New Zealand Fisheries Assessment Research Document 97/23

A summary of biology and commercial landings, and a stock assessment of butterfish, *Odax pullus* (Forster in Bloch and Schneider 1801) (Labroidei: Odacidae)

L. J. Paul

NIWA
PO Box 14-901
Kilbirnie
Wellington

September 1997

Ministry of Fisheries, Wellington

A summary of biology and commercial landings, and a stock assessment of butterfish, *Odax pullus* (Forster in Bloch and Schneider 1801) (Labroidei: Odacidae)

L. J. Paul

New Zealand Fisheries Assessment Research Document 97/23. 25 p.

1. EXECUTIVE SUMMARY

Odax pullus (formerly *Coridodax pullus*) is commonly known as butterfish or greenbone in New Zealand. Juveniles were once known as *Odax vittatus*. A second species, the bluefinned butterfish, *O. cyanoallix*, occurs only in the far north.

The few studies of butterfish biology have mainly covered feeding and reproduction, and there are only brief accounts of its fishery. There is limited but apparently reliable information on age and growth.

Butterfish have been caught commercially for over a century, and landings data exist from 1935. They are taken almost exclusively by setnet from shallow (less than 40 m) seaweed-covered reefs, and generally targeted. Total annual landings were 50–75 t from the mid 1930s until the late 1950s, then 50–100 t until the early 1980s, and 100–200 t until 1995.

The main, and most stable, fishery is around the shores of Cook Strait. A smaller fishery occurs around the Southland and Stewart Island coasts. There have also been a few years of reported catches from the Auckland region.

The Cook Strait fishery can be subdivided into eastern and western components. Landings peak during winter, most strongly and regularly in the western Strait; it has been suggested this results from fishers switching seasonally to butterfish netting from other fisheries, including lobster potting.

There are no CPUE data currently available. As a single-method target fishery a CPUE index is theoretically feasible, but if there are too many participants making only intermittent catches in such a small fishery it may be difficult to carry out a meaningful analysis.

There is traditional and archaeological evidence of prehistoric and 19th century catches of butterfish by Maori.

Butterfish are popular with recreational fishers, but there are no current data on catch levels.

Although widespread around New Zealand, butterfish are restricted to shallow seaweed-covered reefs and are unlikely to undergo significant movement, traversing other habitats, between reefs some distance apart. Geographic variation occurs in some taxonomic characters, and in size range, suggesting localised growth rates. However, there is no information on how strongly these features might reflect regional stocks.

Data on length/weight relationships are presented. An unpublished growth curve derived from scale-reading agrees well with some recent limited otolith-reading from adult fish. The oldest age recorded is 9 years.

Butterfish are protogynous hermaphrodites, about half the females changing to males at about 40 cm, 1 or 2 years after maturity; the sex ratio of adults is approximately 1 : 2 (males : females). Butterfish are serial spawners over a long spawning season extending from July to March in Cook Strait, and August to January in Otago. Postlarvae settle quickly from the plankton, and juvenile fish move deeper with age, males eventually occupying the deepest part of the range.

Butterfish are largely herbivores, eating the dominant large seaweeds in the algal community, which may differ regionally.

MCY has been estimated separately for the eastern and western components of the Cook Strait fishery using the formula MCY = cY_{av}, based on the period of catches between 1960 and 1994–95. A preliminary estimate of MCY for Southland is based on the period 1984–85 to 1994–95. No estimate of CAY is possible.

The geographical distribution of butterfish catches over the entire history of the fishery suggests that an appropriate arrangement of QMAs, from which catch trends could be most easily integrated into stock assessments, would be a large North Island QMA north of 41° S, two Cook Strait QMAs as defined in this review, and a large southern QMA.

2. INTRODUCTION

2.1 Overview

This document presents information on the butterfish or greenbone, *Odax pullus* (Forster, in Bloch and Schneider 1801), and on its fisheries, and provides estimates of sustainable yield. Its species code in research and fisheries databases is BUT.

2.2 Description of the Fishery

Butterfish occur in shallow water and are easily caught by netting. They were used as a food source by Maori for centuries, and were undoubtedly an early component of the commercial inshore fishery, although reliable records of landings exist only from 1936 onward. They currently support a small seasonal target setnet fishery in a few central and southern New Zealand localities, with total landings of 100–150 t. They are also a popular, though not large, component of recreational fisheries (setnet and speargun) over a wider range.

2.3 Literature Review

There are numerous mentions of butterfish (often as "greenbone") in the early literature on New Zealand fishes, but most are listings or only brief notes. The most comprehensive study has been that by Ritchie (1969), principally on the Cook Strait population, of which only the section on the systematics of the species has been published (Ritchie 1976), plus a brief popular summary (Ritchie 1975). An extensive anecdotal account, based on observations made

during the 1930s in the Dunedin region, was given by Graham (1953). Apart from the early descriptions, most other references until the mid 1980s have been faunal listings or brief popular accounts. There have since been studies on feeding patterns of butterfish in the outer Hauraki Gulf (Choat & Ayling 1987, Clements 1985, 1991, Clements & Bellwood 1988, Choat & Clements 1992, 1993, Clements & Choat 1993, and Meekan 1986), and on butterfish reproduction in Otago (Crabb 1993). Hickford & Schiel (1995, 1996) studied the impact of gill-netting on a community of reef fishes, with some emphasis on butterfish, at Kaikoura Peninsula.

The name *Coridodax pullus* has very frequently been used, but the currently accepted name is *Odax pullus*. Small yellowish butterfish were described as a separate species, *Odax vittatus*, but these are now known to be the juvenile form of *O. pullus*.

The blue-finned butterfish, *Odax cyanoallix*, is a smaller species differing in colour pattern (Ayling & Paxton 1983). It occurs at the Three Kings Islands (where *O. pullus* is absent) and at a few headland and island localities in East Northland.

3. REVIEW OF THE FISHERY

3.1 The Commercial Fishery

3.1.1 Catches and landings

Butterfish have been caught commercially for well over a century. Hector (1872) wrote that "Butter Fish ... The Marare of the natives, known as the Kelp Fish among the fishermen and the Butter Fish in the market (*Coridodax pullus*), is the fish most commonly sold in Wellington during the winter months. It has a rather forbidding appearance, having a dark coloured slimy skin and inelegant form; it is nevertheless very good food, the flesh being very short in the grain and well flavoured without being rich, every part being singularly deficient in oil." Hector also stated "that of late large quantities of the Butter Fish are caught in Foveaux Strait and brought to market in Invercargill." Phillipps & Hodgkinson (1922) record moderate quantities of butterfish in the Auckland markets in some months of 1921. The first listed landing values of butterfish in the early 1930s (Figure 1, Table 1) are undoubtedly incomplete (in common with other species at that time, particularly those landed intermittently in small quantities at small ports). Graham (1953), almost certainly referring to this period, notes that "considerable numbers of this fish were sold in the fish markets of Auckland and Wellington", but that in Dunedin there was some prejudice because of their slimy blackish appearance and green bones. Butterfish flesh is often stated to have a high iodine content, but the origin of this information has not been located.

Being an essentially targeted species, taken only by nets set among shallow seaweed-covered reefs, virtually all the butterfish caught are likely to have been landed, and should in theory be included in the official statistics, although some sales from fishers directly to retailers may have gone unreported. By the mid-1930s total landings had reached 50–75 t, and they remained at this level until the late 1950s, reaching about 100 t only briefly in 1946 and 1947. From the late 1950s until 1983 they fluctuated more randomly between (approximately) 50 and 100 t. From 1984 until 1995 they have again fluctuated, still very erratically, between about 100 t and almost 200 t (Table 2).

Actual landings from the last decade are uncertain, as reported catch data from different components of the statistics database are in conflict (Table 2). FSU data appear reliable until the 1986–87 year when the QMS was introduced and a separate set of catch/landing data was required. There appears to be no reason why the CELR "estimated" values should be approximately twice the "landed" values; as butterfish are a target species the two should agree quite closely. The landed values are assumed to be the more reasonable.

The geographical distribution of catches from a reasonably reliable period of reporting (1983–84 to 1987–88) are shown in Figure 2. The most significant fishery is centred on Cook Strait, between Tasman Bay, Castlepoint, and Kaikoura. There is a smaller fishery around Stewart Island. Data from earlier years (*see* Table 1) confirm this, although in the early to mid 1940s there were modest landings (c. 10–40 t) in the Auckland region. The column "Other" in Table 1 gives only the difference between listed regional totals and the listed New Zealand total; it suggests that the reported values from some ports in the main fisheries are too low, as no other ports have significant landings in the periods 1936–43 and 1977–82.

Reported landings from larger fishery management areas (FMA/QMAs) for 1982–83 to 1994–95 also show Cook Strait and "Southland" to be the only significant fisheries, and these are shown in Table 3. Although these values may not be reliable, they show the combined Cook Strait fishery to be relatively stable at about 80–100 t over this period, and the Southland fishery to be very variable, generally less than 25 t, but with one year of 41 t and two years of nearly 100 t.

