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EXECUTIVE SUMMARY

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This report addresses the issue of whether it is possible, from existing information, to define separate geographic stocks of hapuku and/or bass in New Zealand waters. They are currently managed as a series of paired-species Fishstocks, the boundaries between which were established administratively in 1986.

Information on both groper species is reviewed, within each of the standard approaches used to identify fish stocks.

There are no discontinuities in geographic distribution, or in depth range for either species. Insufficient data exist to demonstrate regional differences in life history characteristics (size, growth rate, population age structure, age at maturity, spawning season, fecundity, etc.). There is no clear information on the location of spawning grounds or nursery grounds which might demonstrate the existence of independent populations (potential stocks). The long pelagic phase in juveniles of both species, while poorly known, may distribute the fish widely from even a single spawning locality, and is likely to indicate a single biological stock of each species. Results from some tagging projects on hapuku show that while most fish were recaptured close to the release site (but may have moved and returned), some had travelled several hundred kilometres. There is no information on the parasite fauna carried by either species, which can sometimes identify stocks. There is no information on otolith microchemistry, a feature increasingly used in stock discrimination studies. Morphometrics and meristics are often used to separate fish stocks, but are of no value in groper.

Genetic studies on *Polyprion* using DNA suggests a Northern Hemisphere stock of *P. americanus* (wreckfish/bass), a Brazilian population, and an Australasian population. The latter appeared to be distinctive enough to warrant resurrection of the species *P. moeone* (which has implications in regional comparisons of "*P. americanus*" biology. No DNA work has shown localised stocks. A genetic study of hapuku from central New Zealand using polymorphic enzymes revealed (a) regional variation, and (b) equal temporal variation within Cook Strait. This implied that if stocks existed, they were temporally rather than geographically separated. However, such allozyme studies may only identify groups of adults which have evolved under different environmental selective pressures from the same spawning population, and not stocks which have some degree of reproductive isolation.

Monthly and annual trends in regional catches of groper (species combined) show strong differences between northern and southern New Zealand. These are interpreted as evidence of a north-south migration, probably of hapuku. They may alternatively reflect separate stocks, or they may be an artefact resulting from some unknown pattern in fisher behaviour, such as switching effort seasonally to other target fisheries (e.g., lobster potting).

Existing data cannot describe the stock structure of New Zealand groper. However, some pragmatic changes to Fishstock boundaries are suggested. They are based on the observed distribution of commercial catches, on the likelihood of moderate, possibly extensive fish movements, and on the requirement to monitor the fishery closely and easily. Effective management also urgently requires that commercial catches be recorded by species.

1. INTRODUCTION

This report addresses Objective 3 of Project HPB1999/01: "To determine if existing data can be used to determine the stock structure of hapuku and bass separately." It was clear from a characterisation study of the groper fishery (Paul 2002a) that with less than 10% of the catch recorded by species, there was no prospect of using these data to examine the stock structure of each species. However, the possibility remained that catch data of the combined species might still suggest some useful lines of enquiry, and they are reviewed in this account, in association with other information relevant to the identification of stocks.

Since the inception of the Quota Management System (QMS), hapuku and bass have been managed as a series of paired-species Fishstocks. These are based on the standard Quota Management Areas (QMAs) but with QMAs 1 and 9 combined into a single northern Fishstock (HPB 1). Two problems have directly arisen from these decisions. (1) The standard QMA boundaries were chosen for administrative convenience and have minimal relevance to marine fish stocks, particularly in central New Zealand. (2) The allocation of a combined-species quota provided no incentive for fishers to begin recording their catch by species; in pre-QMS data both are combined as 'groper' (although they are readily identifiable), and until about 1980 small quantities of the superficially similar but unrelated bluenose (*Hyperoglyphe antarctica*) were also included within groper catch and landing values.

The New Zealand fishery for groper is small in terms of tonnage. However, groper are relatively valuable, and are caught by a high proportion of inshore commercial fishers. There is strong demand for quota, both by fishers who target the two species and those who require quota to cover bycatches. In 1997–98 the holdings of groper quota in the industry had a nominal value of over $26 million.

2. STOCK STRUCTURE AND THE QUOTA MANAGEMENT SYSTEM

When the QMS was introduced in 1986 there was minimal information on the two groper species and their fishery. Yield estimates for the coastal components of the fishery were based on regional catch histories, and for offshore grounds (Chatham Rise and Stewart/Snares shelf) on biomass values obtained from some early trawl surveys. The regional yields were summed into a national yield on the assumption that "groper" were a single geographic stock, though comprising two species. To limit localised depletion, however, it was recommended that regional quotas be set. The regions chosen were the standard administratively derived QMAs, although the regional yields had been determined for somewhat different areas which had appeared to define particular fisheries (Paul 1985).

The first (1986–87) TACs reduced landings by different proportions in each Fishstock (Paul 1985). There were several reasons for this: landings were judged more sustainable in some areas than others, although there was some effort to make reductions reasonably uniform between areas, and in some areas the fishers participated more fully in the government's buyback of their quota entitlements. Fishstocks 4 (Chatham Rise) and 5 (Southland and Stewart-Snares shelf) were unaffected because of the high TACs derived from trawl survey biomass estimates. This derivation of absolute biomass values (for all species) from the trawl surveys of offshore grounds in the 1980s was judged unreliable for a variety of reasons in 1992. No replacement yield values for groper could be developed; the original high TACs were retained as TACCs, and have continued to be substantially under-caught (Annala et al. 2001).

One prerequisite to improving management of the groper fishery is to determine whether the existing regime of Fishstocks is based on the best available information on the stock structure of the two component species: hapuku and bass.

3. THE CONCEPT OF STOCK

The concept of 'stock' has altered with time, and has been expressed in different terms by different authors (Begg & Waldman 1999). In general, stocks can be considered as arbitrary groups of fish large enough to be essentially self-reproducing, with members of each group having similar life history characteristics. In a fisheries sense, stocks are usually smaller than natural biological populations, but reflect many characteristics of these. Fishing operations within a defined area may harvest from one stock, or across several stocks, and it is extremely desirable to have some understanding of this when designing, monitoring, or modifying management regimes. This is particularly true when a multi-stock species is differentially exploited, and by extension (as with groper) when more than one species is exploited.

The concept of stock involves more than a simple recognition of genetic or phenotypic differences between fish. At one end of a continuum, a group of fish may contain individuals which are similar in all measurable characters; they arise from one genetic stock, and retain all its characteristics throughout the life span of individuals. At the other, there may be two or more groups of fish which have arisen from one genetic stock but for environmental reasons (e.g., movement to different habitats) have acquired different characteristics, either phenotypic (growth, colour, etc.) or genetic (differential survival of genotypes). Such geographic separation and differentiation may occur with each generation, and identification of these differences is not an identification of stocks. These groups, sometimes termed ecological stocks, may not be self-perpetuating; for several reasons (e.g., proximity to favourable spawning and nursery areas) only a subset may provide ongoing recruitment into the larger stock and ensure its survival. Both New Zealand groper species have a long pelagic juvenile phase, estimated at over 1.5 years for a Brazilian population of *Polyprion americanus* by Peres (2000), and 3–4 years for *P. oxygeneios* by Francis et al. (1999). This will result in wide dispersal from the, as yet unknown, spawning grounds of these species in New Zealand, and may allow some differentiation of both phenotype and genotype which is not necessarily a measure of true stock separation within either species.

Over time, new knowledge will improve our understanding of groper stocks. As this occurs, it may become necessary to review management strategies already in place.

4. STOCK IDENTIFICATION APPROACHES

Fish stocks are usually identified on the basis of differences in characteristics of the fish in separate stocks, which are sometimes associated with a degree of geographical separation.

4.1. Observed distribution patterns

Stocks can sometimes be deduced from clear discontinuities in distribution. This is not apparent for groper within New Zealand. Trawl surveys show both species to be widespread (Anderson et al. 1998). However, bass are much less frequently taken by trawl, and it is not clear whether there are geographical differences in the distribution of each species.

Commercial fisheries data also show groper catches to be widespread (Figure 1). Largest catches (species combined) are from Cook Strait, Canterbury Bight, east coast North Island, and east Northland. Some bass catches are recorded separately, but as with trawl survey information the data are sparse and scattered.

Bass occur at greater depths than hapuku, but both species have a wide depth range that overlaps considerably, and varies with locality and habitat. Bass are much less frequently caught than hapuku during research trawl surveys, probably because they are generally less common, and possibly because they associate more closely with rough, untrawlable seafloor. The main commercial catches of groper are seldom recorded against depth. From available data, depth is not able to separate groper species, and is very unlikely to distinguish stocks.

4.2 Distribution and migration patterns deduced from mark-recapture

The recapture pattern of tagged fish can be a guide to the existence of separate stocks. The most convincing results are obtained when the suspected stocks are marked at a time when they are most likely to be geographically discrete, to determine whether they subsequently intermingle. Conversely, they may be marked during a time when they are suspected to be thoroughly intermixed, to determine what subsequent geographical separation occurs. Although New Zealand hapuku have been tagged, these criteria were not met.

Three tagging programmes have been undertaken on hapuku: Cook Strait (1979–84), southeast South Island (1988–90), and the Poor Knights Islands (east Northland) (1987–89). They were localised and somewhat opportunistic studies, and not designed to determine the number of hapuku stocks in New Zealand or the distributional range of each stock. However, it is possible to draw a few conclusions (Beentjes & Francis 1999). There was considerable movement of fish from the southeast South Island tagging site, mostly northwards. Several fish reached Cook Strait, and two fish travelled to the northern North Island (Ninety Mile Beach and Tauranga). Hapuku tagged in Cook Strait were mainly recaptured locally (which is not surprising given that this region supports the country's largest fishery), but several fish were recaptured to the south, mainly at Kaikoura but one from Timaru. A single fish moved north to Napier. Fewer (20) east Northland hapuku were recaptured, and all remained relatively close to the tagging site (80% within 10 km, one fish at 51 km).

