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Ecosystem indicators for New Zealand fisheries

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EXECUTIVE SUMMARY

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Ecosystem indicators derived from trawl survey data have been developed elsewhere, and used successfully to identify the effects of fishing on fish communities. The most commonly used indicators have been based on measures of diversity or fish size (mean size or size spectra), but indicators incorporating trophic level have also been considered.

Length distributions and catch weight by species are the basic data requirements for a number of species and size based indicators, and are routinely collected from New Zealand trawl surveys. Life history characteristic data may also be available for some of the other indicators.

Trawl survey series are available for New Zealand waters going back to the 1960s for some inshore areas, and to the late 1970s and 1980s for middle depths and deeper waters. However, improvements in taxonomic skills and possible changes in measurement practice are likely to have introduced a bias into any time series trends in indicators calculated from the raw survey data, and considerable "grooming" will be required before analysis can take place.

A review of available indicators, trawl survey data, and initial recommendations for investigation within this project were presented to an Aquatic Environment Working Group / stakeholder workshop. On the basis of discussions at this workshop, a suite of indicators was selected for application to three trawl survey time series (Hauraki Gulf inshore trawl series, Chatham Rise middle depths trawl series, and the Southland and Sub-Antarctic middle depths trawl survey series).

Indicators were examined over time at different spatial scales (survey strata and larger areas), and in relation to a measure of fishing intensity. For each trawl survey series, the trends observed from different data sets (full species list, pelagics excluded, measured species only) were also compared.

At the survey strata larger area level, a number of the indicators showed significant trends over time. However, from the three trawl survey series examined, species based measures of diversity appear to be the most useful in identifying changes correlated with fishing intensity. Pielou's evenness appears to most consistently show a significant correlation with fishing intensity, but the Shannon-Weiner index, species richness, and Hill's N1 and N2 also showed patterns in relation to fishing pressure. Size based indicators did not appear as useful for New Zealand trawl survey series as they have been elsewhere in detecting changes in relation to fishing intensity, and this may be related to the requirement to reduce the data set to key measured species.

1. INTRODUCTION

The strategic framework document 'Changing Course - Towards Fisheries 2010' states that the Ministry of Fisheries is committed to transforming its underlying philosophy from one of resource management to one of an 'ecosystem based approach' to fisheries management, under which "we manage fish in the context of the environment in which they exist". Evaluating the environmental effects of fishing is not an easy task and scientific consensus about how this can best be achieved has not been reached. The Ministry's Strategy for Managing the Environmental Effects of Fishing (SMEEF) signals that the preferred approach in New Zealand will be to develop environmental standards. The ecosystem projects proposed in the 2006–07 Aquatic Environment Medium Term Research Plan were designed to ensure that existing data sets and time series have been fully analysed for information that will form a starting point towards incorporating environmental concerns into fisheries management. This is a cost-effective approach to ensure that maximum benefit is obtained from data already gathered before launching new research programmes. This approach will also enable new programmes to be focussed towards issues not addressed by past research.

Successful incorporation of environmental concerns into fisheries management rests in part on our ability to find ways of monitoring and evaluating ecosystem change. Identifying appropriate measures of change, which can incorporate both natural and human-induced effects, is being undertaken in many parts of the world. The goal of these efforts is to identify cost-effective but sensitive indicators that can readily be applied to data that have been collected consistently over time (such as trawl time series). Indicators that monitor community characteristics (as opposed to use of single population-based indicators to monitor trends in fish populations) are increasingly being applied to survey data sets (Rochet & Trenkel 2003, Trenkel & Rochet 2003, Fulton et al. 2005, Jennings & Dulvy 2005, Mueter & Megrey 2005). Where sufficient data exist, such analyses may document changes in fish communities, and the fisheries that depend on them.

The uses (and limitations) of biological and environmental indicators in fisheries management have been widely published in the international literature. This report seeks to review indicators that may signal ecosystem level changes in fish communities monitored by trawl survey time series and identify the more robust indicators, appropriate for analysis of New Zealand trawl survey data.

Overall objectives

1. To determine appropriate quantitative ecosystem indicators for use in New Zealand fisheries management.

Specific objectives

1. To carry out a literature review of potential fish-based ecosystem indicators and identify a suite of indicators to be tested in Objective 2.
2. To test a suite of fish-based ecosystem indicators (identified in objective 1) on existing trawl survey time series in New Zealand. The utility of these indicators for monitoring the effects of fishing in New Zealand should also be evaluated.

2. FISH-BASED ECOSYSTEM INDICATORS

Adopting a management approach that seeks to take into account the environmental effects of fishing requires that managers are supported by reliable scientific advice and effective management decision making. Indicators support the decision making process by (i) describing the pressures affecting the ecosystem, the state of the ecosystem, and the response of managers, (ii) tracking progress towards meeting management objectives, and (iii) communicating trends in complex impacts and management processes (Jennings 2005).

Environmental management indicators can be classified on the basis of the pressure, state, response framework (Garcia & Staples 2000). In relation to the effects of fishing, pressure indicators would include fleet size, fishing mortality, fishing effort and catch and discard rates; state indicators are species abundance and mean body size; while response indicators include most pressure indicators, expressed as rates of change. Most indicator development in relation to the effects of fishing has concentrated on the state indicators (Jennings 2005), although as managers manage fishing, the state of the environment can only be changed in predictable ways when the relationships between pressure and state indicators are known. Therefore, while this study will focus on state indicators (due to project objectives and data available), pressure and response indicators are required to support decision making.

