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EXECUTIVE SUMMARY

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Trends in incidental catch of finfish, squid, and benthic invertebrates in major fisheries on the Chatham Rise were investigated using three sources of data: fishing returns from commercial vessels; observer records from commercial vessels carrying observers, and research trawl survey abundance estimates obtained independently of commercial operations. In all, 288 species (most of which were finfish and sharks) were reported in observer records. Over 80% of the observed catch comprised just 4 species, and 97% about 40 species. Key target fisheries included hoki *(Macruronus novaezelandiae)*, orange roughy (*Hoplostethus atlanticus)*, oreos (*Allocyttus niger, Pseudocyttus maculatus, Neocyttus rhomboidalis)*, barracouta (*Thyrsites atun)*, silver warehou (*Seriolella punctata)*, arrow squid (*Nototodarus sloanii)*, ling (*Genypterus blacodes*), and hake (*Merluccius australis)*. Many species taken as incidental catch in these fisheries are caught in such small quantities that observer data were insufficient to estimate catch. A method to estimate the total catch for a limited number of species in three target fishery groupings, using a ratio of observed catch to the catch of more abundant species, was developed. The target groupings, 'shallow', 'middle depth', and 'deep water' were defined by the main target fisheries operating in depths of 200–400 m (barracouta, alfonsino (*Beryx splendens, B. decadactylus)*, arrow squid, jack mackerels (*Trachurus* spp.), and tarakihi (*Nemadactylus macropterus*), 400–800 m (hoki, hake, ling, silver and white warehou (*Seriolella caerulea*), and over 800 m (orange roughy, oreos), respectively.

Fishing effort in the shallow target group changed little within the time period, but, estimated catches of barracouta, tarakihi, and gemfish (*Rexea solandrea)* declined, while that of alfonsino increased. The increase in effort by almost 100% in the middle depth target grouping was largely due to increased targeting for hoki. The catch of javelinfish (*Lepidorhynchus denticulatus)*, lookdown dory (*Cyttus traversi)*, spiny dogfish (*Squalus acanthias)*, sea perch (*Helicolenus* sp.*)*, rattails (Macrouridae), and dark ghost shark (*Hydrolagus novaezealandiae)* increased as a direct result of the increased hoki catch. There was also an increase in trawl survey abundance estimates of some of these species, and it is unclear whether this was due to a species replacement effect in response to hoki biomass decline or an increase in absolute abundance. The trawl survey abundance of other species, in particular hake and dark ghost shark, as well as hoki declined. Catch per unit effort (raw unstandardised CPUE) trends within the middle depth target group were consistent with trends in catch and trawl survey abundance estimates.

Trends in the deepwater target group were analysed in three subareas of the Chatham Rise. Orange roughy catches in both the northwest and northeast subareas remained stable within the time period, but in the Southern subarea declined about 7-fold. The southern subarea is a mixed fishery targeting oreo species as well as orange roughy. CPUE indices increased for rattails, deepwater dogfish (mainly *Centroscymnus* and *Etmopterus* spp.), and slickheads (*Alepocephalus* sp., *Xenodermichthys* sp.), and decreased for basketwork eel (*Diastobranchus capensis)*, black oreo (*A. niger)*, orange roughy, Johnson's cod (*Halargyreus johnsonii)*, and ribaldo (*Mora moro)*, in all three areas. CPUE for smooth oreo (*P. maculatus)* and Baxter's lantern dogfish (*Etmopterus baxteri)*, decreased in the northeast, but not in other areas. CPUE indices showed a similar pattern to abundance indices from trawl surveys in areas of the northeast and south Chatham Rise.

Benthic invertebrate records from commercial vessels increased within the time period; however, we believe that this was due to increased requirements for observers to identify such species, rather than an increase in their abundance on the sea-bed.

1. INTRODUCTION

The Chatham Rise is a prominent bathymetric ridge that projects about 500 nautical miles (n. miles) east from Banks Peninsula on the east coast of the South Island to the Chatham Islands (Figure 1). The Chatham Rise has supported a number of important trawl fisheries since offshore exploitation began in the late 1970s, in particular, barracouta (*Thyrsites atun)*, hoki (*Macruronus novaezelandiae*), hake (*Merluccius australis*), ling (*Genypterus blacodes*), and silver warehou (*Seriolella punctata*), to depths of about 800 m, and orange roughy (*Hoplostethus atlanticus*) and oreos (black oreo, *Allocyttus niger*, smooth oreo, *Pseudocyttus maculatus*,spiky oreo, *Neocyttus rhomboidalis*) in deeper waters (Annala et al. 2001). Although there has been a steady increase in catch from the Chatham Rise as commercial development has expanded, the biggest increase has come from the hoki fishery (Table 1). In 1986, the quota for hoki was increased from 60 000 t to 250 000 t, but 80–90% of the catch at that time was taken from spawning aggregations off the west coast of the South Island rather than bottom trawl fisheries in other parts of New Zealand. In 1992, the catch on the Chatham Rise rose to over 40 000 t as a new, year-round fillet fishery was developed in the area. This peaked in 1998 and 1999 at 74 000 t, and there has been concern that the increased fishing effort on the Chatham Rise may have impacted not only on species caught incidentally when target fishing for hoki, but also on the benthic environment subjected to disturbance by bottom trawling.

The ways in which fishing can affect the biological community are many and have been reviewed in New Zealand by Jones (1992), and more recently elsewhere by Hall (1998) and Collie et al. (2000). Fish species that are caught incidentally in the net when targeting commercial species may be vulnerable to over-fishing, particularly where populations are small. Another effect of fishing is the physical damage to fishes that escape though the meshes of the net, and to the benthos where wastes from fish processing are released over a small area. Trawling can also affect macroinvertebrates such as scampi (*Metanephrops challengeri*), other crustaceans, and certain molluscs which are incidentally caught by the bottom trawl.

In New Zealand, some work on the effects of fishing has already been initiated. Cryer et al. (1998) analysed the incidental fish and invertebrate catch of scampi trawlers off the east coast of the North Island. McClatchie et al. (1997) analysed trawl survey data from middle depth surveys of the Chatham Rise and Southern Plateau carried out prior to 1991 to explore demersal fish diversity. Bull et al. (2001) described community structure on the Chatham Rise and some changes in abundance estimates observed in hoki trawl surveys of the Chatham Rise 1992–99. Clark & Tracey (1994) examined changes in the incidental catch of orange roughy fisheries on the Challenger Plateau. Clark et al (2000) investigated the changes in abundance estimates of finfish incidental catch from orange roughy trawl surveys of the Chatham Rise, 1979–97. Gilbert (1998) used the data also used by Clark et al. (2000) to demonstrate the potential use of environmental indicators for deepwater fisheries on the Chatham Rise. Grove & Probert (1998) analysed the incidental catch of megabenthic invertebrates from trawl fisheries on the Chatham Rise and the Southern Plateau, and carried out other studies to sample and describe benthic communities on the Chatham Rise (Probert & McKnight 1993, McKnight & Probert 1997, Probert et al 1997). Ballara & Hurst (1997) summarised the incidental catch of the hoki fishery on the Chatham Rise from 1983 to 1993, and Anderson et al. (2001) estimated the amount of discards and incidental catch over time in the orange roughy and hoki spawning fisheries.

Under Section 9 of the Fisheries Act 1996, the Ministry of Fisheries should consider the effects of fishing on "associated and dependent species and biological diversity" when making decisions. The Ministry also should consider avoidance, remedying, or mitigating adverse effects of fishing on the aquatic environment (Section 8) when making decisions. In 1999, the project reported here was initiated as an important first step towards identifying changes in species composition that may have occurred in one of New Zealand's most heavily fished areas.

Year-round fishing targets hoki and hake to depths of about 800 m, and orange roughy and oreos in depths over 800 m on the Chatham Rise. The hoki catch on the Chatham Rise has increased from about 13 000 t in 1989–90 to a peak of 74 000 t in 1997–98 and 1998–99 (Table 1), and covers all parts of the

Rise. Depth seems to be the main component determining the catch composition and target species identified by commercial vessels, and the depth stratification of commercial data was explored to determine the most useful data subsets for analysis. Orange roughy has been the major deepwater fishery over much of the Chatham Rise. Over the period of the fishery, the distribution of catch and effort has varied, as new fishing grounds have been developed, and as changes in Total Allowable Commercial Catch (TACC) or voluntary catch levels have occurred (Clark et al. 2000). The deepwater catch data were stratified into areas of the Rise that form discrete target fisheries.

Existing research trawl survey data (held on NIWA database at NIWA, Wellington), commercial catch and effort data, and observer data were used to explore trends in abundance of incidental catch species that are estimated by both middle depth and deepwater trawl surveys on the Chatham Rise. This report summarises the results of these investigations and makes recommendations for improving data collection that will enable better monitoring of changes in the commercial catch of incidental catch species.

1.1 Objective

As part of an overall programme objective (MFish Project Code ENV1999/05) to identify trends in abundance of associated or dependent species from selected commercial fisheries, this report documents the findings resulting from the specific objective:

- To estimate trends in abundance of associated and dependent species, including invertebrates, from deepwater and middle depth fisheries on the Chatham Rise.

2. METHODS

Three sources of data were investigated: commercial catches from the Total Catch and Effort Processing Returns (TCEPRs) of commercial vessels operating on the Chatham Rise during fishing years 1989–90 to 1998–99; Observer Programme (OP) data that have been collected from a subset of commercial vessels in the area in fishing years 1985–86 to 1998–99; fishery independent research trawl surveys that have estimated relative abundance in 200–800 m depths (optimised for hoki and hake) January 1992 to 2000, and 800–1600 m depths (optimised for orange roughy and oreos) in various years from 1984 to 1995 on the Chatham Rise. These surveys provide fishery independent estimates of abundance for a wide range of species, and may show trends. To interpret the trends, and determine which species are incidental catch of a particular fishery, it is necessary to determine the commercial catch of these species. This is not straightforward since vessels are required to estimate only the top five species by weight in each tow. Catch totals of both retained and discarded species are required, but only on a daily basis. For the more important species, daily totals are back-calculated from the processed weight. The catch of less important species and discards are more poorly estimated. Observers record all species caught, but the number of observed tows is small, and not necessarily representative of the fisheries as a whole.

In this study we took a new approach, by estimating the catch of principal incidental catch species from their proportional occurrence in observed tows, and scaling them to a ratio of occurrence of the main target species from TCEPR tow data (see below for more details). The intention was not to obtain necessarily accurate estimates of catch for these species, as in most cases they could not be verified. Rather, the aim was to track changes in relative catch to compare with changes in survey abundance estimates, thereby characterising and identifying any gross trends in the incidental catch abundance that could possibly be a result of fishing.

Four steps were taken in the analyses for incidental catch species on the Chatham Rise.

- The identification of a full list of incidental catch species from the OP database, and an appropriate cut-off to allow further analyses on the more abundant incidental catch species.
- The estimation of the proportional catch of this species subset from OP data.
- The scaling of OP catch to the total catch for a range of target fisheries, as determined by TCEPRs using a ratio estimation procedure.
- Identification of significant trends in abundance estimates from trawl surveys using a bootstrapping technique.
- Comparison of trends in the scaled catches to trends in the abundance estimate data from trawl surveys.
- Identification of trends in CPUE.

Invertebrate catches were investigated directly from OP data, as they could not be scaled to total catch. Abundance estimates from trawl surveys are also presented, but we have reservations about the effectiveness of the trawl as a sampling tool for bottom invertebrates, and the quality of species identification and recording has been highly inconsistent within the time series investigated.

2.1 Observer data (1985–86 to 1998–99)

The Ministry of Fisheries has operated an Observer Programme (OP) since the introduction of the Quota Management System in 1986. Observers on board vessels under the OP have also routinely collected a considerable amount of scientific data. On the Chatham Rise, however, OP coverage has been ad hoc, and not all fisheries have been covered in all years. Nevertheless, species composition of the catch (including non-quota species), length data, and records of invertebrates provide the only commercial catch data for many minor species in the area.

Catch by tow data were extracted from the OP database from the first records in 1985–86 to those from the 1998–99 fishing year. Data were checked for obvious errors in depth and amended where possible. Species recorded as caught were listed. Records with non-existent species codes, species codes designating the catch of non-fish species such as seabirds or fur seals (not invertebrates), or where the species was unknown, unidentified, or obviously incorrect were deleted. Records for which there were no catch weights for the species caught were also deleted. From a total of about 197 000 observer records, 194 736 were included in the final dataset. Of the 288 species of finfish and squids identified by observers within this period, just 4 species made up over 80% of the observed catch, and a further 36 species formed 97% of the observed catch (Table 2a). Of the 288 species, 11 were squids, mostly arrow squid (Table 2b). In addition, there were 10 miscellaneous codes that did not relate to a particular species or species group, and there were 14 invalid codes (Table 2b). In addition, there were 32 macroinvertebrate species codes recorded (Table 2b).

We could not estimate the trends in incidental catch for 288 species since the catch of these species was so low. To determine a shorter list of species, we explored the observed catches by target fisheries and by 200 m depth zones. We found that 94% of the observed catch occurred in 15 target fisheries (Table 3). There was also a depth structure to these fisheries, with a typically shallow grouping at about 200–600 m depths, a middle depth grouping 600–800 m deep, and a deepwater grouping in depths greater than 800 m (Table 4).

There was considerable overlap among the incidental catch species associated with each target fishery, particularly in the fisheries at 200–800 m depths. We therefore decided to explore trends in incidental catch of these fisheries by lumping them into three target fishery groups as follows (Table 5):

- A shallow group (mostly within 200–400 m) where the target species were principally alfonsino (code BYX, *Beryx splendens* and *B. decadactylus*), arrow squid (code SQU and NOS, *Notodarus* *sloanii* and *N. gouldi*), barracouta (BAR), gemfish (code SKI, *Rexea solandri*), jack mackerel (code JMA, *Trachurus* sp.) and tarakihi (code TAR, *Nemadactylus macropterus*).

- A middle depth group (mostly within 300–800 m) where the target species were principally hake (code HAK), hoki (code HOK), ling (code LIN), silver warehou (code SWA) and white warehou (code WWA, *Seriolella caerulea*).

- A deepwater group (mostly over 800 m) where the target species were black oreo (code BOE), orange roughy (code ORH) and smooth oreo (code SSO).

The species included in each target group were determined by the following criteria: they formed a target fishery on the Chatham Rise, the bulk of the catch could be assigned to a particular depth range, and they were part of the ITQ system. Red cod (*Pseudophycis bachus)* were excluded from the target groups because of the seasonality associated with that fishery, and spiny dogfish (*Squalus acanthias)* were excluded because we do not believe that they form a true target fishery.

The species investigated for incidental catch trends within each target grouping are listed in Table 6. The species mixes of rattails (Macrouridae) and of deepwater dogfish (mostly *Centroscymnus* and *Etmopterus* spp.) are not reported to species level in the observer database, and will be different in each target group. They were, however, included in the analysis as they form quite substantial portions of the incidental catch.

2.2 TCEPR data (1989–90 to 1998–99)

All fishing vessels over 28 m overall length are legally required to complete TCEPR forms for every tow carried out in New Zealand waters. These returns, held on a Ministry of Fisheries database, cover 99% of the fishing operations on the Chatham Rise in depths greater than 200 m. TCEPR data are available for the fishing years 1989–90 to 1998–99. The data can be extracted with a range of variables such as position, target species, method (e.g., bottom trawl or midwater trawl), time of fishing, duration of tow, vessel speed, wingspread, ground rope depth, and seabed depth. The position data give the coordinates of the start and finish of a tow. The greatest limitation of these data is that only the five most abundant species (greenweight) of the catch are estimated and recorded.

To extract catch data for the Chatham Rise, we defined an area bounded by latitudes 42° to 45° S and 172° E to 172° W. All bottom tows with starting positions within these bounds and a recorded headline height less than or equal to 15 m were included in the TCEPR and OP datasets.

2.3 Estimation of incidental catch within target group

The smaller the catch and the less abundant a species is, the more difficult it becomes to estimate its total catch by commercial vessels. This is because observer coverage of commercial vessels is inconsistent and samples only a fraction of the tows completed in a given year. In order to estimate changes in the catch of incidental catch and associated species not recorded by the TCEPRs, a method using the ratios of OP catch data to the TCEPR tow data was developed.

The OP catch of each incidental catch species listed in Table 6 was extracted for each target fishery group. A ratio (**R**) of the species catch to the total observed target species catch for a given year was calculated. To scale up the OP catch to a total estimated catch, **R** was multiplied by the sum of the TCEPR tow catches for target species within target group. We anticipated that the catch estimated by this procedure is considered to approximate the total annual catch among the target species. The OP ratio catch estimates were compared with the TCEPR tow catches to ascertain how well the two estimates matched each other, within target group. Where observer coverage has been poor, the ratio estimates are likely to be poor.

The TCEPR catch estimates and the OP ratio catch estimates derived from the method described above were plotted by target group, and compared for each of the species listed in Table 6.

Two further plots were made for middle depth and deepwater groups. First, a scaled catch was calculated by scaling the OP ratio catch to the dominant fishery catch (i.e., hoki in the middle group, orange roughy in the deepwater catch). Within the time period of the study, hoki catches on the Chatham Rise increased substantially, while catches of orange roughy dropped because of quota cuts. By scaling the ratio catch to the dominant fishery catch, we were able to compare relative changes in the catch of incidental catch species, as if the target catch had remained constant.

Secondly, an adjusted 'catch' was calculated and plotted. This adjusted catch scaled the OP ratio catch to fishery-independent abundance estimates of hoki and orange roughy. Catches and catch rates can change due to a number of factors that are not necessarily related to abundance (e.g., changes in quotas, fishing patterns, or availability). The adjusted catch allowed us to determine how incidental catch has changed with respect to declining abundance indices for both hoki and orange roughy. For hoki, we used the abundance index of hoki 3 years and older (3++) from the Chatham Rise trawl surveys to adjust the catches. For orange roughy, absolute abundance indices from the stock assessment model were used to adjust the catches.

Within the deepwater target group, the Chatham Rise was subdivided into three broad regions to cover parts of the Rise with different orange roughy stocks (Annala et al. 2001) and different fishing histories:

Northwest: 42°00' S – 43°30' S, 175°00' E – 177°30' W
An established fishery since the 1980s, with a shift from 1991–92 from a slope-based fishery to a more hill-based fishery, mostly operating on the complex of seamounts around longitude 180°.

Northeast: 42°00' S – 44°20' S, 177°30' W – 173°00' W
The historical centre of the fishery, based on the "Spawning Box", with more recent development of hill fishing grounds on the eastern end of the Rise.

South: 43°30' S – 45°00' S, 175°00' E – 175°00' W
Largely hill-based fishing grounds, with high catches on hill features early on in the fishery decreasing over time. Catches were maintained by discovery of new features. Substantial reductions in catches occurred from early 1990s.

2.4 Catch per unit effort

As part of the characterisation of changes in incidental catch fisheries on the Chatham Rise, an unstandardised catch rate (CPUE) was calculated and plotted for the main target and incidental catch species. For shallow and middle depth groupings, CPUE indices were calculated as follows:

The total catch was estimated using the OP ratio estimator except where this was unreliable (see Results, Section 3). In these instances the total estimated catch from the TCEPR tow data was used. The total catch was divided by the total number of tows that targeted any of the key species in a target group. The intention in this study was to look for indicative trends rather than to quantify CPUE.

In the deepwater fisheries, observed catches were divided by the number of tows (estimated from TCEPR tow data). It should be noted that the fishery for orange roughy and oreos targets aggregations of the species. It is often a hit-or-miss type of fishery as mobile aggregations can move rapidly, and the fishery often occurs over foul ground with high risk to fishing gear. Unstandardised CPUE is therefore regarded as an imprecise measure of relative abundance for orange roughy, but is thought to describe general trends in the target fisheries over time. The distribution of fishing in the deepwater fisheries is patchy, and CPUE trends of non-target species are unlikely to be closely related to trends in trawl survey abundance estimates.

2.5 Hoki trawl surveys, 200-800 m

Since 1992, trawl surveys of the Chatham Rise have been conducted annually from *Tangaroa* in January, using standardised gear and deployment procedures, and sampling depths of 200-800 m. Although there were some earlier surveys of the Chatham Rise (e.g., Fenaughty & Uozumi 1989, Livingston et al. 1991, Livingston & Schofield 1995), the analysis presented here was restricted to the time series in January, 1992-2000 (Horn 1994a, 1994b, Schofield & Horn 1994, Schofield & Livingston 1995, 1996, 1997, Bagley & Hurst 1998, Bagley & Livingston 2000, Stevens et al. 2001), because of the difficulties in comparing different vessels, gear, and seasons (e.g. Hurst & Schofield 1990).

Abundance estimation was carried out using the Trawl Survey Analysis Program (Vignaux 1994) and standard procedures and assumptions as described by Hurst et al. (1992). The bootstrap method of testing for significant trends followed that used by Bull et al. (2001). The slope of each abundance estimate series was calculated by least squares linear regression. The statistical significance of the slope was tested against the null hypothesis of no change in abundance. A bootstrap hypothesis test was used, in which the abundance estimates were randomised among years with independent lognormal distributions and c.v.s as given in the survey reports. Trends were considered significant if $p < 0.01$ and borderline significant if $0.01 < p < 0.05$. Only species for which abundance estimates were consistently presented in the survey reports were included. It should be noted however, that the known depth range of occurrence for some species is outside the depth range surveyed in this time series. Trends in abundance estimates may therefore be spurious, particularly where the surveys catch only the fringes of a species distribution, e.g., barracouta, tarakihi, oreo species, orange roughy.

2.6 Deepwater trawl surveys over 800 m

Two series of stratified random trawl surveys over parts of the Chatham Rise, are considered sufficiently similar to compare changes in species abundance between years. They include an oreo series carried out in October–November 1991 (McMillan & Hart 1994a), 1992 (McMillan & Hart 1994b), 1993 (McMillan & Hart 1995), and 1995 (McMillan & Hart 1998); and an orange roughy series carried out annually in July–August, 1984–90, and also in 1992 and 1994 (Anderson & Fenaughty 1996, Tracey & Fenaughty 1997). Although three different vessels were used, (*Otago Buccaneer, Cordella, Tangaroa*), each survey covered a similar area, with similar survey design and similar gear. Each series has been designed to estimate the abundance of the target species, and this has involved stratification to cope with the tightly aggregated nature of orange roughy and oreos that would not have been used for other, more widely dispersed, species. The surveys may not have covered the full distribution or depth range of some species, so care is needed in the interpretation of relative abundance estimates.

2.7 Use of orange roughy stock assessment modelling results

Estimates of stock size and changes over time for orange roughy have been made for northeast and northwest regions of the Chatham Rise. Stock reduction modelling has used relative abundance indices from trawl and acoustic surveys for the northeast stock (Francis 1999), and acoustic and egg production data for the northwest region (Francis & Bull 2000). These have estimates of abundance for orange roughy only, but can be used to adjust the catch of other species relative to orange roughy. Orange roughy catch levels have varied over time, and so there have been three steps taken in this analysis.

1) Estimation of catch of associated species from OP data using ratios to the deepwater target group catch (see above).
2) Scaling of these catch estimates to the 1989–90 catch of orange roughy (so the estimate for each year is that expected if the catch of orange roughy had remained constant).
3) These scaled catches were then adjusted by the relative change of abundance in the modelled orange roughy stocks. So, for example, where the orange roughy biomass in 1998–99 was estimated to be 63% of that in 1989–90, the scaled estimates of catch of associated species were multiplied by 0.63. Thus, if the catch of an associated species has maintained a constant proportionality to that of orange roughy, then we could deduce that it has declined in abundance to 63% of its initial abundance.

The stock assessment results were used with caution, as the estimated abundance values for each year are not precise. They do, however, enable us to extend the analysis of trends beyond simply describing estimated catch levels.

2.8 Macroinvertebrate incidental catch

Invertebrate catch data were extracted from hoki surveys of the Chatham Rise 1992-2000, and deepwater trawl surveys on the Northeast Chatham Rise from 1984 to 1994. The level of species identification and the taxonomic status of species have changed over time, and so broad groupings were defined: crab (e.g., *Lithodes murrayi, Neolithodes brodei*), coral (general), sponge (general), and echinoderm (various species). Records from the OP database were also compiled.

3. RESULTS

3.1 Total fishing effort and observer coverage

The number of observed tows within the defined area of the Chatham Rise varied considerably by fishery and by year (Table 7). Hoki and orange roughy fisheries received most of the observer coverage, but even within these fisheries the coverage from year to year was highly variable. For example, a comparison of the total number of target tows by month from TCEPR data (Table 8) with the number of observed tows by month (Table 9) demonstrates how low and sporadic the coverage for these fisheries has been. Overall, the proportion of observed tows in the shallow target group had a mean of 7% (Table 10). Within the middle depth target group, coverage was more consistent from year to year (except 1992–93 and 1996–97, Table 10), and most months were covered, except July and August. Overall, the mean proportion of observed tows in the middle target group was about 9% (Table 10). Coverage for the deepwater fisheries was slightly better, especially for the northeast area, where the proportion of trawls sampled was over 20% (Table 11). However, even in this region, the distribution of samples was uneven between months, and in some years only one or two months were covered. Differences in temporal sampling may also reflect differences in the fishing grounds, as fishing takes place in several areas depending upon the spawning condition of orange roughy.

The fishing effort, or number of tows used for CPUE analysis in each target group was highest in total for the middle depth target group (Table 12). The most variable was the deepwater target effort, but the only group showing a clear trend was the steady increase in effort within the middle depth target group from 2 562 tows in 1989–90 to over 11 000 tows by 1997–98 (Table 12).

Out of a total of 288 species listed in the OP database, hoki, orange roughy, and smooth and black oreo made up more than 80% of the observed catch (see Table 2). Most species listed in the observer database were finfish or shark species. A range of squid species was recorded, but most were arrow squid (codes SQU and NOS). Other codes included some miscellaneous categories such as 'RUB' for rubbish, and some invalid codes, such as 'BSM'. Most target fisheries succeeded in catching the species identified as 'target' in the greatest quantity (usually 50–75% of total observed catch) with the exception of ling (only 36%), jack mackerel (12%), red cod (40%), spiny dogfish (33%), silver warehou (38%), and white warehou (20%) (see Table 3). The incidental catch and the number of species codes in the incidental catch were generally highest in the larger fisheries (see Table 3). Notable exceptions were the low number of species for the size of the silver warehou fishery, and the disproportionately higher number of species compared with the incidental catch in the oreo and black oreo fisheries (see Table 3).

3.2 Incidental catch trends in shallow target fisheries

Within the shallow target group there was poor agreement between the TCEPR catch estimates and the estimated catches (using **R**) of most species (Figure 2). In many instances, the catches estimated by the ratio method were lower than the TCEPR catch estimates. There was limited correlation between the trends in the two estimates for barracouta, dark ghost shark (*Hydrolagus novaezealandiae*), jack mackerel, and red cod, but neither catch estimate method was considered to be reliable (Figure 2). With the exception of gemfish, which decreased, and alfonsino, which increased, neither the OP ratio catches nor the TCEPR catches showed any unidirectional trend in this group (Figure 2). It seems that gemfish catches, already small in the area, have become non-existent, while alfonsino catches increased in recent years (Figure 2). CPUE trends largely reflect the catch trends, with the possible exception of rattails, which formed an increasing portion of the catch in this shallow target group (Figure 2), while CPUE declined.

The trends in the shallow target fisheries on the Chatham Rise described above are summarised in Table 13, and compared with the abundance estimate trends in these species described in more detail in Section 3.4. Estimated catches and TCEPR catches suggest downward or nil trends in all species except alfonsino (Table 13). CPUE trends suggest that the catches relative to the number of tows has declined for many species, including alfonsino. The trawl survey abundance indices gave a different scenario, with the abundance estimates of barracouta, dark ghost shark, spiny dogfish, rattails, and red cod trending up, although none were statistically significant. Silver warehou, gemfish and tarakihi showed the most consistent downward trends in all categories, but the catch of these three species is so low in depths over 200 m on the Chatham Rise that it is difficult to conclude with any confidence that these trends are real. The survey c.v.s of these species were very high, indicating that the abundance estimates are unreliable.

It should also be noted that although hoki, silver warehou and ling were caught as a incidental catch in the shallow target group, the bulk of the catch for these species was taken in the middle depth group described below.