A large number of the recaptured fish, particularly in Cook Strait, were taken at their tagging site. This suggests that part of the population is resident, that part of the population exhibits homing behaviour, or both.

No tagging studies have been undertaken on bass in New Zealand. However, the wreckfish (*Polyprion americanus*) is strongly suspected to move very considerable distances in both the North Atlantic (Sedberry et al. 1999) and the South Atlantic (Peres 2000, and pers. comm.).

4.3 Size and age structure

Clear geographic differences in the size structure, and particularly the age structure, of fish samples which have been caught with equivalent fishing gear can be an indication of separate stocks with independent patterns of recruitment. No relevant information is available for New Zealand groper. Research catches are small, commercial catches are mostly small and difficult to sample, and age determination is difficult, having only recently been developed for one species (Francis et al. 1999). A compilation of the available research catch size frequencies, mainly from trawl surveys, contains no information which might identify separate stocks (Paul 2002b).

4.4 Life history characteristics

Consistent differences in regional growth rates, age at maturity, spawning season, fecundity, etc. can be used to distinguish stocks. No appropriate information exists for New Zealand groper.

4.5 Spawning areas and nursery grounds

The presence of geographically distinct spawning aggregations can provide indirect evidence for separate stocks. There is limited information for hapuku and bass. "Ripe" hapuku have been observed in Cook Strait, but not running ripe fish; pre-spawning fish disappear in July and reappear as spent fish in October (Johnston 1983). On one occasion one of the latter females had one spent and one running-ripe (but constricted) ovary. It is not known whether these spawning hapuku remain within the broader Cook Strait area between July and October but cannot be taken by line (or by setnet at Kaikoura), or whether they migrate elsewhere. Similar observations were made in the Otago region by Graham (1956); hapuku move "outward" in May and June as roes develop, and "return" (the inference is to inshore waters) in October and November. In both regions, the spent females have rubbed and raw, or scarred areas on their lower body; Graham (1956) speculated that this resulted from seafloor abrasion during spawning behaviour and/or egg "deposition". It is noted that *Polyprion* eggs were not recorded in the Otago ichthyoplankton by Robertson (1980) or Hauraki Gulf and east Northland plankton by Crossland (1981, 1982), although the latter sampling probably lay outside the suspected spawning season.

Spawning of hapuku was inferred to occur in the outer Hauraki Gulf from June to August by Sandager (1888), the fish being in shallower depths (15–30 m) than usual. Hapuku with particularly large roes have been recorded from the east Northland region; the roes were half-full of clear eggs, but were not running-ripe (C. D. Roberts, MoNZ, pers. comm.).

In summary, hapuku move from their usual grounds before spawning, but where they move to is poorly known and apparently contradictory: in the south they are believed to move deeper, in Cook Strait they "disappear", and in the north they may move shallower.

The spawning pattern of bass is even less well known. There is some anecdotal information from a fisher (NIWA, unpublished) that bass "spawn" progressively later, from south to north: February off Westland, March-April on the Challenger Plateau, June at the Three Kings Islands, and August-September on the Wanganella bank. These observations could mean that bass do spawn earlier in the south than in the north, but because running ripe fish are seldom seen could also represent a movement of fish in the later stages of reproductive development from south to north.

The presence of geographically distinct (preferably widely separated) nursery grounds can also be indirect evidence for separate fish stocks. For hapuku and bass, such separation would need to be considerable, given the long (from 1 to 4 years) pelagic phase of juveniles, during which time the fish from a single spawning area could be distributed by currents to quite different parts of the New Zealand coastline. Unfortunately, juvenile hapuku and bass are rarely taken (Roberts 1981, 1986b, 1996).

4.6 Parasites

Parasites, as 'natural tags', can help differentiate stocks of fish by reflecting biogeography, specific requirements of the parasites, and different life history characteristics of the host fish. Their advantage lies primarily in that the fish are naturally tagged; their disadvantages include the requirement for considerable knowledge of the parasites as well as the fish, and the need for comprehensive, quantitative sampling. Minimal information exists on the parasites of hapuku and bass, and sampling the scattered commercial catches of groper would be logistically difficult.

4.7 Otolith microchemistry

The trace element constituents of otoliths reflect the chemical composition of the seawater in which the fish lived. Changes in such a 'chemical signature' within an otolith can demonstrate changes in the habitat or geographic location of a fish during its life history, and differences between the otoliths of groups of fish can be used to define some degree of geographic, possibly stock, separation. This is a developing field, where it is becoming apparent that otolith microchemistry can discriminate stocks more clearly than genetic data if reproductive isolation is weak but there are strong environmental (i.e., water mass) differences. It is unclear whether the life history pattern of hapuku and bass, with lengthy pelagic juvenile phases, is suitable for this technique.

4.8 Morphometrics and meristics

Body shape, proportional measurements, and counts of such features as fin spines and rays, gill rakers, and scale rows, have often been used to distinguish between different fish stocks. These features display the usual variability in groper, but no regional differences have been found in Southern Hemisphere populations of hapuku, and world-wide populations of bass/wreckfish (Roberts 1986a). It is highly improbable that differences would be found within New Zealand. There is morphometric allometry (variation with size), and there is morphometric variation with habitat and season. In practical terms, unless these features allow clear differentiation, large samples of fish must be examined before meaningful results are obtained. This would be difficult with groper, where only a few fish (mainly juveniles) are captured by research vessels, and the commercial catch is processed (headed, gutted, and trimmed) at sea.

4.9 Genetics

Genetic differences between groups or populations of fish reflect the extent of their reproductive isolation. Complete reproductive isolation usually defines a species, although the distinction between good species and a set of geographically isolated subspecies is blurred. At a lower level, some reproductive isolation results in stock separation, and such stocks can be recognised by differences in their inherited genetic characteristics.

Proteins and enzymes

Protein or enzyme electrophoresis used to be the main tool to distinguish the markers (differences in allelic frequency) which reflected genetic difference between stocks. The only work on New Zealand gropers used this technique, as part of a biological study of the hapuku centred on Cook Strait (the less-common bass were not sampled). Smith & Johnston (1985) tested for two polymorphic enzymes in samples of hapuku from 'central New Zealand' (East Cape and Cape Egmont through Cook Strait to Kaikoura and the Chatham Rise) This study did find differences between regions, but perhaps more significantly found equal differences between Cook Strait samples taken in different seasons. It implied that if these differences did represent stocks, these stocks moved into or migrated through Cook Strait at different times of the year. If discrete stocks did exist they were mobile, and in Cook Strait at least they were not geographically separated (although they may not have been present there at the same time). The value of this study was that it demonstrated the possibility of distinguishing several groups of hapuku, and revealed the potential complexity of stock identification work on groper.

Mitochondrial DNA

There is increasing use of mitochondrial DNA (mtDNA) in fish stock identification. It has been applied on a world-wide basis to wreckfish (or bass), *Polyprion americanus*, by Sedberry et al. (1996), who described two populations, one in the North Atlantic (Mediterranean to the eastern United States) and one in the Southern Hemisphere. Fish in the South Atlantic could not be distinguished from Australasian fish. The main thrust of their work was a clarification of the life cycle of wreckfish in the North Atlantic, where the prevailing hypothesis is for spawning off the southeastern U.S., transport of larvae and juveniles across the Atlantic at least to the Azores region, and return of the adults to the western North Atlantic.

Given that this work could not distinguish between South Atlantic and Australasian fish, it cannot be used directly to investigate stocks within New Zealand. It might, however, be possible to refine the technique by locating less conservative regions of the mtDNA molecule. This field of research is rapidly evolving.

Nuclear DNA

Certain nuclear DNA markers, such as minisatellites and microsatellites, may evolve more rapidly than mtDNA and be more suitable for differentiating fish stocks. Ball et al. (2000) were able to distinguish between wreckfish (bass), *Polyprion americanus*, from the South Atlantic (Brazil) and from Australasia. This is still differentiation on a large scale, and not stock separation within a region equivalent in size to

New Zealand's fishery. The research field is still developing, however, and finer discrimination may become possible.

A separate point arose during this study, relevant to any work on New Zealand (or Australian) wreckfish or bass. Ball et al. (2000) used hapuku, *P. oxygeneios*, as an outgroup (a related species included in analyses as an aid to quantifying differences within the study species) in their *P. americanus* study. They found that Australasian *P. americanus* differed from other *P. americanus* populations to about the same extent that any *P. americanus* population differed from *P. oxygeneios*. Although it was a sideline to their work, they suggested that the Australasian bass may represent a distinct species (in which case it would revert to *P. moeone*), and observed that *Polyprion* systematics were still unresolved.

4.10 Trends in regional catches

Large differences in regional catch trends can sometimes demonstrate the presence of separate stocks, once other possible causes for the differences have been investigated and eliminated. The differences can be either regular (e.g., different seasonal patterns) or irregular (e.g., increases or declines which differ between regions).

There are some intriguing regional trends in the catches and landings (which are not necessarily the same) of New Zealand groper which do not directly demonstrate stock differentiation, but do appear to have some bearing on the issue of whether there are small and localised stocks, or large and mobile stocks.