Potential fish-based ecosystem indicators are numerous, diverse, and of varying calculability for trawl survey data. For example, Rochet & Rice (2005) listed 29 indicators, based on variables ranging from genetic diversity to oceanographic oscillation indices, while Rice (2003) found more than 200 indicators of ecosystem status. Several recent reviews (Rochet & Trenkel 2003, Trenkel & Rochet 2003, Fulton et al. 2005, Jennings & Dulvy 2005, Mueter & Megrey 2005) provided comprehensive lists of indicators, including species-abundance based indicators, species trait-based indicators, indicators for communities, total biomass, trophic composition, food web models, trophic level, and size spectra. A limited number of these indicators can potentially be calculated on the data solely from existing trawl series. Other indicators of ecosystem condition can be derived from the trawl series data in conjunction with information related to fish life history features such as generation time, maximum age, maximum size, growth rate, or feeding biology (gut contents, trophic level). Since individual indicators may respond to community changes in different ways, development of a suite of complementary indicators may provide the best approach.

Three main types of fish-based indicator have been developed for ecosystem-based fisheries management (Rochet & Rice 2005): species-based, size based, and trophodynamic. Each of these main types is considered in turn, with the underlying theory explained and potential indicators discussed. While a great many potential indicators have been identified in the literature (Rice 2000, 2003, Rochet & Trenkel 2003, Trenkel & Rochet 2003, Cury et al. 2005), here we focus on those which rely on trawl survey data as their main information source, since it is the analysis of this type of data that is the ultimate aim of the project. Indicators have generally been considered individually over time, although some authors have combined indicators into a form of multivariate analysis to examine changes in community or population characteristics (Ragonese et al. 2005).

2.1. Species based indicators (SpBIs)

Certain species appear to be more sensitive to the effects of fishing than others (either since they are targeted by the fishery, or owing to particular life history characteristics [e.g. slower growth, larger size at maturity, lower rates of potential population increase] which make them more vulnerable). These differences in sensitivity to the effects of fishing may result in changes to community structure that can be detected through examining communities over time. Data requirements vary, but can include life history and fishery information (target/non-target, endangered species) in addition to typical trawl survey output.

2.1.1. Indicator or endangered species

Some species are considered to be particularly sensitive to the effects of fishing (perhaps due to a combination of life history characteristics: slow growth, large size and age at maturity, and low fecundity), and their abundance or size structure may provide an indicator of ecosystem health. Skates and rays have been used in this way in the North Sea (Walker & Hislop 1998, Rogers & Ellis 2000), where the species identified as being most sensitive to fishing (from life history traits) have been observed to decline in abundance since the 1930s. Other work in the North Sea has shown that fishing has greater effects on slower growing, larger species with later maturity and lower rates of potential population increase (Jennings et al. 1999). Large scale annual monitoring surveys are likely to have low power to detect declines or recovery in abundance of vulnerable (generally less abundant) species on time scales under 10 years, but power is increased by developing a composite indicator reflecting trends in abundance of several vulnerable species (Maxwell & Jennings 2005). Potentially sensitive New Zealand species may be identified in a similar way, although skates and rays are considered to be poorly sampled by some New Zealand surveys (N. Bagley, NIWA, pers. comm.) and so these may prove to be unsuitable as indicator species. For use as an indicator, the catch of the endangered species is examined as a proportion of the total catch, although this is sensitive to changes in total catch.

2.1.2. Diversity

Measures of diversity are widely used in community ecology, with a variety of methods available. Diversity measures are a joint construct of how many species are present (richness), and how similar their abundances are (evenness), with some indices giving additional emphasis to the most important species in a community (dominance). Many of the measures vary only in the relative weight given to each of these factors, although measures based on taxonomic distinctiveness are slightly different, in that they also consider the taxonomic “closeness” of species in a community (Warwick & Clarke 1995). Studies employing diversity as an indicator often apply more than one measure to investigate changes in community structure (e.g., Hill’s N1 and N2 examine variation in abundance of rare and dominant species, respectively). Specific changes in diversity will be dependent on the communities being fished. If fishers target communities dominated by few commercial species, then exploitation may increase evenness, and thus biodiversity. When more even communities are targeted, the least abundant species may be depleted, reducing species richness and biodiversity.

In a study examining data from different world regions, no evidence was found of any decline in species richness, while changes in diversity measures (richness and evenness) were caused either by changes in the patterns of dominance or by changes in the numbers of species identified, resulting from improved survey protocol (Bianchi et al. 2000). Within the North Sea, the diversity (N1 and N2) of the whole groundfish assemblage has declined over time in the three most heavily fished areas, but not in the area where fishing pressure was least (Greenstreet et al. 1999, Greenstreet & Rogers 2006). This reduction in diversity appears related to changes in the relative abundance of the dominant species (because both indices show the same trend). Other studies within the North Sea have identified increased diversity in some areas (Rogers & Ellis 2000, Piet & Jennings 2005), and it is likely that the responses of communities to fishing are not consistent in all areas. Taxonomic distinctiveness and associated measures have been used to examine spatial differences in fish communities within the North Sea, but not specifically as an indicator over time (Rogers et al. 1999a). Indicators have previously been calculated for both whole fish assemblages, and also specific subsets of the catch (e.g., demersal groundfish assemblage in the North Sea).

2.1.3. Dominance and Abundance Biomass Comparison (ABC) curves

Dominance curves present the cumulative abundances of species in a community ranked by their abundances (Lambshead et al. 1983). Disturbance to the environment is expected to cause species that tolerate the perturbation to thrive, while intolerant species decline in abundance. These changes in species composition make the dominance curves of disturbed communities lie above and to the left of undisturbed communities. In the most heavily fished areas of the North Sea, the groundfish assemblage appears to have become progressively more dominated by fewer species over the period 1920s–1980s (Greenstreet et al. 1999). Similar trends have also been identified in other cold-water systems (Bianchi et al. 2000).

