*: 324–330.

Thomson, P. 1879: Our fish supply. *Transactions and Proceedings of the N.Z. Institute 11*: 380–386.

Thomson, J.M. 1951: Growth and habits of the sea mullet, *Mugil dobula* Günther, in Western Australia. *Australian Journal of Marine and Freshwater Research* 2: 193–225.

Thomson, J.M. 1954: The Mugilidae of Australia and adjacent seas. *Australian Journal of Marine and Freshwater Research 5*: 70–131.

Thomson, J.M. 1957a: Biological studies of economic significance of the yellow-eye mullet, *Aldrichetta forsteri* (Cuvier & Valenciennes) (Muglidae). *Australian Journal of Marine and Freshwater Research 8*(1): 1–13,

Thomson, J.M. 1957b: Interpretation of the scales of the yellow-eye mullet, *Aldrichetta forsteri* (Cuvier & Valenciennes) (Muglidae). *Australian Journal of Marine and Freshwater Research 8*(1): 14–28

Tong, L.J. & Elder, R.D. 1968: Distribution and abundance of demersal fish from trawl stations in the Bay of Plenty, New Zealand, 1961–63. *N.Z. Journal of Marine and Freshwater Research 2*: 49–66.

Tracey, D. & Van den Broek, W.L.F. 1987: Survey of heavy metal levels in Coromandel shellfish and finfish. *In* Livingston, M.E. (Ed.), Preliminary studies on the effects of past mining on the aquatic environment, Coromandel Peninsula, pp. 119–135 *Water and Soil Miscellaneous Publication No. 104, Ministry of Works and Development.*

Vlieg, P. 1984b: Proximate analysis of commercial New Zealand fish species. 2. *N.Z. Journal of Science 27*: 427–434.

Vlieg, P. 1988: Proximate composition of New Zealand marine finfish and shellfish. Biotechnology Division, DSIR, Palmerston North. 50 p.

Vlieg, P. & Body, D.R. 1988: Lipid contents and fatty acid composition of some New Zealand freshwater finfish and marine finfish, shellfish, and roes. *N.Z. Journal of Marine and Freshwater Research 22*: 151–162.

Waitangi Tribunal 1988a: Ngai Tahu claimants evidence. Working papers for the seventh hearing at Tuahiwi Marae and Te Rau Aroha Marae, Bluff, 11–20 April 1988: Part 1, Documents Wai-27, H1-H27.

Waitangi Tribunal 1988b: Muriwhenua Fishing Report (Wai-22). Waitangi Tribunal Reports, 2.

Webb, B.F. 1972a: Fish populations of the Avon–Heathcote estuary. 1. General ecology, distributions, and length–frequency. *N.Z. Journal of Marine and Freshwater Research 6*: 570–601.

Webb, B.F. 1973b: Fish populations of the Avon–Heathcote estuary. 2. Breeding and gonad maturity. *N.Z. Journal of Marine and Freshwater Research 7*: 45–66.

Webb, B.F. 1973c: Fish populations of the Avon–Heathcote estuary. 3. Gut contents. *N.Z. Journal of Marine and Freshwater Research 7*: 223–234.

Webb, B.F. 1973d: Fish populations of the Avon–Heathcote estuary. 4. Parasites. *N.Z. Journal of Marine and Freshwater Research 7*: 301–305.

Webb, B.F. 1973e: Fish populations of the Avon-Heathcote estuary. 5. Records of less common fish. *N.Z. Journal of Marine and Freshwater Research 7*: 307–321.

Whitley, G.P. 1945: New sharks and fishes from Western Australia. Part 2. *Australian Zoologist 11*: 1–42.

Willan, R.C., Dollimore, J.M., & Nicholson, J. 1979: A survey of fish populations at Karikari Peninsula, Northland, by scuba diving. *N.Z. Journal of Marine and Freshwater Research 13*: 447–458.

Wingham, E.J. 1985: Food and feeding range of the Australasian gannet *Morus serrator* (Gray). *Emu 85(4)*: 231–239.

Wodzicki, K. & Moreland, J. 1966: A note on the food of New Zealand gannets. *Notornis 13(2)*: 98–99.

Young, M.W. & Thomson, G.M. 1926: Occurrence of pilchards and sprats in New Zealand seas. *Transactions and Proceedings of the N.Z. Institute 57*: 314–319.

Table 1: Reported landings (t) of yellow-eyed mullet, 1934 to 1972. New Zealand total and port landings grouped into QMAs. Source: Annual Reports of Fisheries (1934–72). Values for 1934 to 1944 are for April–March years, listed as the April year. "Other" is the nominal difference between the port subtotals and the New Zealand total, and represents incomplete recording of the former; most values are converted from hundredweight and rounded. QMA landings less than 50 kg (including zero) are listed as 0. Negative values in "Other" result from the QMA total being higher than the New Zealand Total

Year	QMA1	QMA2	QMA3	QMA5	QMA7	QMA8	QMA9	"Other"	New Zealand total
1934	0.3	0	0	0	0	0	0	-0.3	0
1935	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	0	0	0	0	0
1937	0	0	0	0	0	0	0	0	0
1938	0.76	0	2.64	1.57	0	0	0	4.22	9.19
1939	0	0	0	0	0	0	0	0	0
1940	0.05	0	2.69	0	0	0	0	2.44	5.18
1941	0	0.1	0.2	0	0	0	0	-0.3	0
1942	0	1.07	0.4	0	0	0	0	2.44	3.91
1943	0.15	1.22	0.15	0	0	0	0	10.27	11.79
1944	1.37	1.93	0.51	0	0.05	0.25	0	9.35	13.46
1945	0	1.52	0	0	0	0.36	0	7.77	9.65
1946	52.93	0.82	0.25	0	13.26	0	0	-0.86	66.4
1947	65.18	0.76	0.1	0	1.27	0.05	0	0	67.36
1948	70.92	0	0	0	0	0	0.05	0	70.97
1949	80.67	0.15	0	0	0	0	0	0	80.82
1950	30.83	0.2	0.66	0	0	0	0	0.01	31.7
1951	35.61	0.3	2.79	0	0	0	0	0.01	38.71
1952	12.64	0.2	1.27	0	0	0	0.05	0.01	14.17
1953	12.96	0.1	2.74	0	0	0.05	0.05	0.05	15.95
1954	15.29	0.56	0.15	0	0	0	0	0.05	16.05
1955	28.09	0.46	1.88	0	0	0.25	0.1	0	30.78
1956	27.9	1.17	0.3	0	0	0.15	0.2	0	29.72
1957	18.69	0.96	2.9	0	0	0.15	0.41	0	23.11
1958	21.89	0.35	0.46	0	0	0	0.46	0	23.16
1959	19.65	0.46	0.15	0	0	0	0.05	3.16	23.47
1960	9.15	0.71	1.02	0	0	0	0	-0.11	10.77
1961	19.66	0.86	20.57	0	0	0	0	0.01	41.1
1962	18.99	0.61	11.02	0	0.41	0	0.71	0.21	31.95
1963	8.43	0.81	9.19	0	0.61	0	0.81	-0.04	19.81
1964	8.69	0.66	18.8	0	0	0	0.25	-0.05	28.35
1965	5.69	4.83	15.09	0	0	0	2.74	0	28.35
1966	4.31	0.66	11.94	0	0.71	0	4.67	0.06	22.35
1967	22.86	2.43	4.37	0	1.68	0	3.51	6.86	41.71
1968	19.1	0	13.51	0	0.3	0	1.93	0.01	34.85
1969	16.91	9.04	0.66	0	0.2	0	1.57	0.02	28.4
1970	17.17	0	1.12	0	0	0	0.86	0.05	19.2
1971	14.02	0	0.36	0	0	0	0.71	0.45	15.54
1972	7.11	1.53	14.68	0	0	0	0.91	0	24.23