4.10.1 Annual landings

Landings before the introduction of the QMS are most easily summarised by port. During exploratory analyses of regional catch histories, it was noticed that some ports had a decline in 1981, while others had a rise. These ports formed two geographic groups: along the northeastern and eastern coast of the North Island, and along the southeastern and southern coast of the South Island. The catch histories of these two groups are shown in Figure 2. In early years the trends track together: an increase in the late 1930s, a drop during the war years of the 1940s, a post-war increase, and an early 1950s decrease. But from the mid 1950s onwards, the two catch histories more often trend in opposite directions: the northern landings increased from 1953 to the early 1970s, while the southern landings decreased. Within and following this period, there were short-term movements in opposite directions, notably in 1976 and 1981. Ports in the Cook Strait region had a combined catch history that generally followed neither of these trends, but did decline in the mid 1970s, and recover in the late 1970s and early 1980s, in common with the northern ports.

There are (at least) three possible explanations. (1) The differences between the northern and southern trends, with an occasional reciprocal pattern, have no simple cause but result from a combination of factors (fluctuations in fish abundance and fishing effort, changes in fishing techniques and efficiency, etc.). (2) The landing trends which sometimes trend in different directions suggest there are two (or more) stocks, with little or no interaction between them. (3) The suggestion of a reciprocal relationship between landings in northern and southern New Zealand may represent a north-south movement of some fish. In some years relatively more of the fish may be in northern waters, in other years they may be in the south. The Cook Strait region matches neither trend well because of its central location, with some fish (probably resident and/or migratory) always present.

Catch and landing records from the late 1980s are unreliable because of a transition between recording systems, but trends from the fishing year 1989–90 onwards can be examined in estimated catch data from groupings of fishing statistical areas chosen to match the previous port groupings as closely as possible (Figure 3). The opportunity for catches (as opposed to CPUE) to vary with fish abundance is lessened by the existence of regional quotas; during the 1990s landings increased from 70 to 90% of the quota, and fishing activity must have been increasingly constrained by quota. However, a similar pattern is evident;

despite a fluctuating increase in both series, northern and southern catches sometimes trend in opposite directions. Catches in the Cook Strait region also increase, but follow neither the northern or southern pattern. These patterns are suggestive rather than convincing, but are worth further investigation if catch data can be obtained by species.

4.10.2 Monthly catches

It is possible to explore this pattern in greater detail by comparing monthly catches for the same three regions (Figure 4). Very strong seasonal signals are present. The most striking of these is for the northern and southern catches to trend in opposite directions. The northern catches peak in September, occasionally a month or two earlier, while the southern catches have a broader and more variable peak from February to May. A secondary feature of these opposing trends is more difficult to quantify, but it seems that either both cycles are very clear, or they are less distinct in magnitude and/or timing. For example, the cycles in 1993, 1994, and 1998 are distinct, while those in 1992 and 1996 are less regular, for both northern and southern catches.

Catches in the Cook Strait region are subdivided here into Cook Strait itself (a major fishing ground) plus less important areas to the northwest, and Kaikoura. There is some seasonal pattern to the Cook Strait catches, but it is not particularly clear; the main peak is in April-May, sometimes with an earlier peak in February. The Kaikoura catches have a very strong and consistent seasonal pattern, with a peak in June (in some years May or July).

These broad trends are not inconsistent with the hypothesis that groper (unfortunately both species have to be considered as a unit) are most abundant in southern waters in summer and autumn (February to May), move northwards past or through Cook Strait in winter (April-June), to reach waters along the eastern and northeastern coasts of the North Island in late autumn (September). This would presumably be a spawning migration. The evidence for a return movement southwards is weaker, though in some years there is a smaller peak of catches in Cook Strait in January or February (Figure 4, lower panel).

When the data are divided into smaller geographic areas they become too sparse and variable, and it is necessary to combine years (Figure 5), at the risk of between-year differences blurring the pattern. The trends from the north of the North Island to the Wairarapa coast are similar. Cook Strait has its own pattern, as does Kaikoura. Catches on the Mernoo Bank are relatively low, but they peak from March to May, shortly before the peak at Kaikoura. Catches from South Canterbury to Southland are comparable. Catches off Fiordland are higher in the first six months of the year, while further north on the west coast of the South Island they are higher in the second; this might represent a comparable northward movement to that on the east coast. Catches from central to western Cook Strait are ambiguous, which is not surprising given the account of different "runs" of fish by Johnston (1983), and the occurrence of different genetic groups during the course of a year (Smith & Johnston 1985). Catches on the northwest coast are too low throughout the year to show any trend.

4.10.3 Relationship with lobster fishing

Groper fisheries are one component of a set of fisheries worked by the same, relatively small vessels at different times of the year. Although the interrelationship between these fisheries has never been quantified, and is almost certainly complex – varying with region – it seems highly probable that groper fishing is seldom the primary activity. Consequently, it is possible that the seasonal patterns of groper catches and landings which appear to demonstrate a north-south migration only result from a strong seasonal signal in some other fishery. The alternative fishery likely to be most important, and at least most consistent at a national level, is the rock lobster fishery, and a brief investigation was made of seasonal trends in this.

The same three regions (northern, southern, and Cook Strait) were chosen (Figure 6); the boundaries differed slightly because of different reporting areas. There is a strong seasonal cycle in the northern and southern lobster catches, which trend together in the early 1990s, with the peaks becoming increasingly displaced in the later 1990s. The northern lobster catches peak from October to December in the early 1990s, form a lower and extended peak in 1993 and 1994, and in subsequent years peak in June-July. In Cook Strait there are usually low values about April, but more generally the pattern of catches is very irregular.

The relationship between groper and lobster catches is more clearly seen by directly comparing the monthly cycles of these two fisheries in the two regions where there is a clear pattern (Figure 7). In the northern region their pattern is similar, with the lobster fishery having a stronger seasonal cycle. In the early 1990s the groper catches peaked a few months earlier than the lobster catches, in 1993 and 1994 the two fisheries peaked together, and in later years the groper catches peaked after the lobster catches. This difference results from a shift in the timing of the lobster fishery, and (in the absence of other information), suggests that the relationship between these two fisheries is not strong. In the southern region, on the other hand, the seasonal cycle of lobster catches has been stable, peaking from September to November, and there is a strong reciprocal relationship between monthly catches in the groper and lobster fisheries (Figure 7). The lobster fishery is dominant, in size (tonnage) and value, and (in the absence of other information) may be driving the seasonal cycle of groper fishing which peaks during the lobster low season.

In Cook Strait the pattern of both lobster and groper catches is irregular (Figure 8), and the relationship between them varies. At times they trend together, at times they trend in opposite directions, and at times there is no apparent relationship at all.

The issue of whether seasonal lobster fishing activity is completely responsible for the variation in seasonal patterns of groper catches (or landings) in different parts of New Zealand is unresolved.

5. DISCUSSION

Information from a variety of sources has been considered in an attempt to determine whether more than one stock each of hapuku and bass exists in New Zealand waters. There are no natural breaks in their distribution around New Zealand which might suggest separate stocks. Tagged fish recaptures show that some hapuku are either resident or return to their home sites, and others have moved considerable distances, but with no clear pattern. Insufficient is known of the life history characteristics of either species, such as age structure, growth rate, or reproductive characteristics, to distinguish separate stocks. Spawning and nursery grounds that are spatially distinct can suggest stock separation, but both groper species have a long – and poorly known – juvenile pelagic phase that renders this option impractical. Parasites, as natural tags that might identify stocks, are inadequately known. Otolith microchemistry is a powerful tool for stock separation, but requires considerable understanding of a species' biology. It remains unclear, also, whether it would be useful for species with a long juvenile pelagic phase, probably in the open ocean. It is unlikely that morphometrics and meristics will be useful; the morphometrics of both groper change with size, and with habitat and fish condition, and their meristics are very stable.

Genetic variation is a powerful tool for distinguishing fish stocks. It has been used with mixed success with both groper species. There are two approaches. (1) Analyses of different DNA components, which are considered not to be under selective pressure, relatively stable, and a good measure of evolutionary relationships over a long time-scale. (2) Analyses of protein or enzyme features (allozymes) which are considered to be under selective pressure and consequently may show more short-term variability, particularly in response to environmental factors. This variability under selection has a weakness in terms of defining stocks. Genetic differences between groups of adults, either between regions, or (in some circumstances) can result either from different spawnings (and potentially different stocks) or from the same spawning from which two or more groups of adults have been derived, undergoing different selection pressure during their life history. Thus, while these adults are distinct, they are separate "stocks" only as adults, and this distinction is not necessarily permanent.

Mitochondrial DNA has so far been able to distinguish only between northern and southern hemisphere populations of bass. Microsatellite DNA was able to distinguish between Brazilian wreckfish and Australasian bass, supposedly both *Polyprion americanus*, but suggested that the Australasian fish might be sufficiently distinct to revert to their original species, *P. moeone*. Different markers might be found which would distinguish local stocks, but with current knowledge this is unlikely to be a straightforward task. The hapuku, *P. oxygeneios*, has been incorporated in DNA studies only as an outgroup in a review of *P. americanus*, to aid calculation of genetic distances in the latter.

The discovery of polymorphic enzymes in hapuku which showed regional differences in "central" New Zealand, and then temporal differences in the central locality, Cook Strait (Smith & Johnston 1985), is promising, but these may show only that there are groups of fish which have become differentiated as adults. If significant migration occurs, as suggested by the occurrence of temporal differences in the fish sampled in Cook Strait, there could still be only one main breeding population, or "stock", from which separate groups of juveniles are derived, subject to different selection pressure during the long juvenile stage as they are transported to different regions around New Zealand.

The discovery of distinct and different seasonal patterns in the commercial catches of groper (both species of necessity combined) in different regions, with a completely inverse relationship between monthly catches in northernmost and southernmost New Zealand, is relevant to the issue of stock separation. It might represent a reasonably large-scale movement of fish, of one or both species, between northern and southern grounds. It might alternatively represent two stocks ("northern" and "southern") of groper that have completely opposing seasons.