3.3 Incidental catch trends in middle depth target fisheries

Within the middle depth target group there was good agreement between our estimated catch (using **R**) and the TCEPR catch estimates for hoki, (Figure 3). The correspondence between our estimates and TCEPR catch weights for the other target species was less, although most followed similar trends within species giving some confidence in the approach taken. The main exception was hake (Figure 3). The OP ratio catch of hake spiked to almost 8 000 t in 1992–93, and 4000 t in 1996–97, a catch level not reached in the TCEPR reported landings. Observer coverage in those two fishing years was extremely poor in the middle depth target group and we suspect that this may have led to spurious estimates in those years for hake and several other species. The OP ratio catches spike upwards for many species in 1992–93 (Figure 3).

In this target group, the OP ratio catch of many species increased, including hoki, hake, ling, dark ghost shark, javelinfish, long-nose chimaerids, rattail species, ribaldo (*Mora moro*), spiky oreo, spiny dogfish, sea perch (*Helicolenus* sp), and skates (Rajidae) (Figure 3). The scaled catch (estimated catch of species scaled to highest hoki catch) shows that most of the trends in catch were a function of the increasing hoki catches. The adjusted catches (i.e., estimated catches adjusted relative to hoki trawl survey abundance estimates, Figure 4) however, suggest that even though hoki trawl survey abundance declined significantly within the time period, the catches of many of the associated species were sustained (Figure 3). The CPUE indices show a different view, with many species, including hoki, dark ghost shark, ling, silver warehou, stargazer (*Kathetostoma giganteum*), white warehou, pale ghost shark (*Hydrolagus* sp. B2), and shovelnose dogfish (*Deania calcea*) declining (Figure 3). The only increases in CPUE were for javelinfish (*Lepidorhynchus denticulatus*) and rattails (Figure 3).

The trends plotted in Figure 4 and the trawl survey abundance trends described in Section 3.4 are summarised in Table 14. The first two columns show that with the exception of hake, stargazer, rattails, and shovelnose dogfish, trends in estimated catches and TCEPR records agree. It appears that much of the increase in catch of these species was related to the increase in hoki catch and the increased number of tows targeting hoki (columns headed 'scaled to hoki catch' and CPUE). Only javelinfish and other rattails showed increases in CPUE and catch irrespective of the hoki catch. Spiny dogfish CPUE has also increased in recent years, but declined in the early part of the time series. Not all the species with increased catch showed increases in trawl survey abundance estimates. While javelinfish, lookdown dory (*Cyttus traversi*), spiny dogfish, and sea perch all showed significant abundance increases, with dark ghost shark of borderline significance, others, specifically hoki, hake, and stargazer showed a significant decline. This decline was consistent with the declining CPUEs also seen for these species.

3.4 Trends in trawl survey abundance indices (200-800 m)

The trawl surveys provide the most reliable estimates of changes in relative abundance of incidental catch species in the shallow and middle depth target fisheries. We did not split them by depth zone as the depth distribution does not necessarily correspond to the target groups identified in the commercial fisheries.

Relative abundance indices for hoki, hake, arrow squid, giant stargazer, hapuku (*Polyprion oxygeneios*), slender mackerel (Murphy's mackerel), ribaldo, bluenose (*Hyperoglyphe antarctica*), alfonsino, and orange roughy, all declined within the time series (Figure 4). Some of these were not statistically significant, largely because the c.v.s of individual surveys and the variability between surveys was high (Table 15). Increases in relative abundance indices were seen for spiny dogfish, sea perch, lookdown dory, lemon sole (*Pelotretis flavilatus*), school shark (*Galeorhinus galeus*), orange perch (*Lepidoperca aurantia*), dark ghost shark, javelinfish, black oreo, red cod, and oblique banded rattail (*Caelorinchus aspercephalus*) (Figure 5) with the last five not statistically significant (Table 15). Little or no trend was observed for pale ghost shark, white warehou, big-eyed rattail (*C. bollonsi*), spiky oreo (*Neocyttus rhomboidalis*), ling, smooth oreo, shovelnose dogfish, or silver warehou (Figure 6, Table 15).

The trends in abundance indices of species estimated from the surveys correlated with trends in commercial catch in different ways. For example, there was an inverse relationship between the abundance of hoki and its catch. The abundance of hoki has declined significantly since 1993 (see Figure 4), while the catch rose from about 10 000 t to 65 000 t within the same period (see Figure 4). The same is true for hake and ribaldo, whereas many of the incidental catch species such as spiny dogfish, lookdown dory, and sea perch that have been caught in increasing amounts have also increased in relative abundance (compare Figures 3 and 5). There is also a positive correlation between trawl survey abundance indices and the estimated catch levels for javelinfish and one of the more dominant rattails (i.e., oblique banded rattail). Interpretation of rattail abundance changes in relation to trends in the commercial data are difficult however because the species composition of rattails changes with depth.

3.5 Shallow and middle depth macroinvertebrate incidental catch

The invertebrate records from the observer database suggest increasing incidental catch trends in sponge, octopus, squids (excluding arrow squid), scampi, and echinoderms (Figure 7a, Table 16). The data, however, are unreliable in that many invertebrate groups were caught but not recorded by observers in the early part of the time series and species identification has been unreliable with no user-friendly identification guides available for observers. Abundance indices of invertebrate groups mostly show an increase although highly variable, within the time series, with the exception of arrow squid (Figure 7b, Table 17). We are cautious in our interpretation of these data, as it is only since 1997 that invertebrate species have been consistently recorded in trawl survey records. Further, the high c.v.s for most species indicate the unsuitability of the trawl as a sampling tool for benthic fauna.

3.6 Incidental catch trends in deepwater target fisheries

The level of observer coverage and confidence in the ratio method was variable between areas and years for the deepwater fishery. Coverage of the northwest fishery, as represented by the percentage of total orange roughy catch observed, varied between 2 and 45% (see Table 11). Levels were generally 10–20%, although 3 years had less than 5% of the catch observed. The northeast fishery has generally been well covered by observers, with 20–40% of the reported catch observed in most years. Coverage of the South Rise has been less, and more variable, than that of the northeast. There was poor coverage of less than 10% in 2 years, and in others between 10 and 20% of the catch.

Catch levels estimated from OP data using the ratio method have been compared with estimated catches from TCEPR tow data for each area (see upper 2 panels of Figures 8, 9, 10). In the northwest fishery, there was good correspondence between estimated and reported catch of orange roughy. It was poorer for the other main quota species of hoki, black and smooth oreo. This is probably a reflection of variation in fishing distribution patterns between years, when the fishery might differ in hill or slope grounds, and also depth of fishing. For the other species, or groups of species, the OP ratio catch was generally above the TCEPR catch, which is expected with discarding of non-commercial species. An exception is Baxter's lantern dogfish (*Etmopterus baxteri*), where more were reported than estimated from the OP database, but this was for one year only and involved a small catch. A similar pattern is seen in the Northeast Chatham Rise, where orange roughy and oreo species show a reasonable fit between OP ratio catches and TCEPR tow estimates. The non-quota incidental catch species are under-reported in catch statistics. Again with the South Chatham Rise, there is generally a good correspondence between the OP estimated catch and the TCEPR catch of commercial species. The marked exceptions to this, for example orange roughy in 1996 and smooth oreo in 1990, probably result from the low levels of observer coverage in those years, and the estimates for these years are probably unreliable.

Generally, the agreement between the OP ratio estimates of catch and TCEPR estimates of catch for commercial species was high, and gives confidence to the application of the ratio method to the other species.

3.6.1 Northwest Chatham Rise

The OP ratio catch of incidental catch species varied between years (top panel of Figure 8). For many there was a strong up-and-down pattern (e.g. basketwork eel (*Diastobranchus capensis*), Johnson's cod (*Halargyreus johnsonii*), hoki, seal shark (*Dalatias licha*)), with no obvious overall trend. However, for the deepwater dogfish group, rattails, ribaldo, slickheads (Alepocephalidae), and smooth oreo there has been a general increase in catch over time, especially in recent years. This has occurred against a similar orange roughy catch each year (except for 1991–92). This is seen in the middle panel of Figure 8, where catches have been standardised to the orange roughy catch in the first year (1989–90).

Trends in abundance over time derived from adjusting catch by the orange roughy modelled biomass, are shown in the fourth panel of Figure 8 (adjusted catch). Overall trends of increasing abundance are seen with the deepwater dogfish group (primarily *Centroscymnus* spp.), hoki, rattails, slickheads, and smooth oreo. Basketwork eel and black oreo have declined in recent years.

CPUE results are plotted in the bottom panel of Figure 8. These show a similar pattern to the other analyses. A linear regression line is drawn to show the general trend, but it does not represent a statistically significant relationship.

3.6.2 Northeast Chatham Rise

Catches in this area have varied in the last decade. The area was closed to commercial fishing for several years, and catches were taken from new fishing grounds to the east. However, despite these spatial changes, catch levels since 1992–93 have been similar which means that the upper three graphs in Figure 9 are comparable for that period of time. From 1989 there are declining trends in catch for basketwork eel, black oreo, Johnson's cod, orange roughy, rattails, and ribaldo. For several of these there were very high catches in 1989–90 and 1990–91, and after that (possibly associated with orange roughy quota cuts) catches were at much lower levels.

Trends in adjusted catch (linked to the modelled orange roughy abundance estimates) and CPUE were similar for most species. Basketwork eel declined to 1995–96 (with a blip in 1994–95), and since then has been stable at low levels. Several species were important incidental catch in the early years, but have decreased to low levels (e.g., black oreo, Johnson's cod, rattails, ribaldo). Seal shark, deepwater dogfish, and slickheads show an increasing trend in the last few years.

3.6.3 South Chatham Rise

The catch of orange roughy in the southern area has decreased considerably since the early 1990s (Figure 10). Accompanying this has been a decrease in the OP ratio estimated catch of Baxter's lantern dogfish, Johnson's cod, and probably basketwork eel in recent years. Slickheads and rattails have shown an increase in catch. Relative to the orange roughy catch in 1989–90, these increases are strong (middle panel) and catches of black and smooth oreo, and seal shark have also increased. Note that the low estimated catches in 1996 (1995–96) could have resulted from low and unrepresentative levels of observer coverage in the fishery.

These trends are reflected also in CPUE (Figure 10, lower panel). The catch of basketwork eel was variable, but has declined in the last few years. Black oreo, seal shark, deepwater dogfish, hoki, ribaldo, and smooth oreo had variable catch rates between years with little overall trend. Baxter's lantern dogfish in all analyses had a very high level of catch in 1989–90, but has been low since. Rattails and slickheads appear to have become more abundant in the depth range covered by the orange roughy fishery.

Trends, summarised in Table 18, have been assessed from examining all the analyses, and subjectively evaluating common patterns in changing abundance or catch estimates.

3.7 Trends in deepwater trawl survey abundance indices

3.7.1 Northeast Chatham Rise

Abundance indices for orange roughy and most incidental catch species showed a decreasing trend over the 10-year period examined (Table 19). For 20 of the 28 species considered here, the mean c.v. during the trawl survey series was less than or very near 30%, implying that the survey design was appropriate for monitoring changes in abundance in the area covered.

Decreased species abundance occurred for orange roughy, basketwork eel, Baxter's lantern dogfish, white rattail (*Trachyrincus aphyodes*), ribaldo, pale ghost shark, Johnson's cod, long-nosed and wide-nosed chimaeras, hake, Mahia rattail (*C. matamua*) and small-headed cod (*Lepidion microcephalus*). Increased abundance was suggested for shovelnose dogfish and longnose velvet dogfish (*Centroscymnus crepidator*) only. All other species showed little change, or were highly variable between years. Despite their high c.v.s, many shark species appeared less affected by the orange roughy fishery than teleosts. Several of the slickhead, oreo, and rattail species which showed little change in abundance have a wider geographical and depth range than that of the target orange roughy fishery.

Changes in the abundance indices are also plotted in Figure 11. A linear trend line has been fitted, but regression analysis was not used to determine the trend, only to indicate increased or decreased abundance.

The trawl survey covered this area between 1984 and 1994. There have been no comparable surveys since then, but it was intended that estimation of relative abundance from this study could be used to extend the time period and enable a more complete evaluation of trends over much of the duration of the orange roughy fishery. Several species are common to both data sets, and relative abundance has been standardised for both trawl survey indices and CPUE to 1990. This enables the trends in both sets of data to be viewed together. Basketwork eel declined dramatically during the 1980s to low levels by 1990 (Figure 12). The trawl survey results in 1992 and 1994 indicated a stabilising of abundance, while the overlapping observer source showed an increase and then strong decrease before levelling at very low abundance. Seal shark abundance from the observer data shows an increase during the 1990s, which is not seen in the trawl survey results. Correspondence between the observer-fishery trends and the trawl surveys is also relatively poor for ribaldo and Johnson's cod, where trawl survey abundance is stable against a decrease in abundance estimates from fishery data. Smooth oreo estimates of abundance show small changes throughout the trawl survey series, yet large fluctuations from observer-fishery estimates with an increase in the early 1990s and a subsequent slow and irregular decline. Baxter's lantern dogfish shows little change in trawl survey abundance estimates, with variable and inconsistent changes in the fishery data with two years where relatively high catch rates were recorded.

3.7.2 South Chatham Rise

The oreo survey series from 1991 to 1995 covers a much shorter time span than that for orange roughy. A total of 30 species was examined with 23 having acceptable c.v.s to describe a meaningful trend (Table 20). The main target species in this area, smooth oreo, showed a strong decline, while that of the other commercially exploited black oreo remained relatively stable. No other species decreased in abundance. Most exhibited no significant change in abundance, while the following 11 species increased in abundance: Baxter's lantern dogfish, brown slickheads, pale ghost shark, basketwork eel, warty squid (*Moroteuthis* sp.), ridge-scaled rattail (*Macrourus carinatus*), long-nosed chimaera (*Harriotta raleighana*), four-rayed rattail (*C. subserrulatus*), black slickhead, and serrulate rattail (*Coryphaenoides serrulatus*).

Changes are also plotted in Figure 13. Unlike the orange roughy fishery on the northeast Chatham Rise, the southern area fisheries appear to have had little effect on associated incidental catch species. Comparison of abundance trends of incidental species between oreo surveys and observer-fishery data, standardised to 1992, are made in Figure 14. This analysis suggests basketwork eel and black oreo increased during the early to

mid 1990s before decreasing. There was little trend in hoki, Baxter's lantern dogfish, smooth oreo, and Johnson's cod. Orange roughy abundance decreased consistently throughout this time period.

3.8 Deepwater invertebrate incidental catch

Data on invertebrates were found to be limited and inadequate for meaningful interpretation of changes over time. The taxonomic status of many species was poorly known when the deepwater fishery began in the 1980s, and there was inconsistent recording of the catch. Coral and sponge, although occasionally caught in the trawl, were not recorded until the 1992 survey, and much more was recorded in 1994 despite anecdotal evidence from scientists involved in the early surveys that much more was caught in the 1980s (but not entered on the catch forms). In addition, a fish trawl with large and heavy ground gear is a poor sampling tool, and crushes much of the invertebrate catch, making it difficult to identify and quantify.

4. DISCUSSION

4.1 Shallow depth fisheries

The changes in fishing on the Chatham Rise within the time period observed seem to have had the least effect on the incidental catch associated with the shallow target group. The number of tows from year to year has not altered or increased in any systematic sense. Catches and CPUE of barracouta have declined, while the abundance estimates appear to trend upwards. However, the estimates of catch from both TCEPR tow data and the OP ratio method do not correlate well and are unreliable. The depth range covered by the analysis and the trawl surveys may not provide reliable indices of change in this stock as much barracouta catch is from waters less than 200 m. The same is true for red cod, tarakihi, and gemfish. Further, there may be two separate stocks of some of these species, some associated with the Chatham Islands, and others associated with the east coast of the South Island. The hoki incidental catch in this target group probably represents mostly juvenile fish (less than 4 years old) (Ballara & Livingston 2001). The abundance of the juvenile hoki, in particular 1 and 2 year old fish varies significantly from year to year, depending on recruitment strength to the Chatham Rise, which is the main nursery ground for hoki. Recruitment in recent years has been weak, giving a borderline downward trend in juvenile hoki on the Chatham Rise within the time period examined (Livingston et al. 2002). The downward trend in trawl survey abundance of stargazers (mostly giant stargazer) maybe statistically significant. A study exploring changes in species composition on the Chatham Rise 1992–2001 using the same trawl survey series used in our study found significant trends in other species that could not be investigated within the scope of the present study, notably lemon sole and school shark (Livingston et al. 2002).

Another study (Bull et al. 2001) investigated community structure and species associations on the Chatham Rise from trawl surveys 1992 –1999 identified four species groupings: the first in 200–350 m depths, was characterised by hoki, dark ghost shark, silver warehou, and spiny dogfish; a second in 350–550 m depths was characterised by hoki, big-eye rattail, ling, javelinfish, and lookdown dory, and two others, 550–800 m depths separated by location on northern or southern slopes of the Rise – were both characterised by hoki, javelinfish, big-eye rattail, ling, and pale ghost shark, but to the north, shovelnose dogfish and spiky oreos were a characterising species, while to the south black oreo were found (Bull et al. 2001). These depth groups differ from the target fishery groups presented in our study. However, this is not unexpected since commercial fisheries target specific parts of a fish population. Thus, although the fish community as a whole may have silver warehou as a characterising species of a shallow group, the fishery targets larger fish, so that more catch comes from depths over 400 m than rather than the shallower depths. In retrospect, perhaps red cod could have been included in the shallow target group, while alfonsino might have been better analysed as part of the middle depth target group. However, the number of tows that targeted alfonsino was a very small proportion of the total and is unlikely to make much difference to the overall conclusions of the study.

4.2 Middle depth fisheries

The changes in fishing on the Chatham Rise have clearly affectedthe catches in this target group. The effort (mostly targeting hoki) has risen almost 4.4 fold, with the number of tows per fishing year rising from 2 562 in 1989–90 to about 11 503 in 1998–99. The result has been marked increases in the catch of several incidental catch species, in particular javelinfish, lookdown dory, spiny dogfish, sea perch, rattails, and dark ghost shark. Because there appears to be reasonable correlation between TCEPR catch estimates and the OP ratio catch estimates in most years, we believe that these trends may be real. We do have reservations about the data for some years where the OP ratio catches were spiky, or for verifiable species such as hake, where the OP ratio catch was higher than the TCEPR catch (Figure 3). A more detailed analysis would better determine the effect of low observer coverage on the OP ratio catches. Some of the species associated with the middle depth target group appear to have increased in abundance (javelinfish lookdown dory, spiny dogfish, sea perch) but others, including hoki, hake, dark ghost shark, and some rattail species have decreased. It is also of interest that most of the species showing no changes in catch showed a declining CPUE. A study exploring changes in species composition on the Chatham Rise 1992-2001 using the same trawl survey series used in our study found significant trends in other species that could not be investigated within the scope of the present study.

The Chatham Rise community study by Bull et al. (2001) reported changes in abundance of key species (also referred to here) but did not find any changes in species associations within the time period. It is clear that the large increase in fishing activity within this target group may have some effect on abundance estimates in some species, notably declines in hoki, hake, and dark ghost shark. Other species appear to have increased in abundance, in particular, javelinfish, rattails, lookdown dory, spiny dogfish, and sea perch. It is unclear whether these species have increased in abundance in response to the dropping hoki abundance (which dominates the middle depths benthic fish community on the Chatham Rise) or if their vulnerability to the bottom trawl has merely increased as they move into habitats previously occupied by fish whose abundance has declined significantly. Bull et al. (2001) reported a rise of 0.6 °C in mean bottom temperature at 450 m in the area. It has also been reported that there is an increased abundance of spiny dogfish in New Zealand waters generally, not just the Chatham Rise (Hanchet & Ingerson 1997). Clearly, these maybe contributing factors in the changes reported in our study.

4.3 Deepwater fisheries

The level of observer coverage in the deepwater fisheries was high compared with shallow and middle depth fisheries. Together with the research trawl survey time series on the northeast and southern Chatham Rise, the results are unequivocal. The orange roughy and oreo fisheries have clearly had an effect on associated species, although changes vary between areas. In general, most incidental catch species showed a decline, with some significant reductions for ribaldo and basketwork eel. Orange roughy decreased in abundance in all regions of the Chatham Rise, but the change in some incidental catch, such as rattails and deepwater dogfish, has been less marked than for other species.

The ratio estimation method appears to work well, but where trawl surveys have been carried out, we have put greater emphasis on those results, particularly where there is direct comparability between surveys over time. Comparison of trends between trawl survey abundance estimates and estimated catches showed variable agreement between the two datasets. However, the period of overlap is short, and fishing patterns changed substantially in the early 1990s with quota changes. The focus in this study has been on relative trends in estimated catch. Catchability for the various species is unknown, and it is therefore difficult to measure changes in absolute abundance. The broad similarity in trends between all methods applied gives greater confidence in the overall changes observed.

Care is needed in the interpretation of trends in incidental catch species over time, especially with the deepwater species where area closures, changes in quota levels, and variation in the distribution of the fishery can all combine to confound estimates of changes in incidental catch level. The surveys and the fisheries are species specific, and the fisheries usually aim to minimise incidental catch. Deepwater incidental catch data plots in the highly targeted fisheries for orange roughy and oreos were quite variable. In northwest and northeast areas, orange roughy is the clear target, but on the South Chatham Rise oreos and orange roughy co-occur on small seamount features, and catches often contained a greater mix of species. The scaling of estimated catch to orange roughy, rather than oreos, was done for two reasons: firstly the target species of the observed trips has generally been orange roughy, and secondly the fishery practise has usually been to target orange roughy as a preferred species, with targeting oreos once the orange roughy quota has been nearly reached, when the level of incidental catch, and hence available oreo quota, can be determined. However, in some years when the level of orange roughy catch observed was extremely low this may have caused inaccurate estimates of incidental catch.

Some species were not well identified within the OP data. The deepwater dogfish group is assumed to comprise mainly *Centroscymnus* spp., as other deepwater dogfish such as seal shark, Baxter's lantern dogfish, and shovelnose dogfish are usually identified separately. However, this can vary between individual observers, and the lack of shovelnose dogfish identification, an important species in the northeast trawl survey, means that trends in the deepwater dogfish category probably represent a wider mix of species.

4.4 Environmental factors

Changes in fish populations can result from real changes in abundance and changes in availability and catchability (and therefore the occurrence of the species in the trawl). While intense fishing can be one cause of these changes, changes in the environment can also impact on population levels and distributions. The Chatham Rise oceanographic environment is influenced by its bathymetry, and the juxtaposition of the Sub-Tropical and Sub-Antarctic water masses, with the STF lying along the crest of the Rise, has not changed within the study period. Clark et al. (2000) noted a very stable temperature and salinity pattern at depths of 800–1000 m on the northern slopes of the Chatham Rise between 1982 and 1997. However, there appears to have been a significant increase in mean bottom water temperature on the upper slopes in the area in January since 1992 (Bull et al. 2001).

A plot of mean sea surface temperature in January at 44° S 180° in Figure 15 shows that an increase in surface temperature has occurred within the time-frame of the Chatham Rise hoki trawl survey time series, but there is no obvious long-term trend visible from 1971 to 2000 (see Figure 15). Further, the Southern Oscillation Index (SOI, plotted in Figure 16), which gives a global indicator of the climate regime in New Zealand in a given year, has gone from mean negative values (cooler temperatures, higher frequency of westerly and southwesterly conditions) in the early part of the study period to a more positive mean value (warmer temperatures, higher frequency of easterly conditions). One effect of SOI that has been explored for several fish species in New Zealand is on the relative year class strength, or survival success of the young larvae when they first hatch. The survival of hoki is negatively correlated to SOI (Bull & Livingston 2001), and it is likely that the lack of recruitment in recent years is contributing to the decline in biomass on the Chatham Rise.

5. CONCLUSIONS

The trends in incidental catch presented for the middle depth and deepwater target fisheries are more reliable than for the shallow target fisheries, largely due to the higher observer coverage and similarity between observer data and research surveys. Coverage in the shallow fisheries was extremely low (6.9%) and variable. In the middle depth fisheries, coverage was a little better (9%) with a large number of tows, but the seasonal variation was great and did not always coincide with fishing effort in the area. The observer coverage was not only higher for the deepwater fisheries (10% for northwest and southern areas, 21% for the northeastern area), but also occurred in most years during the periods of greatest fishing effort.

The trends show that there have been changes in the incidental catch composition and abundance of fisheries on the Chatham Rise since fishing year 1989–90. The abundance indices for these species show some significant trends. Within the time period examined, the fishing effort on hoki has increased approximately 4-fold, while the abundance index of hoki from trawl surveys has declined about 6-fold. It is likely therefore, that the changes in other fish populations in these depths at least are related in some way to the fishing effort on hoki. In deepwater, effort on target fisheries has remained more or less stable within the time period (despite decreasing quotas), but declining trends in some incidental catch species were still apparent.

Interactions and interrelationships between the various fish species and populations on the Chatham Rise are unknown, and cannot be addressed with the data currently available. Similarly, the influence of environmental factors is uncertain. The current study has determined that changes have occurred in the abundance of incidental catch in the main trawl fisheries, but our understanding of the causes is limited. Future progress in addressing such issues will depend upon a higher level of observer coverage and sampling in the main fisheries, and continuation of trawl surveys. Without a reasonable tool to reliably monitor these changes, progress and understanding will continue to be poor. More training is also required for observers in fish and invertebrate incidental catch identification.

6. FUTURE RESEARCH RECOMMENDATIONS

This project was a pilot study, especially with attempts to use OP data to estimate the catch of non-targeted species. This is an important source of information, as trawl surveys do not fully cover a fishing area, or a long time period. Analyses indicate changes in catch or abundance of a number of incidental catch species associated with the major trawl fisheries for hoki and orange roughy on the Chatham Rise. Ongoing monitoring of associated species should occur at regular intervals, but there are several data issues that need to be addressed.

- Adequate levels of observer coverage in the fishery and training to ensure representative sampling and identification of the commercial catch.
- Identification of species (both observer and research), in particular invertebrate fauna.
- Use of the daily processing returns in the TCEPR database could be considered in any future study.
- More species could be examined (only the major incidental catch species were included here) if there is improved reporting of some of the less abundant species.
- Interpretation of changes in abundance and catch requires other concurrent research on the inter-relationships among species, and the effects of environmental change.

Interpretation of changes in catch needs to incorporate changes in fishing patterns. A more detailed assessment of spatial and temporal distribution of catch and effort could be warranted to improve confidence that changes are related to abundance, rather than an artefact of changes in the distribution of the fishery between years.

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Table 1: Catch histories (t) of important fisheries on the Chatham Rise. (Data source: Annala et al. 2001)

Fishing year	Hoki	Hake	Orange roughy	Oreo
1989–90	13 000	977	31 400	16 100
1990–91	12 500	991	20 600	16 700
1991–92	46 000	2 454	16 400	17 500
1992–93	43 000	2 775	14 000	17 100
1993–94	24 000	2 898	13 500	17 400
1994–95	39 000	4 094	8 000	14 200
1995–96	50 000	4 760	7 500	14 500
1996–97	58 000	4 761	7 400	13 800
1997-98	74 000	4 763	8 000	13 300
1998-99	74 000	4 524	7 400	12 500
1999-00	57 000	4 700	7 800	12 900

Table 2a: The total catch weight (kg) by species of the more common fish and squid on the Chatham Rise, as recorded in the observer database. (Data source: Observer database fishing years 1985–86 to 1998–99.)

Species code	Common name	Observed catch (kg)	% Total observed catch
Finfish and squid			
HOK	hoki	52 730 864	37.50
ORH	orange roughy	39 193 275	27.88
SSO	smooth oreo	16 116 420	11.46
BOE	black oreo	7 689 267	5.47
RAT	rattails	2 740 055	1.95
LIN	ling	2 691 348	1.91
SWA	silver warehou	2 643 498	1.88
HAK	hake	1 909 765	1.36
JAV	javelinfish	1 542 421	1.10
BAR	barracouta	1 367 295	0.97
SPD	spiny dogfish	832 120	0.59
SQU	arrow squid	821 497	0.58
GSH	ghost shark	732 619	0.52
SPE	sea perch	647 456	0.46
DWD	deepwater dogfish	607 407	0.43
STA	giant stargazer	437 404	0.31
RIB	ribaldo	404 037	0.29
SND	shovelnose spiny dogfish	398 564	0.28
LDO	lookdown dory	368 187	0.26
WWA	white warehou	352 257	0.25
JMA	jack mackerel	329 472	0.23
RCO	red cod	228 299	0.16
BYX	alfonsino & long-finned beryx	226 110	0.16
SLK	slickhead	180 900	0.13
SOR	spiky oreo	157 495	0.11
ETB	Baxter's lantern dogfish	153 063	0.11
GSP	pale ghost shark	147 623	0.10
HJO	Johnson's cod	114 947	0.08
OEO	oreos	110 722	0.08
BEE	basketwork eel	106 794	0.08
SSK	smooth skate	87 665	0.06
LCH	long-nosed chimaera	84 657	0.06
FHD	deepsea flathead	79 125	0.06
CDL	cardinalfish	60 912	0.04
ETM	deepwater dogfish	54 543	0.04
TAR	tarakihi	53 255	0.04
RBT	redbait	44 646	0.03
Total	All species above	136 445 984	0.975
Grand total	All finfish and squid species on observer database (288)	140 598 077	1.00

Table 2b. Catch weight (kg) of squids, macroinvertebrates, miscellaneous and invalid code categories as recorded in the observer database. (Data source: Observer database fishing years 1985–86 to 1998–99.)