The ABC method was initially proposed as a technique for monitoring disturbance on benthic communities (Warwick 1986), and is a development of dominance curves, comparing dominance in terms of abundance with dominance in terms of biomass. In undisturbed states, communities are expected to be dominated by k-selected species (slow growing, large, late maturing), and the biomass curve lies above the abundance curve. As a community is disturbed (fished) and the larger, slow growing species are removed, the system become increasingly dominated by r-selected species (fast growing, small, opportunistic), and the biomass curve lies below the abundance curve. The difference between the two curves is given by the W statistic, which represents the area between them (-ve sign indicating biomass curve below abundance curve, representing disturbed community). The ABC approach has been applied to trawl survey data from the Mauritanian continental shelf, with the assemblages appearing stressed (biomass curve below abundance curve), but with no trend over time (Jouffre & Inejih 2005). A similar analysis of South African trawl survey data identified a significant declining trend in the W statistic over time (Yemane et al. 2005). The ABC approach has also been used to examine spatial patterns in fish communities, identifying differences between the North Sea and the Channel (Rogers et al. 1999b) and areas of different fishing pressure (analysis also including benthic invertebrates) (Blanchard et al. 2004).

2.1.4. Absolute and relative species abundance

Abundance estimates are relative measures of population numbers (Trenkel & Rochet 2003). Catchability may differ among species, and gear changes will alter catchability in time series. If estimates of catchability are available, abundance estimates can be corrected; otherwise CPUE reflects the combined effect of catchability and abundance. Relative abundance is a relative metric of population numbers, and thus has the same limitations as CPUE: if estimates of catchability are available, abundance estimates can be corrected; otherwise CPUE reflects the combined effect of catchability and abundance. Other than rare or vulnerable species, CPUE of individual species have not been widely adopted as ecosystem indicators, although the distribution of slopes of CPUE against time have been examined for two Alaskan surveys, with significantly more species than expected showing a decreasing trend in the Bering Sea (Mueter & Megrey 2005). Another similar indicator examined in this same Alaskan study was the distribution of slopes of species frequency of occurrence (FO) over time, which were tested in the same way. The fact that more species than expected showed an increase in FO over time was interpreted as a result of reduced fishing effort during the 1990s (Mueter & Megrey 2005).

2.1.5. Exploitation rate

Exploitation rate is measured at the population level, and is defined as the ratio of fishing mortality to total mortality. As fishing pressure increases, this indicator would increase, and reference points can be defined on the basis of theoretical population modelling. However, additional data requirements (commercial catches and population numbers) mean that application of this indicator is beyond the scope of the current project.

2.1.6. Genetic diversity

There is concern that since fishing is selective in terms of age and size, there is the potential to reduce genetic diversity within populations through the effects of fishing (Smith 1994). However, data requirements for such an investigation considerably exceed those routinely collected on trawl surveys, and application of this indicator is beyond the scope of the current project.

2.1.7. Species distribution

Species distribution is a metric of the geographic locations of occurrences of a species. Species may exhibit range contractions as abundance decreases. Species distribution may be sensitive to spatial differences in the size structure of populations, combined with catchability. Species distribution has not been widely considered as an ecosystem indicator, but for other investigations, the percentage area of the survey within which x% (typically 90%) of the population occurs has been used (Swain & Sinclair 1993, Fisher & Frank 2004). Other spatial indicators have also been considered (Freon et al. 2005), but these have generally related fisheries to species distributions, and have not been based on trawl survey data. Distribution indicators have generally been used at an individual species level, and not considered as ecosystem indicators.

2.1.8. Proportion of non-commercial species

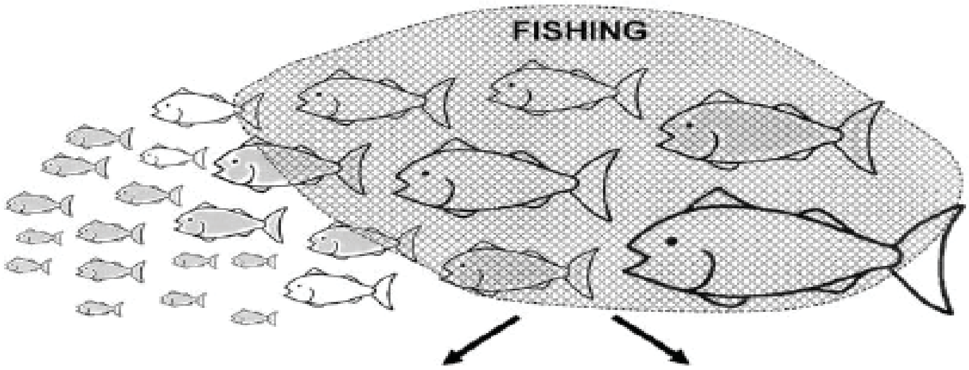
The relative importance of non-commercial species in the community is expressed in terms of either abundance or biomass. Under the impacts of fishing, this proportion might be expected to increase, although availability, bycatch, or incidental mortality may affect this. Information is required to define species as commercial or non-commercial. Previously non-commercial species may become commercial as markets develop, introducing difficulties with this approach.