There are other possibilities that are less relevant to the concept of stock. The northern and southern fisheries may contain different proportions of hapuku and bass, either throughout the year, or in different seasons. The geographical distribution and abundance of these two species is not well known, and the commercial catch data are of no assistance. Of equal or greater importance, these seasonal patterns of catches (and landings) do not include any measure or assessment of variations in fishing effort. Effort is a difficult concept in the groper fishery, where the usual measures (days, number of hooks, length of nets, number of sets, etc.) are almost certainly less important than "activity", i.e., whether the fisher is targeting groper, or has switched to a completely different fishery, such as lobster potting. In general, the fishers whose catches make up the major part of the observed seasonal peaks, either fish for groper and make good catches, or do not fish for groper at all. Many also work the more lucrative rock lobster fishery. It is not known whether the seasonal peaks in the groper fishery are the consequence of seasonal activity in other fisheries, including that for rock lobster.

There are several points to consider when evaluating the cyclic pattern of northern and southern catches.

- The catches are of two species, which may have different patterns of availability. It is essential that future catch records are identified by species, to clarify what is occurring.

- There is a strong reciprocal relationship in all years. The seasonal peaks are clearer in some years than in others, and this variability occurs and is matched in both series of catches. It appears more likely that the series are linked, than that they are separate.

- When catches from smaller regions are plotted, east coast areas from the Wairarapa coast trend together. The September peak might represent end-of-year fishing to use quota, but why is this pattern not seen elsewhere? Unfortunately, the catch quantities are too small for detailed analysis.

- In annual catches and landings, a similar reciprocal north-south relationship exists. The signal is neither strong nor consistent, but it could result from some fish remaining at one end of their range for longer than one year. They either do not migrate (i.e., there is a resident component in the population), or they migrate but do not return in the same year.

- The assumed migration of groper into and through Cook Strait is not inconsistent with the complex seasonal pattern of catches there, and the "mixture" of genetic stocks of hapuku observed by Smith & Johnston (1985). The nature and movements of hapuku and bass in Cook Strait will almost certainly be difficult to resolve.

- The recorded movements of tagged hapuku are not inconsistent with a relatively large-scale movement of groper from southern to northern waters. Tagged fish have moved between Otago waters and Cook Strait, and two fish (from a relatively small sample) have moved from Otago to northern New Zealand (Beentjes & Francis 1999).

- The information does not suggest that one or both species of groper move from southernmost to northernmost New Zealand. It suggests that there may be some north-south movement of a substantial number of fish, either seasonally, or on a time-scale of two or more years.

- There is almost certainly some interaction between groper fisheries, and fisheries for other species. Where the latter are more important (e.g., the lobster fishery), they will tend to drive seasonal patterns. Information on the extent to which this might be influencing the northern and southern groper cycles is incomplete and ambiguous.

Begg & Waldman (1999) recommend "an holistic approach to fish stock identification." That is, a broad range of complementary techniques should be employed: biological characteristics, mark-recapture data, genetics, fishery patterns, etc. In the groper fishery, biological information is scanty and should be improved, with particular emphasis on the reproductive cycle and the movements (or at least the localised occurrence) of fish associated with this. Further tagging work will be most productive if undertaken on a moderate scale, with emphasis on the mature adults most likely to undergo migration, and on regions most likely to be involved in any migration route. Genetic work should also be planned with the possibility of a north-south migration in mind. Synoptic samples should be collected from across the total range of the two groper species in New Zealand to identify any regional differences, and a series of samples should be collected at appropriate northern, central, and southern localities to identify temporal changes to regional patterns. It would be useful to build on the existing allozyme results of Smith & Johnston (1985), but as this may only be measuring differences between adult populations, rather than more completely independent stocks, it would be desirable to investigate the newer DNA techniques likely to define the latter. For further investigation of fishery patterns likely to be of value in stock identification, it is essential that all catch data be recorded by species (bass, hapuku).

Given the probable complexity of groper biology (both species), and the requirement to refine the commercial catch reporting regime to record each species separately, it is unlikely that there will be a good answer on whether there is more than one true biological stock of either hapuku or bass in New Zealand for several years. The present catches being taken from groper Fishstocks around the mainland are close to the regional TACCs, in most cases having risen during recent years. In 1986 the total estimated yield (subsequently TACC) was subdivided in order to prevent localised depletion, although there was no evidence for more than one stock of each species. It was a purely pragmatic decision. The regional subdivision, however, was unfortunate, in not recognising that Cook Strait was the largest fishery, and reasonably discrete despite being worked by vessels from ports between Wanganui, Nelson, Picton/Blenheim, and Wellington. This ground was subdivided between three Fishstocks: 2, 7, and 8, and perhaps 3 if Kaikoura is regarded as a southern extension of the Cook Strait region.

This had two unforeseen and interrelated consequences. (1) Fishers working Cook Strait are required to hold at least two, probably three, and possibly four separate quotas, depending on how many Fishstock boundaries their fishing grounds straddle. Their catches from "Cook Strait", as QMR data, are amalgamated with catches from as far afield as New Plymouth, East Cape, south Westland, and – if grounds towards Kaikoura are worked – the Otago Peninsula. (2) If a fisher's quota holding is not perfectly matched with his fishing strategy (fishing in response to weather, fish abundance, distance from home port, etc.) it would be in his economic interest to misreport his fishing locality within the Strait by a few miles in order to match his landings against his quota held.

As a result, the present Fishstock boundaries through Cook Strait serve only to obscure any real trends in regional catches, are almost certainly a hindrance to fishers, and serve no useful stock assessment purpose. To monitor regional trends, it is necessary to base analyses on estimated catches from fisheries statistical areas (landings are recorded only by Fishstock). Estimated catches have two significant deficiencies: they are incomplete when groper are below the top five species threshold, and are a mixture of processed weights and greenweights (Paul 2002a).

It is suggested that a second pragmatic decision be made, in order to simplify future monitoring of the groper fishery, and increase the value of QMR data. The boundaries which subdivide the Cook Strait fishery should be removed. There are a number of options for doing this, some of which are shown in Figure 9. They range from using the "regions" adopted during this present review of the groper fishery, retaining as many existing boundaries as possible while increasing the number of Fishstocks, through to eliminating all boundaries except that between the Kermadec Islands and New Zealand. Apart from the new information which indicates a north-south movement of groper across distances greater than defined by existing Fishstocks, there is no information on natural stock distributions that can be used to define stock boundaries.

6. ACKNOWLEDGMENTS

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7. REFERENCES

Anderson, O.F.; Bagley, N.W.; Hurst, R.J.; Francis, M.P.; Clark, M.R.; McMillan, P.J. (1998). Atlas of New Zealand fish and squid distributions from research bottom trawls. *NIWA Technical Report 42*. 303 p.

Annala, J.H.; Sullivan, K.J.; O'Brien, C.J.; Smith, N.W. McL. (comps) (2001). Report from the Fishery Assessment Plenary, May 2001: stock assessments and yield estimates. 515 p. (Unpublished report held in NIWA library, Wellington.)

Ball, A.O.; Sedberry, G.R.; Zatcoff, M.S.; Chapman, R.W.; Carlin, J.L. (2000). Population structure of the wreckfish *Polyprion americanus* determined with microsatellite genetic markers. *Marine Biology 137(5-6)*: 1077–1090.

Beentjes, M.P.; Francis, M.P. (1999). Movement of hapuku (*Polyprion oxygeneios*) determined from tagging studies. *New Zealand Journal of Marine and Freshwater Research 33(1)*: 1–12.

Begg, G.A.; Waldman, J.R. (1999). An holistic approach to fish stock identification. *Fisheries Research 43(1)*: 35–44.

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

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

Francis, M.P.; Mulligan, K.P.; Davies, N.M.; Beentjes, M.P. (1999). Age and growth estimates for New Zealand hapuku, *Polyprion oxygeneios*. *Fishery Bulletin 97(2)*: 227–242.

Graham, D.H. (1956). A treasury of New Zealand fishes. Second edition. A.H. & A.W. Reed, Wellington. 424 p.

Johnston, A.D. (1983). The southern Cook Strait groper fishery. *Ministry of Agriculture and Fisheries, Fisheries Technical Report No. 159*. 33 p.

Paul, L.J. (1985). The estimation of hapuku and bass yields for New Zealand fishing regions. Fisheries Research Division Internal Report No. 26. 31 p. (Unpublished report held in NIWA library, Wellington.)

Paul, L.J. (2002a). A description of the New Zealand fisheries for the two groper species, hapuku (*Polyprion oxygeneios*) and bass (*P. americanus*). *New Zealand Fisheries Assessment Report 2002/13*. 47 p.

Paul, L.J. (2002b). Size structure of hapuku (*Polyprion oxygeneios*) and bass (*P. americanus*) populations in New Zealand. *New Zealand Fisheries Assessment Report 2002/16*. 17 p.

Peres, M.B. (2000). Dinâmica populacional e pesca do cherne-poveiro *Polyprion americanus* (Bloch e Schneider, 1801) (Teleostei: Polyprionidae) no sul do Brasil. Unpublished PhD thesis, Fundação Universidade do Rio Grande. 144 p.

Roberts, C.D. (1981). Why the scarcity of small bass? *Catch '81 8(1)*: 19.

Roberts, C.D. (1986a). Systematics of the percomorph fish genus *Polyprion* Oken 1817. Unpublished PhD thesis, Victoria University of Wellington. 283 p.

Roberts, C.D. (1986b). Where are all the juvenile groper? *Catch '86 13(11)*: 12.

Roberts, C.D. (1996). Hapuku and bass: the mystery of the missing juveniles. *Seafood New Zealand 4(1)*: 17–21.