Species code	Common name	Observed catch (kg)	% of total
Squids only			
SQU	arrow squid	821 497	84.9
WSQ	warty squid	79 338	8.2
NOS	arrow squid	57 124	5.9
MIQ	warty squid	5 663	0.6
RSQ	red squid	3 035	0.3
GSQ	giant squid	923	0.1
	5 other squid species	228	0.0
Total squid catch (kg)		**967 808**	
Macroinvertebrates			
SCI	scampi	290 303	66.1
ONG	sponge	74 690	17.0
SFI	starfish	34 562	7.9
CRB	crab	14 322	3.3
JFI	jellyfish	9 807	2.2
OCT	octopus	2 595	0.6
SCC	sea cucumber	1 974	0.4
SPI	spider crab	1 750	0.4
ANT	sea anemones	1 440	0.3
COU	coral	1 397	0.3
CRU	crustacean	1 204	0.3
CTU	Cook's turban shell	1 068	0.2
SUR	kina	9 68	0.2
ECH	Echinodermata	690	0.2
URO	sea urchin	612	0.1
ECN	Echinoid (sea urchin)	544	0.1
SAL	salps	496	0.1
	15 other species	646	0.1
Total catch (kg)		**439 068**	

Species code	Common name	Observed catch (kg)	% of total
Miscellaneous			
RUB	rubbish	25 371	96.3
ROE	roe	441	1.7
MEA	meal	232	0.9
SEA	seal	200	0.7
OIL	fishoil	37	0.1
KBL	bull kelp	35	0.1
SEO	seaweed	15	0.0
EGC	egg case	6	0.0
FIH	fish heads	5	0.0
MUD	mud	1	0.0
Total catch (kg)		**26 343**	
Invalid codes			
CRS		100	28.7
PSH		80	23.0
LFC		48	13.8
NUB		30	8.6
BSM		22	6.3
WSH		16	4.6
DSO		15	4.3
BSN		12	3.4
LNC		6	1.7
RIG		6	1.7
SPN		5	1.4
PRG		4	1.1
SPB		2	0.6
FLT		1	0.3
SBX		1	0.3
Total catch (kg)		**348**	

Table 3: The total observed catch of target and incidental catch by target fishery (column 2) and the percentage of fish each target fishery takes out of the grand total (column 3). The catch weight of the target species and its proportion of the total catch within each fishery (columns 4, 5). The incidental catch of finfish and arrow squid species within the main target fisheries on the Chatham Rise (column 6), with data on the main incidental species and its proportion of the target catch (column 7), and total number of incidental catch species in each fishery (column 8). *(Data source: Observer database fishing years 1985–86 to 1998–99.)*

1. Target fishery	2. Total observed catch (kg) by fishery	3. % of each target fishery	4. Target species catch (kg)	5. % of total within target fishery	6. Incidental catch within target fishery (kg)	7. Main incidental catch species and % of target catch	8. Number of species in incidental catch
Hoki	64 458 652	48.6	50 674 470	78.6	13 784 182	Ling (3%)	222
Orange roughy	53 316 455	40.2	38 679 850	72.5	14 636 605	Smooth oreo (19%)	198
Oreo#	3 563 484	2.6	3 143 586	88.2	419 898	Orange roughy (3%)	85
Black oreo	3 028 102	2.2	2 155 689	71.2	872 413	Smooth oreo (16%)	80
Barracouta	2 291 516	1.7	1 166 559	50.9	1 124 957	Jack mackerels (12%)	92
Silver warehou	2 116 751	1.5	580 128	27.4	1 536 623	Hoki (38%)	50
Hake	1 395 311	1.0	710 970	54.6	590 868	Hoki (14%)	83
Arrow squid	955 728	0.7	623 070	65.2	332 658	Hoki (6%)	66
Ling	822 947	0.6	294 149	35.7	528 798	Hoki (34%)	61
White warehou	126 545	0.09	24 785	19.6	101 760	Hoki (47%)	29
Spiny dogfish	119 124	0.08	32 643	27.4	86 481	Barracouta(15%)	51
Alfonsino*	95 656	0.07	3 139	50.0	62 517	Orange roughy (15%)	41
Red cod	80 234	0.06	31 749	39.6	48 485	Silver warehou (21%)	28
Murphy's mackerel†	76 310	0.05	9 237	12.1	67 073	Barracouta (37%)	42
Tarakihi	16 715	0.01	6 026	36.0	10 689	Hoki (30%)	26
Totals	132 529 101	100	98 136 050	-	34 393 051	-	-

includes all oreo species, * includes *Beryx splendens* and *Beryx decadactylus*, † includes all jack mackerels

Table 4: Number of observed bottom tows for target species* by 200 m depth zones† on the Chatham Rise. (Data source: Observer database fishing years 1985–86 to 1998–99.)

	Depth range (m)							
	200–400	400–600	600–800	800–1000	1000–1200	1200–1400	1400+	Total observed tows
BAR	260	2	-	-	-	-	-	262
BYX	22	5	16	-	-	-	-	43
JMA	9	2	-	-	-	-	-	11
RCO	19	-	-	-	-	-	-	19
SCI	716	243		-	-	-	-	959
SPD	25	1	-	-	-	-	-	26
TAR	8	-	-	-	-	-	-	8
SQU	109	4	-	-	-	-	-	113
SKI	2	-	-	-	-	-	-	2
SWA	115	185	-	-	-	-	-	300
HAK	12	210	3	-	-	-	-	225
HOK	437	5 659	1 207	33	2	-	-	7 338
LIN	123	19	-	-	-	-	-	142
BOE	-	-	206	352	19	-	-	577
OEO	-	1	98	384	80	1	-	564
ORH	3	13	962	3 080	1 674	401	23	6 156
SSO	-	-	73	485	334	5	1	898
Total	1 860	685	1 358	1 254	435	407	24	17 643

* See Table 2a for species codes.

† Depth range is defined from the depth of the seabed as recorded by the observer.

Table 5: Target groupings used for estimation of total catch and CPUE analyses of incidental catch species.

Species	Common name	TCEPR catch (t) 1989–90 to 1998–99	Observed catch (t) 1989–90 to 1998–99
Shallow target group			
BAR	Barracouta	27 710	606
BYX	Alfonsino	2 586	0
JMA	Jack mackerel, Murphy's mackerel	4 154	19
SKI	Gemfish	266	0
SQU	Arrow squid	44 733	521
TAR	Tarakihi	1 012	9
Middle depth target group			
HAK	Hake	23 132	1 042
HOK	Hoki	341 232	32 602
LIN	Ling	17 006	1 474
SWA	Silver warehou	16 400	1 030
WWA	White warehou	2 631	211
Deep water target group			
BOE	Black oreo	11 719	2 439
OEO	Mixed oreos	2273	9
ORH	Orange roughy	116 783	21 763
SSO	Smooth oreo	57 211	10 183

Table 6: Species investigated as incidental catch and catch within each target group.

Shallow target group		
Alfonsino	Ling	Red cod
Barracouta	Spiny dogfish	Gemfish
Dark ghost shark	Squids (arrow)	Tarakihi
Hoki	Stargazer	Silver warehou
Murphy's mackerel	Rattails (mixed)	
Middle depth target group		
Dark ghost shark	Lookdown dory	Silver warehou
Hake	Rattails (mixed)	Pale ghost shark
Hoki	Ribaldo	Stargazer
Javelinfish	Spiny dogfish	White warehou
Ling	Sea perch	Shovelnose dogfish
Deep water target group		
Basketwork eel	Orange roughy	Johnson's cod
Black oreo	Rattails (mixed)	Ribaldo
Seal shark	Deepwater dogfish (mixed)	Slickhead
Hoki	Baxter's lantern dogfish	Smooth oreo

Table 7: Total number of bottom tows for target species* in each target group on the *Chatham Rise*. (*Data source:* Observer database fishing years 1985–86 to 1998–99.)

Fishing year	BAR	BYX	HAK	HOK	JMA	LIN	SKI	SQU	TAR	SWA	WWA	BOE	OEO	ORH	SSO	Total
1985–86	8	-		338	-	-	-	-	-	-	-	-	30	80	13	469
1986–87	45	-	1	933	6	1	-	36	3	133	-	85	144	691	174	2 252
1987–88	87	-		428	3	3	-		5	80	-	127	39	79	48	899
1988–89	17	-	65	344	-		-	5	-	31	-	248	175	892	65	1842
1989–90	28	-	18	311	-	7	-	-	-	22	29	37	4	401	46	903
1990–91	66	-	41	662	-	130	-	-	-	25	-	-	23	416	203	1 566
1991–92	5	-	5	459	-	1	1	-	-	6	1	10	-	435	89	1 012
1992–93	2	-	50	60	-	-	1	5	-	-	-	-	-	299	3	420
1993–94	-	3	-	604	-	-	-	54	-	1	-	-	37	839	1	1 539
1994–95	1	37	6	310	-	-	-	-	-	1	-	57	-	799	-	1 211
1995–96	-	-	-	458	1	-	-	-	-	-	-	11	4	126	50	650
1996–97	-	-	14	217	-	-	-	1		1	-	1	50	454	13	751
1997–98	1	3	19	1 084	1	-	-	1	-	-	-	-	13	479	111	1 712
1998–99	2	-	6	1 130	-	-	-	11	-	-	-	1	45	166	82	1 443
All years	262	43	225	7 338	11	142	2	113	8	300	30	577	564	6 156	898	16 669

* *Target species as listed in Table 6*

Table 8: Total number of tows (TCEPRs) by vessels targeting the shallow target group on the Chatham Rise, by month, in fishing years 1989–90 to 1998–99. (Data source: Ministry of Fisheries database.)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989-90	16	12	16	9	194	341	96	260	223	7	14	60	1 248
1990-91	63	74	105	98	27	58	4	170	234	93	-	5	931
1991-92	2	7	5	31	6	110	387	387	281	12	9	11	1 248
1992-93	7	5	4	21	27	155	196	201	137	-	6	11	770
1993-94	10	11	12	52	6	29	287	555	216	4	8	26	1 216
1994-95	27	13	55	47	36	128	196	385	215	27	19	121	1 269
1995-96	39	10	19	47	115	377	315	380	246	-	2	33	1 583
1996-97	31	109	52	42	97	246	337	363	257	40	-	1	1 575
1997-98	70	18	108	74	54	162	152	367	277	4	5	1	1 292
1998-99	25	64	165	85	83	218	159	228	46	1	6	55	1 135
Total	290	323	541	506	645	1 824	2 129	3 296	2 132	188	69	324	12 267

Table 9: Total number of observed tows by vessels targeting fisheries in the shallow target group on the Chatham Rise, by month, in fishing years 1989–90 to 1998–99. (Data source: Observer database.)

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1988-89	3	-	-	-	-	8	-	-	-	-	11	-	22
1989-90	-	-			-	13	4	-	-	10	1	-	28
1990-91	32	-	3		-	-	1	-	-	19	-	10	65
1991-92		-	-		-	-	2	0	1	-	3	-	6
1992-93	-	-	-	5	-	-	-	2	-	1	-	-	8
1993-94	3	-	-	5	49	-	-	-	-	-	-	-	57
1994-95	1	-	-	-	-	-	-	-	-	-	-	37	38
1995-96	-	-	0	-	-	-	-	-	-	-	-	1	1
1996-97	-	-	1	-	-	-	-	-	-	-	-	-	1
1997-98	-	-	-	1	-	-	-	-	-	2	1	2	6
1998-99	-	-	3	8	-	-	-	-	-	-	-	2	13
Total	39	0	7	19	49	21	7	2	1	32	16	52	245

Table 10: Percentage observer coverage in the hoki fishery, by shallow and middle depth target group. (Data sources: Observer and Ministry of Fisheries TCEPR databases.)

	Shallow target grouping			Middle target grouping		
Fishing year	Observed hoki catch (t)	TCEPR hoki catch (t)	% Observed	Observed hoki catch (t)	TCEPR hoki catch (t)	% Observed
1989–90	11.4	305.0	3.73	2 086.8	11 922.6	17.50
1990–91	34.9	386.3	9.04	3 657.7	17 042.1	21.46
1991–92	20.1	378.9	5.30	4 889.9	41 255.7	11.85
1992–93	2.1	122.0	1.74	529.1	37 379.5	1.42
1993–94	52.7	94.3	55.82	3 557.6	16 832.3	21.14
1994–95	3.1	128.8	2.44	1 243.2	28 987.2	4.29
1995–96	4.9	126.5	3.90	2 934.5	34 874.9	8.41
1996–97	0.0	172.3	0.01	1 035.2	40 493.9	2.56
1997–98	1.0	97.8	1.03	5 411.3	53 516.4	10.11
1998–99	0.2	91.2	0.27	7 257.5	58 927.5	12.32
Mean % observed			6.94			9.26

Table 11: Reported catch (t) of orange roughy (from TCEPRs), catch observed, and percentage of catch observed by the Observer Programme by region on the Chatham Rise (NW, Northwest; NE, Northeast; SC, South). (Data sources: Observer and Ministry of Fisheries TCEPR databases.)

Year	NW TCEPR	NW OP	NW % observed	NE TCEPR	NE OP	NE % observed	SC TCEPR	SC OP	SC % observed
1989–90	2 503.8	89.9	3.6	12 239.9	3 782.9	30.9	7 774.2	53.9	0.7
1990–91	1 267.9	566.2	44.7	11 276.3	1 952.5	17.3	6 292.8	1 445.0	23
1991–92	274.0	40.6	14.8	12 331.8	2 571.9	20.9	1 720.6	213.4	12.4
1992–93	3 467.8	77.3	2.2	4 330.3	1 179.8	27.2	4 840.1	779.1	16.1
1993–94	3 242.0	290.1	8.9	4 514.6	1 730.0	38.3	4 629.1	721.5	15.6
1994–95	2 249.1	326.3	14.5	3 746.0	1 094.8	29.2	1 442.5	237.4	16.5
1995–96	2 240.5	202.7	9.0	3 498.4	775.4	22.2	1 201.1	37.1	3.1
1996–97	2 094.7	233.8	11.2	3 349.9	812.0	24.2	1 282.3	157.8	12.3
1997–98	2 158.3	246.3	11.4	4 213.2	1 459.7	34.6	1 509.6	180.5	12
1998–99	2 416.0	61.8	2.6	3 558.6	266.0	7.5	1 117.3	176.9	15.8
Mean % observed			10.24			21.03			10.63

Table 12: *Total effort (number of tows) used for CPUE analyses in each target group.* (Data source TCEPR data, Ministry of Fisheries database, fishing years 1989–90 to1990–91.)

Fishing year	Shallow target group	Middle depth target group	Deep water target group	Total
1989–90	1 248	2 562	7 136	10 946
1990–91	931	4 047	5 202	10 180
1991–92	1 248	5 927	4 083	11 258
1992–93	770	5 884	3 778	10 432
1993–94	1 216	3 742	5 422	10 380
1994–95	1 269	6 605	5 004	12 878
1995–96	1 583	8 318	3 633	13 534
1996–97	1 575	9 593	4 665	15 833
1997–98	1 292	11 693	6 319	19 304
1998–99	1 135	11 503	6 088	18 726
Total	12 267	69 874	51 330	133 471

Table 13: A summary of trends in species associated with the shallow target fishery on the Chatham Rise. (↑ upward trend, ↓ downward trend, nil no trend.)

Species code	OP ratio catch	TCEPR catch	CPUE	Trawl survey abundance index
BAR	↓	↓	↓	↑
GSH	nil	nil	nil	↑
SPD	nil	↓?	↓	↑
RAT	↑	nil	↓	↑
RCO	nil	nil	nil	↑
BYX	no data	↑	↑	↓
SKI	no data	↓	↓	–
SQU	nil	nil	nil	↓
STA	nil	nil	↓	↓
HOK	nil	↓	↓	↓
JMA	nil	nil	nil	↓
LIN	nil	↓	↓	nil
TAR	↓	↓	↓	nil
SWA	↓	nil	nil	nil

Table 14: Summary of trends in catch and relative abundance of species associated with the middle depth target fisheries. (↑ upward trend, ↓ downward trend, nil no trend.)

Species code	OP ratio catch	TCEPR estimated catch	Scaled to hoki catch	Adjusted to hoki biomass	CPUE	Trawl survey abundance index
JAV	↑	↑	↑	↑	↑	↑
LDO	↑	↑	nil	nil	nil	↑
SPD	↑	↑	↑	↑	nil	↑
SPE	↑	↑	nil	↓	nil	↑
GSH	↑	↑	nil	↓	↓	↑
HOK	↑	↑	nil	↓	nil	↓
HAK	nil	↑	nil	nil	↓	↓
STA	nil	↓	↓	nil	↓	↓
RAT	↑	nil	nil	↑	↑	nil
SND	↓	nil	↓	↓	↓	nil
LIN	nil	↑	↓	nil	↓	nil
RIB	nil	nil	nil	↓	↓	nil
SWA	nil	nil	nil	nil	↓	nil
WWA	nil	nil	nil	nil	↓	nil
GSP	nil	nil	nil	nil	nil	nil

Table 15: Trends in relative changes in biomass from 1992 to 2000 expressed as a ratio of each biomass to the initial estimate in 1992, Chatham Rise trawl surveys 200–800 m. (c.v., coefficient of variation; Rsq, R squared coefficient; p, probability that trend is statistically significant, ↑ upward trend, ↓ downward trend, ? slight trend, nil no trend.)

		Ratios relative to 1992											
	Mean c.v.	1992	1993	1994	1995	1996	1997	1998	1999	2000	trend	Rsq	p
Hoki	9.8	1.0	1.54	1.21	1.00	1.27	1.31	0.72	0.91	0.60	↓	0.40	0.0001
Hoki 3+	9.2	1.0	1.54	0.92	0.74	1.14	0.99	0.81	0.72	0.31	↓	0.50	0.0001
Hake	14.9	1.0	0.71	0.80	0.79	0.59	0.67	0.69	0.55	0.50	↓	0.71	0.0007
Arrow squid	29.6	1.0	0.85	0.79	1.07	0.71	0.73	0.16	0.61	0.25	↓	0.61	0.01
Giant stargazer	13.3	1.0	1.00	1.11	0.56	1.18	0.91	0.66	0.74	0.84	↓	0.19	0.02
Hapuku	48.3	1.0	0.71	0.91	0.32	0.56	0.56	0.18	0.45	0.40	↓	0.56	0.03
Murphy's mackerel	46.9	1.0	2.14	1.51	0.13	0.89	0.66	1.40	0.61	0.22	↓	0.27	0.05
Ribaldo	16.8	1.0	0.66	1.25	0.77	0.89	0.63	0.96	0.75	0.66	↓	0.16	0.07
Bluenose	66.1	1.0	2.19	0.5	0	0.06	0.19	0.04	0.66	0.59	↓	0.29	0.08
Alfonsino	50.5	1.0	1.09	3.92	0.2	0.27	0.63	0.35	0	0.18	↓	0.25	0.09
Orange roughy	50.4	1.0	1.00	12.33	5.60	0.00	1.87	0.00	0.80	0.53	↓?	0.09	0.12
Oliver's rattail	24.6	1.0	0.00	1.00	0.22	0.40	0.42	0.65	0.42	0.51	↓?	0.06	0.20
Tarakihi	53.7	1.0	0.59	0.49	0.32	1.06	0.66	0.28	0.27	0.66	↓?	0.14	0.30
Barracouta	52.7	1.0	0.58	1.23	0.04	0.64	0.18	0.13	0.52	0.86	↓?	0.10	0.39
Lookdown dory	6.8	1.0	1.34	1.60	0.93	1.57	1.37	1.46	1.55	1.59	↑	0.32	0.0001
Sea perch	10.5	1.0	1.02	1.28	0.49	0.99	0.91	1.13	1.59	1.57	↑	0.30	0.0001
Spiny dogfish	13.4	1.0	0.93	1.44	1.19	2.08	4.00	2.39	3.58	3.73	↑	0.76	0.0001
Lemon sole	24.5	1.0	1.00	1.86	1.00	0.83	1.37	2.77	1.66	3.11	↑	0.61	0.0003
School shark	38.9	1.0	2.00	2.16	0.00	4.32	2.51	1.77	3.82	10.26	↑	0.46	0.007
Oblique ban. ratt.	22.6	1.0	1.00	0.31	0.36	0.54	1.00	1.01	1.19	1.14	↑	0.40	0.02
Orange perch	56	1.0	1.00	0.37	0.35	0.59	5.04	0.60	3.47	1.04	↑	0.12	0.05
Javelinfish	12.5	1.0	0.96	0.75	0.54	1.07	0.58	0.89	1.21	1.22	↑	0.13	0.07
Dark ghost shark	14.8	1.0	0.89	1.55	0.52	0.92	0.93	1.00	1.81	1.37	↑	0.17	0.08
Black oreo	32.3	1.0	1.37	0.55	0.42	1.47	0.99	1.50	1.33	1.40	↑	0.20	0.15
Red cod	42.2	1.0	1.42	1.94	0.57	0.82	0.90	0.45	3.72	11.68	↑?	0.36	0.20
Pale ghost shark	8.7	1.0	0.59	0.97	0.45	1.30	0.47	0.67	0.87	0.81	nil	0.01	0.29
White warehou	28.7	1.0	1.35	0.72	0.34	0.25	1.05	0.47	1.45	1.10	nil	0.01	0.76
Big-eyed rattail	11.7	1.0	1.07	1.55	0.47	0.81	0.64	0.87	1.26	1.12	nil	0.00	0.87
Spiky oreo	41.9	1.0	1.55	0.04	1.05	2.45	1.45	0.92	0.80	0.91	nil	0.00	0.89
Ling	9.5	1.0	1.05	1.13	0.82	0.94	0.96	0.82	1.36	0.93	nil	0.00	0.91
Smooth oreo	58	1.0	1.81	1.50	0.22	2.09	2.73	3.43	0.71	0.00	nil	0.00	0.91
Shovelnose dog.	25.3	1.0	0.75	0.37	0.82	0.75	0.73	0.55	0.81	0.87	nil	0.00	0.95
Silver warehou	41	1.0	0.60	2.59	0.83	0.38	0.47	1.05	1.51	1.21	nil	0.00	0.99

Table 16: Annual catch (kg) of invertebrate groupings 200-800 m, Chatham Rise, recorded by the Observer Programme Database. (Species names where known are held on NIWA database, Wellington.)

Fishing year	Sponge	Coelenterates	Coral	Salps	Shell-fish	Octopus	Squid	Crabs	Prawns	Scampi	Other crustaceans	Echinoderms
1989–90				50		26	4 959	189		42		62
1990–91	470	2 248		446	30	185	7 492	301		31	2	50
1991–92	14 842					39	1 837	687		602		
1992–93	2				5	100	3 531					22
1993–94	6 930	1				73	6 689	211		35		398
1994–95		13				35	3 813	23				8
1995–96						126	2 831	62	1	2 674		
1996–97	2 170	14	10 220			121	5 865	213	1	319		231
1997–98	7 906	20	28		30	241	12 544	151	2	2 121	101	2 475
1998–99	31 849	1 304	355			305	8 797	657		1 871		16 842
Codes	ONG	ANT	COR	SAL	COC	AMP	GSQ	GSC	AFO	SCI	CRA	CAL
		COE	COU		GAS	DWO	MIQ	KIC	CAM		CRU	ECH
		JFI			MOL	OCP	MRQ	SPI	PRA			ECN
						OCT	RSQ	SSC				SCC
						OPI	TSQ					SFI
							VSQ					SUR
							WSQ					URO

Codes: AFO royal red prawn, AMP amphipod, ANT sea anemone, CAL sea urchin, CAM sabre prawn, COC cockle, COE Coelenterata, COR red coral, COU coral, CRA crab, CRU crustacean, DWO deepwater octopus, ECH Echinodermata, ECN echinoid, GAS gastropod, GSC giant spider crab, GSQ giant squid, JFI jellyfish, KIC king crab, MIQ warty squid, MOL mollusc, MRQ warty squid, OCP octopod, OCT octopus, ONG sponge, OPI umbrella octopus, PRA prawn, RSQ red squid, SAL salp, SCC sea cucumber, SCI scampi, SFI starfish, SPI spider crab, SSC giant masking crab, SUR kina, TSQ Todarodes squid, URO sea urchin, VSQ violet squid, WSQ warty squid.

Table 17: Trends in relative changes in biomass of invertebrates from 1992 to 2000 expressed as a ratio of each biomass to the initial estimate in 1992, Chatham Rise trawl surveys. (↑ upward trend, ↓ downward trend, nil no trend.)

	Mean cv	1992	1993	1994	1995	1996	1997	1998	1999	2000	Trend
Sponge	53.5		1.00	0.00	1.82	3.19	2.46	2.54	2.16	2.12	↑
Coelenterate	38.0		1.00	0.11	0.05	6.84	1.09	0.90	4.98	3.01	↑
Coral	63.9			1.00	41.00	37.00	103.00	303.50	117.50	86.00	↑
Octopus	34.7	1.00	1.40	1.01	0.88	7.28	4.10	2.29	2.08	1.13	↑
Crabs	49.6	1.00	0.57	0.73	0.77	3.10	0.50	0.78	1.05	2.37	↑
Prawns	52.2	1.00	0.71	1.00	0.43	1.64	0.57	4.00	0.64	4.29	↑
Scampi	17.7	1.00	2.60	2.12	2.00	3.62	7.33	7.00	10.02	5.00	↑
Echinoderms	38.0	1.00	0.12	1.18	3.25	0.42	0.79	6.30	1.56	0.00	↑
Other squid	17.6	1.00	1.95	2.45	1.39	6.91	1.70	1.03	1.65	1.78	nil
Other crustaceans	86.1	1.00	0.25	0.00	0.50	0.00	0.00	1.50	0.00	0.50	nil
Shellfish	58.1		1.00	8.33	2.00	11.17	0.83	0.00	0.00	10.17	nil
Arrow squid	29.6	1.00	0.85	0.79	1.07	0.71	0.73	0.16	0.61	0.25	↑
Salps	63.8		1.00	3.26	0.00	0.00	0.00	371.57	53.87	0.00	↑

Table 18: Overall trends in relative abundance (trawl surveys and CPUE interpreted together) of species/species groups in deepwater fisheries on the Chatham Rise. (↑ upward trend, ↓ downward trend, ? slight trend, nil no trend.)

	Northwest	Northeast	South
Basketwork eel	?	↓	?↑
Black oreo	↑↓	↓	nil
Seal shark	?↑	↑	↑
Deepwater dogfish	↑	?↑	?↑
Baxters dogfish	nil	?↓	?
Johnsons cod	nil	↓	nil
Hoki	?↑	nil	?↑
Orange roughy	↓	↓	↓
Rattails	↑	↓	↑
Ribaldo	↓↑	↓	nil
Slickheads	↑	↓↑	↑
Smooth oreo	nil	?↑	↓

Table 19: Change in relative biomass of the main species associated with orange roughy from trawl surveys of the NE Chatham Rise. *The 1984 column gives the relative index (t), 1985 to 1994 columns is the* proportion of the 1984 survey value. Trend was assessed by bootstrap (see text), evaluated at 1% level of significance, NS, not significant. Bold indicates species where the overall c.v. >0.40.