2.2. Size-based indicators (SBIs)

Individual size or mass of animals in marine ecosystems spans 20 orders of magnitude, from bacteria to whales. Most life history traits are correlated with size, including metabolic rate, energy assimilation, growth, reproduction, and survival. Marine foodweb processes are also strongly related to size, and predator-prey relationships appear to lead to powerful size-based trophic structuring (Badalamenti et al. 2002, Jennings et al. 2002). Given the dominant role of size in marine ecosystems, there are strong justifications for adopting size-based analyses. Fishing may lead to substantial modifications in the size structure of exploited populations because (i) high-value, generally larger species are targeted by fisheries, (ii) fishing gears are size selective, often designed to catch larger fish and let smaller ones escape, (iii) the cumulative effects of fishing (over the life of a cohort) lead to fewer older (larger) fish, and (iv) large sizes species tend to be more vulnerable as they have lower potential rates of increase. By removing large fish, fishing may also have indirect effects, reducing predation pressure on smaller individuals. Each of these changes may be measured by SBIs reflecting both the direct and indirect effects of fishing (Figure 1). The only data required are the size distributions of animals.

2.2.1. Mean or maximum fish length (or weight) of population / community

At a population level, the removal of larger fish may be reflected in changes in the mean length or weight of a population in surveys, or some index of maximum length. Because observed maximum length is highly dependent on sample size, upper quartiles [i.e., $L_{90\%}$ or $L_{95\%}$] may be more robust. At a community level, the same indicators would reflect changes in the relative abundance of different sized species, which may also be an effect of fishing. Population level metrics may be more sensitive to recruitment fluctuations than those at the community level.



PROCESS SCALE	DIECRT EFFECTS	INDIECRT EFFECTS
Individual		• Compensation effects: faster growth and matutarion, better condition
Population	• Number and biomass of larger fish decrease	• Genetic effects: selection of slow-growing and early maturing individuals
Community	• Number and biomass of species fish decrease	• Better survival of small fish (less predation and competition) • Depensation effects

Figure 1: Theoretical direct and indirect effects of fishing on fish populations and communities (N: abundance, B: biomass). (Adapted from Shin et al. (2005))

Average length in an exploited population was used as an estimator of fishing mortality in a coral-reef fish community, and was found to be relatively insensitive to trends in recruitment, demonstrating favourable properties for detecting statistical differences between sustainable and non-sustainable rates of exploitation (Ault et al. 2005). Within an area closed to fishing, mean size in the population was found to increase over nine years for the angler fish *Lophius budegassa*, but not for smaller bodied and less sedentary species, with higher intrinsic rates of population increase (Badalamenti et al. 2002). In Alaska, the distribution of trends in mean weight of individual species over time was examined, and in most cases the distribution of slopes was not significantly different from zero, although in one area more commercial species than expected showed an increase in weight over time (Mueter & Megrey 2005).

Over the whole fish community, both average weight and average maximum size have declined in the North Sea and Celtic Sea (Jennings et al. 2002, Blanchard et al. 2005, Greenstreet & Rogers 2006), showing a similar trend to the slope of the size spectra. The statistical power of surveys to detect trends in mean or maximum size has not been widely investigated, but those studies that have taken place suggest it is likely to be low (Nicholson & Jennings 2004).

2.2.2. Mean length at age in a population

The mean length at age reflects the size and age structure of a population, as well as differential growth rates that may be caused by density dependent effects and/or environmental conditions. Exploitation releases stocks to some extent from intra-specific competition, and may increase food availability. Short term density dependent responses to exploitation such as increased growth rate will lead to increased length at age at a population level. Age data are not routinely collected for all species, but such analysis would be possible for some key species from some surveys (e.g., hoki).

2.2.3. Fulton's condition index

Fulton's condition index provides a measure of individual fish condition, and reflects overall habitat quality for growth and reproduction (Winters & Wheeler 1994). As with mean length at age (Section 2.2.2) short term density dependent responses to exploitation would be expected to lead to an increase in the index. The index requires individual weight and length of fish, and it is therefore unlikely that sufficient data will be available to use this approach routinely within the current project.

2.2.4. Proportion of large (individuals) species in (population) community

As fishing often targets large individuals or species, the proportion of large species in a community may reflect fishing pressure. This metric will detect ecosystem effects of fishing if large species are removed by fishing; it thus reflects selectivity of gears, and may be sensitive to low catch rates of large species. Indicators such as Proportional Stock Density (PSD) or Relative Stock Density (RSD) are widely used in freshwater ecosystems at the population level, and relate the abundance of fish above a specific size (e.g., size at maturity or minimum length of recreational value) to the abundance of fish above a different specific size (minimum landing size) (Willis et al. 1993). To date, the definition of reference lengths has been set almost exclusively from a recreational point of view, and their use would need to be considerably expanded in relation to commercial fisheries. The proportion of the stock that are juveniles has been previously proposed as an indicator for marine stocks (Hilborn & Walters 1992). Within the North Sea, temporal trends in the percentage of fish over 30 cm was used to successfully discriminate between areas of high, medium, and low fishing effort (Greenstreet & Rogers 2006).

2.2.5. Mean length (or age) at maturity of population / community

Mean length at maturity in a population may be affected by fishing; removal of larger individuals may select for individuals which mature earlier. Decreases in length at maturity may also represent a compensatory response to declining population size. Mean length at maturity may vary geographically, as well as in response to fishing, so that usage of such indicators is likely to be stock specific. Fishing may select for faster growing fish, so that age at maturity decreases as the population is fished down. This indicator is obviously species-specific, and may also be stock-specific (Trippel 1995).

From a comparative study of key demographic characteristics among stocks subject to various levels of exploitation, the short-term effects of fishing on growth and reproductive patterns have been examined (Rochet 1998). Trait variations were partitioned into effects attributable to size, phylogeny, and population, and exploited populations were characterised by earlier age and increased size at maturity (Rochet 1998). At the community level within the North Sea, temporal trends in age and length at maturity were used to successfully discriminate between areas of high, medium, and low fishing effort (Greenstreet & Rogers 2006).