The Cook Strait fishery is fairly evenly divided between "eastern" (North Island: the coastline and ports from Castlepoint to Paraparaumu) and "western" (South Island: Tasman Bay, Marlborough Sounds, and Kaikoura). These two sub-regions had different catch trends until about 1980 (Figure 3), and have subsequently been similar.

Total New Zealand monthly data from 1983 to 1995 show a seasonal landing pattern in some years, and no pattern in others (Figure 4). The most obvious trend is for a peak in winter months. This was noted by Ritchie (1969) who stated "Today [the late 1960s] the fishery is a part time winter industry for crayfishermen. Catches of butterfish decline over the summer months during which most fishermen concentrate on more profitable crayfishing." This seasonal pattern becomes less clear in the total New Zealand data from about 1988 onwards.

A shorter time series of data (1983–88) can be subdivided into eastern Cook Strait, western Cook Strait, and Southland (Figure 5). The regular seasonal occurrence of a winter peak is very clear in western Cook Strait landings. In fact, in each year it is a double peak, with the second stronger than the first; the second peak is almost always in August, though the first is variable. The cause of this double peak is not known, and data are not yet available to demonstrate whether the pattern continues in subsequent years. The pattern of landings from eastern Cook Strait is much less regular, but sometimes there is a double peak, the first in summer-autumn (February-April), the second in winter (July-October). Landings in the Southland fishery are irregular.

The relationship between landings of butterfish and landings of rock lobster, the most important potentially related fishery in the Cook Strait region, is shown in Figure 6 (1981–86) and Figure 7 (1989–94/95). In eastern Cook Strait there is only a weak and erratic seasonal

pattern, but in 1983–86 the earlier of the two peaks occurred in the rock lobster low season of March-June, and in 1994 and 1995 a single peak also occurred in the low season. In western Cook Strait there is greater seasonal fluctuation in butterfish landings, and a more complex relationship with rock lobster. In broad terms, the bimodal winter peak in butterfish landings coincides with the low rock lobster season. The first butterfish peak coincided with the lowest lobster landings in 1983–86 (Figure 6), the second with the start of the new lobster season. In 1990–94 (Figure 7) the pattern is less clear, perhaps because the lobster catch data are from a much larger region, but until 1993 the inverse relationship between catches still existed.

3.1.2 Effort

There are no data on trends in fishing effort, and consequently CPUE. As a single-method target fishery, developing a CPUE index is theoretically feasible for at least the Cook Strait butterfish "stock(s)". In such a small fishery, however, with patterns of activity which may be primarily driven by cycles of activity and profit in much larger fisheries, or where there may be a large number of fishers each making only small catches from time to time, obtaining appropriate measures of CPUE might well be difficult.

3.1.3 Management

There have been few management measures until recently, apart from those applying to the commercial setnet fishery in general. A setnet mesh size of 108 mm and a minimum fish size of 35 cm is in force for commercial and recreational fishers, with some regional variation in netting restrictions. In the Cook Strait region (QMAs 2 and 7), since 1986 fishing permits for butterfish have been re-issued only to existing holders. In FMA (= QMA) 5, butterfish have a competitive quota of 30 t, which $CELR_{Landed}$ data (Table 3) show has been exceeded by 227% in 1993–94 and by 37% in 1994–95. Recreational fishers have daily bag limits, set at 30 fish in 1986 (Amateur Fishing Regulations 1986, 1986/221) and subsequently reduced to 20 (Northern, Central, Challenger regions, 1995) or 15 (Southern, 1993).

3.2 Traditional Maori Fishing

Anderson (1983) listed setnets as the traditional method for catching butterfish in Southland. The bones of butterfish have been regularly recorded in coastal Maori middens in central and southern New Zealand (Anderson 1983, Leach & Boocock 1993). Graham (1953) summarised the account by Knox (1871) of 19th century fishing in Cook Strait, "In days gone by the Maori caught Greenbone with a large net in the shape of a long, tapering bag with a hoop around the mouth, which was fastened at high tide between large kelp where the rise and fall of the tide caused a free run of water, and as the tide receded large numbers of these fish were caught in the net." New Zealand-wide, archaeological evidence suggests the species was not important, numerically making up 0.5% of the catch of all species represented by midden bone remains (Leach & Boocock 1993); it was more important (4.7%) in the southern North Island. Its importance to Maori in recent times has not been recorded, and there is no quantitative information on the current level of Maori customary take.

3.3 Recreational Fishery

Butterfish are popular with recreational fishers in many parts of New Zealand, and are taken primarily by setnet and spear. They can also be enticed to take a small hook baited with a small crustacean or marine worm (Graham 1953). The extent of the recreational catch has not been assessed, but data from the marine recreational fishing diary surveys are being assembled. Recreational catches are small in the North region, moderate in the Central and Southern regions (Table 4). Overall, the recreational catch is likely to be at least equal to the commercial catch.

4. RESEARCH

4.1 Distribution

Butterfish are present from North Cape to the Snares Islands, and at the Chatham, Bounty and Antipodes Islands (Francis 1988, 1996), but not at the Three Kings Islands, where the bluefinned butterfish, *Odax cyanoallix*, occurs. Both species are restricted to New Zealand. The other two species in this genus (cale, or weed whitings) are restricted to southern Australia. Butterfish inhabit rocky coastlines, with their main habitat in moderately turbulent water with dense beds of macroalgae, predominantly the large brown seaweeds *Ecklonia* and *Carpophyllum*. They generally occur from the immediate subtidal zone to about 20 m, but appear to have a shallower depth range in the north (to 10 m) than in Cook Strait (to 20 m) and southern waters (to 40 m) (Ritchie 1975). They are more common from the Cook Strait region southwards. Waite (1911) recorded butterfish as being "freely caught in the nets set in the kelp ... round the Chatham Islands."

4.2 Stock Structure

There is no clear information on whether biologically distinct stocks occur. The species is present wherever suitable habitat exists around New Zealand, so in most regions where weed-covered reefs are not separated by too great a stretch of sandy coastline there is potential for some local movement of adults and genetic mixing. There is probably little dispersal at the egg and larval stage, with localised inshore spawning and postlarvae settling out from the plankton at an early stages (Ritchie 1969, Francis 1988, Doak 1991). Ritchie (1969) investigated the geographic variation in some taxonomic characters (vertebrae, scale rows, finrays), which was often gradual between regions, rather than abruptly different, and which he interpreted as being linked to regional differences in water temperature. These characters were similar wherever the surface sea water temperatures were similar. However, he did not define likely regional stocks, as considerable variation also occurred within local populations. The butterfish populations at offshore islands (Chathams, Antipodes, Bounties, and Snares), however, are likely to be reasonably distinct from the mainland population(s) simply because of their greater isolation.

4.3 Fish Size

Adult butterfish average 45–50 cm in length. Maximum sizes have been reported as 50 cm (Thompson 1981, Paulin & Roberts 1992), 55* cm (Ritchie 1969), c. 60* cm (Graham 1953), 70 cm (Paul 1986, Francis 1988), 75 cm (Ayling & Cox 1982, Doak 1991). In general, they

reach larger sizes in the southern part of their range. (*, maximum size in the fish actually sampled, i.e., is not recorded as an absolute maximum.)

4.4 Length-weight relationships

Because of large variations in stomach fullness and gonad size, Ritchie (1969) used gutted weights to establish length/weight relationships separately for juveniles, males, and females. He listed the following linear regressions, where Y is weight in grams and X is length in centimetres, for the limited length range 40–55 cm:

Juveniles:	$Y = 21.205X - 362.28$
Males:	$Y = 67.034X - 1885.9$
Females:	$Y = 67.699X - 1947.8$

Although there were slightly different regressions for male and female fish, in general terms adults at 45 cm were 1100 g, and at 55 cm were 1800 g gutted weight. A precise conversion to whole weight is not possible from available data, but from the generalised conversion factor of 1.10 for bony fishes in the Fisheries (Conversion Factors) Notice 1993 the above weights would be 1210 g and 1980 g. Whole weight values are likely to be higher, considering the relatively large gut of this herbivorous fish.

Doak (1972) recorded a mean whole weight of 162 butterfish speared at Stewart Island in 1971 as 4 lb. 6 oz [2.0 kg], with the largest at 7 lb. 4 oz [3.3 kg]. He also recorded the mean whole weight of 228 butterfish speared at Kapiti Island in 1967 as 3 lb. 6 oz [1.5 kg], with the largest at 8 lb. [3.6 kg], and the mean weight of 50 Kapiti fish in 1970 as 3 lb. 1 oz [1.4 kg].

4.5 Age and Growth

Although no definitive studies have been published, ages as well as sizes are often mentioned in accounts of sex change and reproduction (*see* 4.6, Reproduction). Ritchie (1969) covered age and growth only briefly in his thesis, his study being limited by having few small fish. He described the extremely small otoliths, which made the collection of good samples difficult, and found that growth rings were "irregular, often incomplete and intergrading" and poorly formed. He noted that opercular and subopercular bones had "very well defined growth layers" but were also difficult to obtain and prepare. From 92 Wellington fish he used scale annuli to develop a back-calculated growth curve to age 9, with successive mean lengths-at-age of about 8, 15, 24, 32, 38, 43, 46, 48, and 50 cm.