Species	1984	1985	1986	1987	1988	1989	1990	1992	1994	Trend
ORH	130 573	0.85	0.59	0.46	0.56	0.42	0.26	0.17	0.47	↓
SND	1 517	0.60	1.54	1.83	1.94	0.91	2.07	1.78	1.14	↑
BEE	1 280	0.72	0.39	0.35	0.18	0.16	0.18	0.19	0.13	↓
ETB	770	0.45	0.64	0.71	0.51	0.16	0.49	0.43	0.26	↓
SSO	704	0.48	0.69	0.56	1.57	0.36	0.74	0.47	1.18	NS
WHX	655	0.71	0.70	0.79	0.63	0.28	0.53	0.41	0.21	↓
RIB	650	1.36	1.08	1.03	0.50	0.35	0.36	0.54	0.37	↓
SBI	507	0.56	0.39	0.36	0.40	0.11	0.29	0.49	0.63	NS
HJO	470	0.95	0.83	0.74	0.57	0.38	1.03	0.37	0.42	↓
GSP	468	0.81	0.63	0.76	0.76	0.26	0.49	0.44	0.16	↓
CYP	370	0.75	1.49	1.58	5.33	3.03	4.69	4.32	3.65	↑
RCH	362	0.91	0.86	0.58	1.23	0.45	0.94	0.64	0.50	↓
HAK	338	0.40	0.87	0.64	0.42	0.35	0.84	0.26	0.38	↓
CYO	248	1.10	2.37	2.92	1.67	1.05	0.99	2.81	1.94	NS
LCH	214	0.49	0.74	0.45	0.44	0.19	0.29	0.42	0.13	↓
SOR	113	0.60	1.27	0.79	0.65	0.74	1.26	0.79	1.27	NS
CMA	108	0.58	0.87	1.24	0.56	0.21	0.45	0.95	0.38	↓
BSH	93	0.42	0.29	0.16	0.34	0.03	0.84	0.11	0.17	NS
PLS	49	0.16	0.14	0.53	0.35	0.31	0.10	0.33	0.06	NS
BSL	46	0.04	0.43	1.11	0.67	0.09	0.70	2.20	0.48	NS
CSQ	45	0.24	1.00	0.44	0.20	0.36	1.07	0.71	0.02	NS
SMC	38	0.42	0.87	1.42	0.08	0.03	0.05	0.08	0.03	↓
MCA	31	0.48	0.45	0.48	0.42	0.26	1.26	0.35	0.65	NS
EPT	19	0.63	1.95	0.58	0.32	0.68	0.37	0.42	0.05	↓
LIN	19	3.21	3.32	3.05	2.21	1.84	0.58	0.42	0.58	↓
SSM	6	0.17	1.17	5.50	0.17	14.67	0.33	1.17	2.00	NS
SBK	5	0.60	0.80	0.20	0.20	0.20	0.60	0.40	0.60	NS
TRS	2	2.50	3.00	1.50	1.00	0.50	2.00	2.00	0.50	NS

Table 20: Change in relative biomass of the main species associated with oreo species in trawl surveys of the southern Chatham Rise. The 1991 column gives the relative index (t), 1992 to 1995 columns is the proportion of the 1991 survey value. (Bold indicates species where the overall c.v. >0.40.)

Biomass	1991	1992	1993	1995	Trend
SSO	217 455	0.68	0.70	0.29	↓
BOE	82 500	0.68	0.53	0.77	NS
HOK	5 751	2.25	1.81	2.85	NS
ORH	4 863	1.15	0.42	0.59	NS
SND	4 382	1.07	1.41	1.10	NS
GSP	2 011	1.10	2.11	3.51	↑
LIN	509	1.53	0.99	0.46	NS
RIB	320	0.77	0.84	1.79	NS
HAK	151	2.70	8.54	9.87	NS

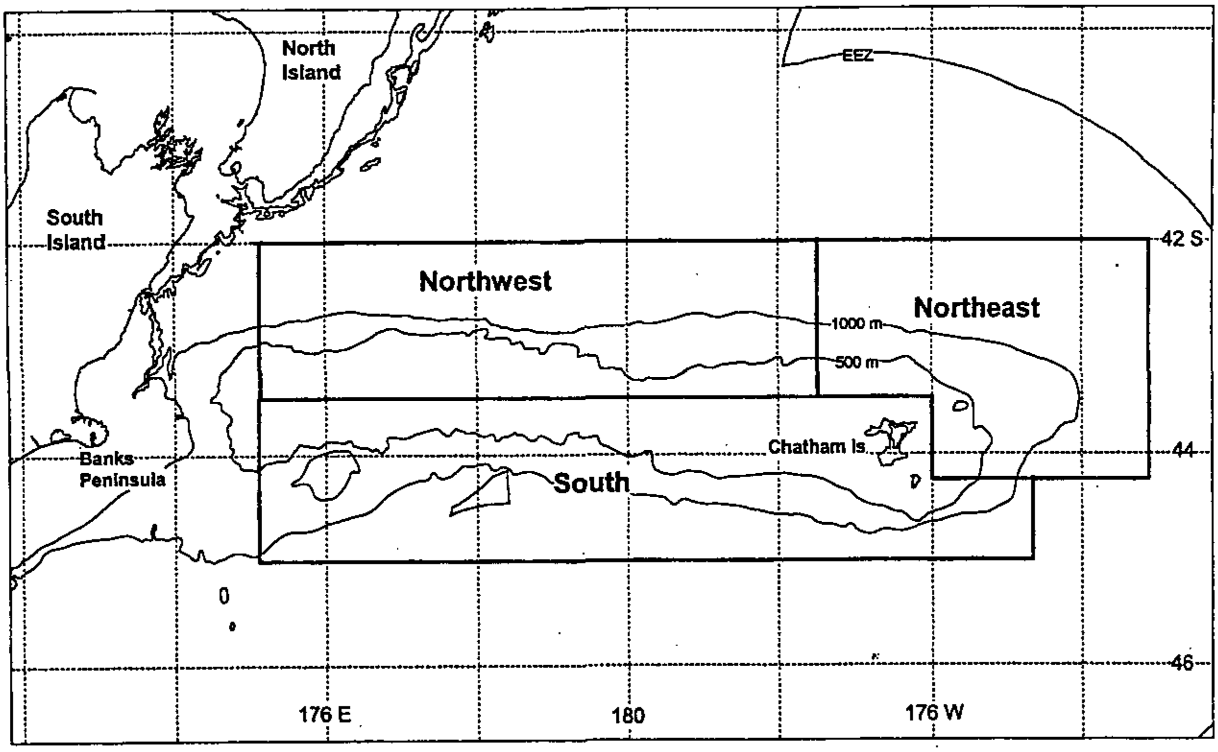


Figure 1: Location and bathymetry (500 and 1000 m contours) of the Chatham Rise, showing subarea boundaries used for the analyses of the deepwater target fisheries.

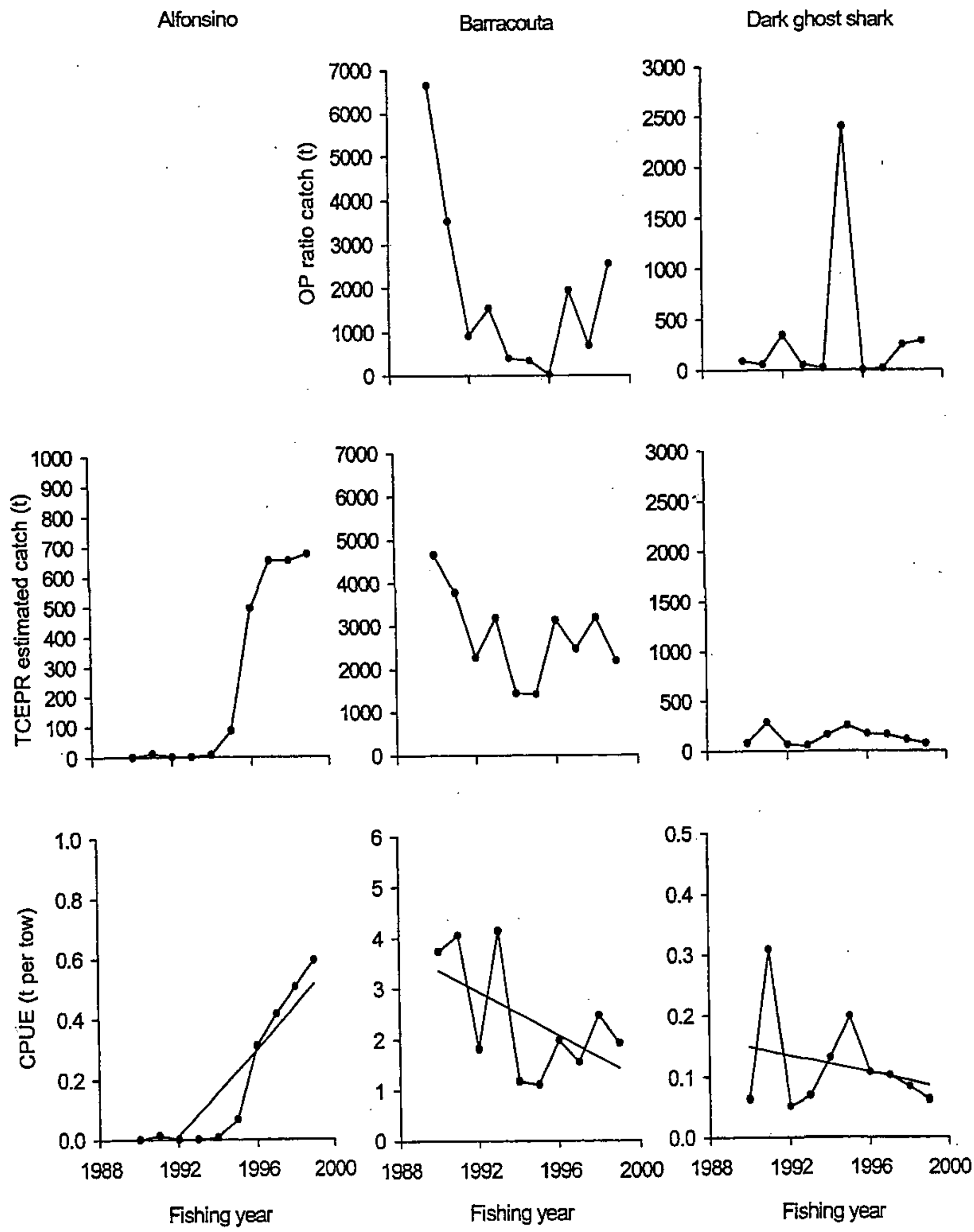


Figure 2: Trends in catch and CPUE of species caught in the shallow depth target group on the Chatham Rise, fishing years 1989–90 to 1998–99. (OP ratio catch estimated from OP database, TCEPR catch estimated from tow by tow TCEPR records, CPUE is the TCEPR estimated catch divided by the total effort within the target group.)

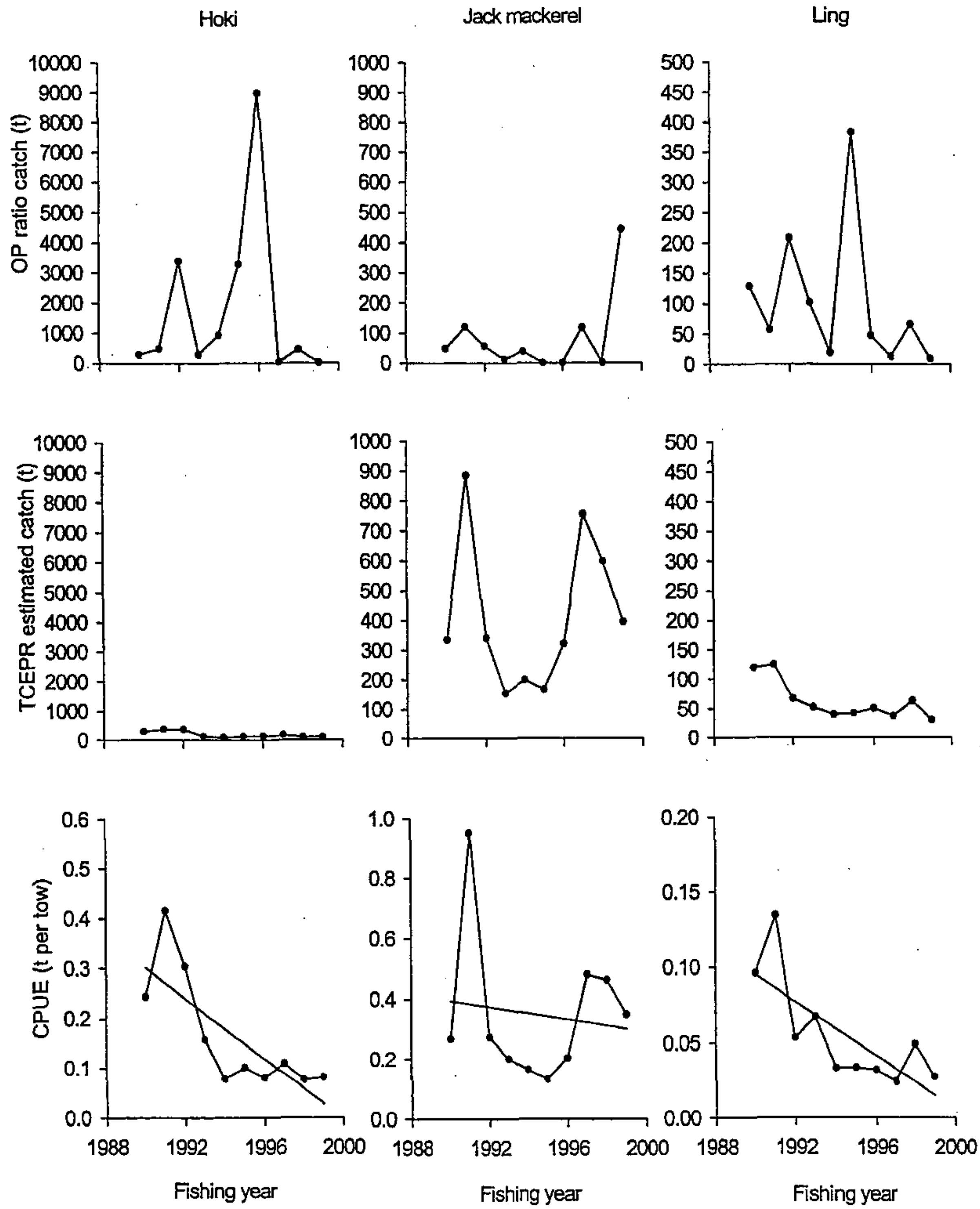


Figure 2: *Continued.*

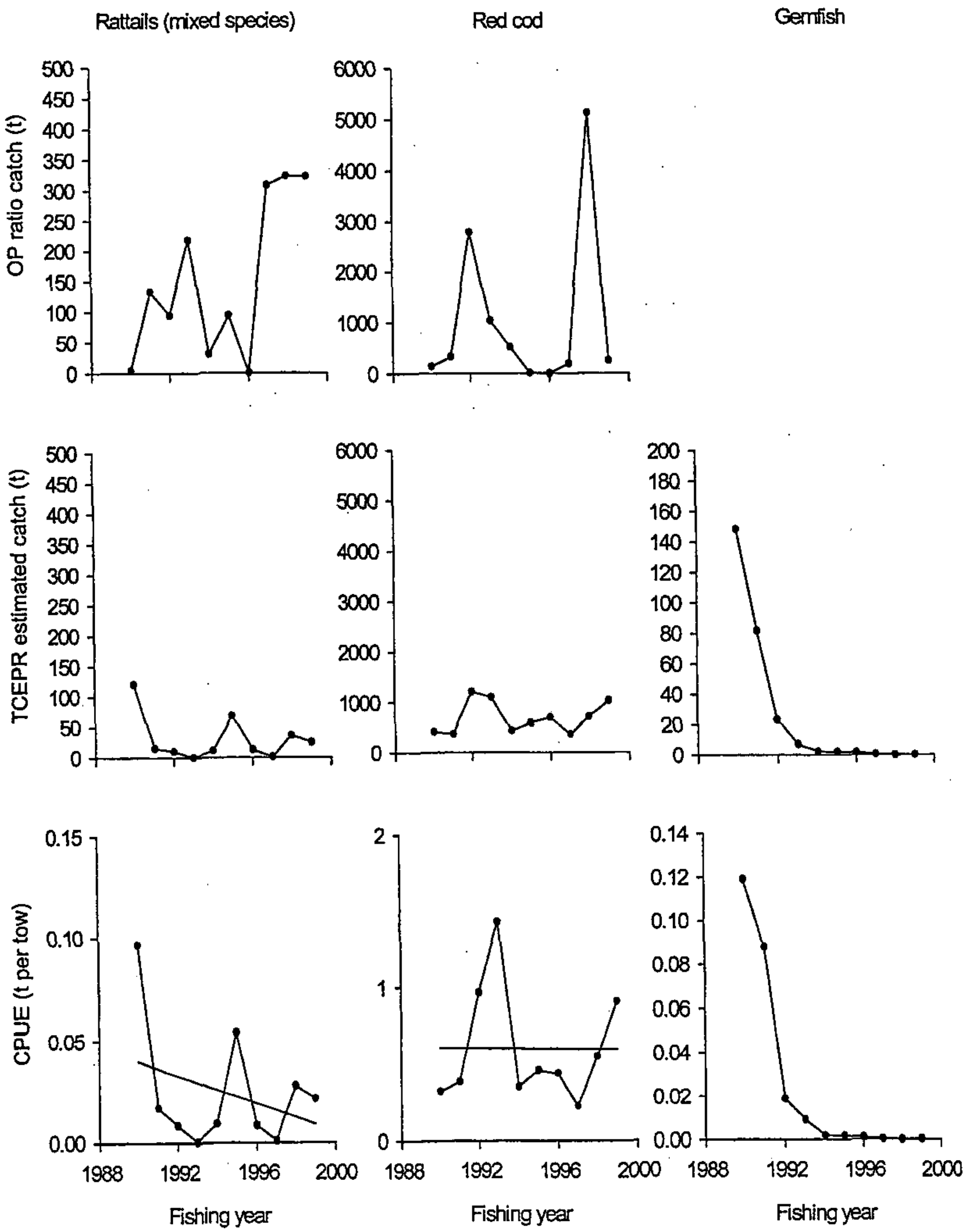
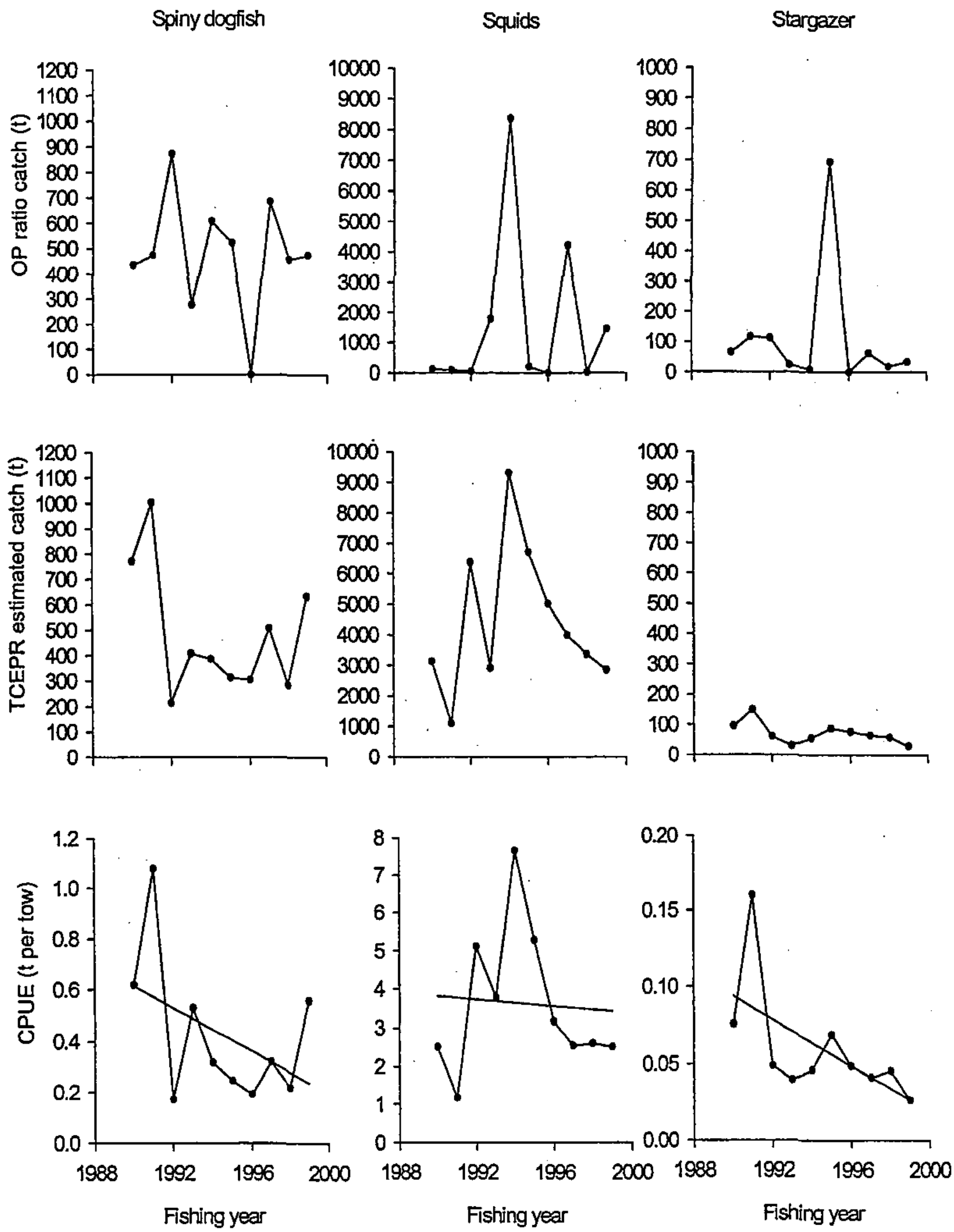


Figure 2: ***Continued.***



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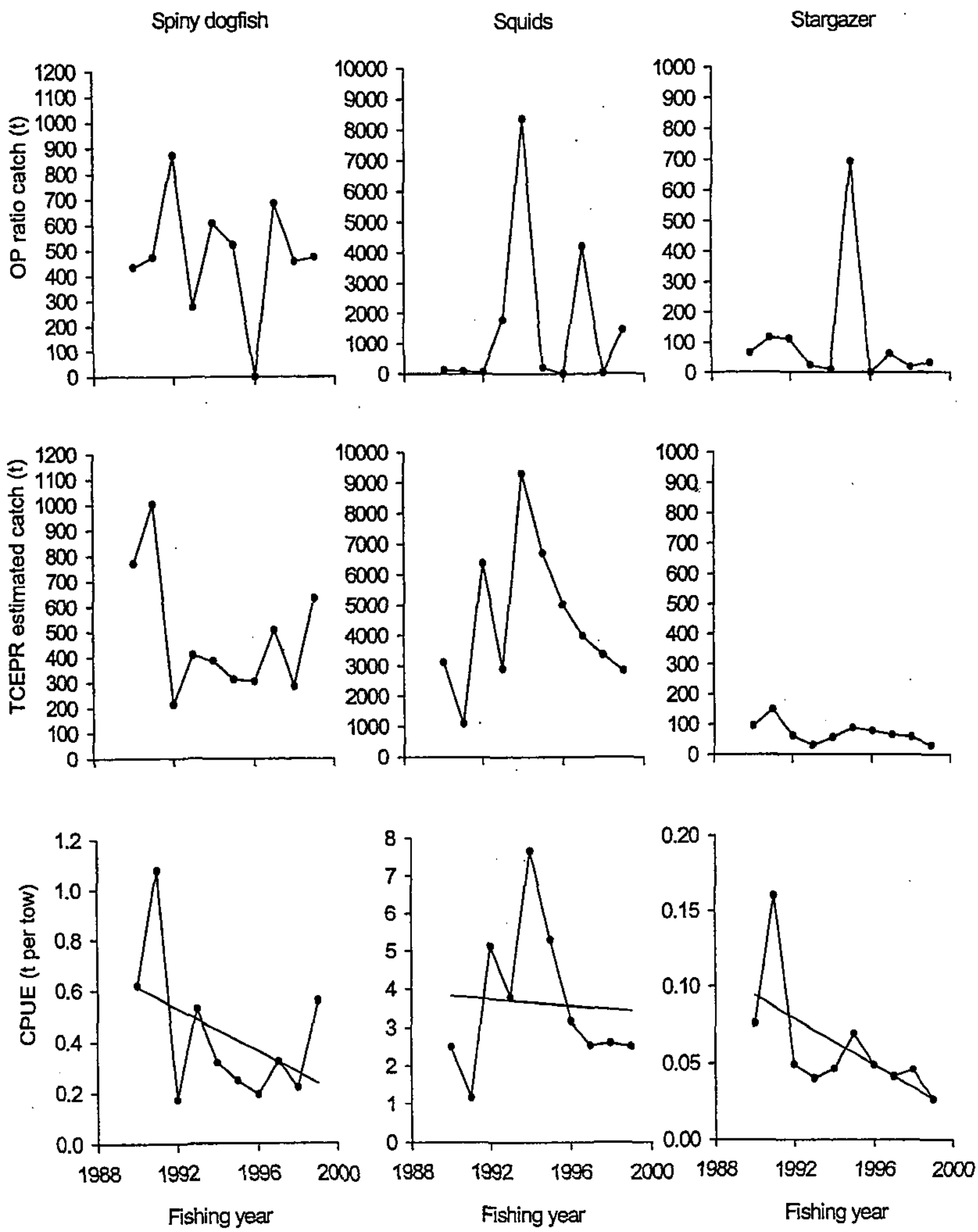

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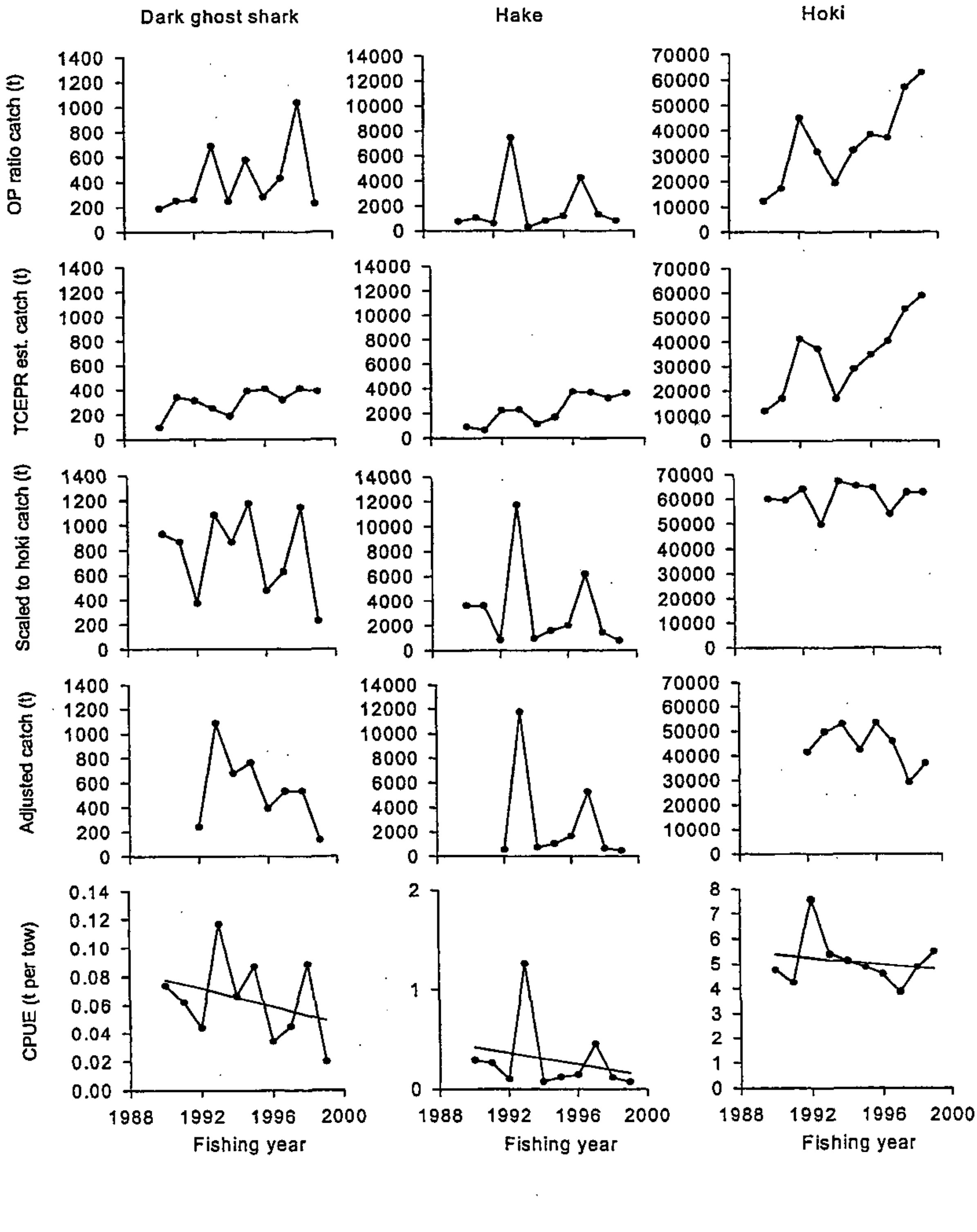
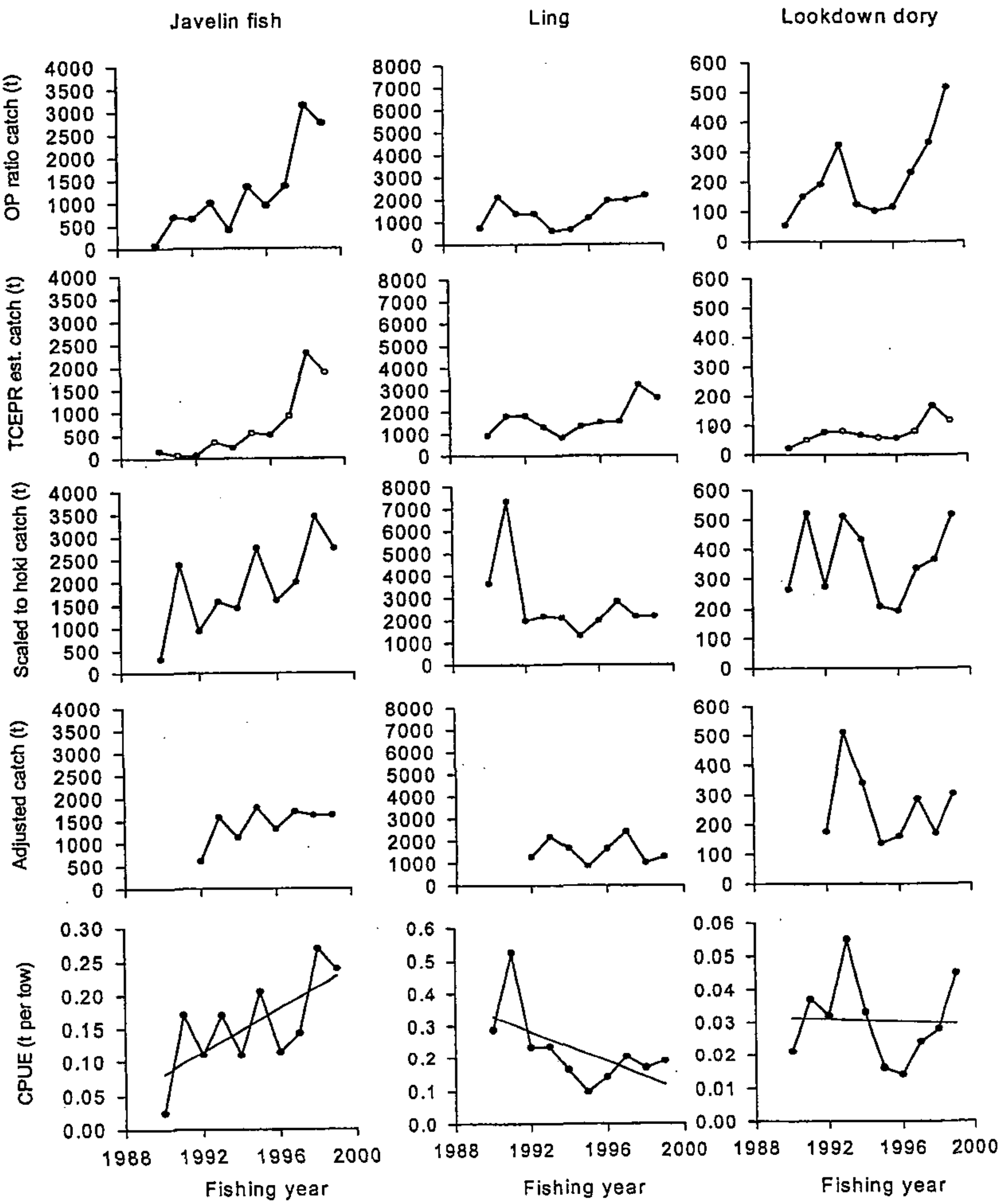


Figure 3: Trends in catch and CPUE of species caught in the middle depth target group on the Chatham Rise, fishing years 1989–90 to 1998–99. (OP ratio catch estimated from OP database, TCEPR catch estimated from tow by tow TCEPR records, scaled catch is the OP ratio catch scaled to the relative hoki catch, adjusted catch is scaled to the relative abundance index of hoki estimated by trawl surveys, CPUE is the TCEPR estimated catch divided by the total effort within the target group.)