Table 2: Reported landings (t) of yellow-eyed mullet aggregated over several ports, 1934 to 1972. Values converted from hundredweight

Year	Nth	Ack	Thm	BoP	WCt	Hwk	Wgt	Kai	Cnt	Snd	SWN	Wld	GTB
1934	0	0	0.3	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	0	0	0	0	0	0	0	0	0
1937	0	0	0	0	0	0	0	0	0	0	0	0	0
1938	0.1	0	0	0.66	0	0	0	0	2.64	0	0	1.57	0
1939	0	0	0	0	0	0	0	0	0	0	0	0	0
1940	0.05	0	0	0	0	0	0	0.05	2.64	0	0	0	0
1941	0	0	0	0	0	0.1	0	0	0.2	0	0	0	0
1942	0	0	0	0	0	1.07	0	0.2	0.2	0	0	0	0
1943	0	0	0	0.15	0	0.66	0.56	0	0.15	0	0	0	0
1944	0.51	0	0.05	0.81	0.25	1.93	0	0.15	0.36	0	0	0.05	0
1945	0	0	0	0	0.36	1.52	0	0	0	0	0	0	0
1946	52.37	0.56	0	0	0	0.36	0.46	0.25	0	0	0	0.66	12.6
1947	57.61	0	7.52	0.05	0	0.76	0	0.1	0	0	0.05	0.25	1.02
1948	57.35	0.1	12.45	1.02	0.05	0	0	0	0	0	0	0	0
1949	39.98	0	40.54	0.15	0	0.1	0.05	0	0	0	0	0	0
1950	8.03	0.3	22.35	0.15	0	0.2	0	0.66	0	0	0	0	0
1951	15.14	1.37	18.54	0.56	0	0.25	0.05	2.79	0	0	0	0	0
1952	12.04	0.3	0	0.3	0.05	0.2	0	1.27	0	0	0	0	0
1953	12.24	0.36	0	0.36	0.05	0.1	0	2.74	0	0	0.05	0	0
1954	14.99	0.15	0	0.15	0	0.51	0.05	0.15	0	0	0	0	0
1955	23.57	3.25	0	1.27	0.1	0.46	0	1.83	0.05	0	0.25	0	0
1956	20.12	6.15	0	1.63	0.2	1.02	0.15	0.3	0	0	0.15	0	0
1957	12.14	6.5	0	0.05	0.41	0.76	0.2	2.9	0	0	0.15	0	0
1958	19.66	0	2.18	0.05	0.46	0.15	0.2	0.46	0	0	0	0	0
1959	14.27	4.01	1.32	0.05	0.05	0.41	0.05	0.15	0	3.15	0	0	0
1960	4.88	3.76	0.46	0.05	0	0.71	0	1.02	0	0.05	0	0	0
1961	6.76	10.41	2.49	0	0	0.86	0	20.52	0.05	0	0	0	0
1962	3.96	10.41	4.62	0	0.71	0.61	0	10.92	0.1	0	0	0	0.41
1963	3.3	4.67	0.46	0	0.81	0.81	0	9.19	0	0	0	0	0.61
1964	6.1	0.25	0.05	2.29	0.25	0.66	0	18.8	0	0	0	0	0
1965	3.81	0.61	0.25	1.02	2.74	4.83	0	15.09	0	0	0	0	0
1966	0.1	2.13	0	2.08	4.67	0.56	0.1	11.94	0	0	0	0	0.71
1967	1.22	0.61	0	21.03	3.51	0.25	2.18	4.22	0.15	0	0	0	1.68
1968	0.1	0	0	19	1.93	0	0	13.46	0.05	0	0	0	0.3
1969	0	4.72	0	12.19	1.57	9.04	0	0.66	0	0	0	0	0.2
1970	1.17	3.71	0	12.29	0.86	0	0	0.97	0.15	0.05	0	0	0
1971	0.05	2.03	0	11.94	0.71	0	0	0.36	0	0.46	0	0	0
1972	0.3	0	0.05	6.76	0.91	1.07	0.46	14.68	0	0	0	0	0

Key, with individual ports included in aggregate and number of years represented for each:

Nth, Northland: Mongonui (2), Russel (7), Bay of Islands (22), Whangarei (6)
Ack, Auckland: Auckland (22)
Thm, Thames: Thames (12), Coromandel (9), Mercury Bay (3)
Bop, Bay of Plenty: Waihi Beach (1), Tauranga (25), Whakatane (1)
WCt, West Coast: Manakau Harbour (15), Raglan (7), New Plymouth (2)
Hwk, Hawkes Bay : Napier (28), Gisborne (1)
Wgt, Wellington: Wellington (7), Paremata (5), Paraparaumu Beach (3)
Kai, Kaikoura-Banks Peninsula: Kaikoura (4), Lyttleton (9)
Cnt, Canterbury-Otago: Timaru (4), Oamaru (3), Port Chalmers (6)
Snd, Marlborough Sounds: Picton (3), Blenheim (1), Pelorus (1)
SWN, South-West North Island: Manawatu Heads (5), Wanganui (1)
Wld, Westland-Bluff: Westport (3), Hokitika (1), Bluff (1)
GTB, Golden & Tasman Bays: Golden Bay (3), Motueka (6), Nelson (2)