During this present study the otoliths of seven adult fish 42–57 cm in length were examined. When immersed in oil and viewed under reflected light against a black background, alternating dark and light bands were readily visible, the former being similar in appearance to the typical hyaline otolith rings generally formed by fish in winter. Four of these otoliths were also read in thin section under reflected light, and identical ring counts obtained. The 42 cm fish had six rings, and the five fish between 47 and 57 cm had eight or nine rings, readings which agree closely with Ritchie's interpretation of scales.

4.6 Reproduction

Ritchie (1969) demonstrated dimorphism between juvenile and adult fish, as well as between adult male and females. Males have a longer soft portion to the anal and dorsal fins, possess a larger girth, and are not found at total lengths shorter than 40 cm.

Butterfish are protogynous hermaphrodites. Protogynous sex reversal was suggested from strong circumstantial evidence by Ritchie (1969), and supported by Crabb (1993); although probable, it has yet to be confirmed. Juveniles, most common among the shallowest reefs or in other seaweed-covered areas, are initially reddish brown with a pale midbody stripe, later golden yellow still with the stripe, becoming darker above. At about 30 cm they progress to a deeper-bodied, brownish or greenish female phase which lasts to about 40 cm; as females they are most common in depths less than 10 m. Maturity occurs at 35–40 cm, at the age of 4 or 5, when the silver lateral stripe breaks into a series of white to pale brown blotches. At about 40 cm, about half the mature females transform into males, which are dark greenish to black above, paler olive green laterally and below, with a less distinct pale lateral stripe, but brighter fin markings. During the breeding season both sexes develop blue chin markings. Males generally occur beyond 15 m, but during the breeding season the depth ranges of the sexes overlap, males become territorial, and breed with the females in their shallow depth range. (These depth values are based on observations in central and southern New Zealand; there may be some variation from these in some regions, particularly in the north.)

There is a long spawning season. In the Cook Strait region it extends from July to March, apparently peaking in September-October and possibly again in December-January (Ritchie 1969). As well as being defined by the reproductive state of mature adults, with spent fish rare, the long season was also demonstrated by the presence of eggs in the plankton between July and February. There may be regional differences in the peak season, but this has not been identified. Crabb (1993) described the spawning season in Otago as extending from August to January. Robertson (1973) found eggs only close inshore from October to January in Otago waters, and suggested that the spawning season in the south was shorter than in Cook Strait because of the cooler water. Butterfish are serial spawners, releasing several batches of 2000–6000 eggs. Total fecundity of Cook Strait fish ranges from 113 000 to 389 000 eggs (Ritchie 1969). Graham (1953) noted that "between November and January [i.e., when some spawning may have occurred] the average female Greenbone carried about seventy thousand eggs." From observations on his artificially reared larvae, and the apparent absence of planktonic larvae, Ritchie (1969) hypothesised that they "leave the plankton and begin a demersal life soon after hatching".

4.7 Sex Ratios

There is a complex pattern of sex ratios, as butterfish are protogynous hermaphrodites, males are territorial, and juveniles, males, and females have different but overlapping depth ranges (*see* 4.6, Reproduction). The sex ratio of adults has been given as approximately 2 : 1 females : males (Ritchie 1969), but because of the different depth distribution of sexes this ratio varies with locality.

4.8 Feeding

Butterfish are almost exclusively herbivorous, feeding on a variety of the larger seaweeds, particularly the laminarians *Macrocystis pyrifera* and *Ecklonia radiata*; there are variations in the main species eaten, dependent on the regionally dominant seaweed in the algal community. This contrasts with most other herbivorous fishes (e.g., marblefish, *Aplodactylus arctidens*, hiwihiwi, *Chironemus arctidens*, parore, *Girella tricuspidata*), which prefer smaller and finer algae. Butterfish also eat some small invertebrates, including worms, crustaceans, and salps; these are sometimes accidentally ingested with weed, but Graham (1953) recorded active feeding on invertebrates. As measured by gut fullness, the feeding activity of adult fish is much higher in summer than winter in Cook Strait (Ritchie 1969), and in spring in northern waters (Clements & Choat 1993). Feeding activity is also greatest early in the day (Choat & Clements 1993), and there appears to be a tidal effect on dietary composition (perhaps reflecting access to the intertidal habitat) but not on feeding rate (Clements & Choat 1993).

4.9 Movement and Behaviour

The only published information on movements relates to feeding behaviour within algal stands (Choat & Clements 1993, Clements & Choat 1993). The restriction of butterfish to a seaweed-covered rock habitat, the territorial behaviour of males, and localised spawning activity strongly suggest that only minimal movement occurs. There are tidal feeding movements, some seasonal shift in distribution within seaweed covered reef areas connected with breeding activity, and a gradual shift to deeper parts of the narrow depth range with increasing age and size. Based on these observations, butterfish populations appear likely to be localised.

5. STOCK ASSESSMENT

5.1 Biomass Estimates

No biomass estimates have been undertaken. For such a patchily distributed and cryptic fish it may prove difficult to conduct comparable biomass monitoring surveys in different regions which could be reliably replicated over time. Willan *et al.* (1979) suggested that although large cryptic species such as butterfish would undoubtedly be under-estimated on diver-observation transects, if these were properly standardised some indication of change over time was possible. However, Hickford & Schiel (1995) compared visual censuses and gill-net (setnet) catches to show that butterfish are extremely poorly estimated by visual surveys. A further problem would occur in localities where the fish were being periodically exploited by commercial and/or recreational fishers, with very localised and temporary depletions introducing fluctuations into the time series that would not necessarily be valid for the larger regional population. Standardised sampling by setnet would face the same difficulties, as well as unknown catchability factors.

It is not clear whether it will be possible to measure biomass changes by monitoring CPUE trends in the commercial fishery. Although it is a target fishery, fishing activity may be dependent as much on what is happening in the rock lobster fishery as on the optimum season for butterfish. Patch fishing and progressive depletion of localised populations may also not provide a true measure of regional CPUE. It is also a small fishery, and only a few anomalous entries in the CELR database may render it unreliable.

5.2 Estimation of Maximum Constant Yield (MCY)

The butterfish fishery comes within the category of fisheries for which only catch data and some information on fishing effort are available, and Method 4 in Annala & Sullivan (1996) must be used, i.e., $MCY = cY_{av}$.

The period of catches from which Y_{av} is derived should be at least half the exploited life span of the fish (Guide to Biological Reference Points in Annala & Sullivan (1996)). Thus for butterfish (with maturity at age 4 or 5, and a maximum recorded age 9 or 10) it should be at least 6 years. It should also contain no systematic changes in catch, or in fishing effort (= fishing mortality). The latter is poorly known in the butterfish fishery. In eastern Cook Strait the catch has fluctuated since the late 1940s, and has generally risen since the mid 1970s. In western Cook Strait the catch rose steadily to peak in the mid 1960s and has since fluctuated at a slightly lower level. To avoid over-representing periods of high catches, the sequence of catches from 1960 to 1994–95 has been chosen for both sub-regions. The Southland fishery's catch history is so erratic (and the data somewhat suspect) that only the period 1984–85 to 1994–95 can be used, and then with great uncertainty.

The natural variability factor *c* should be based on the mean natural mortality of the stock. For butterfish, M can only be estimated from the formula,

$$M = -\frac{\log_e(p)}{A}$$

where p is the proportion of the population that reaches age A (Annala & Sullivan 1996).

The value of p is often set to 0.01, when A is the maximum age observed.

With p at 0.01, and the maximum observed age of 10 years, M = 0.46.

In an exploited stock, the maximum observed age may correspond to a p of 0.05 or higher.

Butterfish have certainly been exploited; it is not known how heavily, but catches have remained relatively stable over a long period of time.

With p at 0.05, and the maximum observed age of 10 years, M = 0.30.

With p at 0.05, and the maximum age increased to 15 years, M = 0.15.

M is likely to lie within the range 0.15 to 0.46; the best available estimate is 0.03. From the table of relationships between natural mortality rate and natural variability factor (Annala & Sullivan 1996, p. 18) the most probable value of c is 0.8.

Then $MCY = cY_{av}$ for eastern Cook Strait = 0.8 x 37 t = 30 t

And $MCY = cY_{av}$ for western Cook Strait = 0.8 x 45 t = 36 t

And $MCY = cY_{av}$ for Southland = 0.8 x 37 t = 30 t

These can only be regarded as approximate and provisional estimates. There is a lack of reliable information on changes in fishing effort for butterfish over the history of both the commercial and recreational fisheries, and hence variations in mortality over this time.