Applications of mean length at maturity as an indicator at the community level are likely to be greatly influenced by species identity within communities and geographic location. Such indices require data comprising maturity and length of individual fish, and it is therefore unlikely that sufficient data will be available to use this approach routinely for many species within the current project.

2.2.6. Slope and intercept of biomass or abundance size (weight or length) spectra

Although richness and relative abundance of species in a series of samples may be highly variable, the biomass and numbers of individuals (pooled across all species) decreases log-linearly with size. The slope and intercept of size spectra are properties which can be compared between communities or over time, quantifying the relative abundances of small and large fish and the overall productivity of the system. In theory, differences in productivity appear as differences in intercepts, while differences in transfer efficiencies and mortality appear as differences in slope. In reality, slopes and intercepts are often correlated, and cannot be interpreted independently. The slope of size spectra appears to respond in a consistent way to changes in exploitation levels, and a decreasing trend in the slope has been observed in most areas studied, reflecting changes in size composition towards a relative decline in larger fish (Rice & Gislason 1996, Bianchi et al. 2000, Jennings et al. 2002, Blanchard et al. 2005, Daan et al. 2005, Jennings & Dulvy 2005, Duplisea & Castonguay 2006). Although an overall declining trend was observed for the North Sea (Daan et al. 2005), there was a distinct change in the pattern, with the change in slope being most pronounced early in the series, and largely stable thereafter. Overall exploitation rate appears to have declined in this more recent period, and the slope was significantly correlated with the exploitation rate for lags over 6 years (Daan et al. 2005).

Biomass spectra (log biomass ($g.haul^{-1}$) at log body weight distributions) provide a different set of indicators. The biomass spectra follow a parabolic curve, and the curvature of the parabola, and body size and biomass at the parabola vertex have been used as indicators (Duplisea & Castonguay 2006). While the curvature is considered to be related to predator–prey body size ratio and specific production, and relatively insensitive to fishing, both the body size and biomass at the vertex would be expected to ultimately decrease as exploitation increased, although biomass may initially increase in the early stages of exploitation, owing to competitive release from the largest fish removed by new fisheries. These indicators are considered to be less sensitive to changes in size range end point gear catchability than spectra slope (Duplisea & Castonguay 2006). Interpretation is less straightforward than for abundance size spectra, but the approach may still be useful in identifying changes in size composition in the community.

2.2.7. Slope and intercept of diversity size spectra

In a typical community, fewer individuals are present in larger size classes, therefore reducing the difference in abundance between the rarest and commonest species, and also increasing the probability that a species will have zero abundance in larger size classes. Both these factors cause diversity to decrease with increasing size class. As with the abundance size spectra, the slope and intercept of size spectra are properties which can be compared between communities or over time, quantifying the species diversity along the energy flow. This indicator has not been widely used to date, but a study in the North Sea identified no significant trend in diversity spectra slope over time (Rice & Gislason 1996).

2.2.8. Size distribution of species

Fishing typically removes individuals of a species in a size-selective manner. Thus the size distribution of a species will likely reflect fishing pressure. Fishing effects are typically exhibited by the removal of larger individuals. Cumulative frequency plots of fish length have been examined for individuals and species groups (target, non-commercial, elasmobranchs) in comparing fish populations around Britain in the early and late 20th century (Rogers & Ellis 2000), where marked reductions in the proportion of larger fish were observed.

2.3. Trophodynamic indicators (TIs)

Trophodynamics represent a major aspect of ecosystem functioning relevant to fisheries (Cury et al. 2003). The strength of ecological processes such as trophodynamic interactions, i.e., predation and competition, have been identified as being very important in fish population dynamics (Bax 1988). The issues for trophic interactions associated with the effects of fishing are (i) the decline in the food resource upon which some component of the ecosystem relies, and (ii) the indirect effect of decreasing fish biomass on ecosystem functioning (e.g., regime shifts). These indicators require additional information on the species life history in the assemblage, typically including functional group (e.g., pisciverous, herbivorous) or trophic level and diet, and while some of this more basic information is available, most of the potential indicators are beyond the scope of the current project. This additional information is likely to be age or size specific. A recent review identified 46 indicators derived from models and emergent patterns (trophic cascades and regime shifts)(Cury et al. 2005).

2.3.1. Catch or biomass ratios

The relative change in species (or functional group) composition within the catch can be quantified by means of ratios (of biomass or catch) to characterise ecosystem changes. Such ratios are easily measurable and understood, and are often sensitive to fishing (Cury et al. 2005). Determination of reference points would be difficult, however, and would require historical data. This indicator has previously been applied to commercial catch data, examining the ratio of demersal to total catch (Cury et al. 2003) or pisciverous to zooplanktiverous fish (Caddy & Garibaldi 2000), and used as such reflects changes in the exploitation pressures on the fish communities. Applied to survey catch data it would provide information on the relative community composition, but would be sensitive to differences in catchability. These ratios may be useful as an indicator of change, but it is difficult to predict probable effects of fishing (in terms of trends in the ratios) as they are likely to be fishery and community specific.