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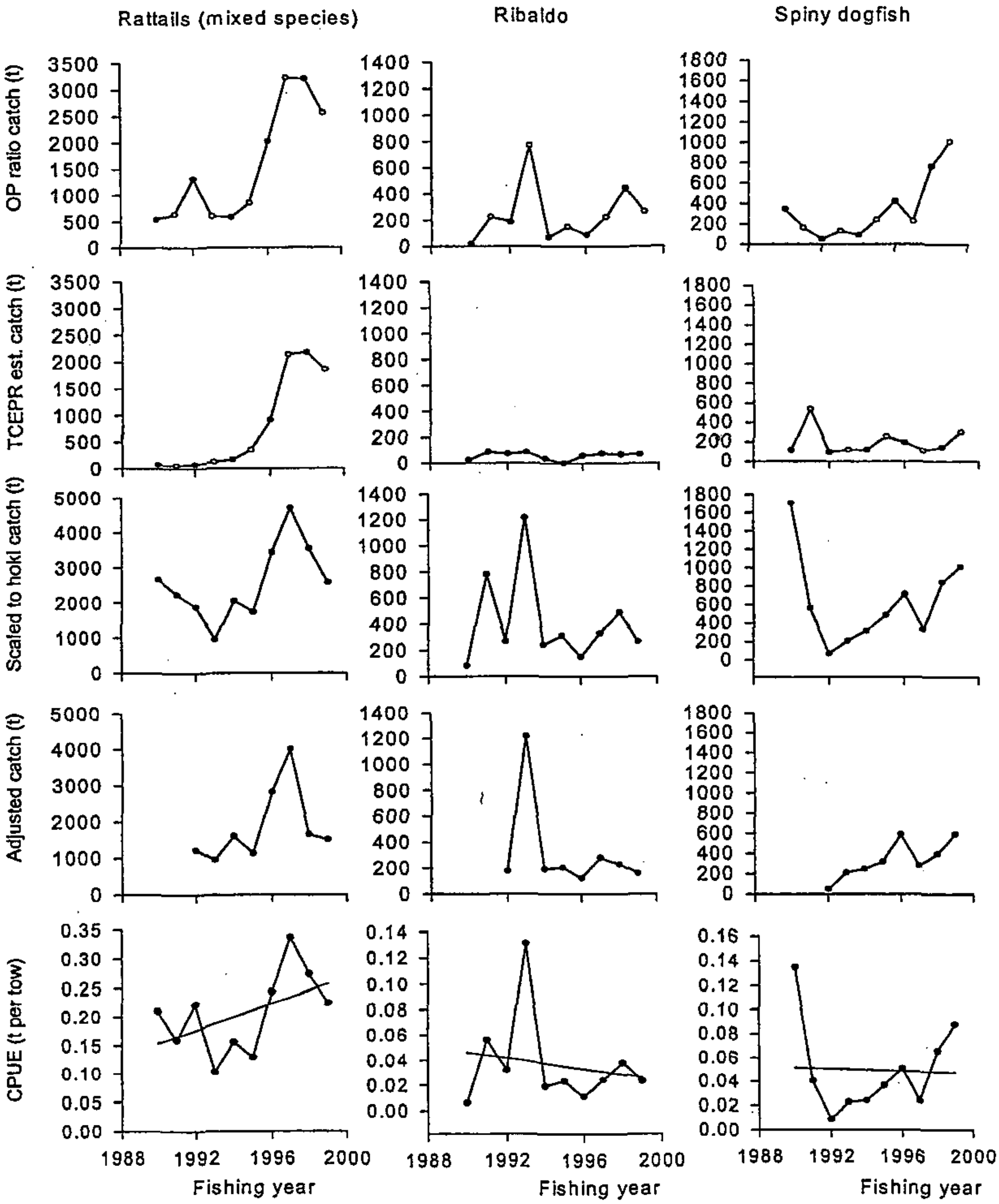

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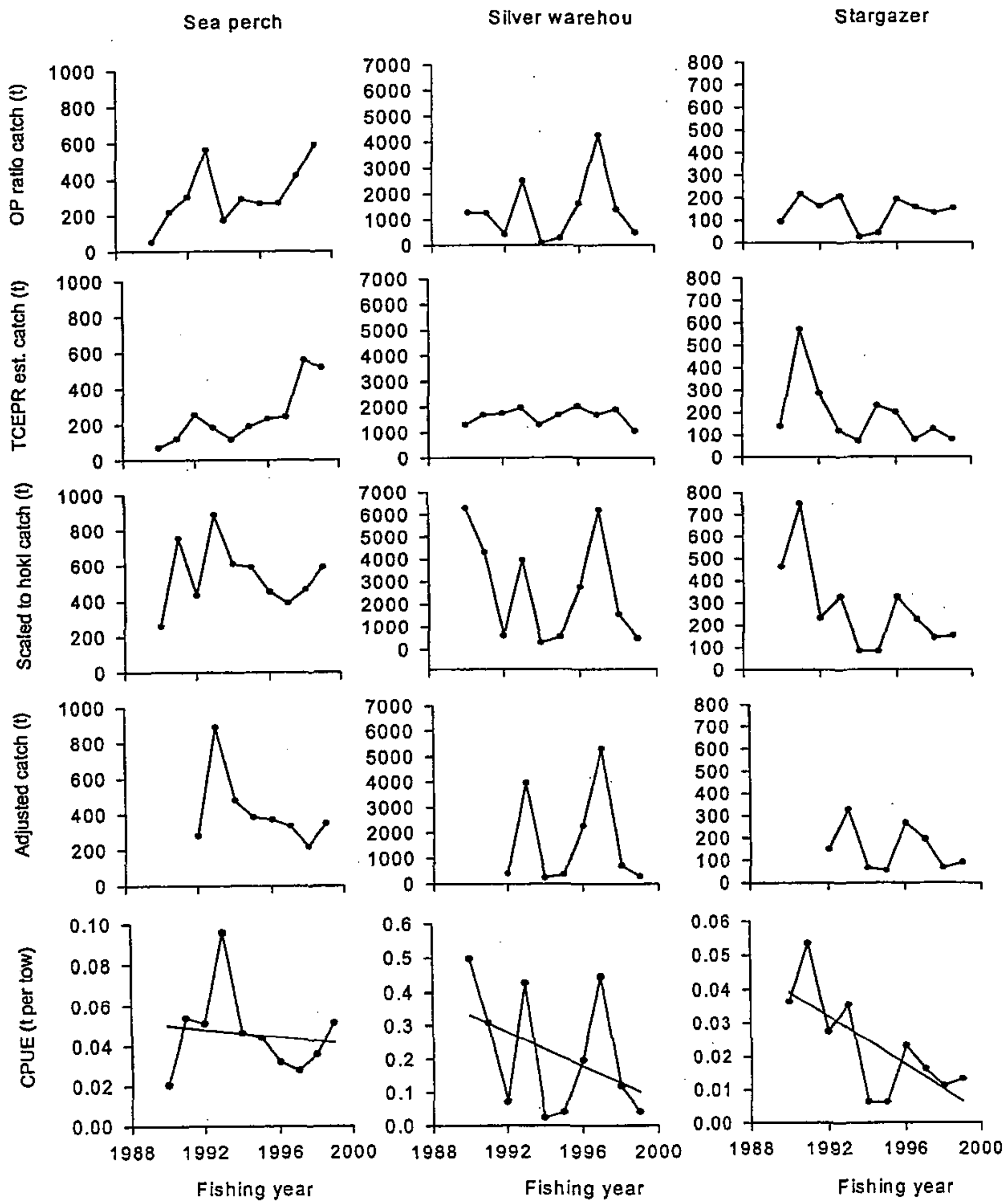

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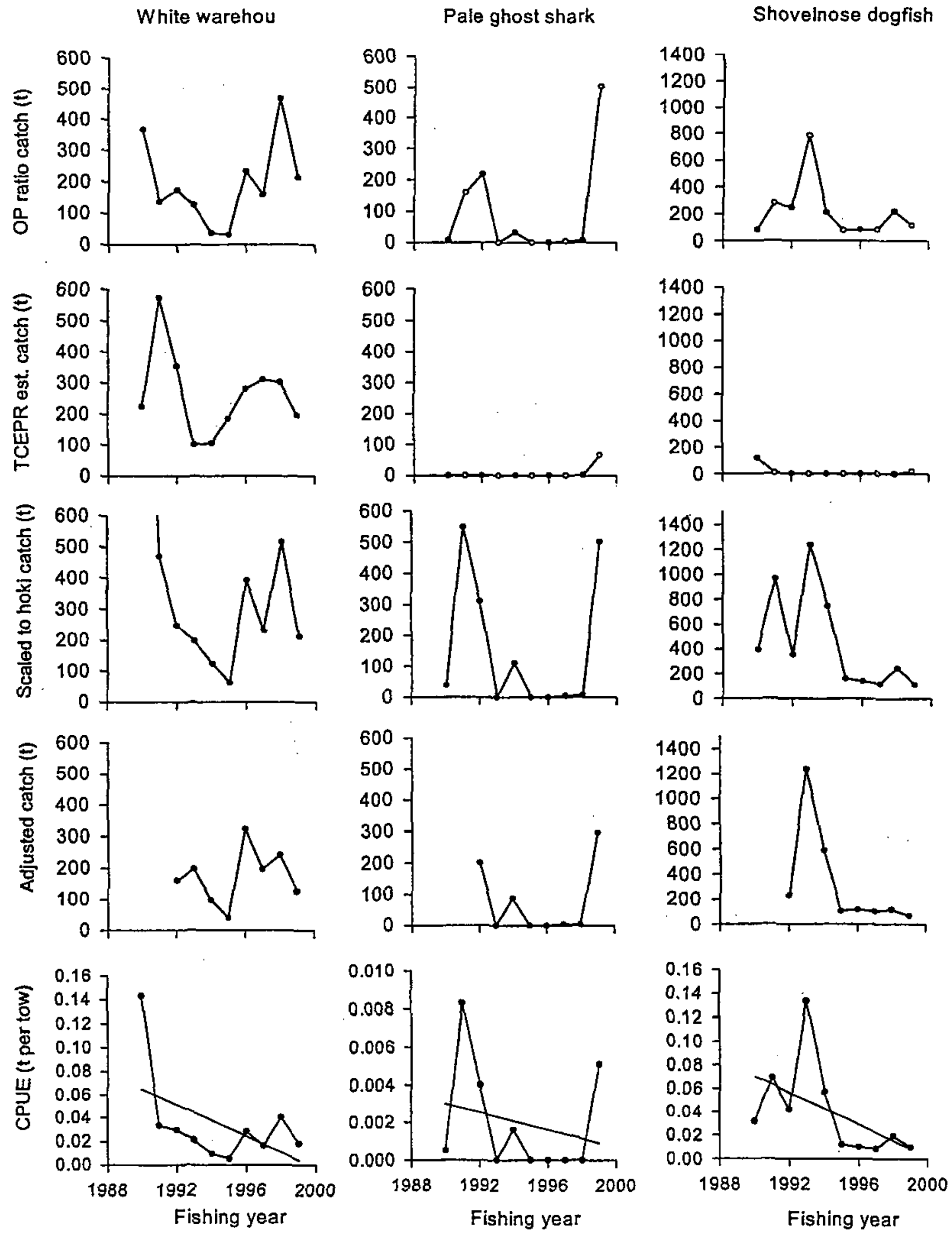

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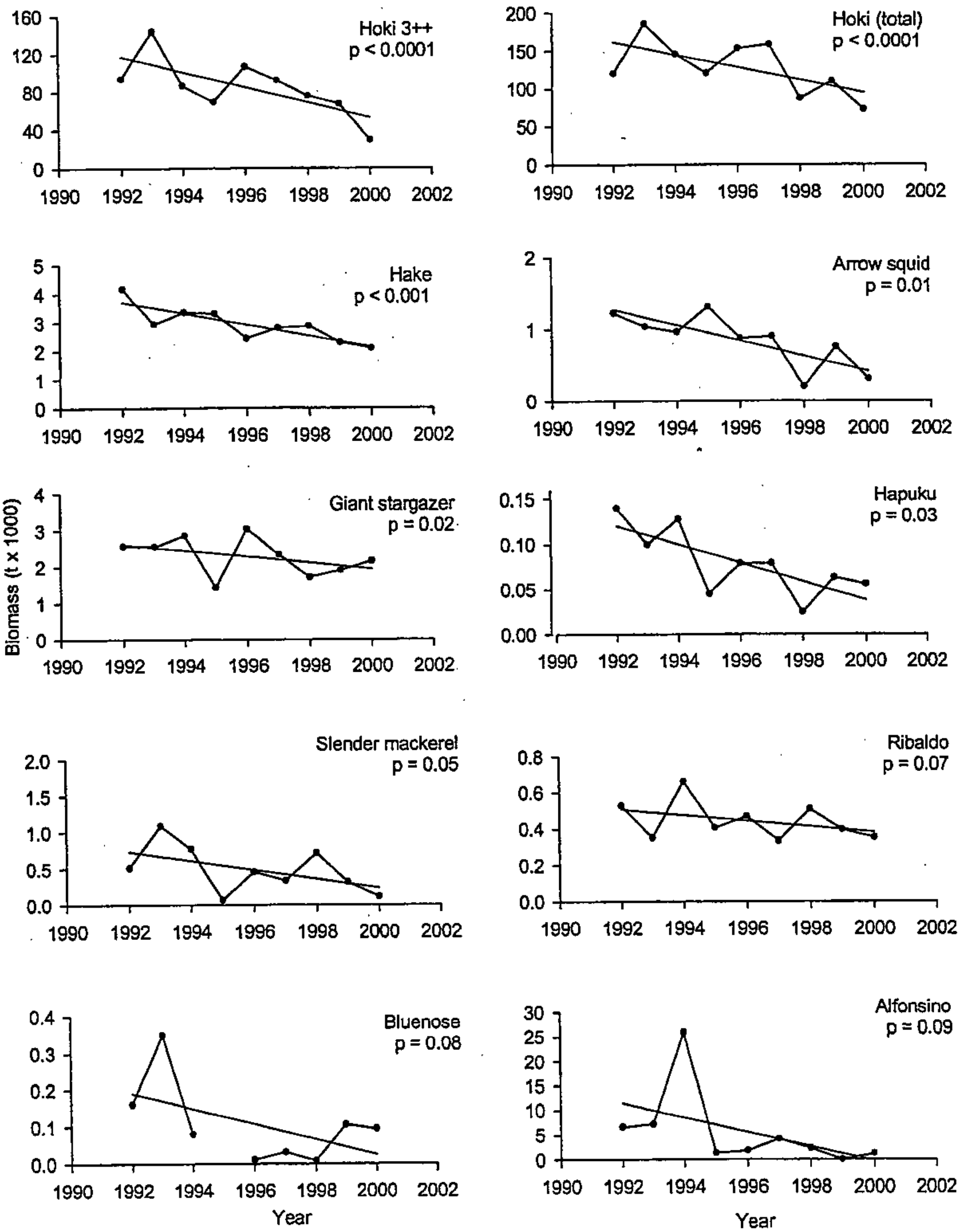


Figure 4: Downward trends in biomass estimates ('000 t) of species from research trawl surveys of the Chatham Rise, January 1992–2000. P values represent the significance of the trend from a bootstrap analysis.

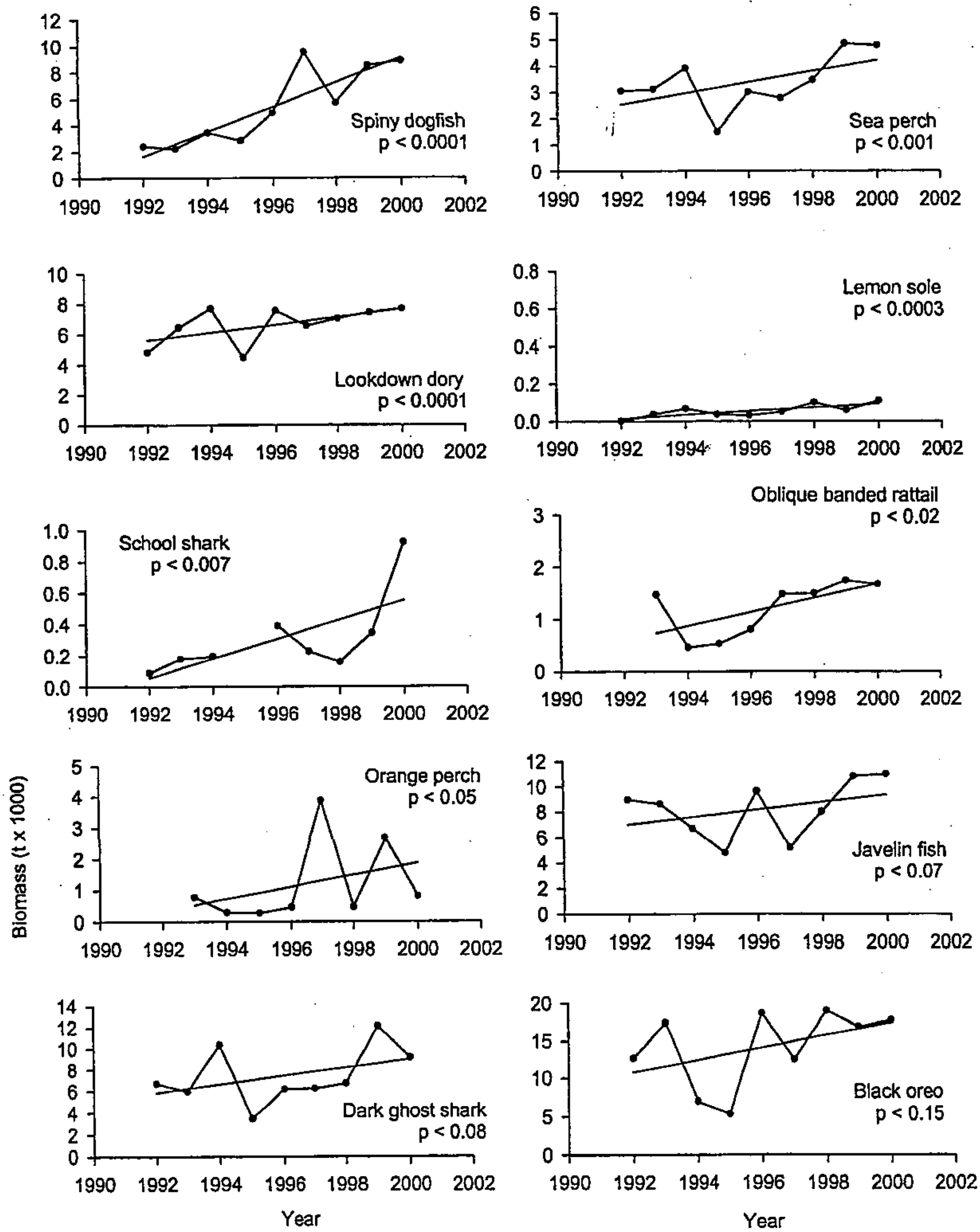


Figure 5: Upward trends in biomass estimates ('000 t) of species from research trawl surveys of the Chatham Rise, January 1992–2000. P values represent the significance of the trend from a bootstrap analysis.

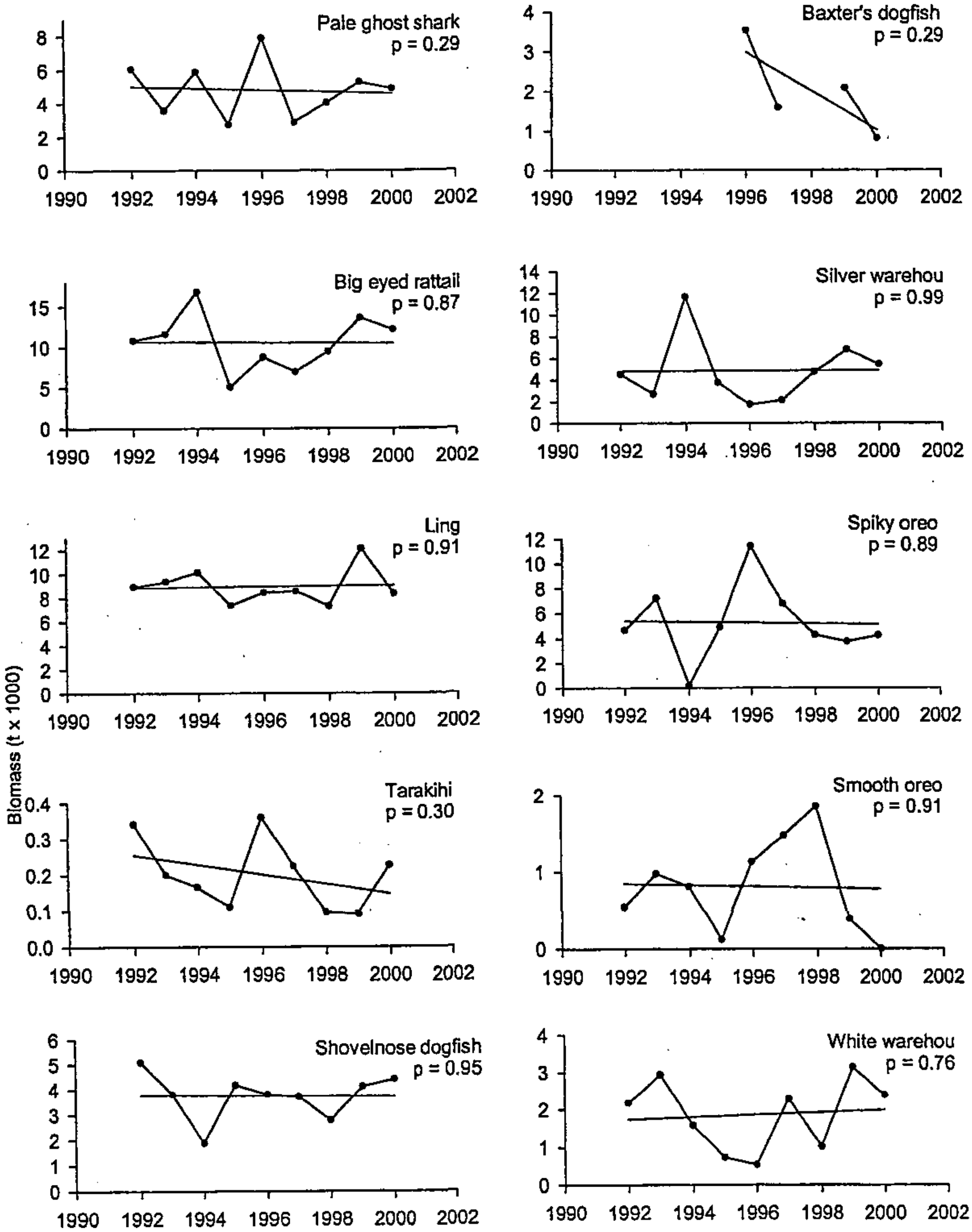


Figure 6: No significant unidirectional trends in biomass estimates ('000 t) of species from research trawl surveys of the Chatham Rise, January 1992–2000. P values represent the significance of the trend from a bootstrap analysis.