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

The reliability of commercial landings data, for recent years particularly, is uncertain, which could have a significant effect on these MCY estimates, which apply only to the commercial component of the catch. Catches in the main (Cook Strait) fishery may have been constrained after 1986 because permits were issued only to fishers already in the fishery, butterfish being regarded as a "stressed species". In the small southern fishery (QMA 5) a competitive TACC has been in force in recent years.

When reliable data become available on the recreational catch, which from preliminary estimates is likely to be at least equal to the commercial catch, they will have to be incorporated into the total yield estimate (or regional estimates).

6. MANAGEMENT IMPLICATIONS

The total of the regional MCY estimates approximate the total reported New Zealand catch for 10 of the years during the period 1980–95; in the other 6 years landings have been up to double this.

Butterfish are almost certainly susceptible to localised depletion. The total quota should be subdivided into QMAs, preferably smaller areas than the standard QMAs and perhaps with different boundaries, to minimise this. The main fishery for butterfish is centred on Cook Strait, and for practical reasons, as well as simplifying the task of monitoring the state of this important butterfish "stock", it should be subdivided into eastern and western sectors similar to those used in for the analyses in this document. There are two main options for establishing QMA boundaries.

(1) To use combinations of the present QMAs. QMAs 1 and 9 would make up a northern QMA. QMAs 2 and 8 would be the eastern Cook Strait QMA. QMA 7 would be the western Cook Strait QMA. QMAs 3 and 5 would be the southern QMA, with the only difficulty being the inclusion of Kaikoura, more logically part of western Cook Strait.

(2) To establish slightly different QMA boundaries which more closely matched the regional distribution of fisheries. The North Island north of Cook Strait (approximately north of 41° S) has only a small dispersed fishery and could be a single large northern QMA. The eastern coast of Cook Strait would combine the southern ends of QMAs 2 and 8, and the western Strait the northern ends of QMAs 3 and 7; these two Cook Strait QMAs could be defined as the statistical areas listed in Table 3. The Southland fishery is almost totally

contained within QMA 5, although it would be feasible to add the southern parts of QMAs 3 and 7 to create a large southern QMA.

Under both options, although the Chatham Islands fishery is at present small, for practical and stock separation reasons it would be appropriate to treat it separately.

Commercial landings from this fishery have been reasonably stable for the last 15 years and appear to have been sustainable. However, appropriate measures of fishing effort, and hence an evaluation of CPUE, are not available. It is not known whether the most recent catch levels in the commercial plus recreational fisheries, the former somewhat higher than this 15 year mean, are sustainable and/or will allow the stock to move towards a size that will support the maximum sustainable yield.

7. ACKNOWLEDGMENTS

This work was financially supported by the Ministry of Fisheries, project number PIQM01.

8. REFERENCES

Anderson, A.J. 1983: Analysis of fish remains from southern Fiordland and Stewart Island. *N.Z. Archaeological Association Newsletter 26(4)*: 264–270.

Annala, J.H. & Sullivan, K.J. (Comps) 1996: Report from the Fishery Assessment Plenary, April-May 1996: stock assessments and yield assessments. 308 p. (Unpublished report held in NIWA library, Wellington.)

Ayling, [A.M.] and Cox, G.J. 1982: Collins Guide to the Sea Fishes of New Zealand. Collins, Auckland. 343 p.

Ayling, A.M. & Paxton, J.R. 1983: *Odax cyanoallix*, a new species of odacid fish from northern New Zealand. *Copeia 1983(1)*: 95–101.

Choat, J.H., Ayling, A.M. 1987: The relationship between habitat structure and fish faunas on New Zealand reefs. *Journal of Experimental Marine Biology and Ecology 110(3)*: 257-284.

Choat, J.H. & Clements, K.D. 1992: Diet in odacid and aplodactylid fishes from Australia and New Zealand. *Australian Journal of Marine and Freshwater Research 43(6)*: 1451-1459.

Choat, J.H. & Clements, K.D. 1993: Daily feeding rates in herbivorous labroid fishes. *Marine Biology 117(2)*: 205-211.

Clements, K.D. 1985: Feeding in two New Zealand herbivorous fish, the butterfish *Odax pullus* and the marblefish *Aplodactylus arctidens*. Unpublished M.Sc. Thesis, University of Auckland. 201 p.

Clements, K.D. 1991: Endosymbiotic communities of two herbivorous labroid fishes, *Odax cyanomelas* and *Odax pullus*. *Marine Biology 109(2)*: 223–229.

Clements, K.D. & Bellwood, D.R. 1988: A comparison of the feeding mechanisms of two herbivorous labroid fishes, the temperate *Odax pullus* and the tropical *Scarus rubroviolaceus*. *Australian Journal of Marine and Freshwater Research 39(1)*: 87–107.

Clements, K.D. & Choat, J.H. 1993: Influence of season, ontogeny and tide on the diet of the temperate marine herbivorous fish *Odax pullus* (Odacidae). *Marine Biology 117(2)*: 213-220.

Crabb, P.L. 1993: Reproduction in greenbone, *Odax pullus* (Teleostei, Odaciidae). Unpublished M.Sc. Thesis, University of Otago.

Doak, W. 1972: Fishes of the New Zealand Region. Hodder and Stoughton, Auckland. 132 p.

Doak, W. 1991: Wade Doak's World of New Zealand Fishes. Hodder and Stoughton, Auckland. 223 p.

Francis, M.[P.] 1988: Coastal Fishes of New Zealand. A Diver's Identification Guide. Heinemann Reed, Auckland. 63 p.

Francis, M.P. 1996: Geographic distribution of marine reef fishes in the New Zealand region. *N.Z. Journal of Marine and Freshwater Research 30(1)*: 35–55.

Graham, D.H. 1953: A Treasury of New Zealand Fishes. A.H. & A.W. Reed, Wellington. 424 p. (Revised 1956, reprinted 1974.)

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.

Hickford, M.J.H. & Schiel, D.R. 1995: Catch vs count: Effects of gill-netting on reef fish populations in southern New Zealand. *Journal of Experimental Marine Biology and Ecology 188(2)*: 215–232.

Hickford, M.J.H. & Schiel, D.R. 1996: Gillnetting in southern New Zealand: duration effects of sets and entanglement modes of fish. *Fishery Bulletin (U.S.) 94(4)*: 669–677.

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

King, M.R. 1986: Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January-December, 1983. *Fisheries Research Division Occasional Publication: Data Series No. 21*. 150 p.

King, M.R., Jones, D.M., Fisher, K.A., & Sanders, B.M. 1987: Catch statistics for foreign and domestic commercial fishing in New Zealand waters, January-December 1984. *Fisheries Research Division Occasional Publication: Data Series No. 30.* 153 p.

Knox, F.J. 1871: Observations on *Coridodax pullus*. *Transactions and Proceedings of the N.Z. Institute 3*: 130-132.

Leach, B.F. & Boocock, A.S. 1993: Prehistoric fish catches in New Zealand. *British Archaeological Reports, International Series, 584.* 38 p. + 259 p. of microfiche appendices.

Meekan, M.G. 1986: The distribution and abundance of the herbivorous fish *Odax pullus* and its influence on the food plant *Ecklonia radiata* within a temperate reef environment. Unpublished M.Sc. Thesis, University of Auckland. 68 p.

Paul, L.J. 1986: New Zealand Fishes. An Identification Guide. Reed Methuen, Auckland. 184 p.

Paulin, C.D. & Roberts, C.D. 1992: The Rockpool Fishes of New Zealand. Museum of New Zealand Te Papa Tongarewa. Wellington. 177 p.

Phillipps, W.J. and Hodgkinson, E.R. 1922: Further notes on the edible fishes of New Zealand. *N.Z. Journal of Science and Technology 5(2)*: 91–97.

Ritchie, L.D. 1969: Aspects of the biology of the butterfish *Coridodax pullus* (Forster). Unpublished M.Sc. Thesis, Victoria University of Wellington. 145 p.

Ritchie, L.D. 1975: Butterfish. *New Zealand's Nature Heritage 5(64)*: 1769–1770. Hamlyns Ltd., Wellington.

Ritchie, L.D. 1976: Systematics and meristic variation in the butterfish (*Odax pullus* (Forster)). *Fisheries Technical Report No. 145.* N.Z. Marine Department. 46 p.

Robertson, D.A. 1973: Planktonic eggs and larvae of some New Zealand marine teleosts. Unpublished Ph.D. Thesis, Otago University Library, Dunedin. 480 p.

Thompson, S. 1981: Fish of the Marine Reserve. A guide to the identification and biology of common coastal fish of north-eastern New Zealand. Leigh Laboratory, University of Auckland. 364 p.

Waite, E.R. 1911: Scientific results of the New Zealand Government Trawling Expedition, 1907. Pisces. Part II. *Records of the Canterbury Museum 1(3)*: 157-258.

Willan, R. C., Dollimore, J. M., & Nicholson, J. 1979: A survey of fish populations at Karikari Peninsula, Northland, by scuba diving. *New Zealand Journal of Marine and Freshwater Research 13(3)*: 447–458.