Robertson, D.A. (1980). Hydrology and the quantitative distribution of planktonic eggs of some marine fishes of the Otago coast, south-eastern New Zealand. *Fisheries Research Bulletin No. 21*. 68 p.

Sandager, F.S. (1888). List of fishes found round the Mokohinau Islands; their spawning time; and observations regarding some of the species. *Transactions and Proceedings of the New Zealand Institute 20*: 127–133.

Sedberry, G.R.; Carlin, J.L.; Chapman, R.W.; Eleby, B. (1996). Population structure in the pan-oceanic wreckfish, *Polyprion americanus* (Teleostei: Polyprionidae), as indicated by mtDNA variation. *Journal of Fish Biology 49 (Suppl. A)*: 318–329.

Sedberry, G.R.; Andrade, C.A.; Carlin, J.L.; Chapman, R.W.; Luckhurst, B.E.; Manooch, C.S.; Menezes, G.; Thomsen, B.; Ulrich, G.F. (1999). Wreckfish *Polyprion americanus* in the North Atlantic: fisheries, biology, and management of a widely distributed and long-lived fish. pp. 27–50 *In* Musick, J.A. (ed), Life in the slow lane: ecology and conservation of long-lived marine animals. Proceedings of the symposium, Conservation of long-lived animals held at Monterey, California, USA 24 August 1997. *American Fisheries Society Symposium 23*.

Smith, P.J.; Johnston, A.D. (1985). Glucosephosphate isomerase and α-glycerophosphate dehydrogenase electromorph frequencies in groper *Polyprion oxygeneiosis* from central New Zealand. *New Zealand Journal of Marine and Freshwater Research 19(2)*: 173–177.

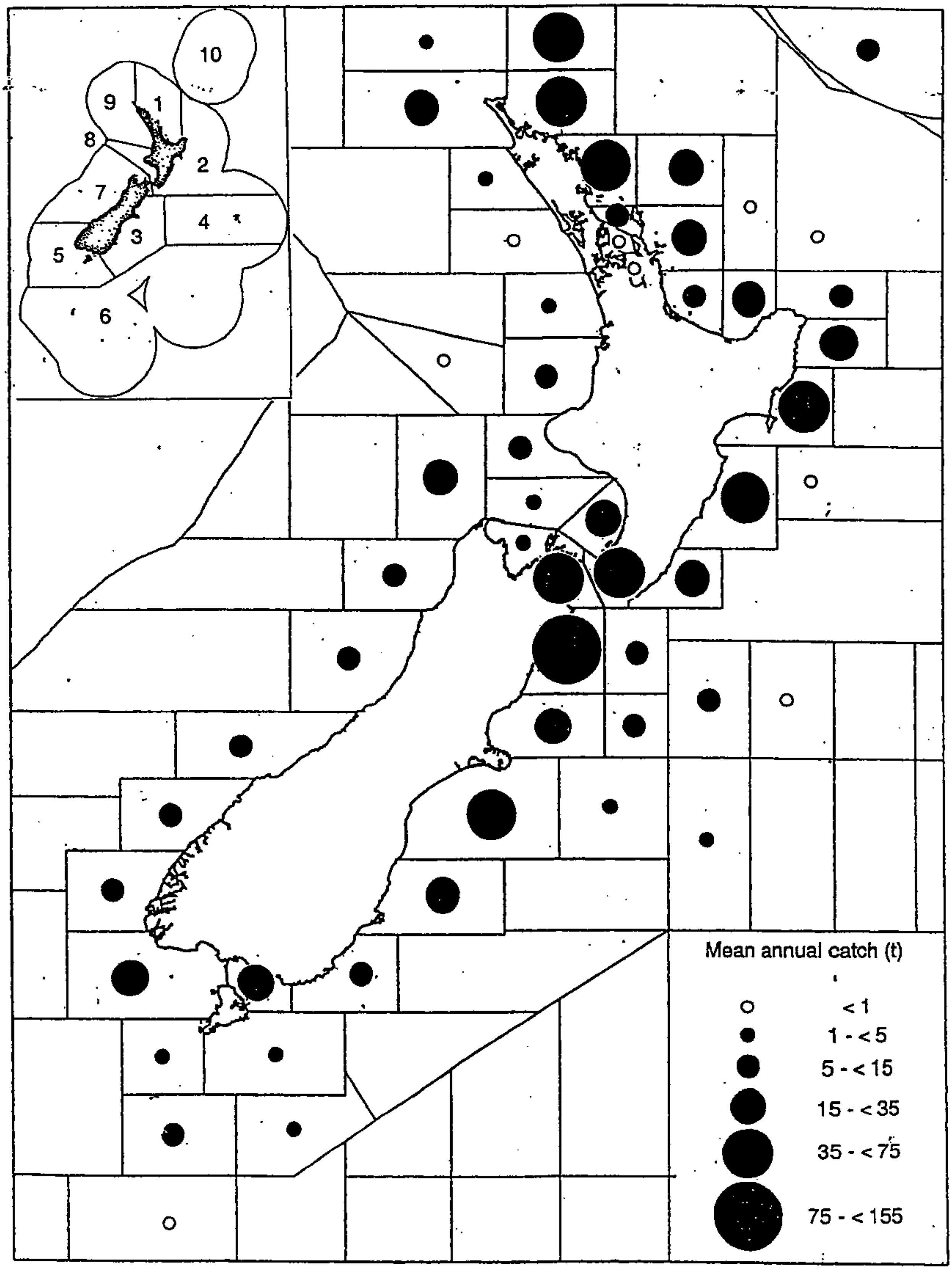
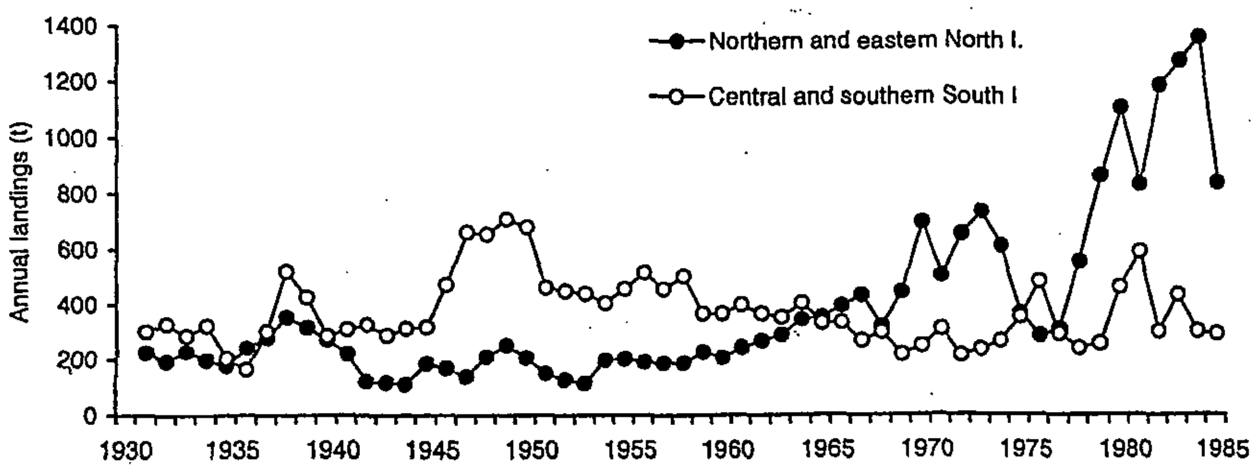


Figure 1: Distribution of the groper (hapuku plus bass) catch around New Zealand, by fishing statistical area. Values are means of the estimated catches for the decade 1989–90 to 1998–99 (Oct-Sep fishing years). For several reasons estimated catches are less than actual catches or landings. A mean 34 t cannot be allocated to area. The quantity assigned to 'fishing statistical area 1', northeast of North Cape, is too high; an unknown proportion of this is actually caught in 'Fishstock 1', areas 1–10 and 42–48. Inset, upper left: the standard QMAs on which groper Fishstocks are based; Fishstock 1 = QMAs 1+9, and Fishstock 5 = QMAs 5+6.



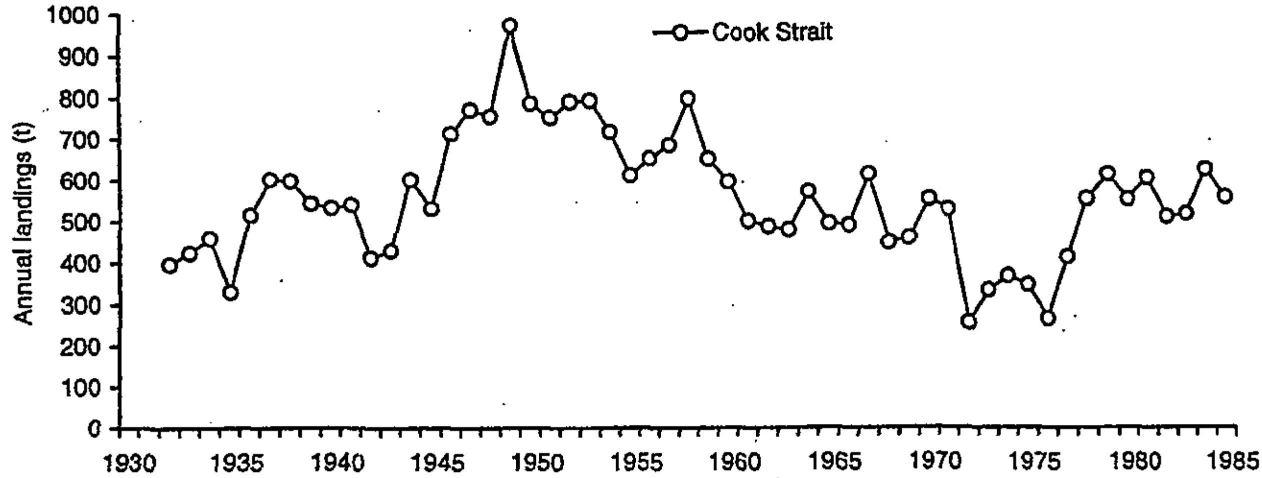


Figure 2: Landings (t) of groper, 1931 to 1984, from northeastern and southeastern New Zealand, and Cook Strait. Based on groupings of ports; northern and eastern North I. comprises ports from Mangonui to Napier; central and southern ***South I. comprises ports from Lyttelton to Greymouth; Cook Strait*** **comprises ports between Castlepoint, Kaikoura, Paremata, and Nelson.**