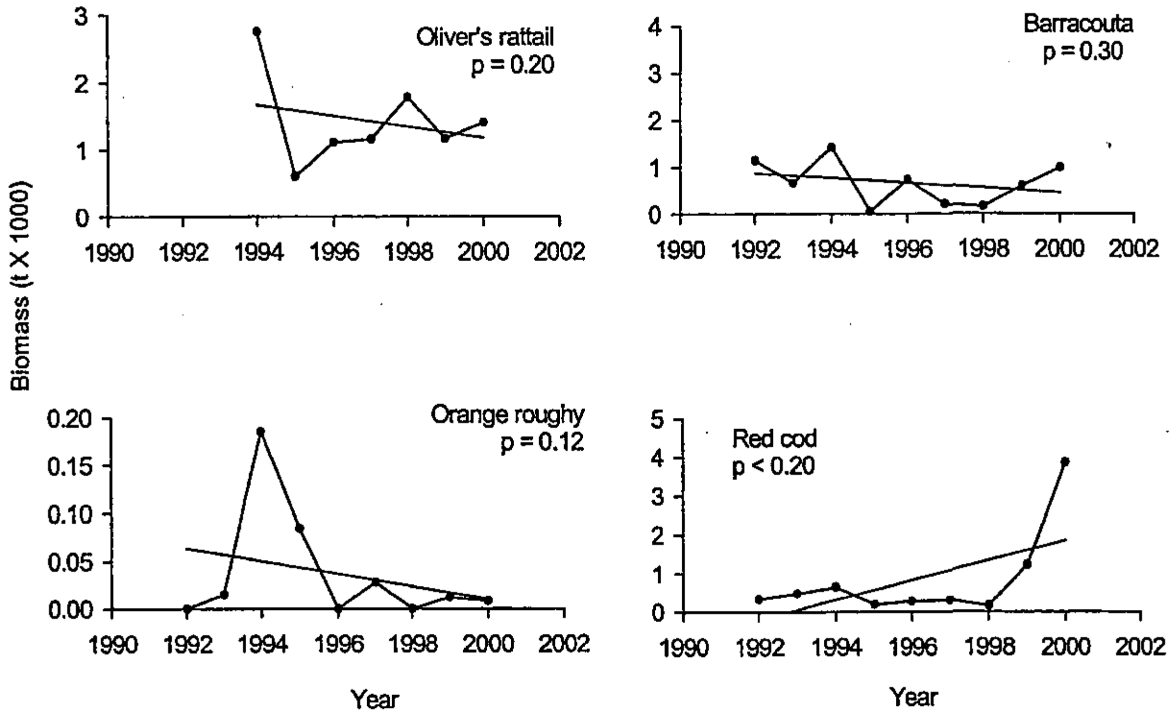


Figure 6: *Continued.*

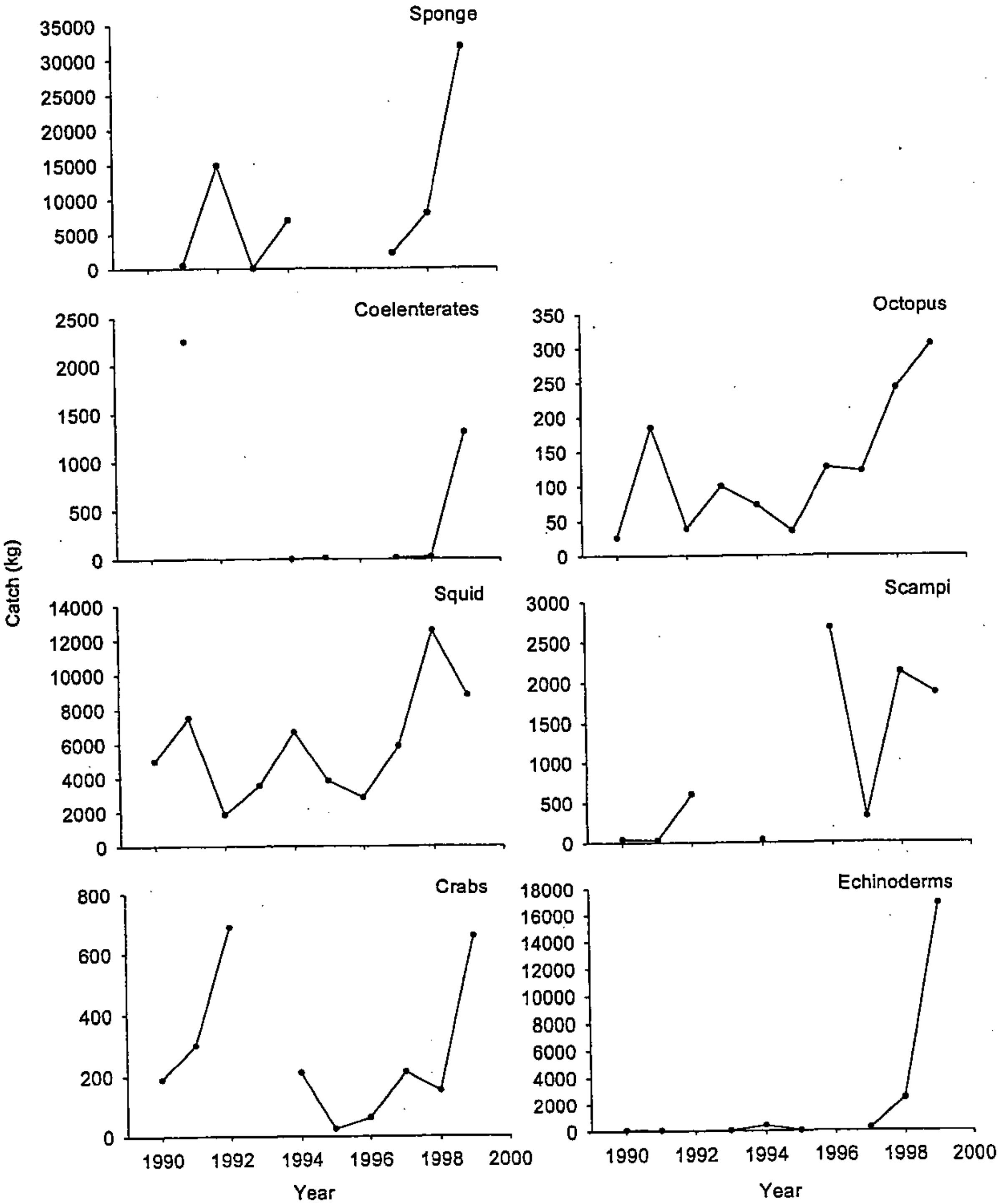


Figure 7a: Annual (fishing year) catch (kg) of invertebrate groupings as recorded in the Observer database.

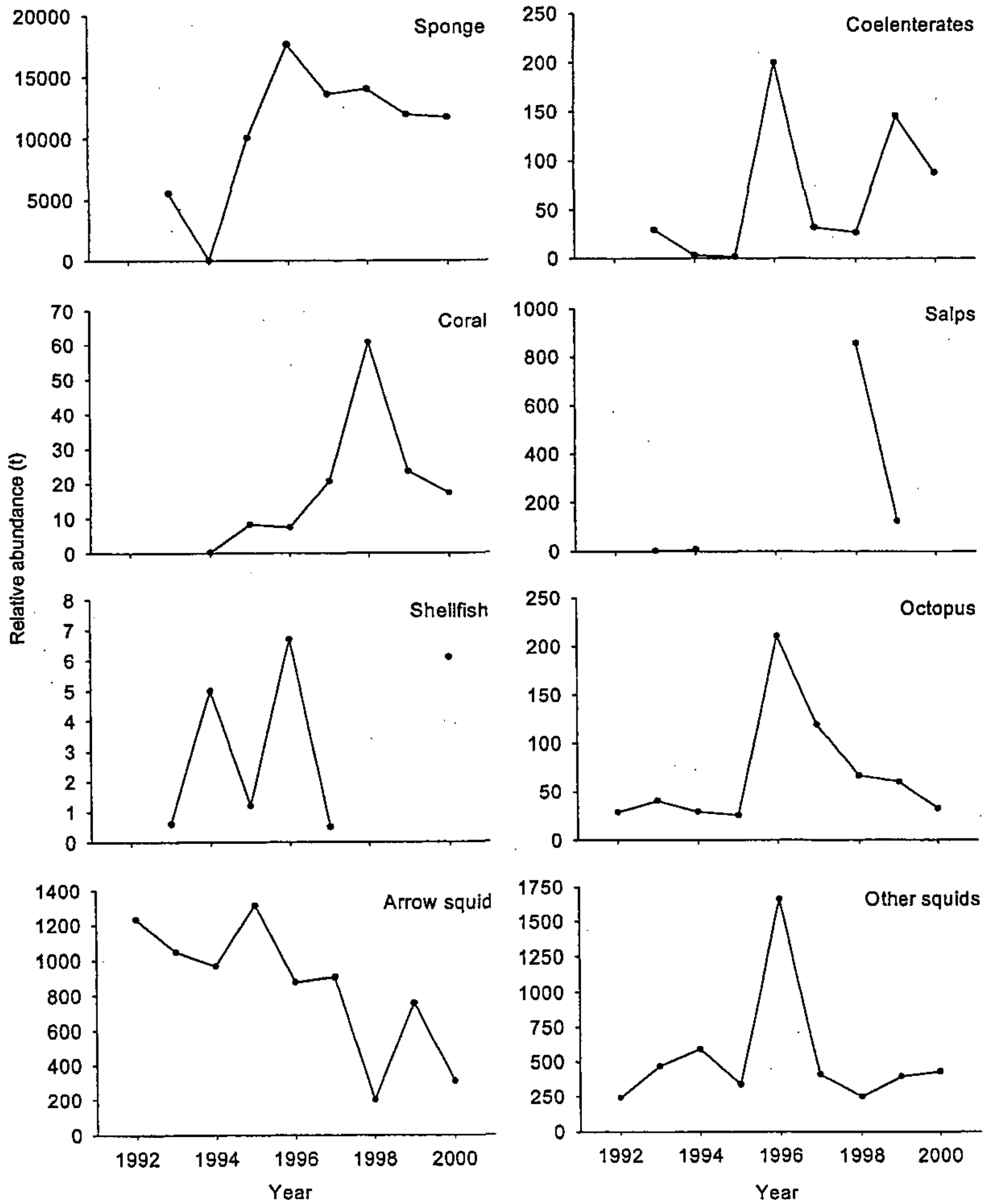


Figure 7b: Changes in relative abundance (t) of invertebrates sampled during surveys of the Chatham Rise 1992–2000

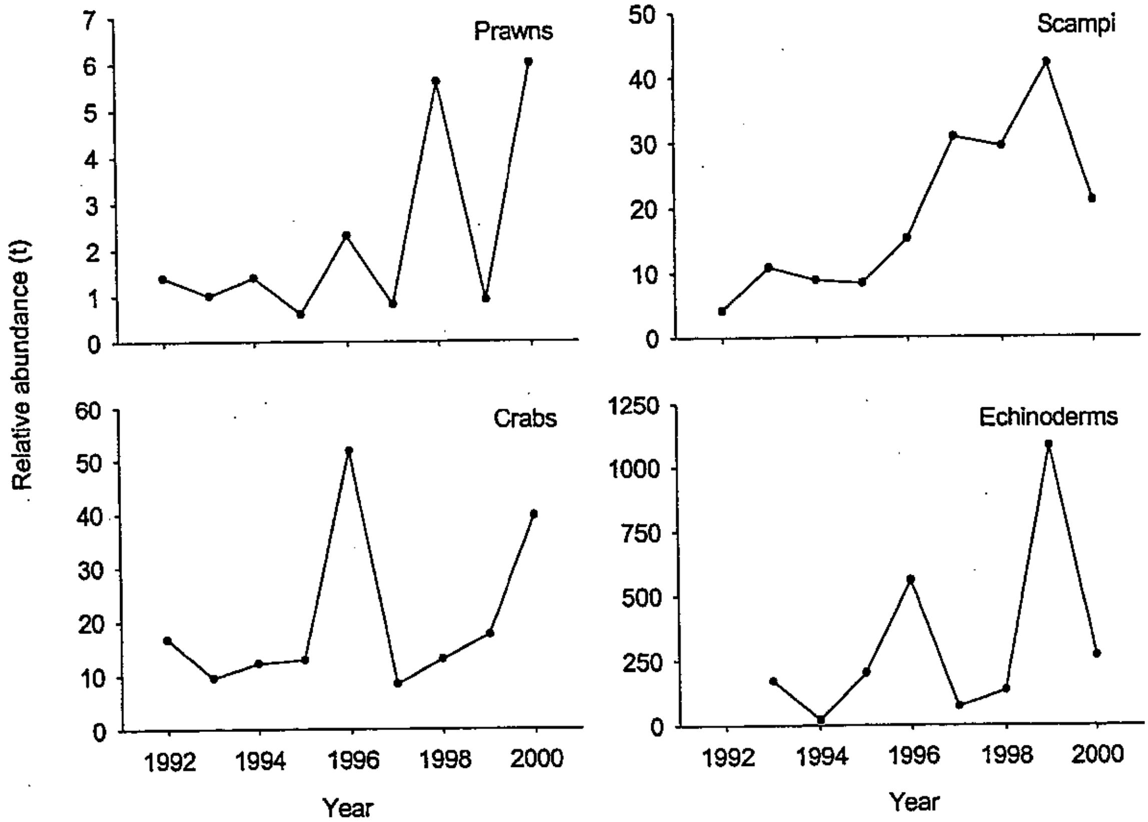


Figure 7b: ***Continued.***

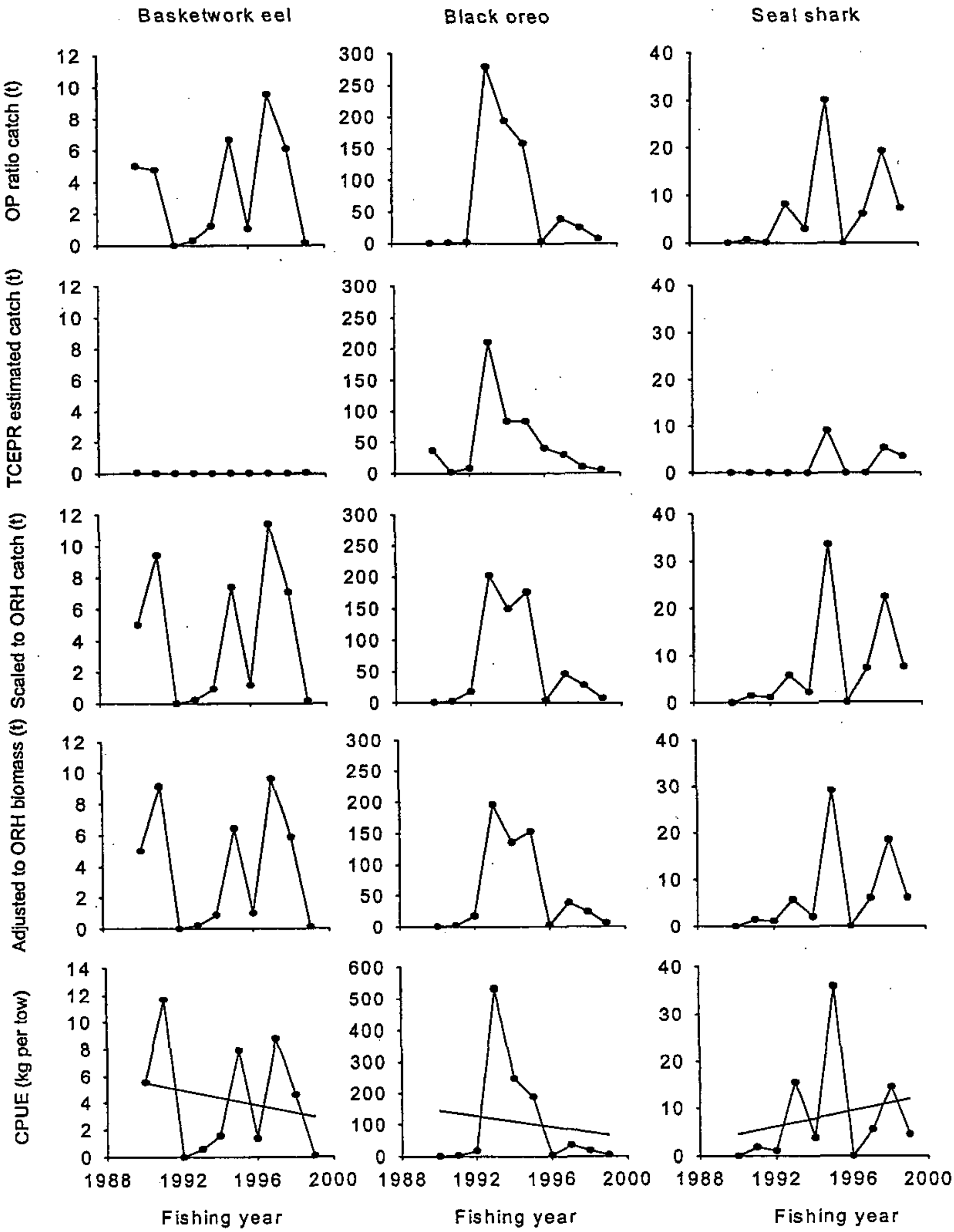


Figure 8: Trends in catch (t) and CPUE from the northwest Chatham Rise subarea, fishing years 1989–90 to 1998–99. (OP ratio catch estimated from OP database, TCEPR catch estimated from tow by tow TCEPR data, CPUE is the OP ratio catch (kg) divided by the number of tows that targeted orange roughy.)

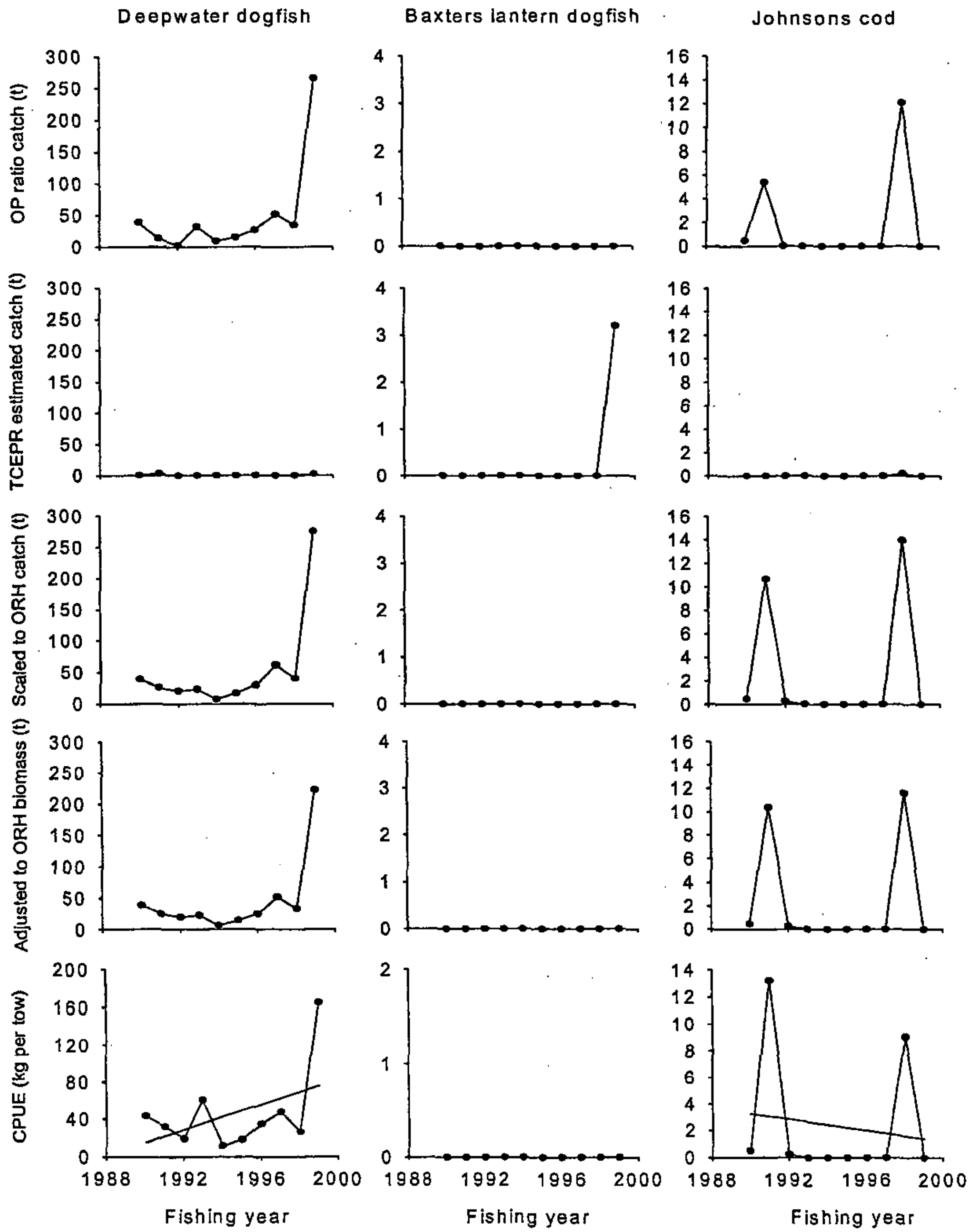


Figure 8: *Continued.*

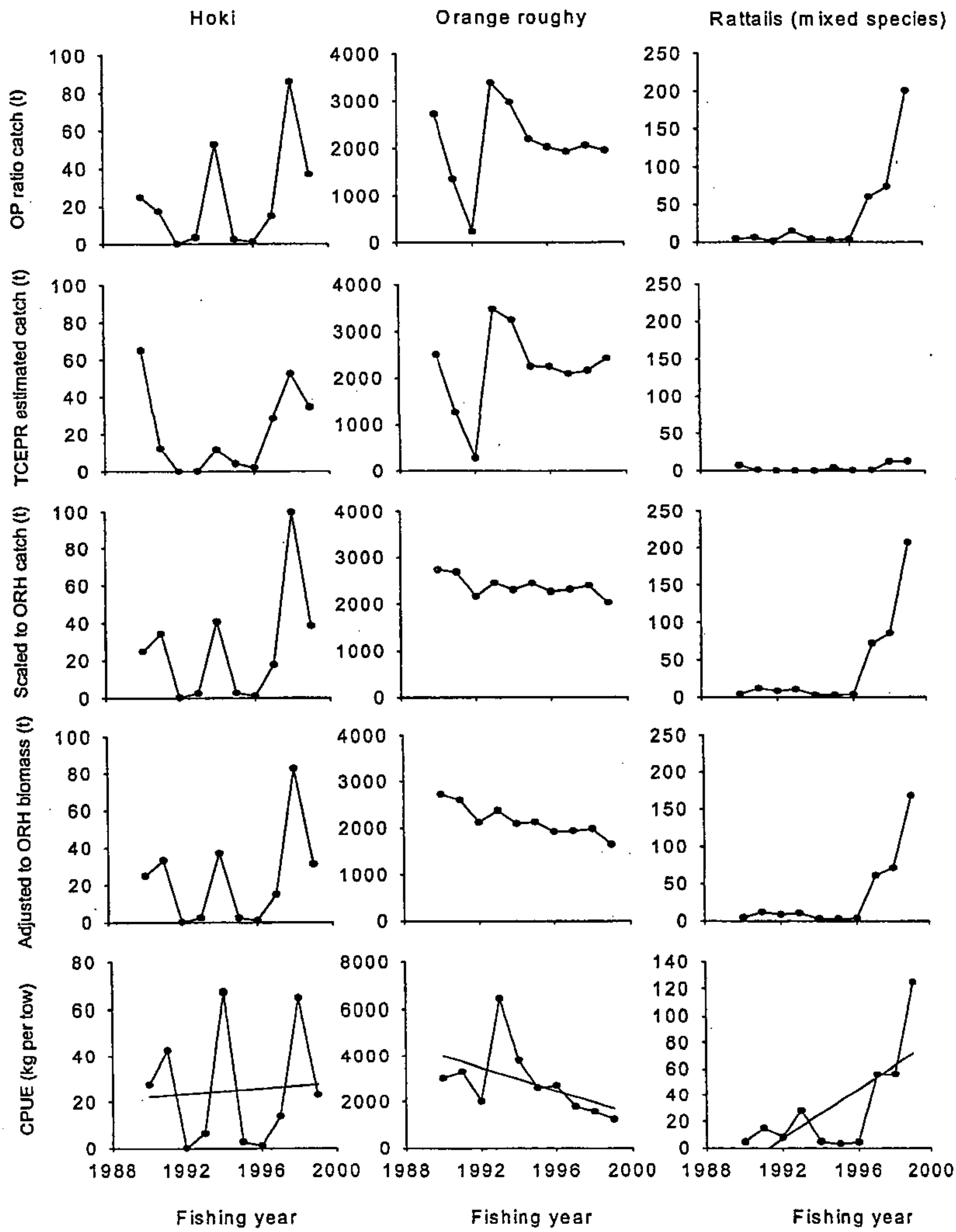
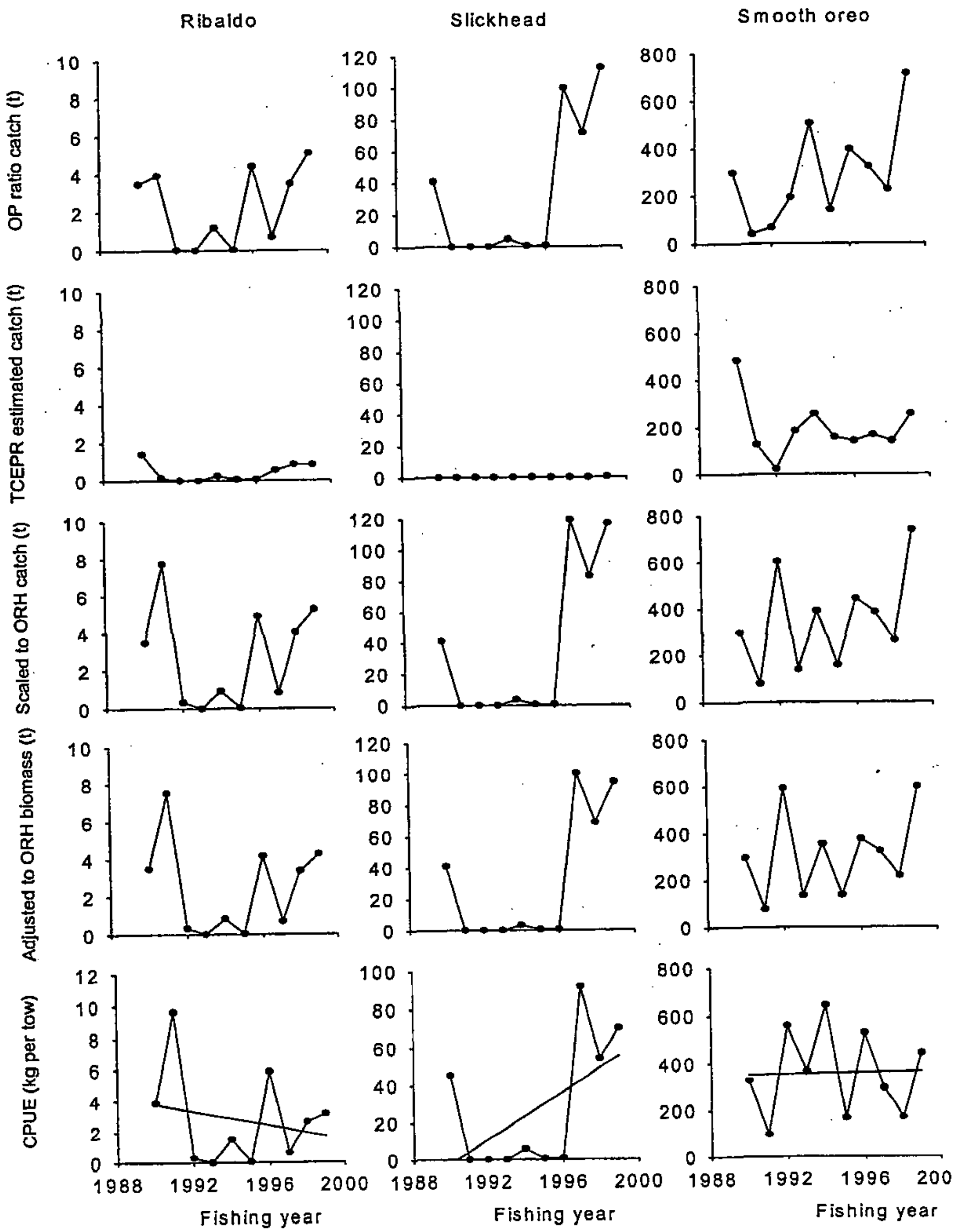


Figure 8: ***Continued.***



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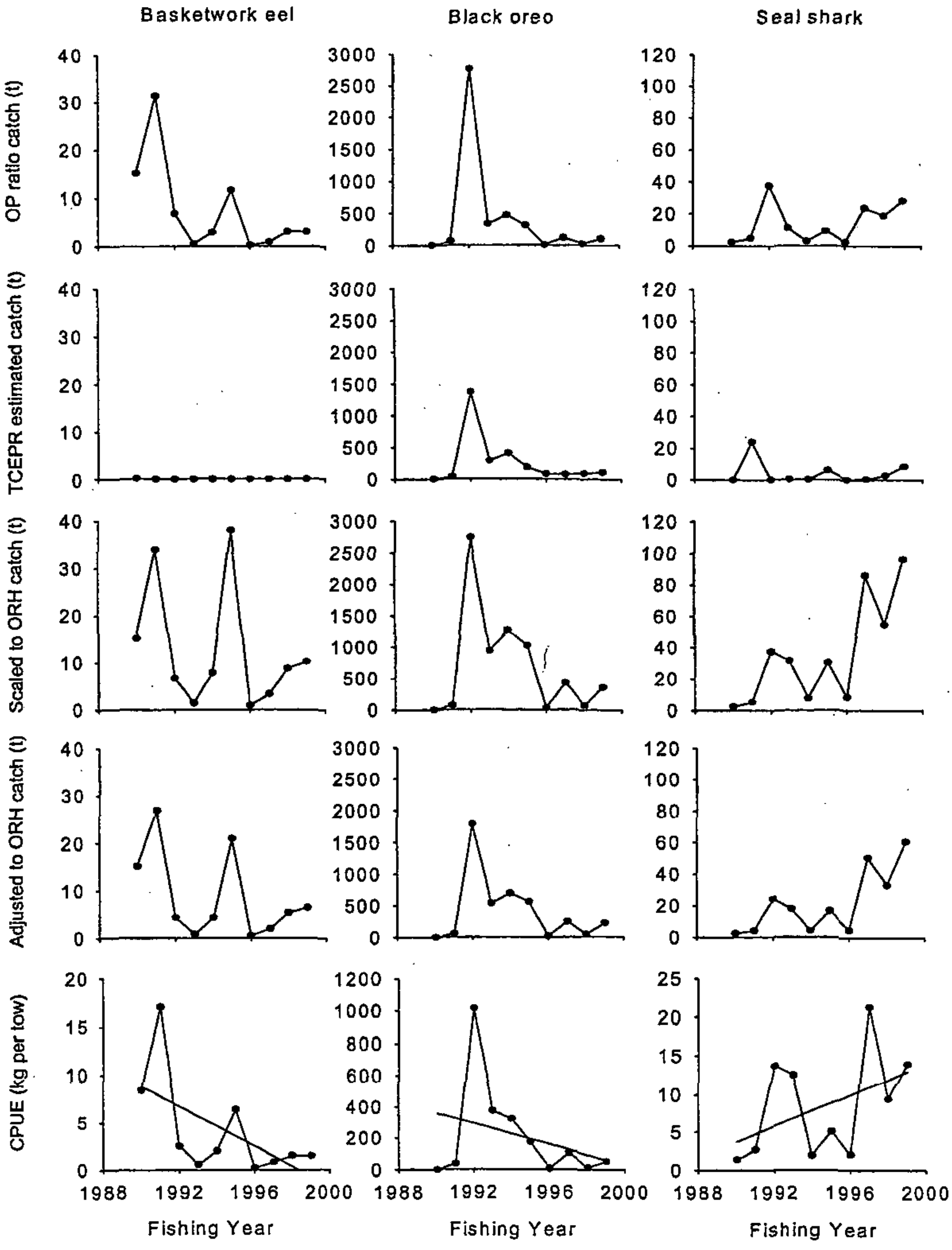


Figure 9: Trends in catch (t) and CPUE from the northeast Chatham Rise subarea, fishing years *1989–90* to 1998–99. (OP ratio catch estimated from OP database, TCEPR catch estimated from tow by tow TCEPR data, CPUE is the OP ratio catch (kg) divided by the number of tows that targeted orange roughy.)