Table 1: Reported landings (t) of butterfish by region, derived from port landings in Annual Reports on Fisheries (1931–73), King 1985 (1974–82), King 1986 (1983), King *et al.* 1987 (1984). Values for 1931 to 1944 are for April-March years, listed as the April year. "Other" is the difference between the total of the listed regions and the New Zealand total, and is not necessarily the actual value at other ports

Year	Auckland Region	Cook Strait east coast	Cook Strait west coast	Southland/ Stewart I	"Other"	New Zealand Total	Year
1931			3		1	4	1931
1932			5	2		7	1932
1933			6			6	1933
1934		14				14	1934
1935			9			9	1935
1936		35	12	3	26	76	1936
1937	1	40	9	1	16	67	1937
1938		29	14		8	51	1938
1939		15	12		31	58	1939
1940		15	14		34	63	1940
1941		15	15	5	27	63	1941
1942	7	14	11	5	16	53	1942
1943	24	16	10		22	72	1943
1944	23	19	23	2	6	74	1944
1945	19	20	22		13	74	1945
1946	42	30	21	3	2	98	1946
1947	17	47	32	3		96	1947
1948		36	27	15	2	80	1948
1949	2	30	20	5		57	1949
1950		32	29	1	2	64	1950
1951		36	21	1	2	59	1951
1952		33	32	1		66	1952
1953		27	37	10	1	75	1953
1954		28	32	5	13	78	1954
1955		30	40	6		67	1955
1956	3	40	36	7	1	87	1956
1957	1	29	28	4	1	63	1957
1958	1	30	38	4	1	74	1958
1959	1	35	54	10	1	101	1959
1960		31	45	1		78	1960
1961		36	52	5	1	94	1961
1962		48	59	4	1	111	1962
1963		26	57	2	1	86	1963
1964		38	63		1	102	1964
1965		32	61	1	6	100	1965
1966		39	61		2	102	1966
1967		29	63		2	94	1967
1968		35	53	1	2	90	1968
1969		27	46		8	80	1969
1970		26	62			85	1970
1971		32	38		8	78	1971
1972		15	32		3	50	1972
1973	1	30	37	2	1	71	1973
1974		24	29	3	2	58	1974
1975		14	22		11	47	1975
1976		22	51		7	80	1976
1977		20	38	1	13	71	1977
1978		25	49		25	99	1978
1979		32	31	1	18	82	1979
1980		40	32		17	89	1980
1981		39	36		26	101	1981
1982		39	52	1	17	109	1982
1983	–	–	–	–	–	137	1983
1984	–	–	–	–	–	153	1984

Table 2: Reported landings (t) of butterfish by fishing year, from various sources. FSU, Fisheries Statistics Unit; CELR, catch, effort and landing return; TCEPR, trawl, catch, effort and processing return; CLR, catch 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 these columns. The "best estimate" was taken as the FSU total from 1982–83 to 1986–87, and the LFRR total from 1987–88 onwards. The two-fold difference between $CELR_{estimated}$ and $CELR_{landed}$ values is unexplained

Year	FSU Inshore	FSU Deepwater	FSU Total	CELR Estimated	CELR Landed	TCEPR Estimated	TCEPR Processed	CLR	LFRR	Best estimate
82–83	110	–	110	–	–	–	–	–	–	110
83–84	159	–	159	–	–	–	–	–	–	159
84–85	127	–	127	–	–	–	–	–	–	127
85–86	108	–	108	–	–	–	–	–	–	108
86–87	193	–	193	–	–	–	–	–	174	193
87–88	124	–	124	–	–	–	–	–	160	160
88–89	41	–	41	62	20	–	–	–	168	168
89–90	–	–	–	253	106	–	–	–	108	108
90–91	–	–	–	227	104	–	–	–	105	104
91–92	–	–	–	235	111	–	–	–	118	118
92–93	–	–	–	256	123	–	–	–	116	116
93–94	–	–	–	343	216	–	–	–	163	163
94–95	–	–	–	274	148	–	–	–	144	144

Table 3: Reported landings (t) of butterfish for eastern and western Cook Strait, Southland, and total New Zealand, 1982–83 to 1994–95. Eastern Cook Strait comprises statistical areas 15 + 16 + 18 + 39 (FSU data), or QMA 2 (CELR data); western Cook Strait comprises statistical areas 17 + 38 (FSU data), or QMA 7 (CELR data). Southland comprises statistical areas 25 + 27–32 (FSU data), or QMA 5 (CELR data). The 1988–89 listed values are low (and incorrect) because of a transition between two catch recording systems; the best estimate is a combination of the two. Some other values in this table differ from values derived from other database summaries (see Table 2), and unfortunately all must be regarded with caution. –, = no relevant data

Year	Cook Strait East FSU data	Cook Strait West FSU data	Cook Strait East $CELR_{Landed}$ data	Cook Strait West $CELR_{Landed}$ data	Southland [QMA 5] FSU data	Southland QMA 5 $CELR_{Landed}$ data
82–83	57	44	–	–	6	–
83–84	77	54	–	–	14	–
84–85	43	50	–	–	23	–
85–86	34	50	–	–	14	–
86–87	45	42	–	–	97	–
87–88	37	44	–	–	26	–
88–89	8	14	7	9	3	1
89–90	–	–	51	34	–	15
90–91	–	–	44	36	–	19
91–92	–	–	40	51	–	7
92–93	–	–	50	43	–	25
93–94	–	–	68	40	–	98
94–95	–	–	61	41	–	41

Table 4: Estimated tonnage of butterfish caught by recreational fishers, by QMA and survey. Surveys were in different years: South 1991–92; Central 1992–93; and North 1993–94. Many of these estimates have high *c.v.*s, and the estimate of total harvest is a guide only because of the different survey years. Line-caught "butterfish" in QMA 3 and QMA 5 are excluded because of apparent species misidentification; these survey totals should be slightly higher.

	Survey by MAFFish region	Number caught	Survey harvest (t)	QMA harvest (t)
QMA 1	North	9 000	10	10
QMA 2	Central	61 000	80	80
QMA 7	Central	6 000	10	{
QMA 7	South	4 000	5	{ 15
QMA 3	South	36 000	65	65
QMA 5	South	8 000	10	10
Total				180

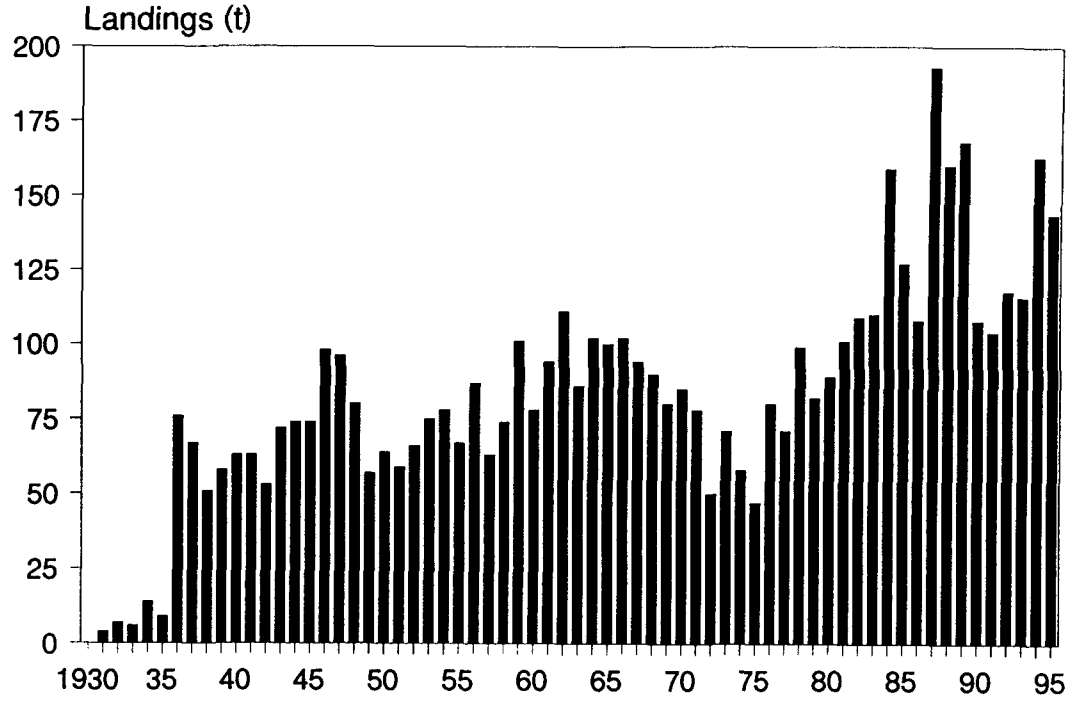


Figure 1. Reported total landings (t) of butterfish for New Zealand, 1931 to 1994–95. Values for 1931–73 from Annual Reports on Fisheries (Marine Department, later Ministry of Agriculture and Fisheries), for 1974-82 from King 1985, for 1983 from King (1986), for 1984 from *King et al.* (1987), for 1985–95 from unpublished FSU or QMS data (see Table 2). Values for 1931 to 1944 are for April-March years, listed as the April year. Values for 1945 to 1984 are for calendar years. Values for 1985 to 1995 are for October to September years, listed against the September year.