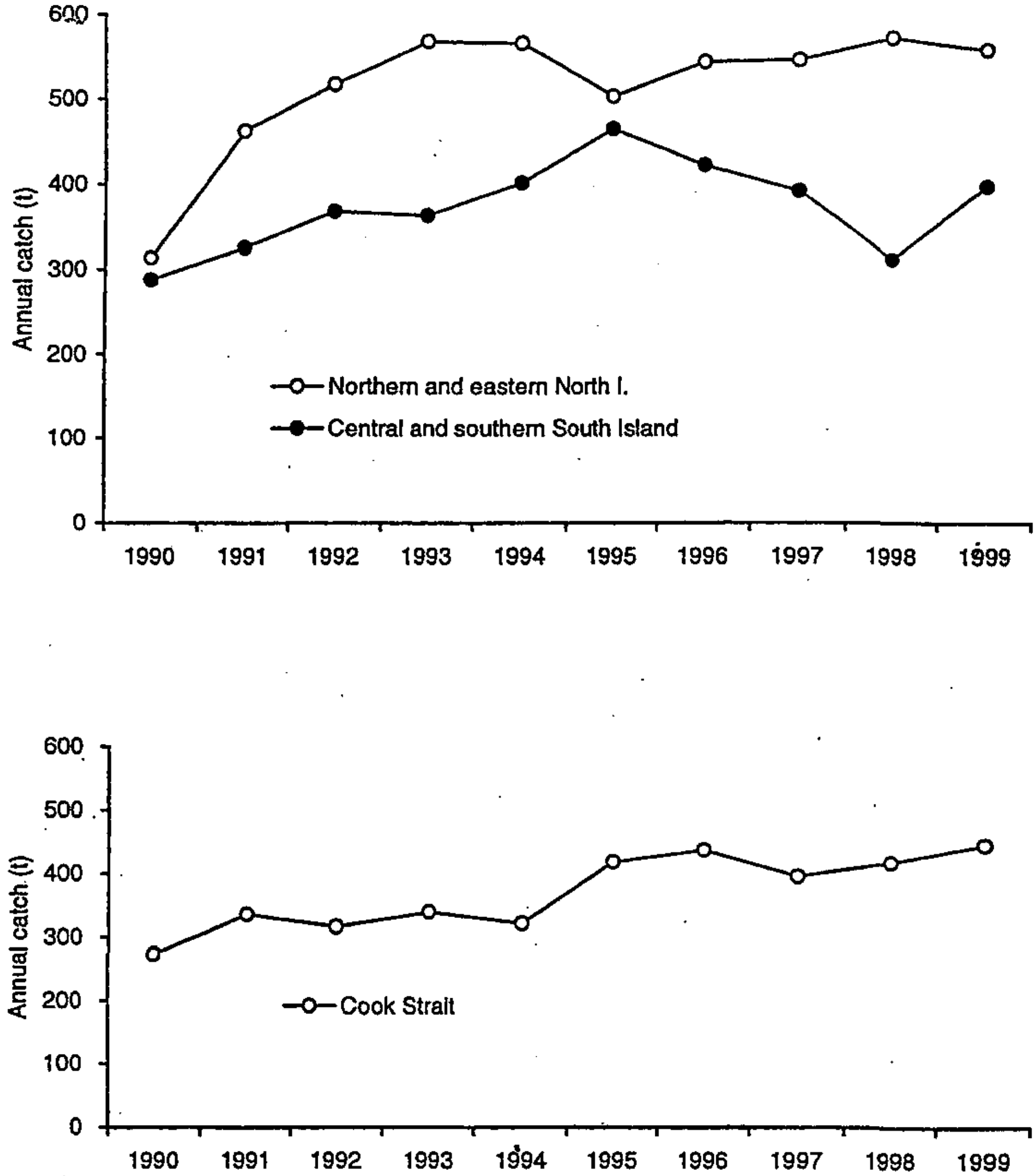


Figure 3: Catch of groper by year (estimated catches, t, fishing years 1989–90 to 1998–99), from northeastern and southeastern New Zealand, and Cook Strait. Based on data from fishing statistical areas; northern and eastern North I. comprises areas 1–15 + 47–48; central and southern South I. comprises areas 20–35; Cook Strait comprises areas 16–17 + 37–39.

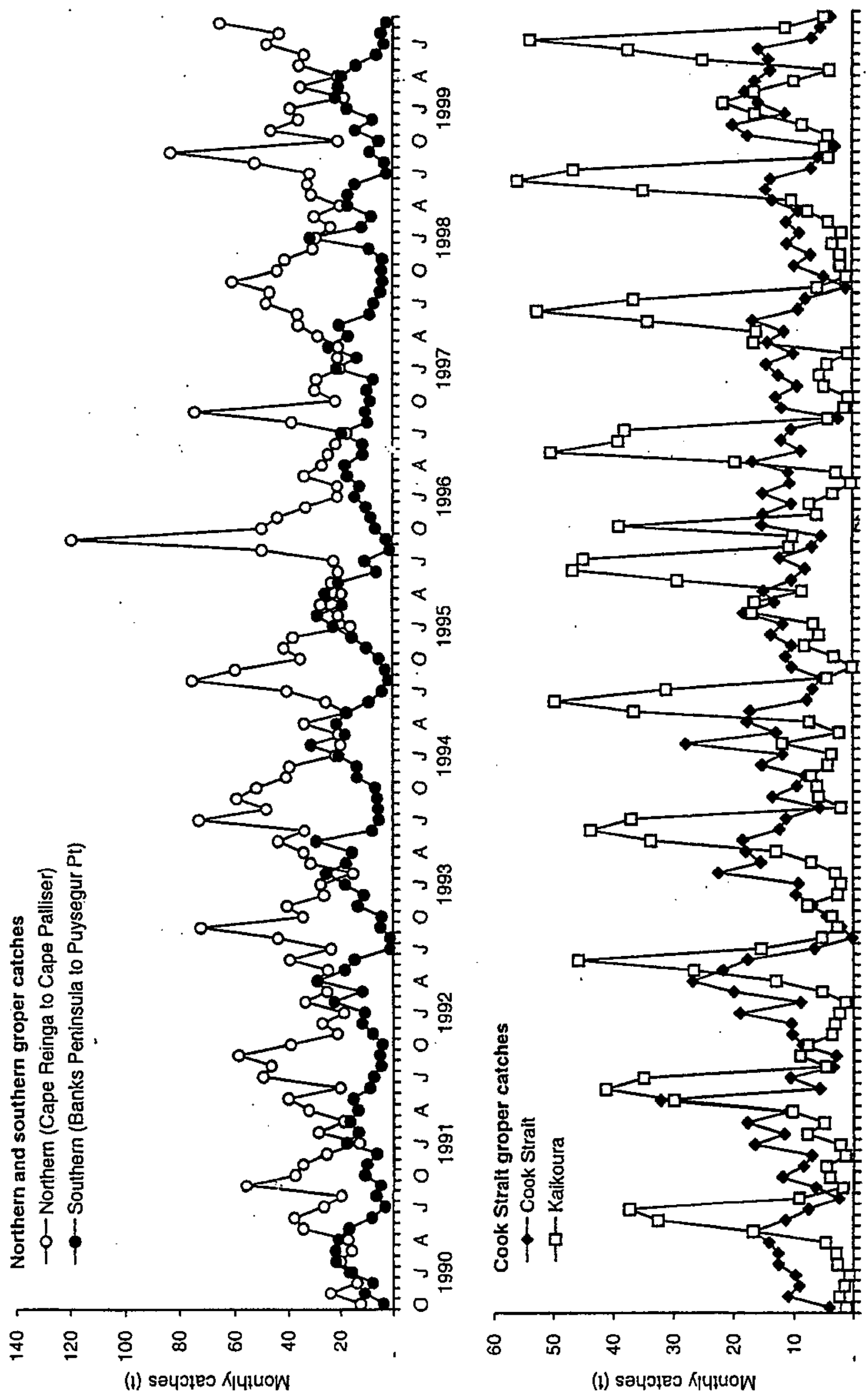


Figure 4: Catch of groper by month (estimated catches, t, fishing years 1989–90 to 1998–99), from northern and southern New Zealand, and Cook Strait. Based on data from fishing statistical areas; northern comprises areas 1–15 + 47–48; southern comprises areas 20–35; Cook Strait comprises areas 16–17 + 37–39; Kaikoura is area 18.