2.3.2. Trophic Level (TL) of the catch

Trophic level identifies the position of organisms within a foodweb. The mean TL in catches can be used as an index of sustainability. TL increases with fish age, and fisheries generally remove the older predatory fish first, therefore reducing the mean TL of the remaining assemblage. A decline in TL may occur within and among species, leading to a decline in mean TL in catches, known as "*fishing down marine foodwebs*" (Pauly et al. 1998). As with catch ratios (Section 2.3.1), this indicator has previously been applied to commercial catch data (Cury et al. 2005), and as such has been driven by fishing industry choice to target certain species. Applying the approach to survey catch data as a measure of the TL of the assemblage would provide information on the trophic structure of the resident community. At the population level, an increase in mean length and TL was observed for the angler fish (*Lophius budegassa*) after nine years of exclusion of fishing from an area, but not for hake (*Merluccius merluccius*) or red mullet (*Mullus barbatus*) (Badalamenti et al. 2002). Data from the North Sea shows a progressive decline in TL of the demersal community for the most recent time period (1982–2000), but not for the whole assemblage, or the demersal community over longer time periods (Jennings et al. 2002). These authors suggest that for the North Sea changes in size structure (due to differential effects of fishing on species with different life histories) are stronger and a more universal indicator than changes in mean TL (Jennings et al. 2002), although based on simulation models, mean TL, and maximum length in the catch both performed consistently as indicators comparing four fishing pressure scenarios (Fulton et al. 2005). A later study in the North Sea also found the nitrogen stable isotope ratio to be unaffected by variations in fishing activity, while size and diversity based measures showed strong effects (Greenstreet & Rogers 2006).

2.3.3. Trophic spectra

Trophic spectra represent the distribution of biomass, abundance, or catch by trophic level, and have been proposed for use as indicators of the trophic structure and functioning of aquatic ecosystems in a fishing context (Gascuel et al. 2005). They are considered to be a useful indicator for describing and comparing systems, detecting phase shifts and differences in ecosystem functioning where trophic level information is available. As with TL of the catch (Section 2.3.2), ideally size-specific TL information is required for each species. Survey catches tend to be dominated by species of mid TL, and the analysis of trophic spectra cannot be carried out using the same approaches as size spectra.

Developing this approach further, cumulative relative biomass trophic level spectra (BTLS) have been used to compare spatio-temporal patterns of fish community trophic structure in a Mexican coastal lagoon (Sosa-Lopez et al. 2005). This approach plots cumulative biomass against TL and in this application, identified a shift from an omnivore dominated community (sigmoidal BTLS) to a more linear (even) distribution, and proposes statistical comparison of the curves with a Kolmogorov–Smirnov test.

2.4. Indicators considered

The data requirements of the various indicators are summarised in Table 1. Data availability largely dictated those indicators which were adopted for use. Routine data collection on trawl surveys includes weight by species by tow, which meant that most of the species based indicators could be calculated for the full data set (with some additional information on life history parameters and characteristics). Numbers at length are routinely recorded for a subset of species, and so the more simple (size only) size based indicators can be applied to this data set. Additional information on maturity, age, and weight at length are recorded for an even smaller subset, and indicators requiring these data have not been applied in this study. Life history or functional group and trophic level information is available from the internet, from sites like FishBase (http://filaman.ifm-geomar.de/home.htm), and this has allowed application of the trophodynamic indicators, although only single TL values have been used for each species, and size related changes in feeding for each species have not been accounted for.

A wide range of diversity indicators is available, and we have considered those most frequently used in similar studies previously (N1, N2, species richness, Margalef's d, Pielou's evenness, Shannon-Weiner, average taxonomic distinctiveness, and variation in taxonomic distinctiveness). It is acknowledged that species richness (number of species observed) is very sensitive to sample size and alternatives are available, but the alternative measures considered require data on the number of individuals of each species, and these data were not available within the full catch weight data sets examined.

3. NEW ZEALAND TRAWL SURVEYS

Trawl surveys are routinely used in fisheries throughout the world to provide fishery-independent data on stock size and distribution. As such, they are generally designed to provide a consistent measure of abundance over time, using standardised fishing gear and the same vessel.

Trawl surveys have been widely used in New Zealand fisheries research, and a number provide time series data sets suitable for analysis using fish-based ecosystem indicators. Surveys are categorised by depth range and main target species or area, and are described below. This is not a complete list of all surveys, but all survey series considered to be potentially useful for this study were discussed at the AEWG/stakeholder workshop.

Table 1: Specific data requirements for various fish-based indicators, indication of use and reference direction of change under fishing pressure (based on theory and empirical evidence).

Indicator	Data requirements	Routinely available	Adopted for use	Reference direction
Species based				
Proportion of indicator species	Life history characteristics	✓	✓	Decrease
Diversity (various measures)	Numbers by species	✓	✓	Decrease*
Dominance (& ABC)	Numbers (and biomass) by species	✓	✓	Decrease in W statistic
Exploitation rate	Stock assessment			
Genetic diversity	Genetic analysis			
Proportion endangered	Endangered species list	✓		
Species abundance	Catch rates (and catchability)	✓ (?)		
Species distribution	Catch composition by location	✓	✓	Decrease
Proportion non commercial	Commercial species list	✓		
Size based				
Mean (max) length	Numbers at length	✓	✓	Decrease
Mean length at age	Length at age data	?		
Fulton's condition index	Individual weight data	?		
Proportion of large species	Numbers at length, definition of large species	✓	✓	Decrease
Mean length at maturity	Maturity at length	?		
Abundance (biomass) size spectra	Numbers at length	✓	✓	Decrease in slope
Diversity size spectra	Numbers at length by species	✓	✓	?
Size distribution	Numbers at length	✓		
Age at maturity	Maturity at length and length at age	?		
Trophodynamic				
Catch (or biomass) ratios	Allocation of species to group	✓	✓	?
Trophic level of catch	Trophic level by species (and size)	✓ (?)	✓	Decrease
Trophic spectra	Trophic level by species (and size) & numbers at length	✓ (?)	✓	?

* - a decrease in diversity would generally be one of the predicted effects of fishing, but changes in specific indicators will depend on the community composition (eg reductions in dominance of key species may increase evenness of the community).