Table 3 : Catch (t) of yellow-eyed mullet by gear type

Fishing year	Bottom single trawl	Beach seine & drag net	Miscellaneous nets	Setnet & gillnet	Handline	Bottom longline	Trotline	Totals
1982–83	0	< 0.1	0	10.1	0	0	0	10.1
1983–84	< 0.1	< 0.1	0	25.2	0	0	0	25.2
1984–85	0	< 0.1	0	46.4	0	< 0.1	0	46.4
1985–86	0	3.7	0	94.3	0	< 0.1	< 0.1	98
1986–87	< 0.1	6.7	< 0.1	71.5	< 0.1	< 0.1	0	78.2
1987–88	0	3.9	< 0.1	42.8	0	0	0	46.7
1988–89	0	< 0.1	0	19.8	0	< 0.1	0	19.8
totals	< 0.1	14.3	< 0.1	310	< 0.1	< 0.1	< 0.1	324.3

Table 4: Catch (t) of yellow-eyed mullet by target species

Fishing year	FLA	GAR	GMU	KAH	SPO	SQU	YEM	Other	Totals
1988–89	0.05	0.08	0.01	0	0.01	0	10.53	0.75	11.43
1989–90	1.43	0.92	0.15	0.80	0.03	4.95	30.68	0.34	39.30
1990–91	1.96	0.89	1.86	0.14	0.03	0	47.61	0.94	53.43
1991–92	0.69	1.88	0.64	0.01	0.03	0	77.07	0.37	80.32
1992–93	1.79	1.08	0.56	0.35	0.07	0	73.17	0.42	77.44
1993–94	1.84	2.31	0.86	0.94	0.35	0	73.38	0.96	80.64
1994–95	1.12	4.65	1.84	0.83	0.03	0	49.74	0.48	58.69
1995–96	1.19	2.09	0.95	0.22	0.17	0	25.31	0.46	30.39
1996–97	1.12	3.00	0.29	0.01	0.01	0	42.93	0.14	47.50
1997–98	0.03	0.06	0.01	0	0	0	11.99	0.18	12.27
Totals	11.22	16.96	7.17	3.30	0.73	4.95	442.41	5.04	491.41

Key:

FLA	flatfish various species	GAR	garfish (*Hyporhamphus ihi*)
GMU	grey mullet (*Mugil cephalus*)	KAH	kahawai (*Arripis trutta*)
SPO	rig (*Mustelus lenticulatus*)	SQU	squid (*Nototodarus* sp)
YEM	yellow-eyed mullet (*Aldrichetta forsteri*)	Other	all other species

N.B. A small amount of catch (0.20 t) is unassigned in this table

Table 5: Reported landings (t) of yellow-eyed mullet, 1974 to 1996–97. New Zealand total, and statistical fishing areas grouped into QMAs. Sources: King 1985 (1974–1982), FSU data (1982–83 to 1988–89), QMS (CELR$_{landed}$ data (1989–90 to 1996–97). Values for 1974 to 1982 are for calendar years, from 1982–83 for October-September fishing years. " Other" is the difference between the total of the QMAs and the New Zealand total (i.e., the "Best Estimate" in Table 7), and represents incomplete values from the former; a negative value indicates a QMA total > the New Zealand total. –, no data

		QMA								New Zealand
Year	Unknown	1	2	3	5	7	8	9	"Other"	total
1974	–	–	–	–	–	–	–	–	–	14
1975	–	–	–	–	–	–	–	–	–	18
1976	–	–	–	–	–	–	–	–	–	18
1977	–	–	–	–	–	–	–	–	–	6
1978	–	–	–	–	–	–	–	–	–	7
1979	–	–	–	–	–	–	–	–	–	8
1980	–	–	–	–	–	–	–	–	–	53
1981	–	–	–	–	–	–	–	–	–	69
1982	–	–	–	–	–	–	–	–	–	55
1982–83	0.03	2.155	2.412	2.774	0	0.304	4.648	5.237	–	17.56
1983–84	4.681	2.099	1.162	4.618	0	0.145	4.887	26.145	–	43.737
1984–85	0.765	11.577	0	1.343	0	3.163	3.331	33.288	–	53.467
1985–86	0.498	24.052	0	6.801	0	4.269	2.084	60.623	–	98.327
1986–87	4.222	14.477	2.637	3.679	0	5.877	0.675	68.03	2.258	101.825
1987–88	2.644	11.043	10.015	9.303	0	4.458	0	42.821	25.288	105.572
1988–89	0	3.448	4.331	3.572	0	4.977	0.975	20.503	32.518	70.324
1989–90	0	1.411	0.448	16.937	0	0.537	3.471	11.381	10.232	44.417
1990–91	0	8.139	0	16.451	0	9.793	0.137	18.389	-0.342	52.567
1991–92	0	11.258	0	23.333	0	14.508	1.079	28.132	2.205	80.515
1992–93	0	31.482	0.001	1	0.148	1.601	4.877	41.622	5.556	75.175
1993–94	0	17.94	0.01	1.861	0.001	2.579	4.119	53.876	0.228	80.614
1994–95	0	8.607	0	0.666	0	7.92	1.521	40.943	0.965	60.622
1995–96	0	3.408	0.07	1.812	0	3.279	0.345	21.911	-7.797	23.028
1996–97	0.012	2.101	0.007	1.844	0	2.068	1.194	25.104	–	32.33

Table 6: Estimated number of yellow-eyed mullet and unassigned mullet (MUU) harvested by recreational fishers by Fishstock and survey, the corresponding estimated survey harvest, and the estimated Fishstock harvest. Surveys were carried out in different years in Ministry of Fisheries regions: South in 1991–92 (Teirney & Kilner, unpublished data), Central in 1992–93 (Kilner & Coddington, unpublished data), North in 1993–94 (Bradford 1996), and national in 1996 (Bradford 1998). The estimate of total harvest is a guide only because of the different survey years. Estimates of c.v. and harvest tonnages are not presented where sample sizes are considered too small. The mean weight (100 g) used to convert numbers to catch weight is assumed from work by Manikiam (1963) and considered the best available estimate, but could be in error. Survey tonnages are presented as a range to reflect the uncertainty in the estimate. It is assumed that some proportion of unassigned mullet are yellow-eyed mullet