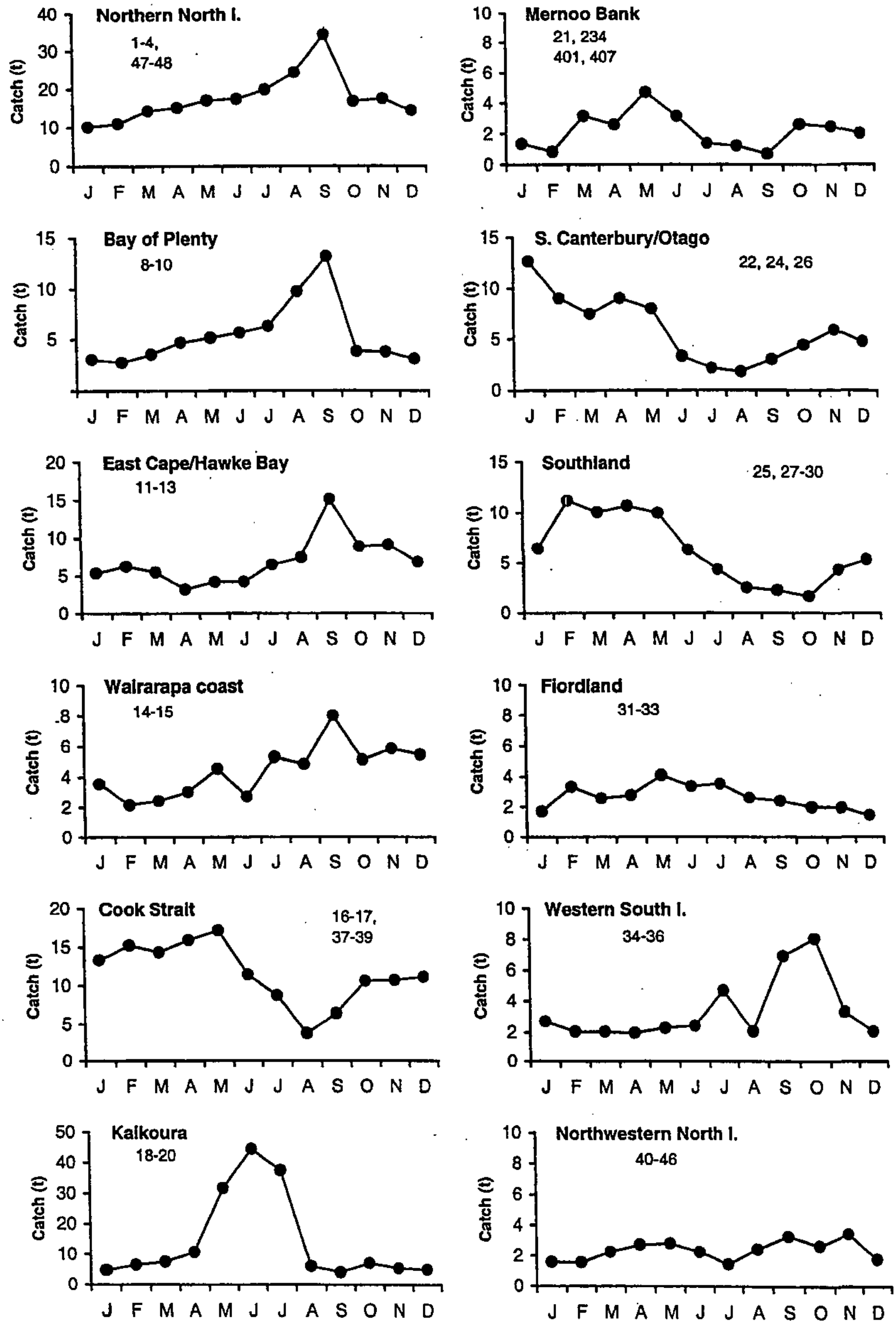


Figure 5: Catch of groper by month (estimated catches, t, fishing years 1989–90 to 1998–99 combined) from regional fisheries. The fishing statistical areas making up each region are listed.

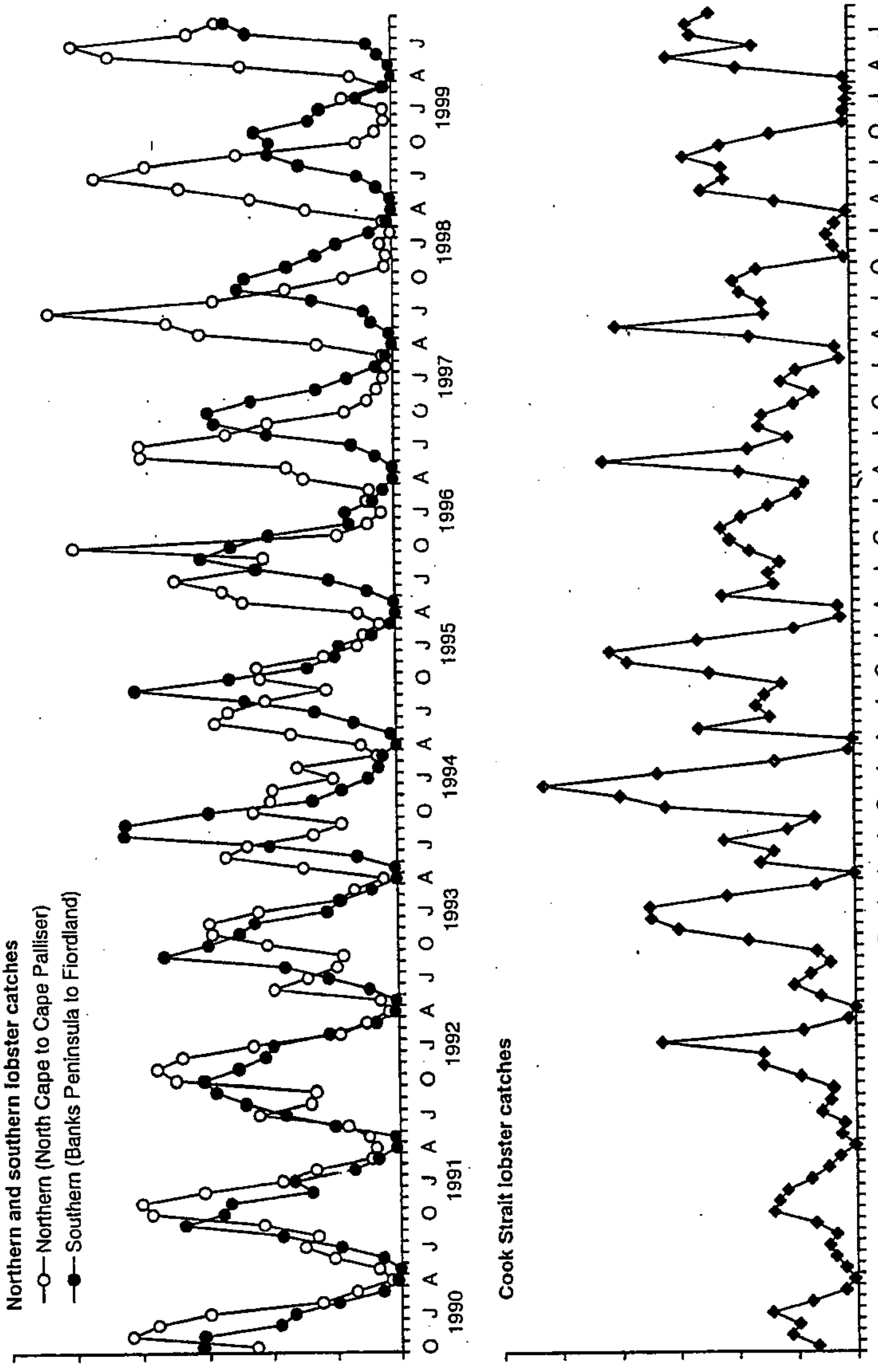


Figure 6: Catch history of rock lobster by month (estimated catches, t, fishing years 1989–90 to 1998–99), from northern and southern New Zealand, and Cook Strait. Based on data from rock lobster fishing areas; northern comprises areas 902–914; southern comprises areas 918–927; Cook Strait comprises areas 915–916 + 932–935.