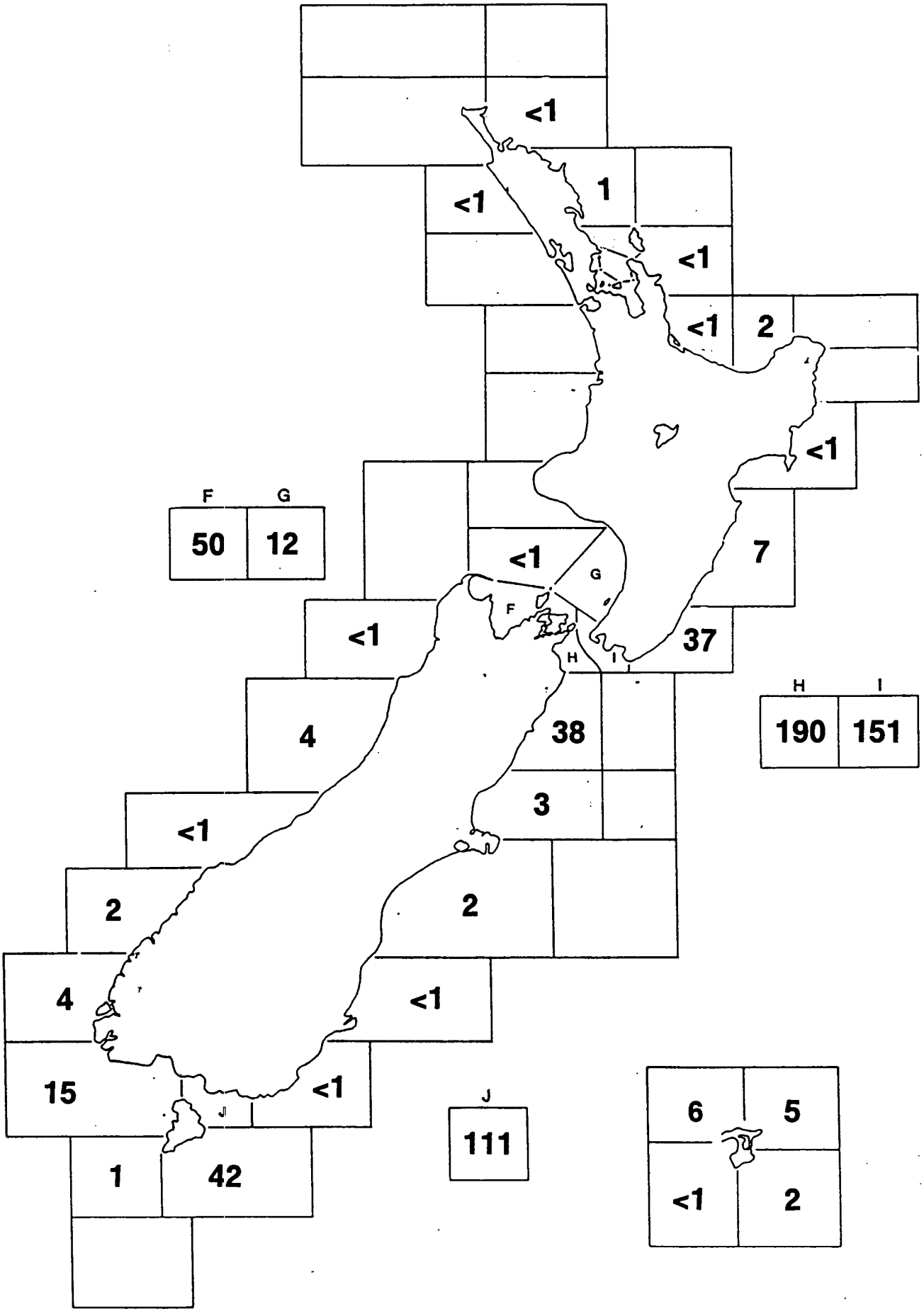


Figure 2: Cumulative reported catches (t) of butterfish for the fishing years 1983–84 to 1987–88, by fishing return statistical areas.

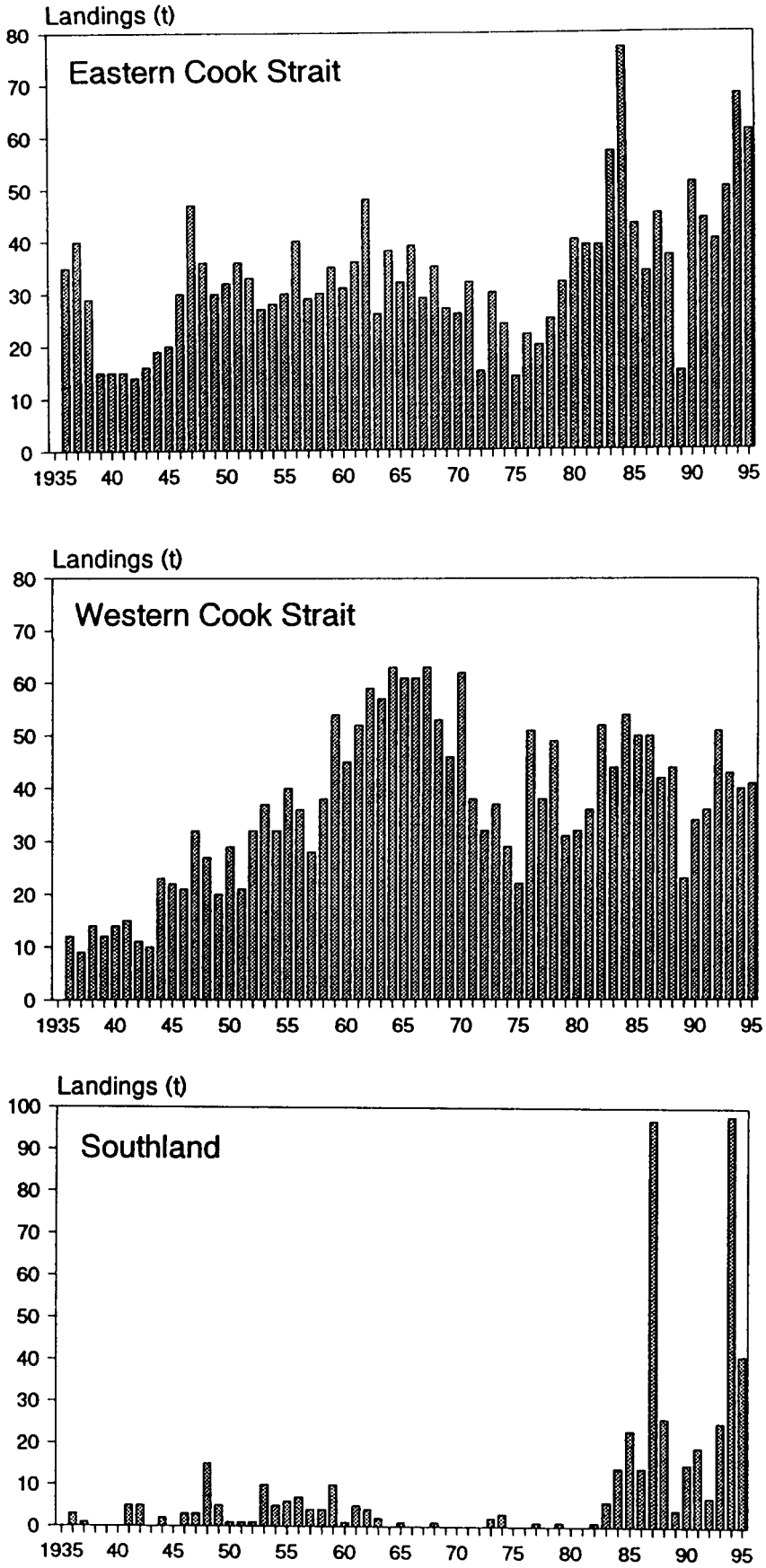


Figure 3: Reported annual landings (t) of butterfish, in the three main fishing regions, 1936 to 1994–95. Eastern Cook Strait: (i) ports Castlepoint + Wellington + Horowhenua, (ii) fishing return statistical areas 15 + 16 + 18 + 39, (iii) QMA 2. Western Cook Strait: (i) ports Nelson + Marlborough Sounds + Kaikoura, (ii) fishing return statistical areas 17 + 38, (iii) QMA 7. Southland: (i) Ports Bluff + Stewart Island, (ii) fishing return statistical areas 25 + 27–32, (iii) QMA 5. Sources: ports 1936–84, see Figure 1 caption; fishing return statistical areas 1985–1987/88, FSU data; QMAs 1988/89–1994/95, QMS data.