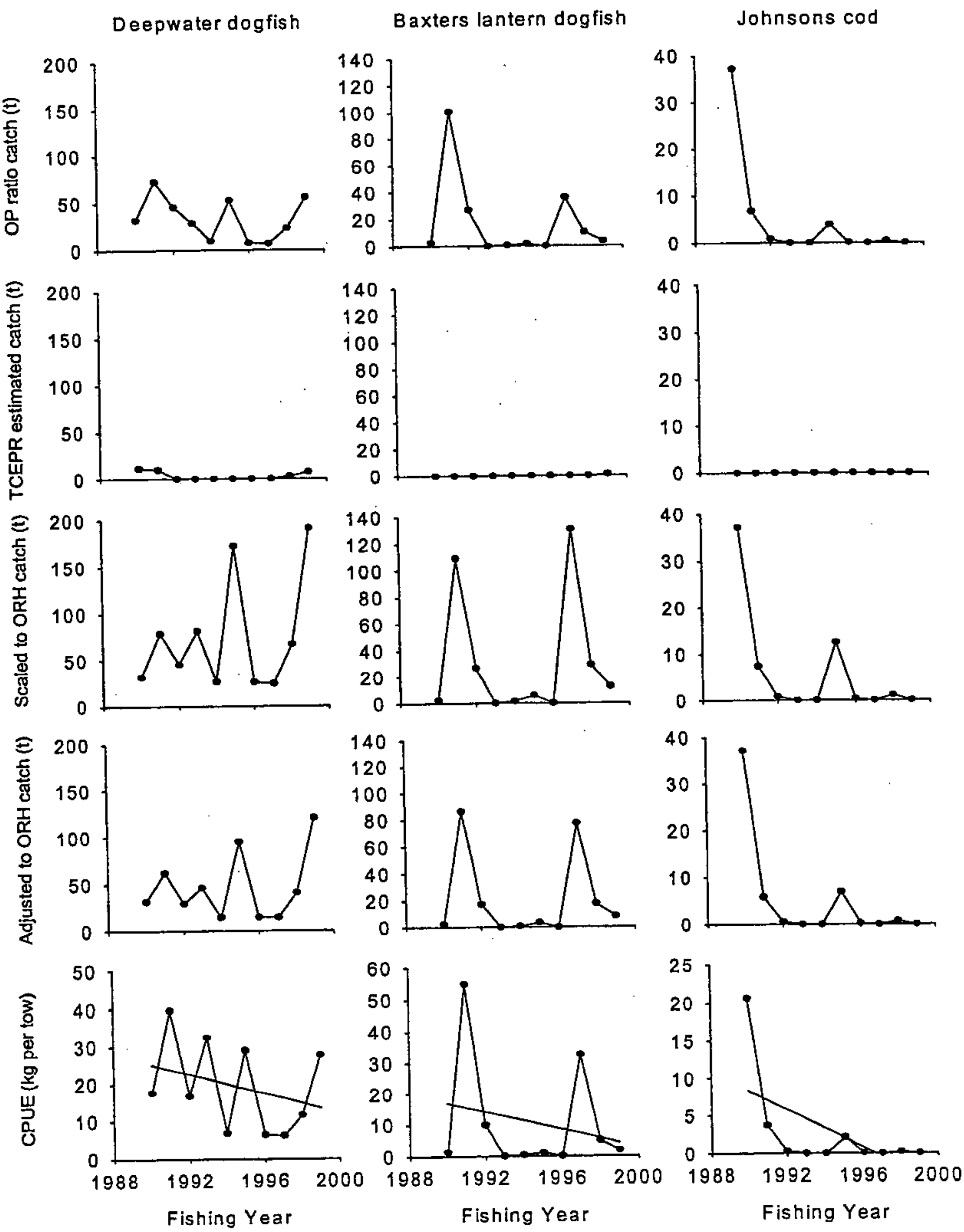
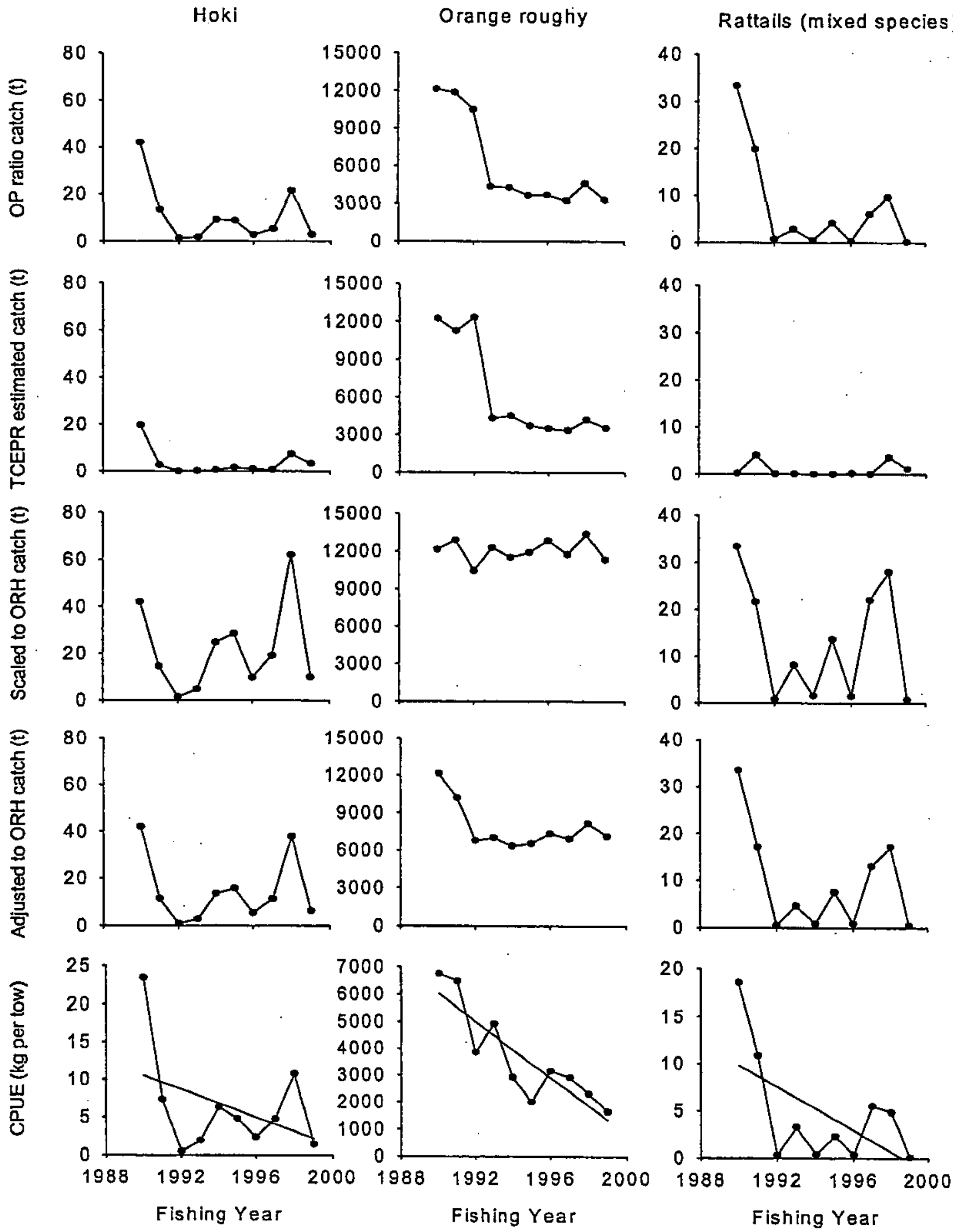


Figure 9: *Continued.*



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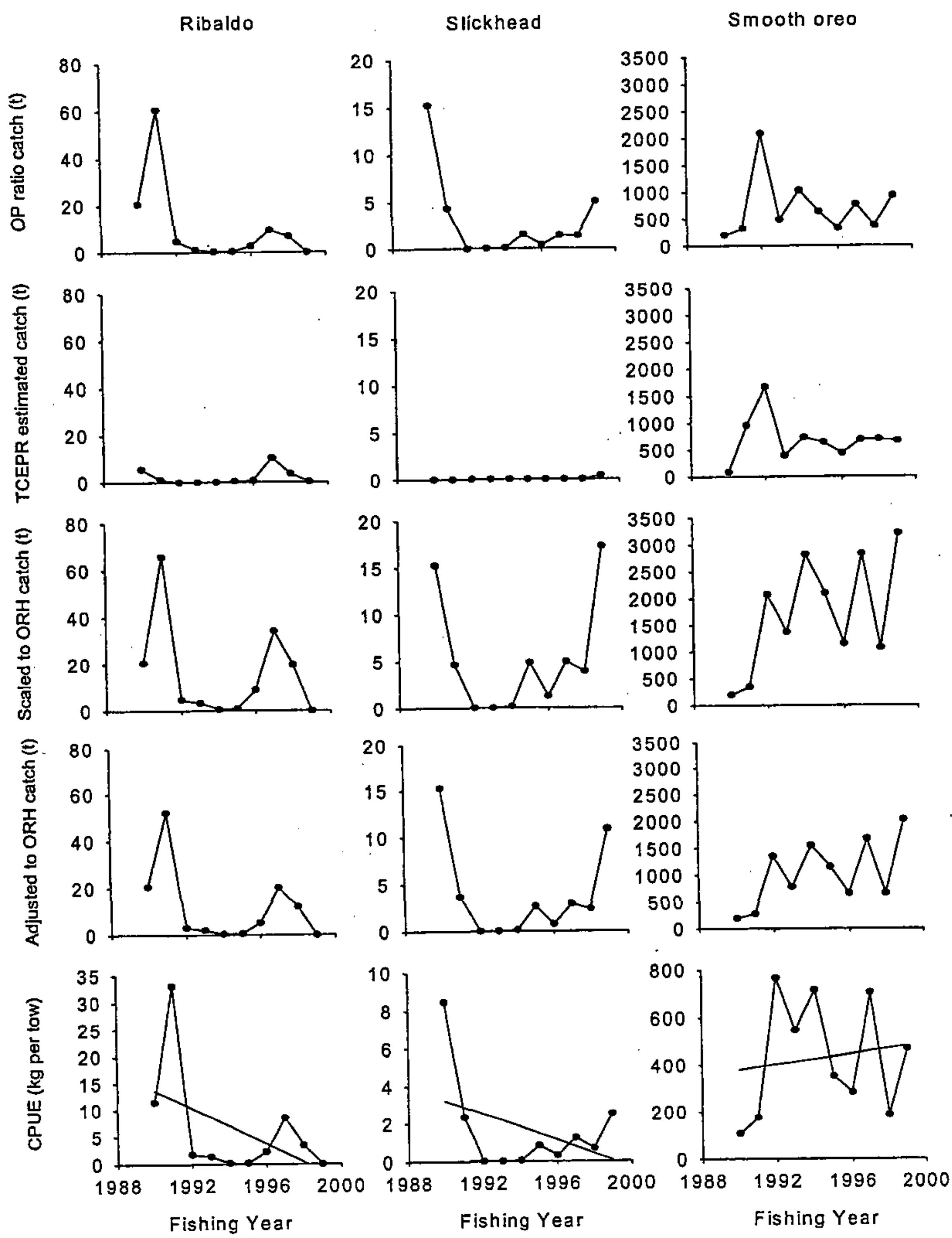


Figure 9: ***Continued.***

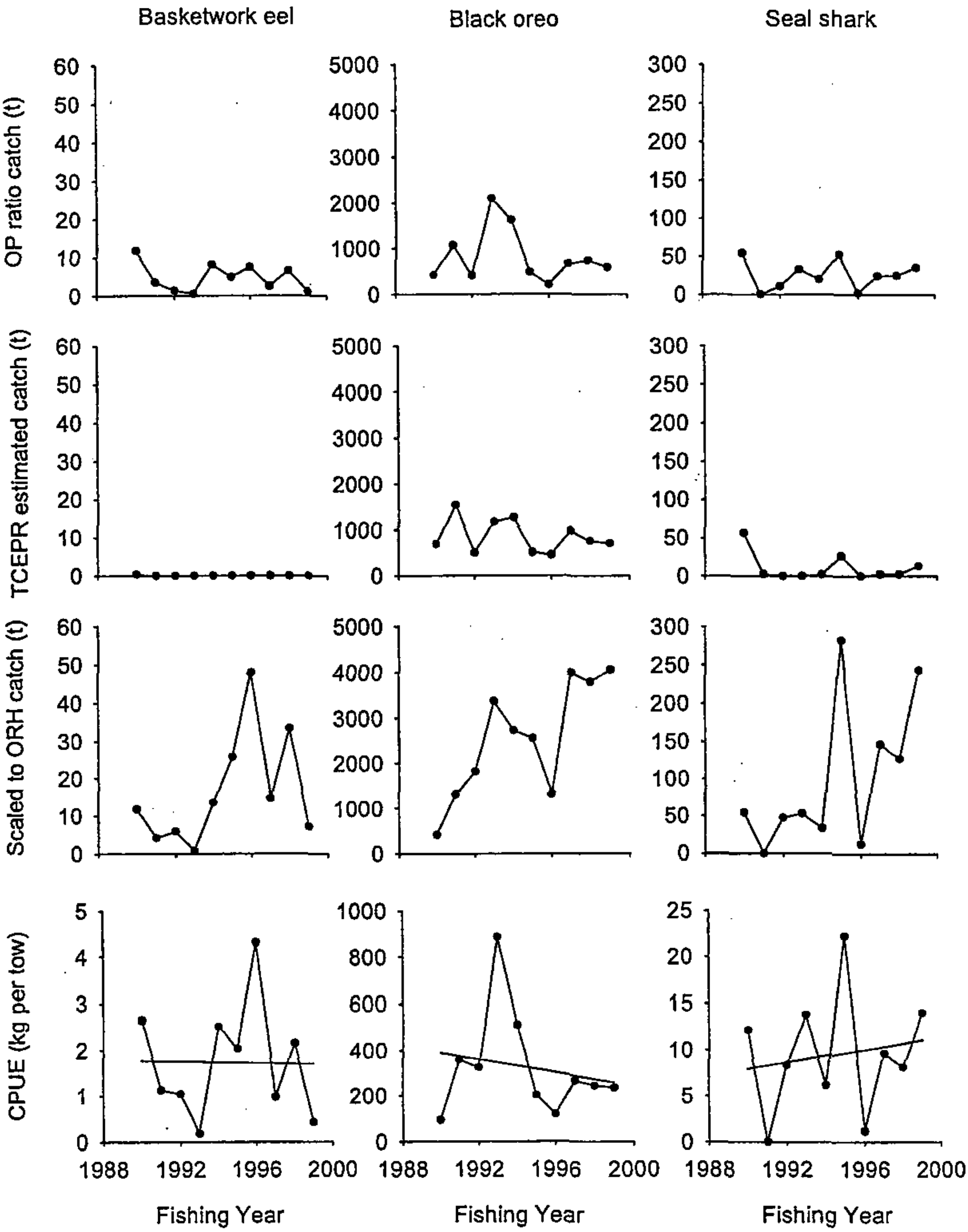


Figure 10: Trends in catch (t) and CPUE from the south Chatham Rise subarea, fishing years 1989–90 to 1998–99. (OP ratio catch estimated from OP database, TCEPR catch estimated from tow by tow TCEPR data, CPUE is the OP ratio catch (kg) divided by the number of tows which targeted orange roughy.)

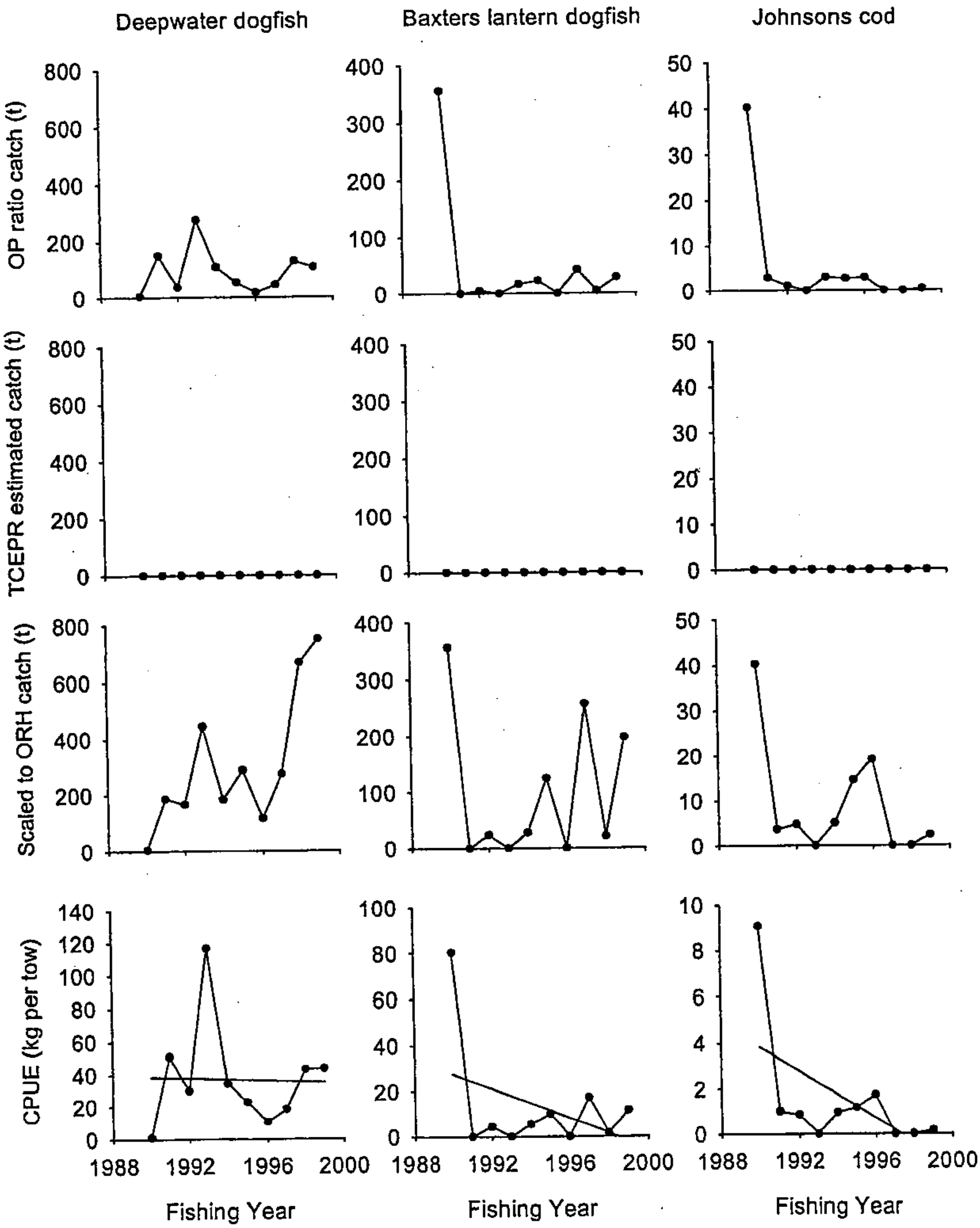
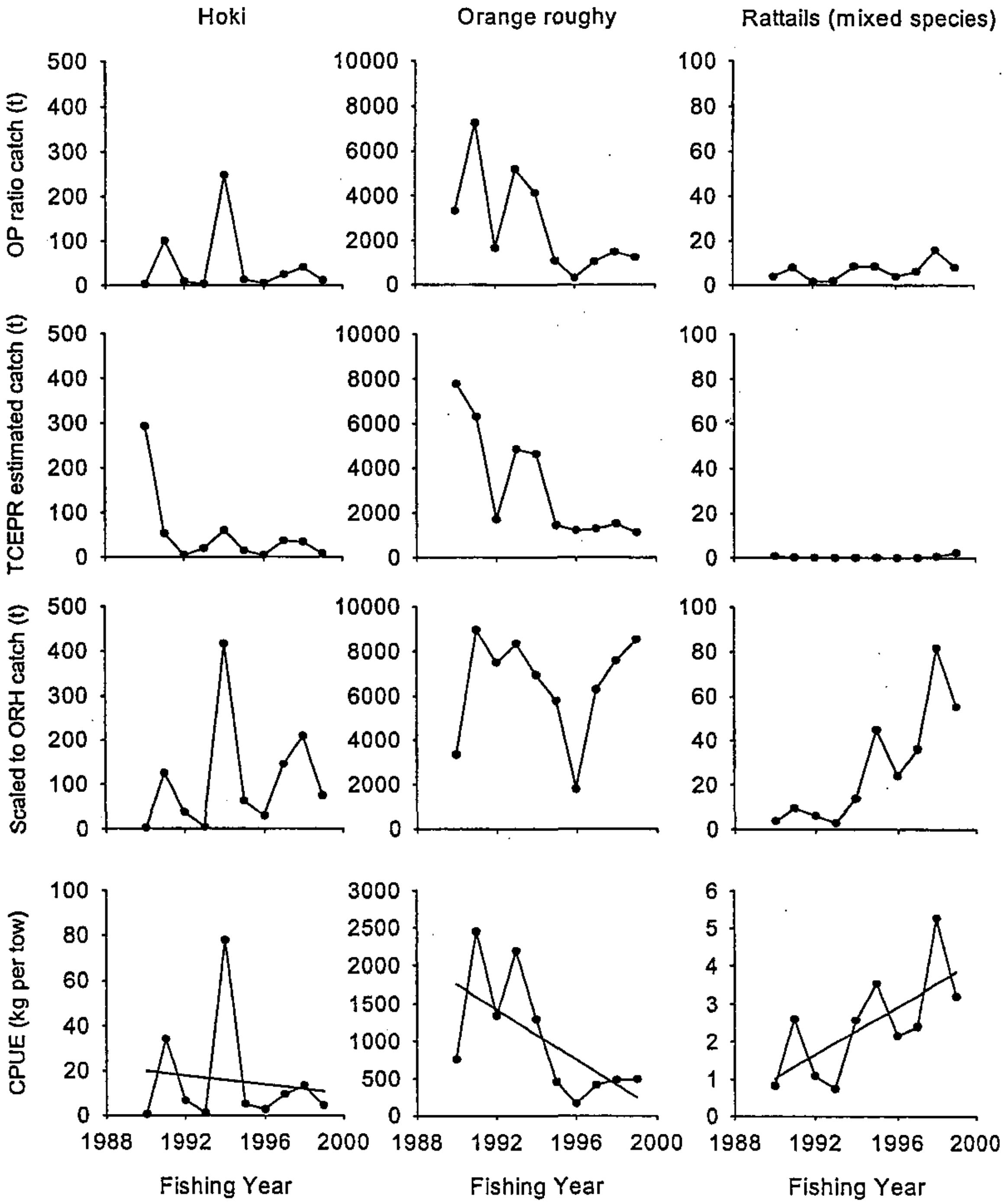


Figure 10: *Continued.*



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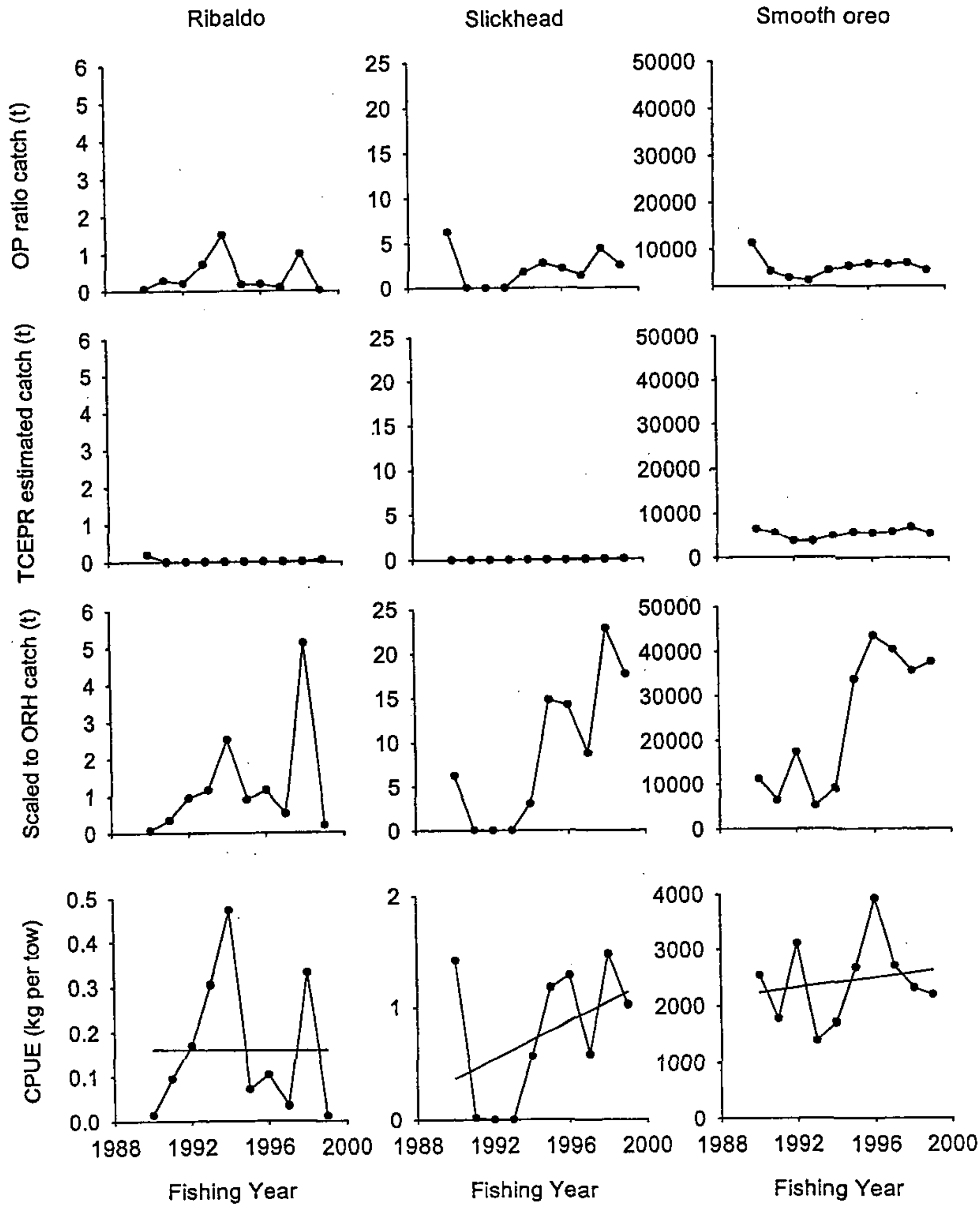