(i) Yellow-eyed mullet – South, Central, and North surveys

		Total			
Fishstock	Survey	Number	*c.v.*	Survey harvest (t)	Fishstock harvest (t)
QMA1	South	1 000			
QMA1	Central	14 000			
QMA1	North	237 000	19	20–30	25
QMA2	Central	57 000			
QMA2	North	7 000			
QMA3	South	29 000	34	1-5	3
QMA7	South	3 000			
QMA8	North	1 000			
QMA9	South	2 000			
QMA9	North	52 000	33	2-8	5

(ii) Yellow-eyed mullet – national surveys

		Total			
Fishstock	Survey	Number	*c.v.*	Survey harvest (t)	Fishstock harvest (t)
QMA1	National	91 000	14	5–15	9
QMA2	National	80 000			
QMA3	National	38 000			
QMA5	National	2 000			
QMA7	National	66 000	19	5–10	7
QMA8	National	74 000	21	5–10	7
QMA9	National	31 000			

(iii) Unassigned mullet – national surveys

		Total			
Fishstock	Survey	Number	*c.v.*	Survey harvest (t)	Fishstock harvest (t)
QMA1	National	43 000	23	3–5	4
QMA2	National	1 000			
QMA3	National	6 000			
QMA7	National	16 000			
QMA8	National	5 000			
QMA9	National	1 000			

Table 7: Reported landings (t) of yellow-eyed mullet by fishing year, from various sources. FSU, Fisheries Statistics Unit; CELR, catch, effort, and landing return; LFRR, licensed fish receiver return. Fishing years are from 1 October to 30 September. This table follows the standard format for documentation of proposed new QMS species; "—" indicates that there are no relevant data for the cell. The "best estimate" was taken as the FSU total from 1982-83 to 1986-87, and the LFRR total from 1987-88 onwards, except in 1996-97 where the estimate of landed catch from the CELR data was used

Fishing		CELR		TCEPR			Best
year	FSU	Estimated	Landed	Estimated	Landed	LFRR	estimate
1982–83	17.6	—	—	—	—	—	17.6
1983–84	43.8	—	—	—	—	—	43.7
1984–85	53.5	—	—	—	—	—	53.5
1985–86	98.3	—	—	—	—	—	98.3
1986–87	99.6	—	—	—	—	101.8	101.8
1987–88	80.3	—	—	—	—	105.6	105.6
1988–89	37.8	11.0	10.7	—	—	70.3	70.3
1989–90	—	33.9	34.2	—	—	44.4	44.4
1990–91	—	49.2	53.0	—	—	52.6	52.6
1991–92	—	79.7	78.3	—	—	80.5	80.5
1992–93	—	77.4	80.7	—	—	75.2	75.2
1993–94	—	80.2	80.4	—	—	80.6	80.6
1994–95	—	58.5	59.7	—	—	60.6	60.6
1995–96	—	29.7	30.8	—	—	23.0	23.0
1996–97	—	31.8	32.3	—	—	—	32.3

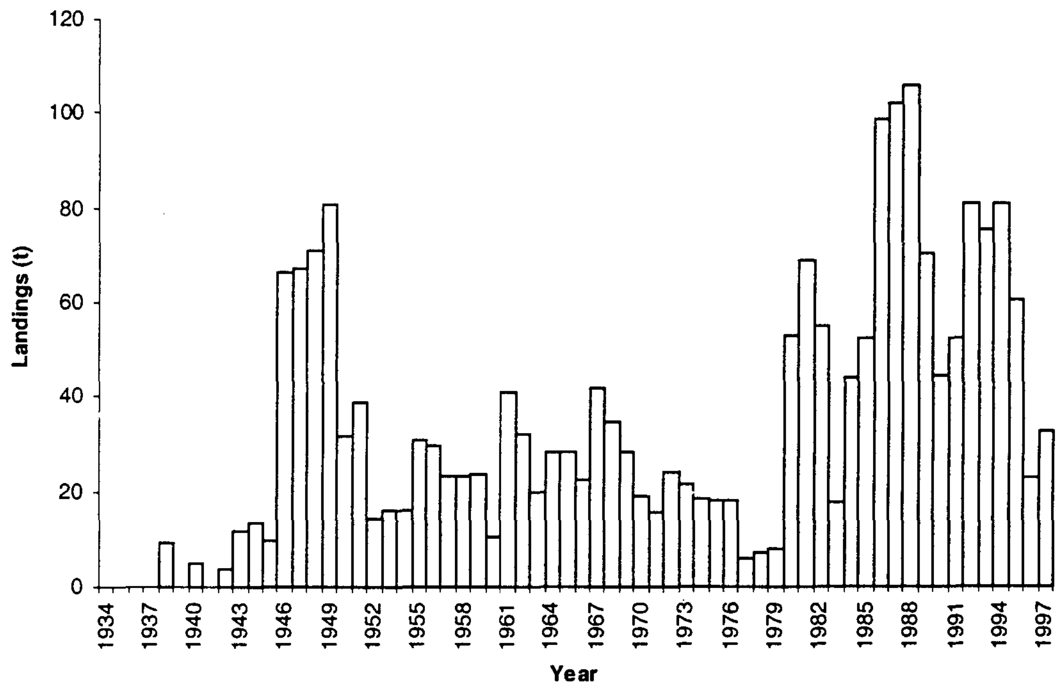


Figure 1: Reported total landings (t) of *Aldrichetta forsteri* for New Zealand, 1934 to 1996–97. Values for 1934–72 from Annual Reports on Fisheries (Marine Department, later Ministry of Agriculture and Fisheries), for 1973 estimated as the mean of 1972 and 1974 values, for 1974–82 from King (1985), for 1983 to 1997 from unpublished FSU or QMS data (*see* Table 2). Values for 1934–1944 are for April–March years, listed as the April year. Values for 1945 to 1982 are for calendar years. Values for 1983 onwards are for fishing years (October–September) listed against the September year