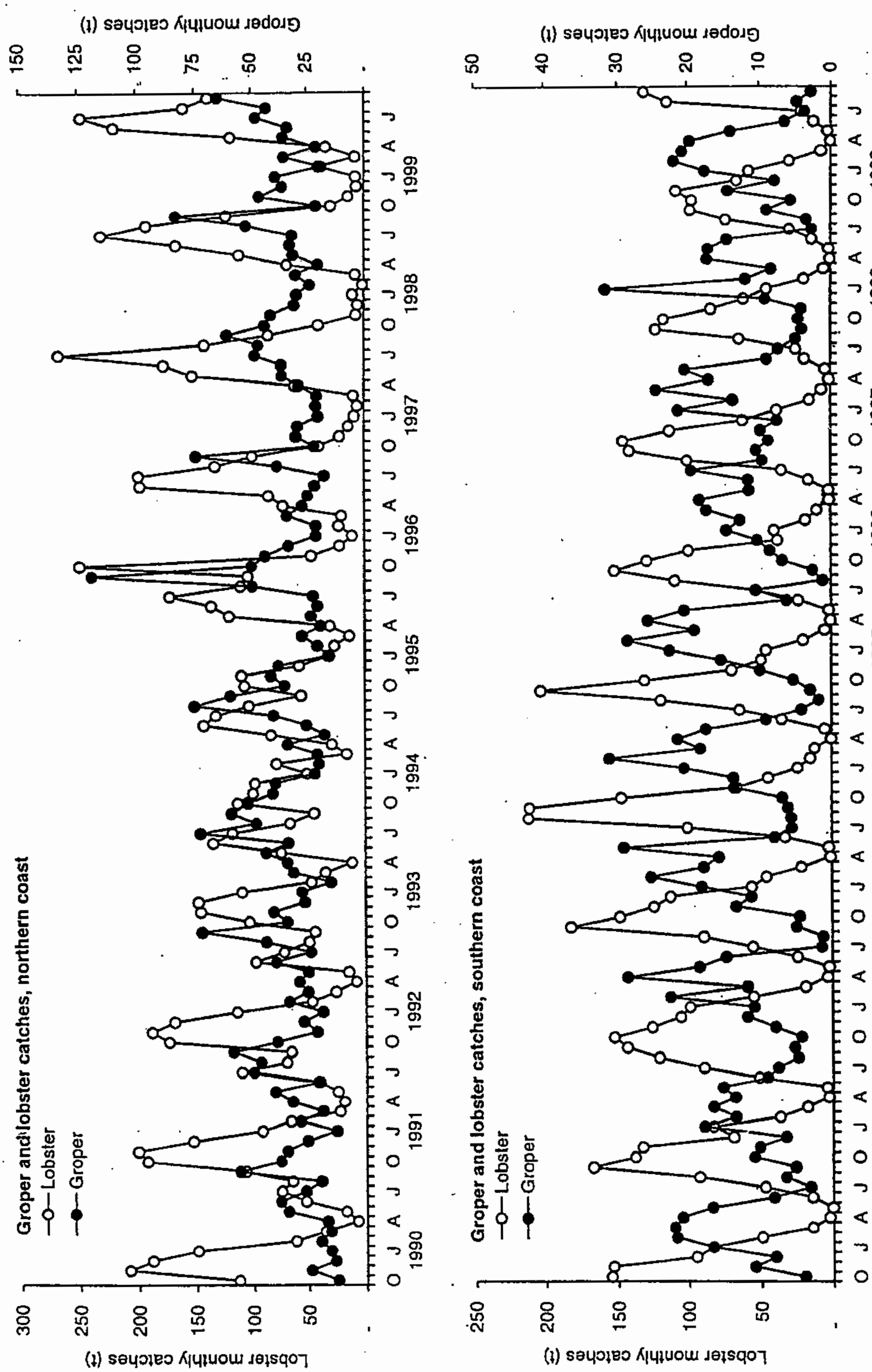


Figure 7: Relationship between monthly groper and lobster catches (t), northern and southern New Zealand. Based on the same data as Figures 4 and 6.

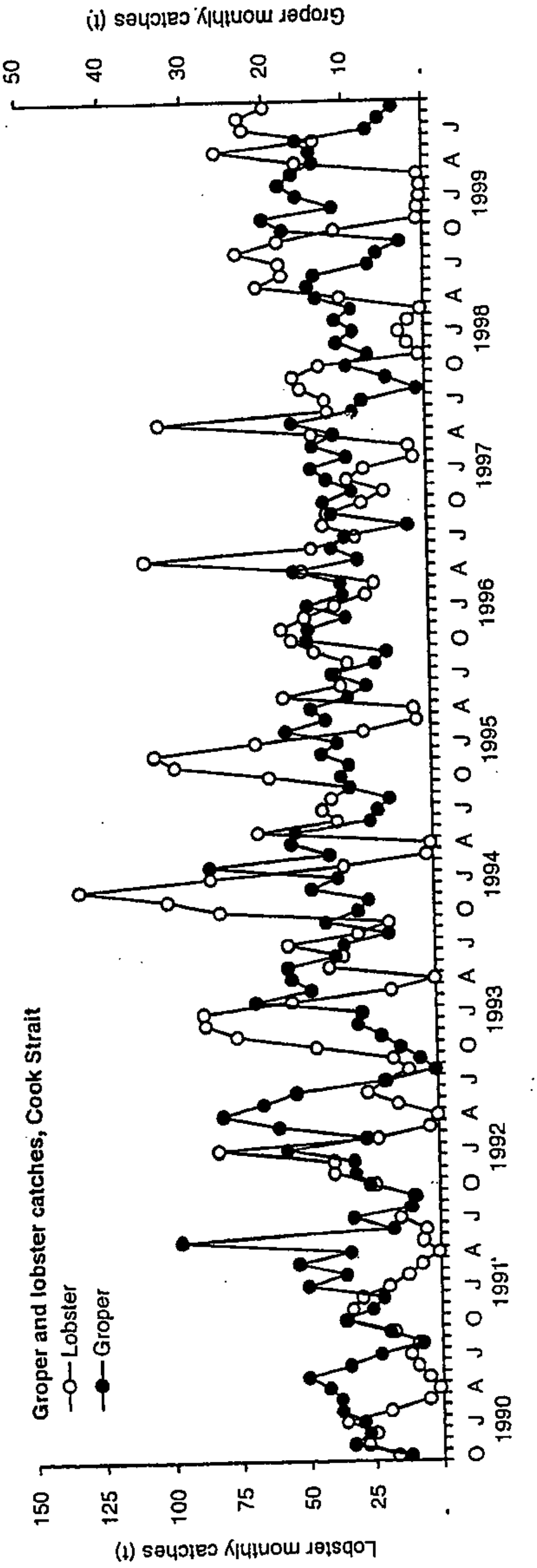


Figure 8: Relationship between monthly groper and lobster catches (t), Cook Strait. Based on the same data used in Figures 4 and 6.

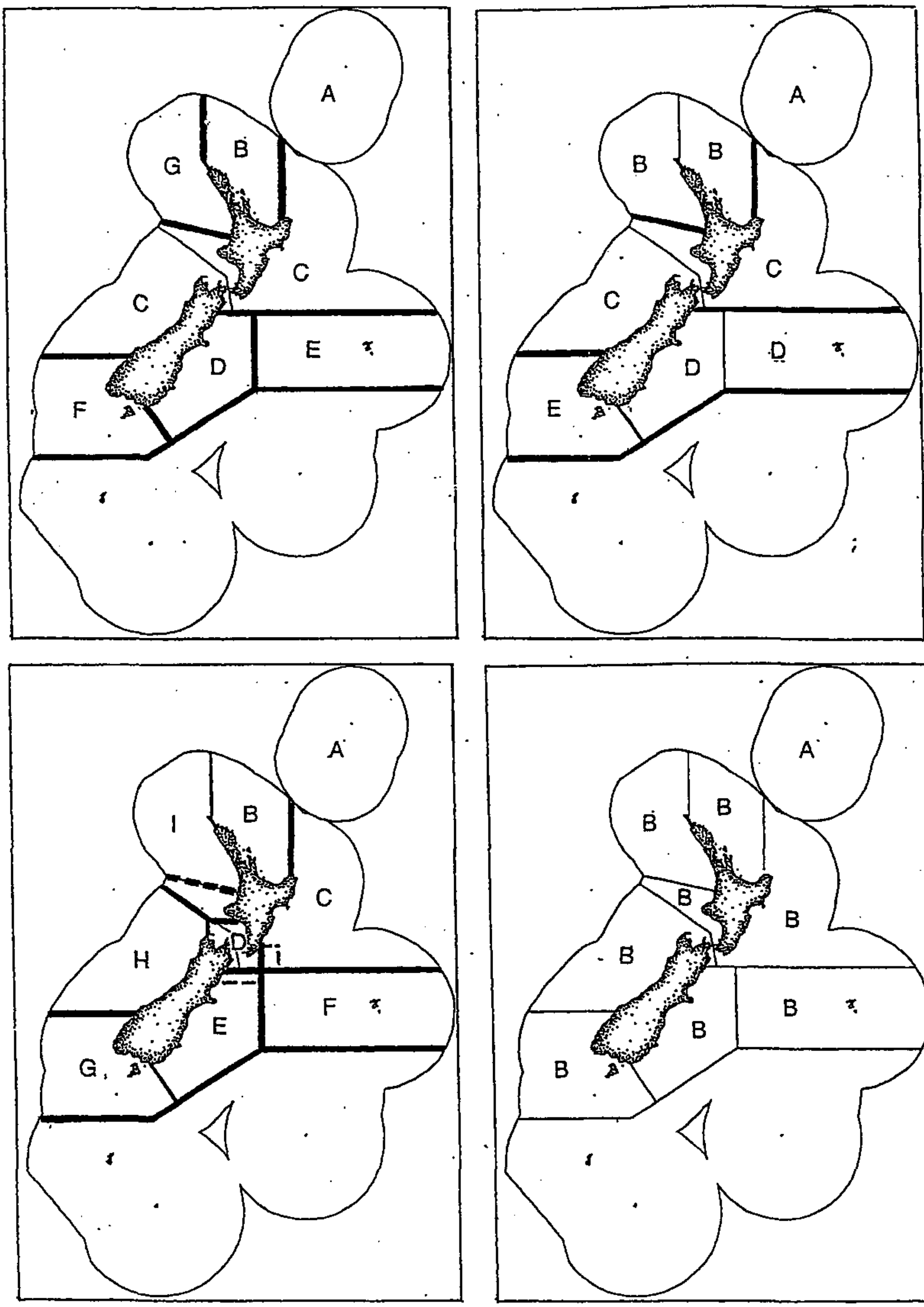


Figure 9: Some options for revised groper Fishstock boundaries, based on the distribution of commercial catches, the possibility of more extensive fish movement between regions than previously assumed, and the lack of good knowledge on biological stocks. The Kermadec Islands (A) are kept separate in all cases. Top left: All QMA and some Fishstock boundaries are retained. The northern area is subdivided into east and west. A large central Fishstock is created by combining QMAs 2, 7, and 8. Top right: All QMA and some Fishstock boundaries are retained. The northern area remains a single unit. A large central Fishstock is created by combining QMAs 2, 7, and 8. A larger southeast Fishstock is created by combining QMAs 3 and 4. Lower left: some Fishstock boundaries are retained, but a new Cook Strait Fishstock is created from parts of QMA 2, 3, 7, and either part or all of 8. Lower right: All New Zealand QMAs are combined into a single Fishstock. Variations on these are also possible.