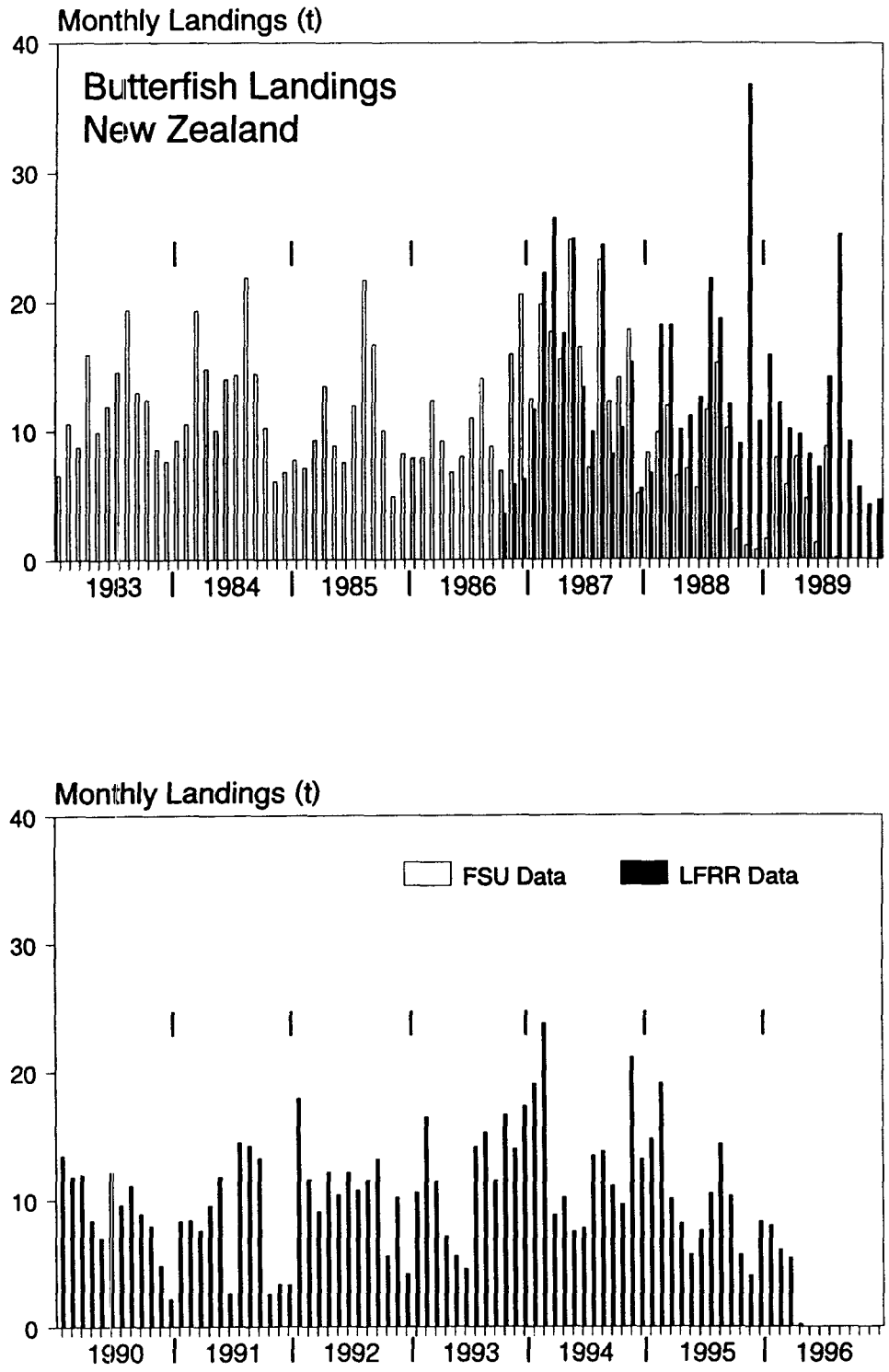


Figure 4: Reported total monthly landings (t) of butterfish for New Zealand, 1983 to 1995. There is an overlap of data between 1986 and 1989 as the FSU data system was phased out and the QMS (LFRR) data became more complete.

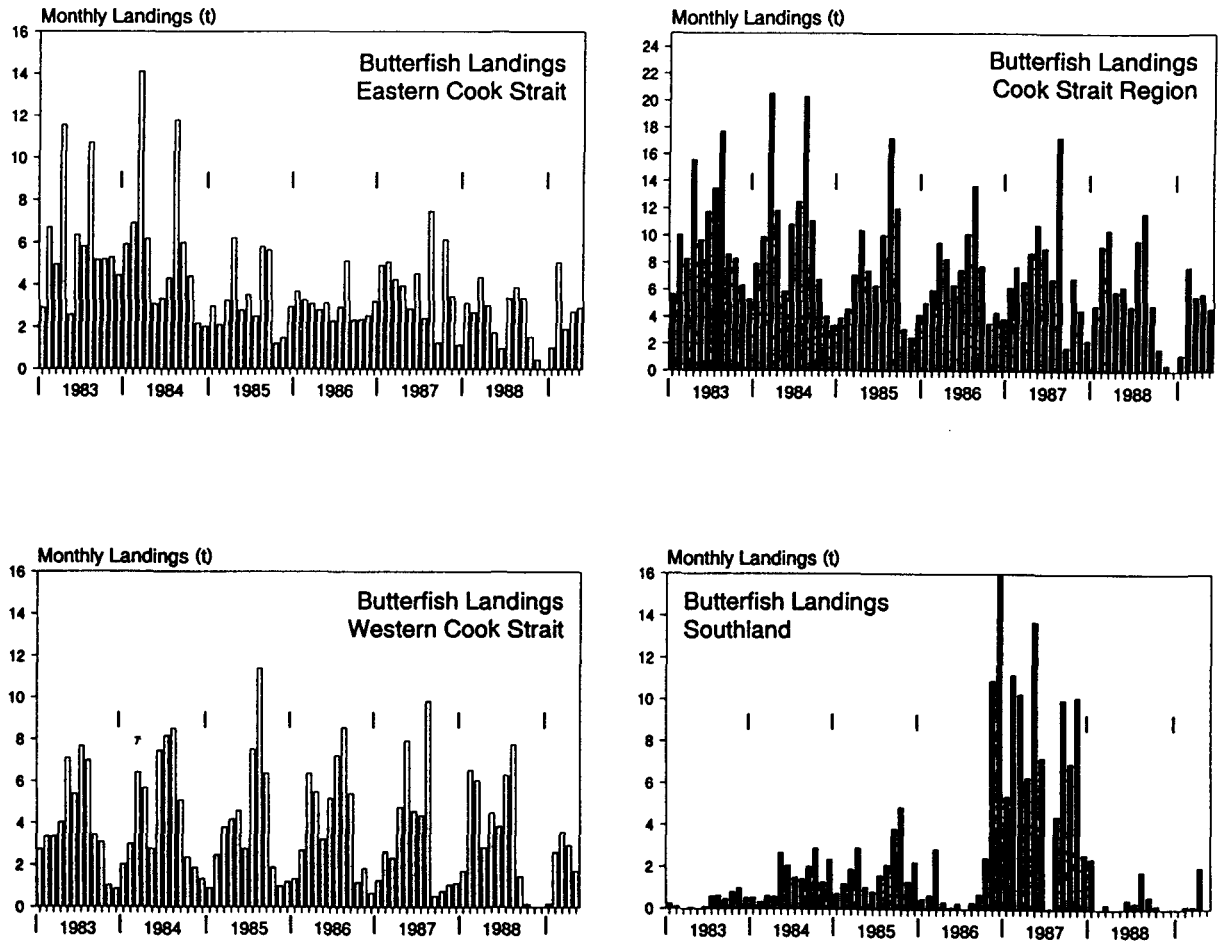
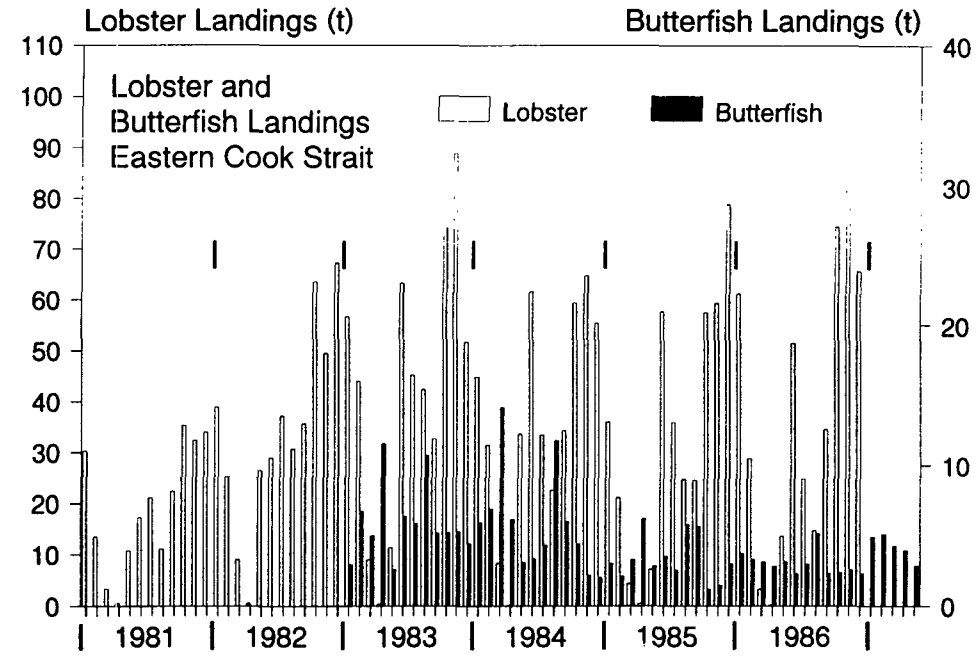


Figure 5: Reported monthly landings (t) of butterfish, 1983 to 1988–89, in the three main fishing regions, and in Cook Strait (total). Eastern Cook Strait: fishing return statistical areas 15 + 16 + 18 + 39, part of FMA 2. Western Cook Strait: fishing return statistical areas 17 + 38, part of FMA 7. Southland: fishing return statistical areas 25 + 27–32, the coastal of FMA 5. Source: FSU data. Reliable monthly data by these statistical areas are not at present available after 1988.