Preliminary extractions were made from the MFish *trawl* database (maintained by NIWA) to identify the spatial and temporal coverage of the various trawl time series data sets available. These data sets are routinely analysed to provide abundance indices for individual target species, and have also been examined to look at distributions of species (Anderson et al. 1998), but have not been analysed in relation to the types of ecosystem indicators addressed here. Acoustic surveys involving trawl sampling for mark identification (e.g., Cook Strait hoki survey, southern blue whiting survey) are not considered, as sampling has been targeted on specific marks, and catches are not likely to be representative of the fish assemblage. Surveys have been conducted on a number of different research or chartered commercial vessels, and the comparability between vessels must be born in mind if time series are split between vessels. Changes to vessels involved in surveys may also be significant, and for this reason, voyages on RV *Ikatere* before 1959 have not been considered, since a new engine was fitted in 1958, considerably improving the vessel's trawling performance (Paul 1992).

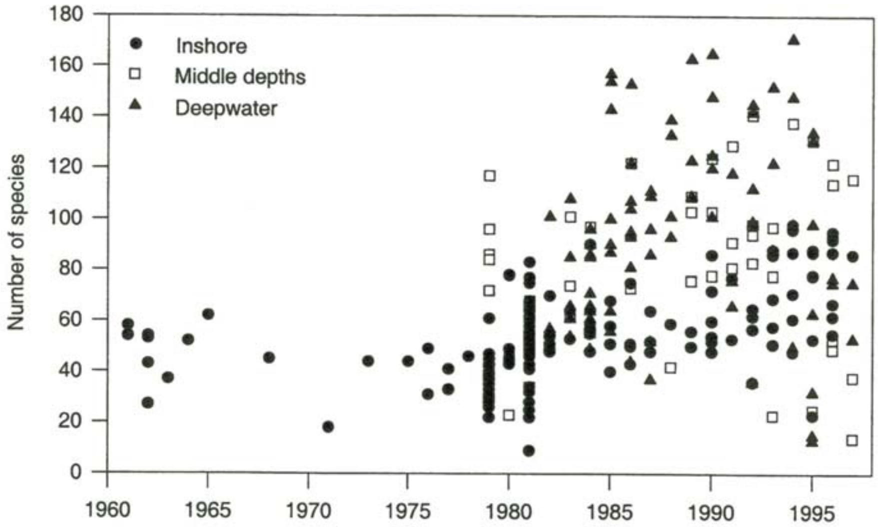


Figure 2: The number of fish and squid species recorded by survey, 1961–97. Survey types were classified by the following depth ranges: inshore, most stations shallower than 250 m depth; middle depths, most stations 250–800 m depths; deepwater, most stations deeper than 700 m depth. (Source: Anderson et al. 1998).

Previous examination of the *trawl* database (Anderson et al. 1998) has identified that the number of individual species recorded on a survey shows an increase over time (Figure 2). In the 1960s and 1970s, most surveys were in shallower waters, and the maximum number of species recorded was about 60. After New Zealand declared a 200 n.mile EEZ in 1978, the number of middle depth and deepwater surveys increased, and the maximum number of species recorded immediately increased to 120, and increased to 170 during the 1990s. The increase in the number of species recorded during the 1980s is associated with the exploration of new areas, as well as increased effort focused on improving species identification. This can be seen from the numbers of new species added to the database since 1961 (Figure 3).

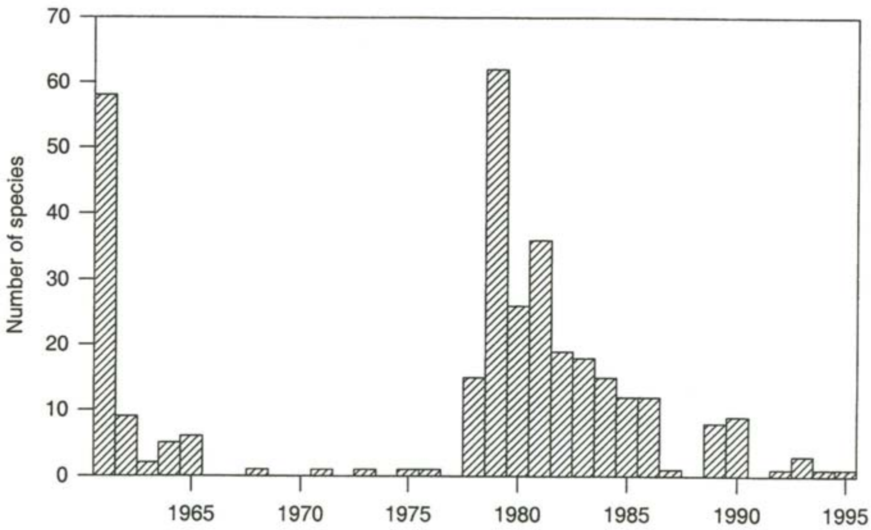


Figure 3: The number of new fish and squid species codes added to the Ministry of Fisheries research trawl database by the year of first use. (Source: Anderson et al. 1998).

While changes in the distribution of surveys can be taken into account in the data analysis (e.g., through examination of specific strata where appropriate), improvements in the level of taxonomic identification (e.g., deepwater rattails [Macrouridae] that were lumped into generic groups in early surveys were identified to species in later years, when keys became available) will introduce a inherent increase in diversity that will potentially confound any analysis involving species identifications. Within some survey series, the species measured have also changed (with the numbers of species measured usually increasing over time), which will potentially confound any analysis involving fish length. Therefore, careful consideration and grooming of the available data has been required before analysis can take place. NIWA staff familiar with the various trawl survey data series have been consulted in this grooming process.