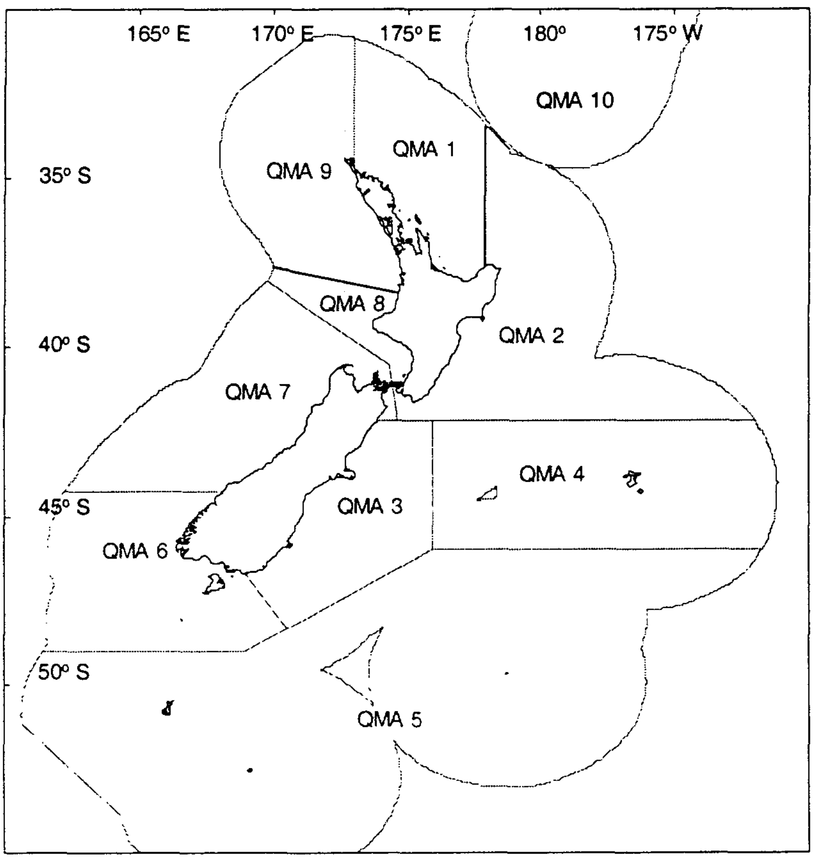


Figure 2: Quota Management Areas (QMAs) within the New Zealand Exclusive Economic Zone

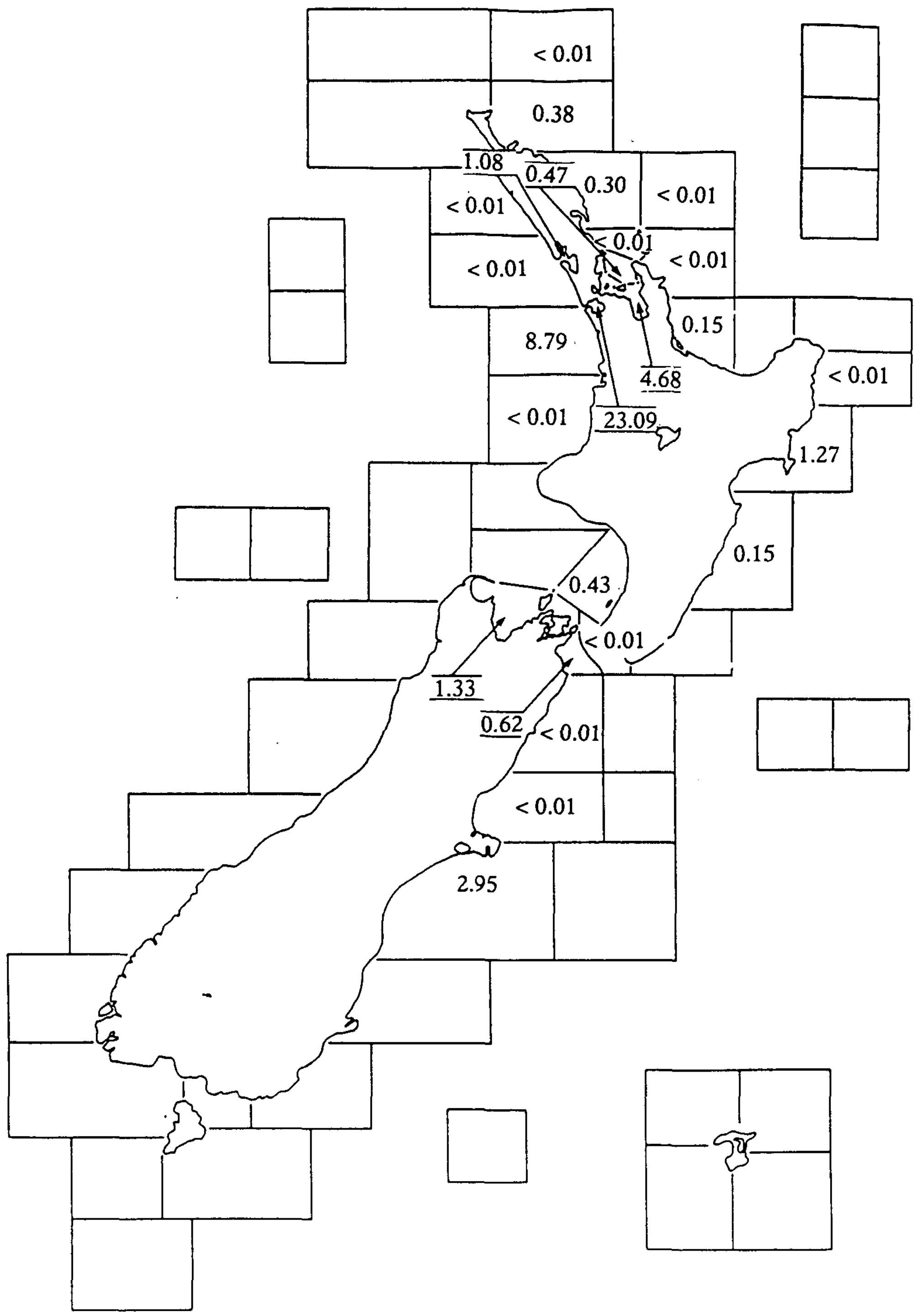
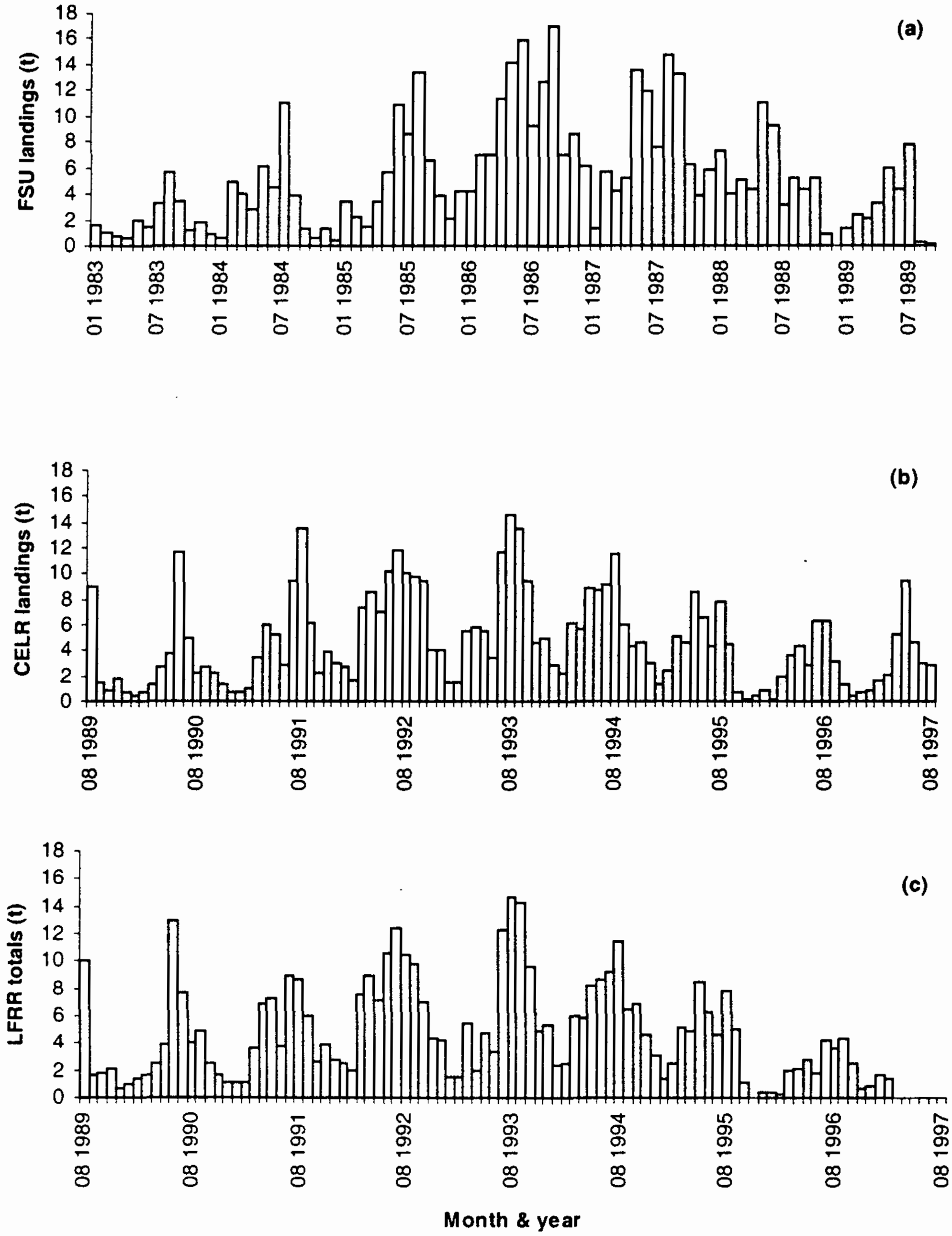