Figure 10: ***Continued.***

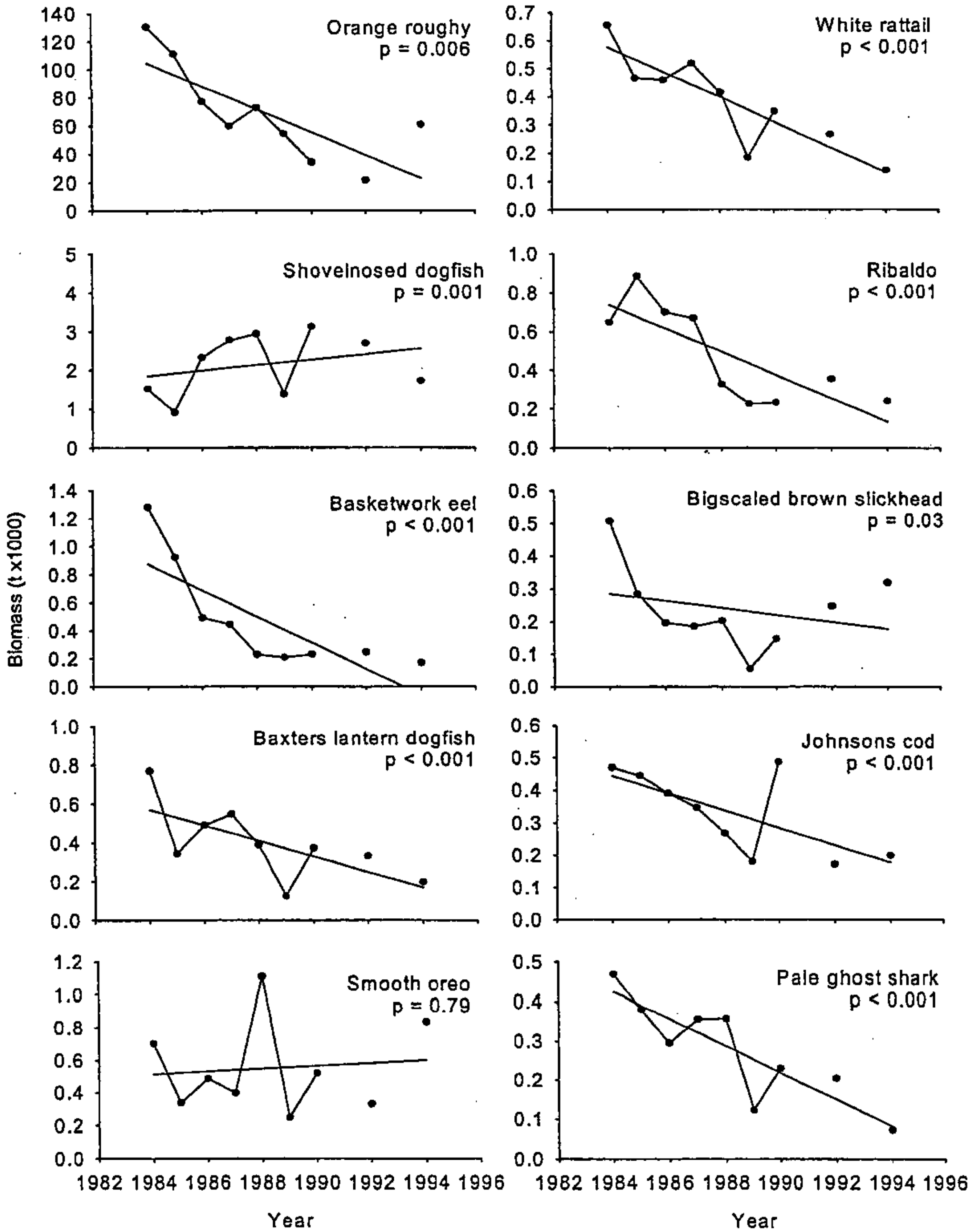

Figure 11: Trends in biomass estimates from research trawl surveys in the northeast Chatham Rise subarea. A linear trend has been fitted. P values represent the significance of the trend from a bootstrap analysis.

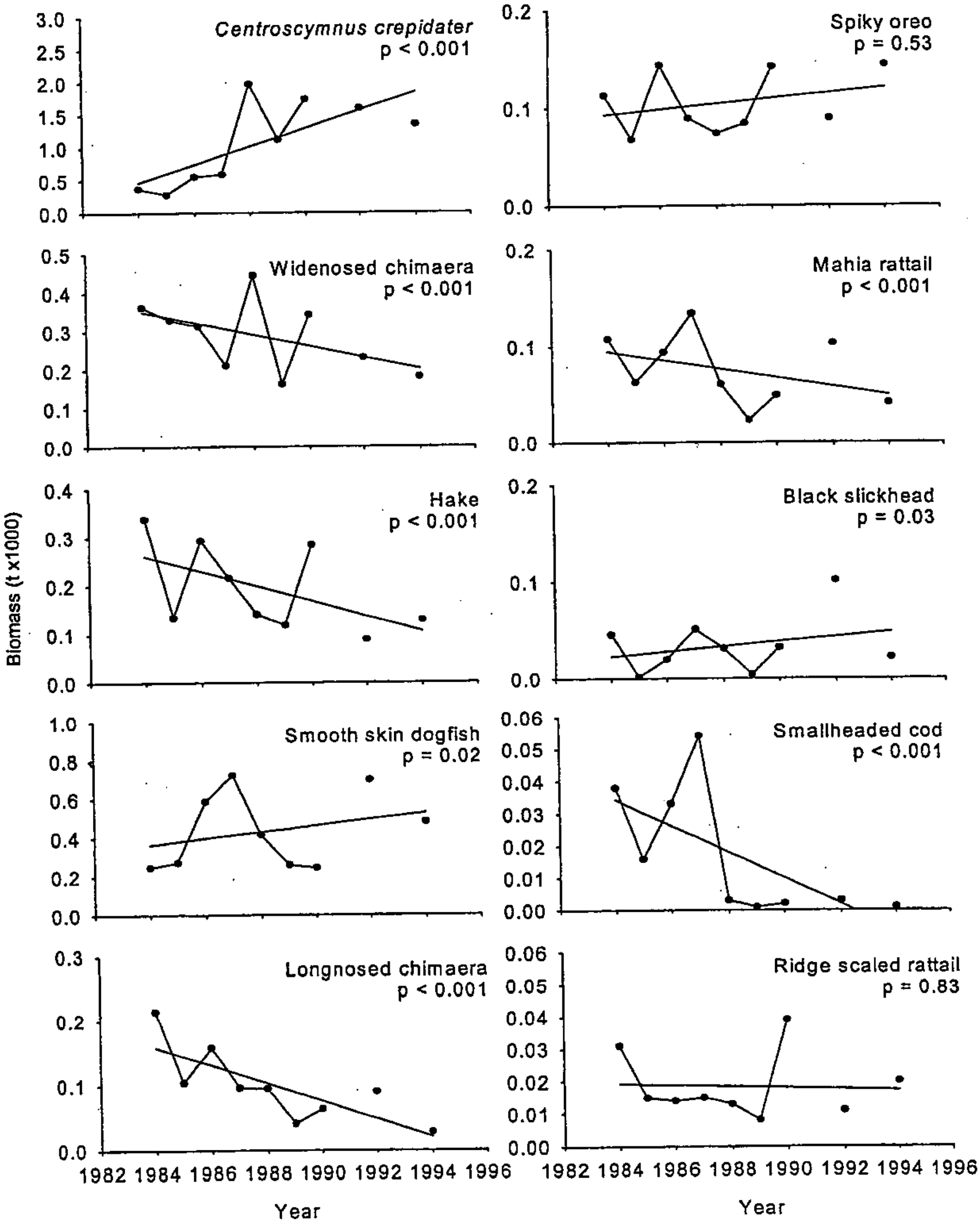

Figure 11: ***Continued.***

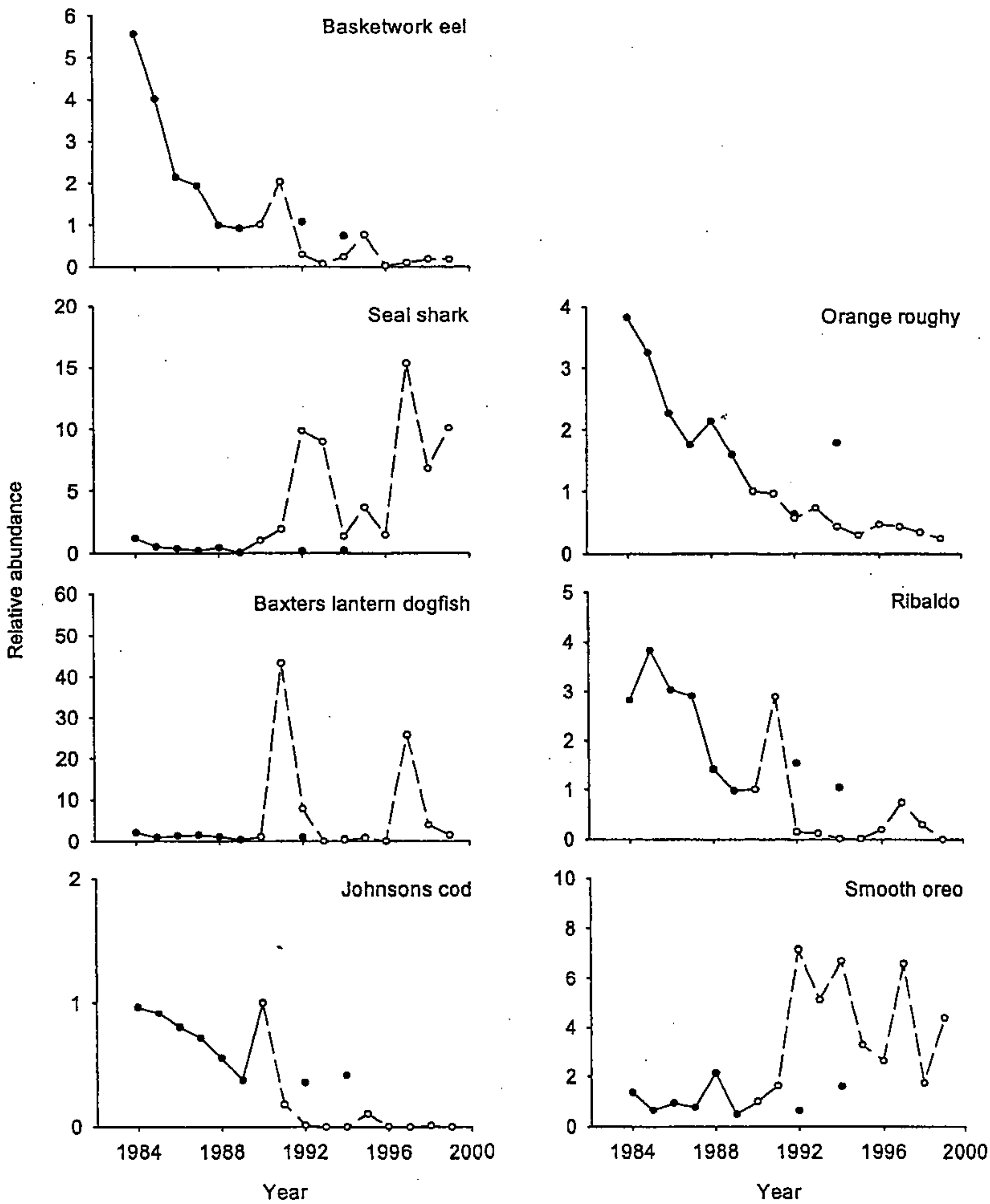

Figure 12: Comparison of relative abundance trends in the northeast Chatham Rise subarea from trawl surveys (solid circles, solid lines) and commercial CPUE (open circles, dotted lines) for species in common. Abundance indices standardised to 1990.

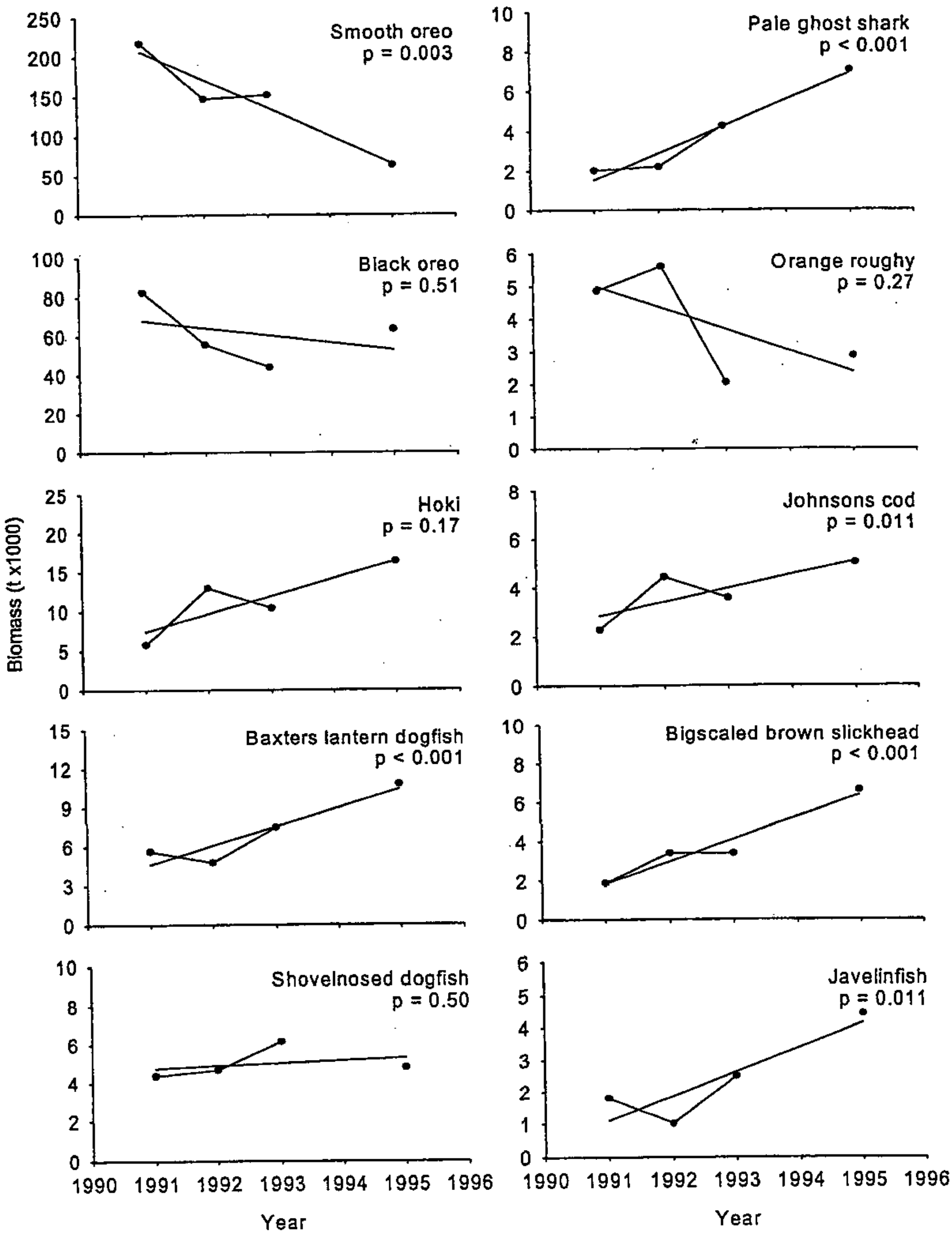

Figure 13: Trends in biomass estimates from research trawl surveys in the south Chatham Rise subarea. A linear trend has been fitted. P values represent the significance of the trend from a bootstrap analysis.

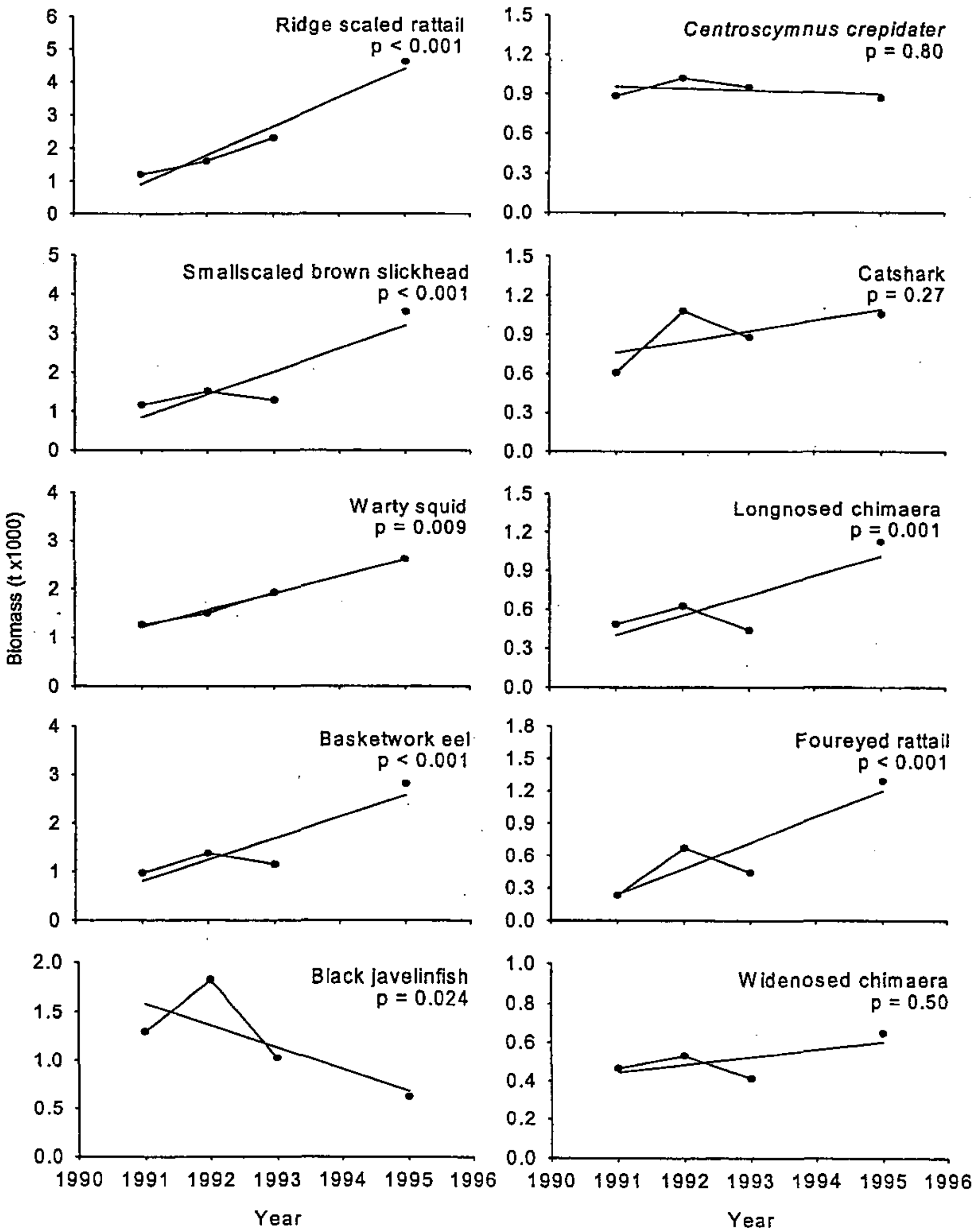

Figure 13: *Continued.*

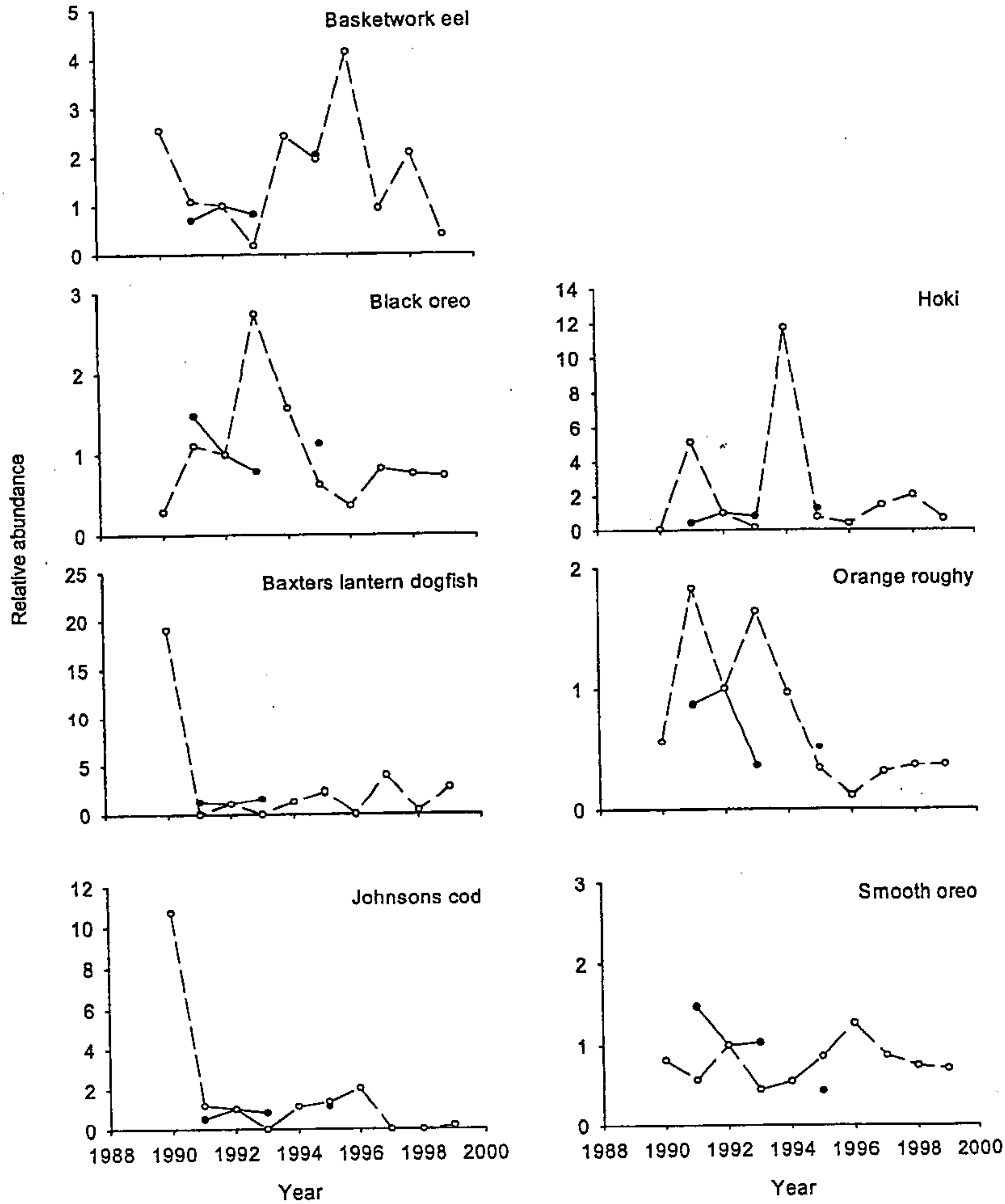

Figure 14: Comparison of relative abundance trends in the south Chatham Rise subarea from trawl surveys (solid circles, solid lines) and commercial CPUE (open circles, dotted lines) for species in common. Abundance indices standardised to 1992.

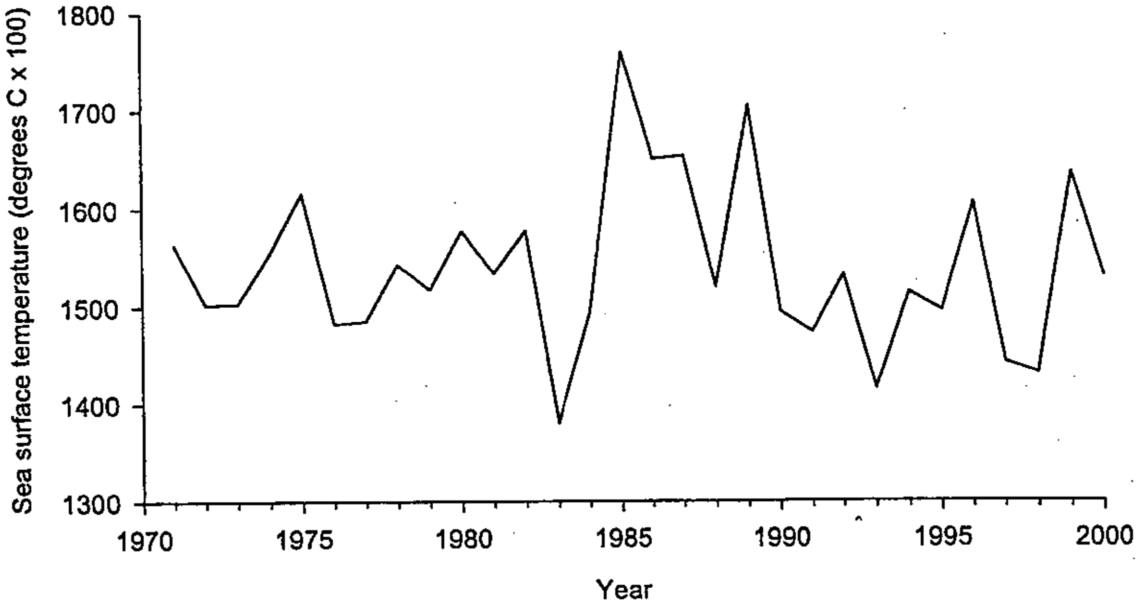

Figure 15: Mean sea surface temperature in January, 1971 to 2000, at longitude 44 degrees S, latitude 180 degrees, on the Chatham Rise. (Data source NIWA climate database.)

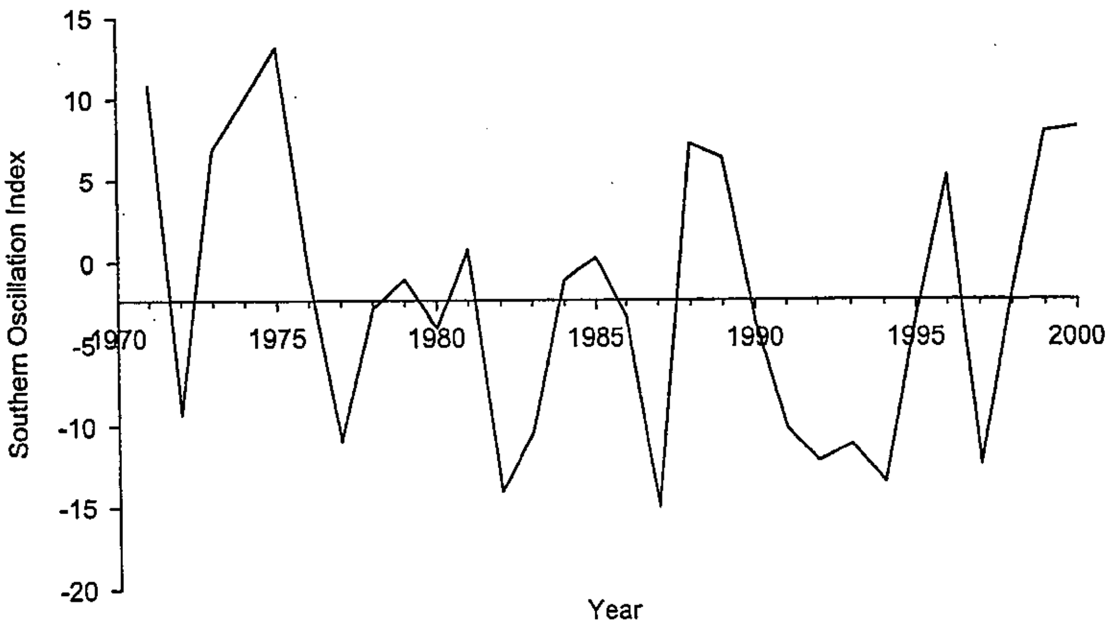

Figure 16: Mean (annual) Southern Oscillation Index 1971 to 2000. (Data source NIWA climate database.)