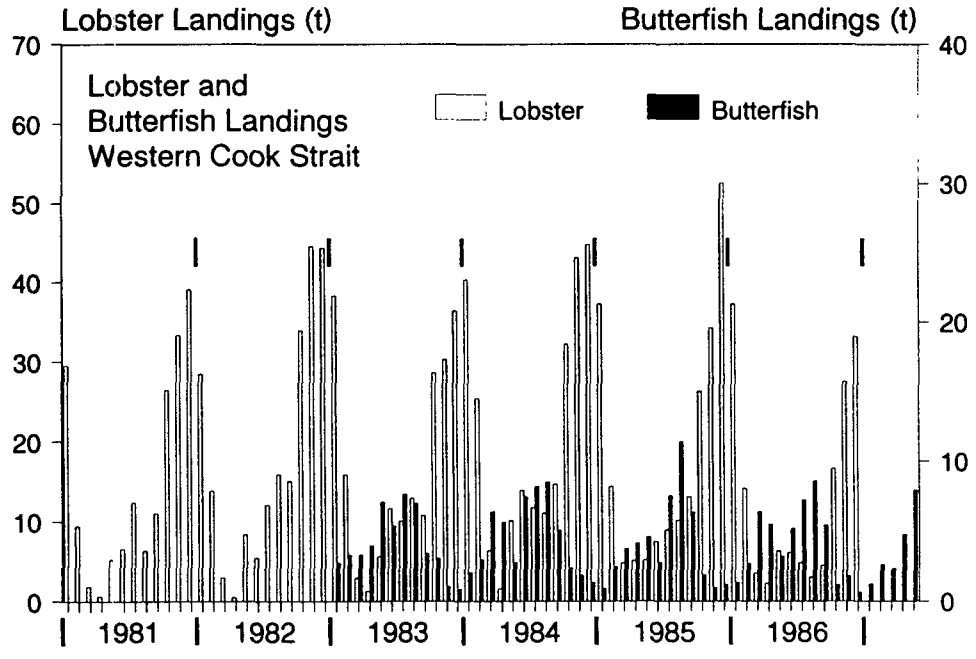
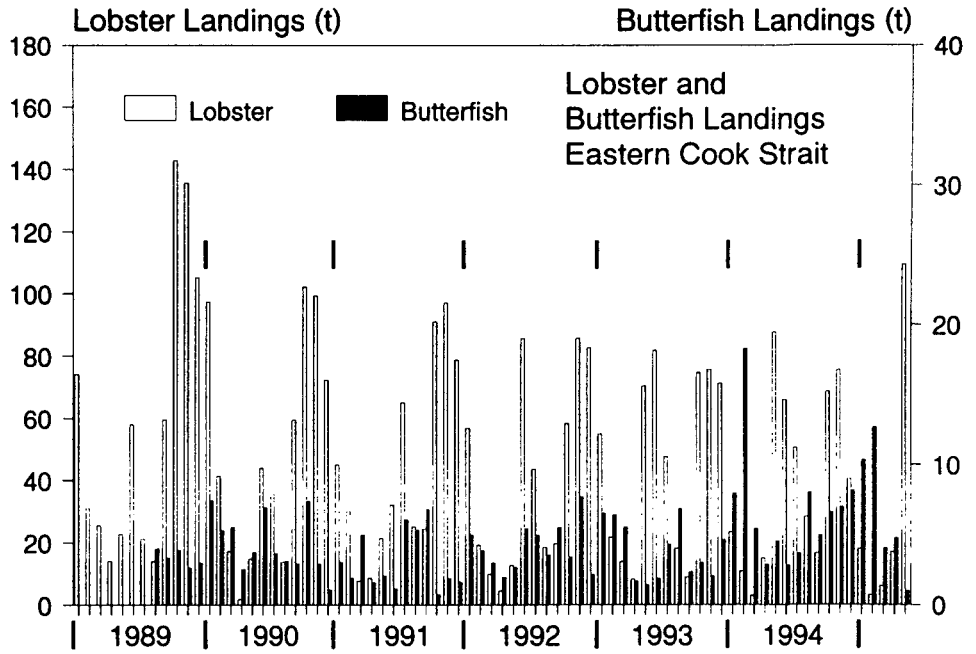


Figure 6: Reported monthly landings (t) of butterfish and rock lobster, Jan 1981 to May 1987, for the eastern and western coasts of Cook Strait. Eastern Cook Strait (butterfish): fishing return statistical areas 15 + 16 + 18 + 39, part of FMA 2. Western Cook Strait (butterfish): fishing return statistical areas 17 + 38, part of FMA 7. Eastern Cook Strait (rock lobster): areas 914 + 915 + 934, the lower Wairarapa, Wellington, and Horowhenua coastline. Western Cook Strait (rock lobster): areas 916 and 833, the Marlborough coast and Sounds, and eastern Tasman Bay. Source: FSU data.



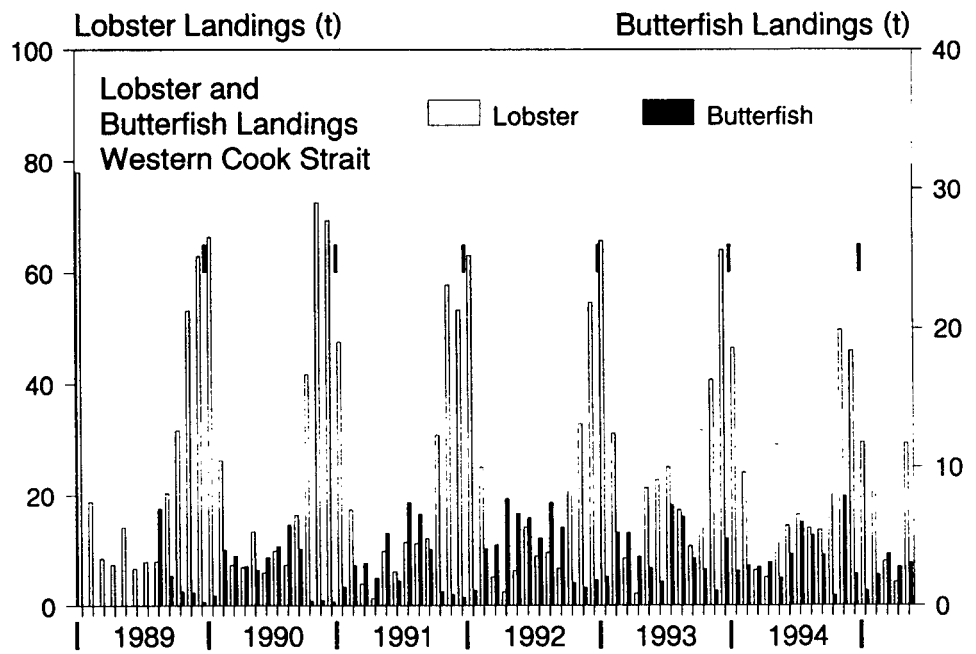


Figure 7: Reported monthly landings (t) of butterfish and rock lobster, Jan 1989 to May 1995, for the eastern and western coasts of Cook Strait. Eastern Cook Strait (butterfish): fishing return statistical areas 11–16, or FMA 2 (East Cape to Mana Island). Western Cook Strait (butterfish): fishing return statistical areas 33–38 + 17, or FMA 7 (Cape Campbell to Cascade Point). Eastern Cook Strait (rock lobster): rock lobster QMA 4 (Hawke Bay, Wairarapa, Wellington, and Horowhenua coastline). Western Cook Strait (rock lobster): rock lobster QMA 5 (Tasman Bay, Marlborough, and Canterbury). Note: although these areas incorporate the eastern and western Cook Strait, they are different from and larger than those in Figure 6. Source: QMS data.