Figure 3: Geographical distribution of *Aldrichetta forsteri* catches around New Zealand. Catch by fishing return area: mean annual catch (t) for the fishing years 1982–83 to 1988–89. Mean catches of about 10 kg or less were taken in areas with catch recorded as "< 0.01"



Figures 4a, b, c: Reported total monthly landings (t) of yellow-eyed mullet for New Zealand, 1983 to 1997; FSU data 1983–89 (Top), QMS CELR data 1989–97 (Centre), QMS LFRR data 1989–97 (Bottom)

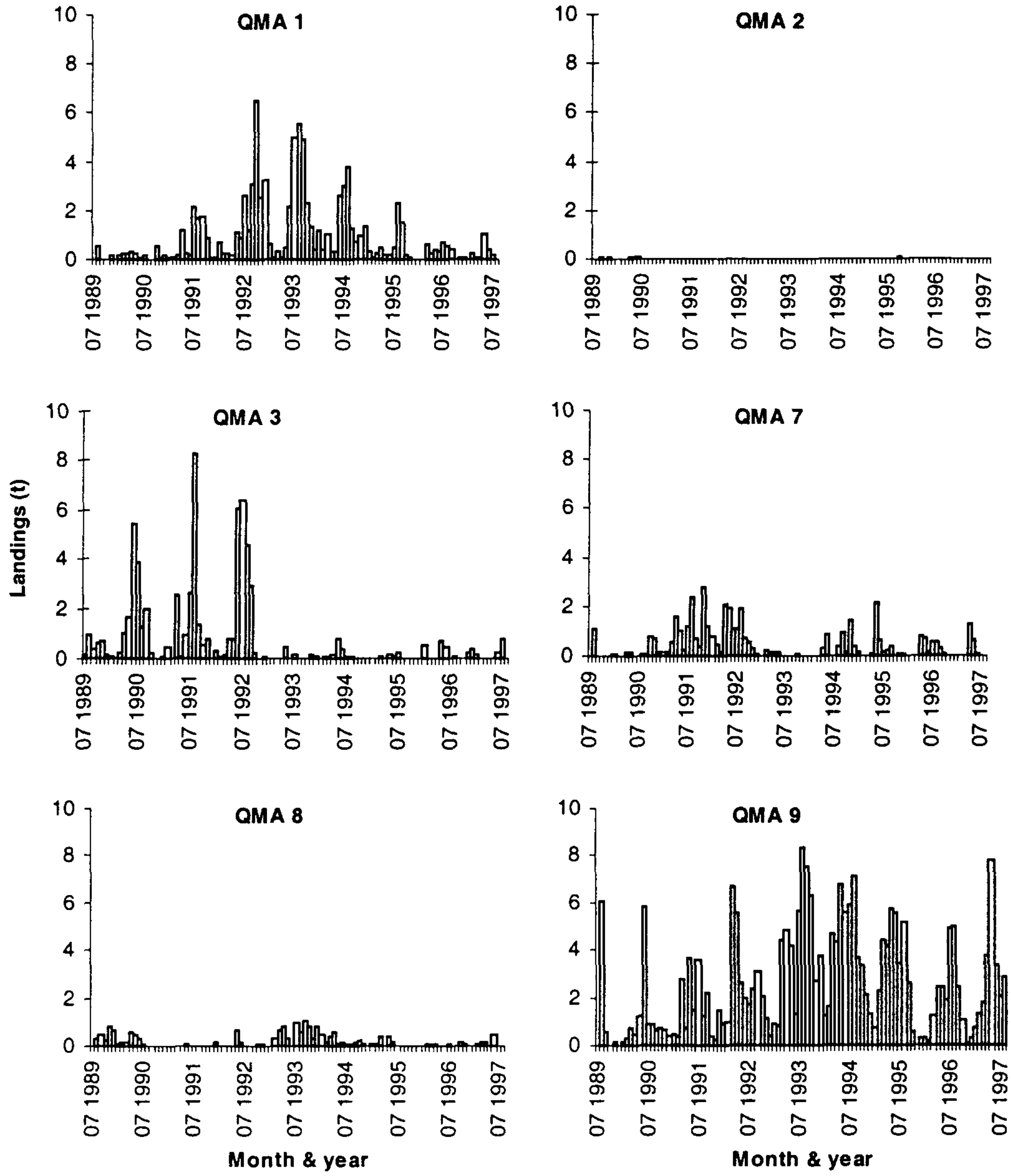


Figure 5: Reported total monthly landings (t) of yellow-eyed mullet by QMA, July 1989 to August 1997. QMS CELR data

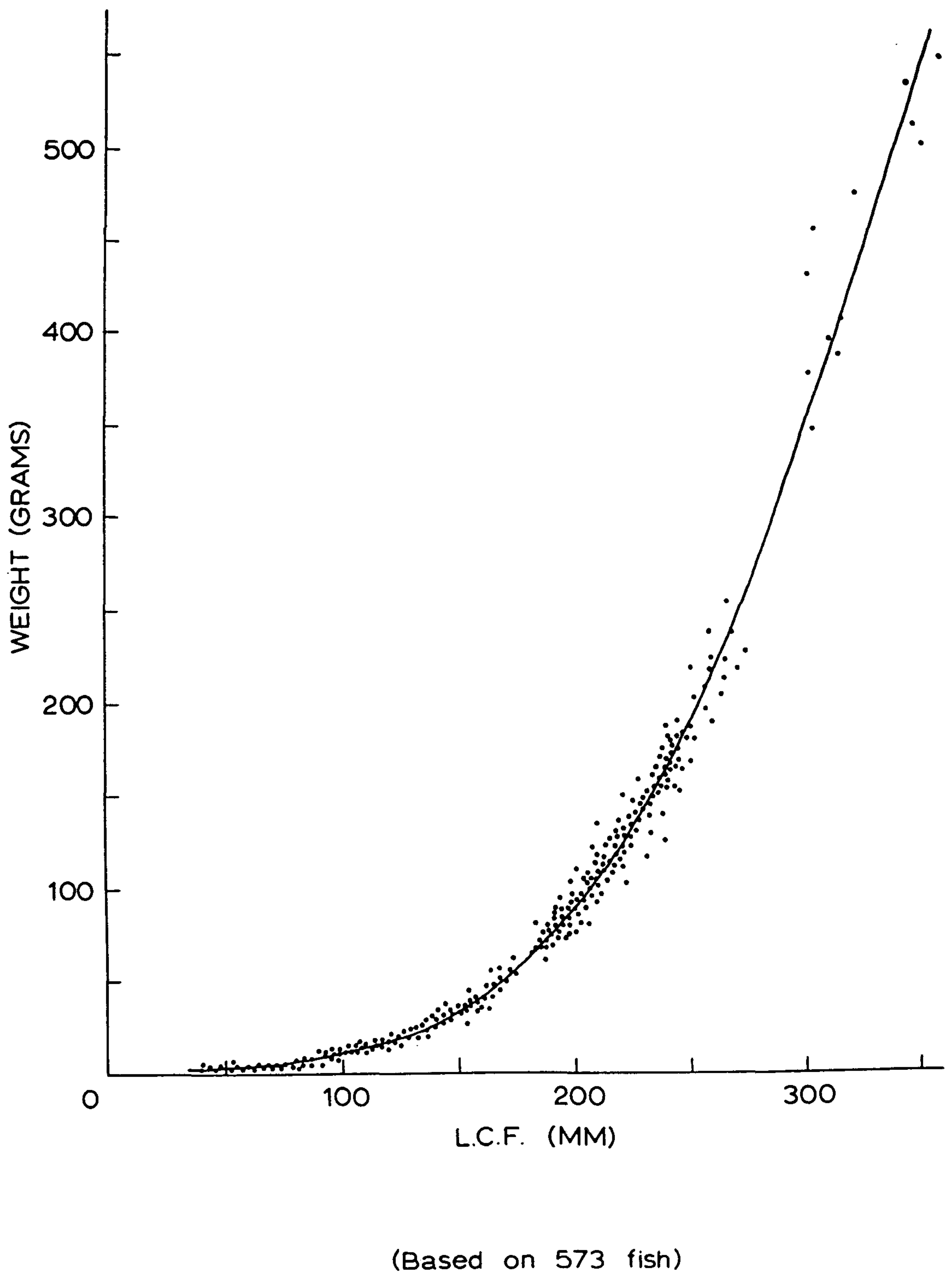


Figure 6: Length-weight relationship for yellow-eyed mullet taken from Wellington Harbour in 1963. LCF (length to caudal fork) is the same as fork length (FL). *From*: Manikiam (1963)

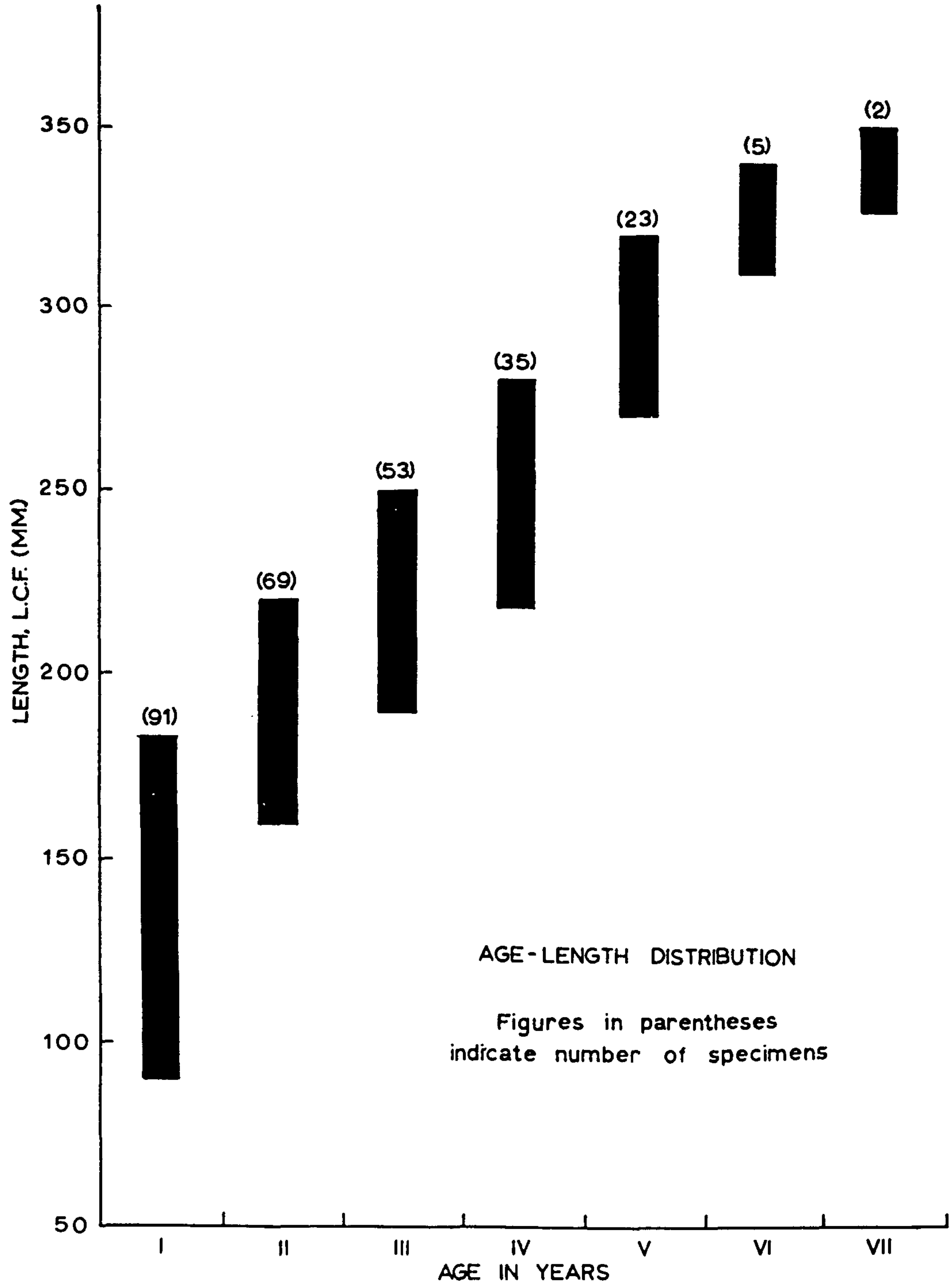


Figure 7: Age-length relationship for yellow-eyed mullet taken from Wellington Harbour in 1963. LCF (length to caudal fork) is the same as fork length (FL). *From* Manikiam (1963)

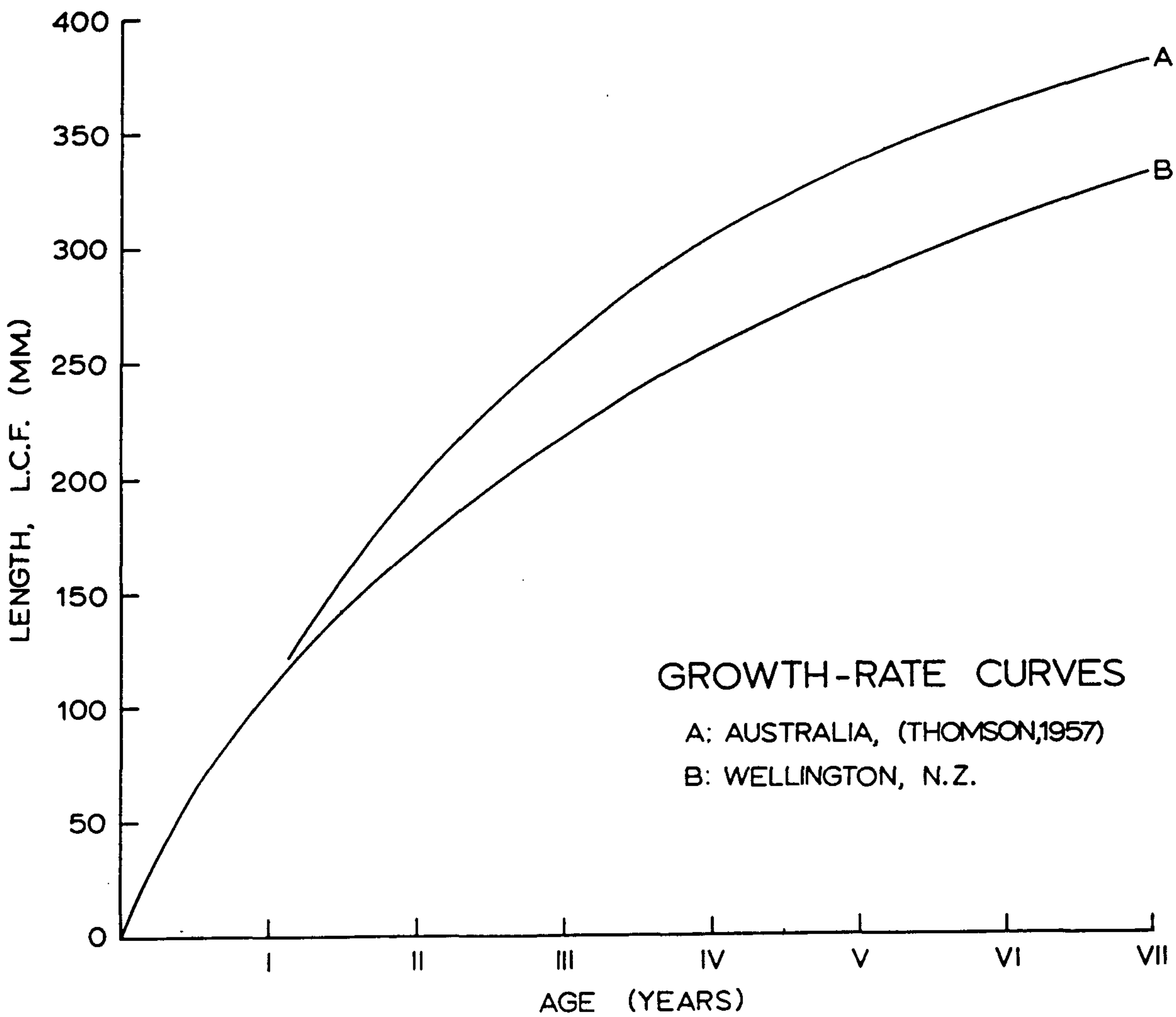


Figure 8: Comparative growth curves for yellow-eyed mullet taken from Wellington Harbour in 1963, and Australian. LCF (length to caudal fork) is the same as fork length (FL). ***From*** **Manikiam (1963) with reference to Thomson (1957b)**