Previous research conducted by NIWA (Anderson et al. 1998) has developed a fish community (*fish_comm*) database from the *trawl* database, and although this has not been regularly updated with new surveys, it was updated in 2000). The *fish_comm* database includes only successful research, random, bottom trawl records for fish and squid. These species are considered to have been identified to species most consistently. The *fish_comm* database has been used as the main source of data for our analysis, but we have also used the *trawl* database (groomed in the same way) for the most recent data, and the length data, which are not included within *fish_comm*. It was considered appropriate to exclude some species from certain data sets (e.g., mesopelagic fish caught infrequently in middle depths surveys, and identified to varying taxonomic levels, depending on survey staff), as discussed at the AEWG/stakeholder workshop.

A standard catch sampling protocol is followed on trawl surveys. Voyage codes for each survey series are provided in Appendix 2.

3.1. Inshore surveys

Inshore surveys have been conducted around New Zealand since the 1940s, although only data since the 1960s are considered to be comparable over time (Paul 1992).

3.1.1. Bay of Plenty surveys

A regular grid of survey stations was established in the Bay of Plenty in 1961, with sampling conducted initially on a four monthly basis in 1961 and 1962. Further voyages sampled some of the same stations, and established others, between 1963 and 1968 (Paul 1992). In 1980 and 1981, surveys were conducted sampling the earlier stations, and also examining new stations, to establish a basis for subsequent groundfish trawl surveys by the replacement vessel (RV *Kaharoa*).

Six summer autumn (February–March) trawl surveys have been conducted in the Bay of Plenty from RV *Kaharoa* (1983, 1985, 1990, 1992, 1996, 1999), with an additional October survey conducted in 1987. Survey area coverage has remained relatively constant between years, although deeper strata (over 150 m) were excluded from the 1990 and 1993 surveys. The surveys were conducted to a 2-phase stratified random design (Francis 1984), with station allocations on the basis of stratum area and previous target species catch rates. Phase 2 stations were allocated to improve the precision of biomass indices of target species. The purpose of these surveys has varied between years, but has generally been to provide relative abundance indices for snapper, John dory, red gurnard, and tarakihi, and the surveys were reviewed by Morrison (2001a). All trawling was carried out using a high-opening bottom trawl, with cutaway lower wings and a nominal 40 mm codend.

3.1.2. West coast North Island surveys

Seven spring/summer (October–December) trawl surveys have been conducted on the west coast of North Island with the primary purpose of providing an index of juvenile snapper abundance. The surveys took place from RV *Kaharoa* (1986, 1987, 1989, 1991, 1994, 1996 and 1999), and were reviewed by Morrison

(2001b). The surveys cover the area from Cape Reinga to New Plymouth, although survey area and stratification have varied greatly between years. Surveys from 1986 to 1994 were conducted to a single phase random stratified design, while those in 1996 and 1999 followed a 2-phase stratified random design (Francis 1984), with station allocations on the basis of stratum area and previous target species catch rates. Phase 2 stations were allocated to improve the precision of biomass indices of target species. All trawling was carried out using a high-opening bottom trawl, with cutaway lower wings and a nominal 40 mm codend.

3.1.3. Hauraki Gulf surveys

A wide range of surveys have been conducted in the Hauraki Gulf area, for a variety of purposes. The most consistent of these appear to have been a spring/summer (October–December) series conducted from the RV *Kaharoa*, with the primary purpose of providing an index of snapper and other inshore fish species, although some previous surveys from the RV *Ikatere* also sampled similar areas.

Stratification in *Kaharoa* surveys has remained relatively consistent in depth and area, and a two phase random stratified design has been employed. All trawling used a high-opening bottom trawl, with cutaway lower wings and a nominal 40 mm codend. Alltogether, 17 voyages took place, with data available from 1964, 1965, 1980, 1984–90, 1992–94, 1997, and 2000.

3.1.4. East coast South island

The east coast South Island surveys were originally conducted in the winter (May–June) of 1991, 1992, 1993, and 1996, and then shifted to the summer (December–January) of 1996, 1997, 1998, and 1999. These two sets of surveys were reviewed by Beentjes & Stevenson (2000, 2001). The winter survey has now recommenced, with a survey conducted in May–June 2007. In both survey series, a two phase random stratified design has been adopted, but stratification has changed slightly over time. All trawling uses a two-panel trawl net based on an ’Alfredo’ design, specifically designed for South Island inshore trawl surveys. The cod end mesh size is 28 mm.

3.1.5. West coast South island

Five autumn (March–April) trawl surveys have been conducted on the west coast of South Island, and in Tasman and Golden Bays, with the primary purpose of determining the distribution and relative abundance of a range of species found in inshore waters, and collecting biological information to inform the stock assessment process. The survey design has remained consistent over time, with a two phase stratified random approach adopted. Stratification is by depth, with the two phase methodology applied separately to the west coast and Tasman and Golden Bay areas, because of geographic separation. Surveys have been conducted in 1992, 1994, 1995, 1997, and 2007, with the first four surveys reviewed by Stevenson & Hanchet (2000). All trawling is carried out with a two-panel trawl net based on an ’Alfredo’ design, specifically designed for South Island inshore trawl surveys. The cod end mesh size is 74 mm.

3.2. Middle depth trawl surveys

With declaration of a 200 n.mile EEZ in 1978, middle depth surveys commenced around New Zealand. These have been conducted in a number of areas around the coast, but the longer series have mostly focussed on the Chatham Rise and Southland / Sub-Antarctic areas.

3.2.1. Scampi trawl surveys

Trawl surveys were conducted from RV *Kaharoa* to estimate relative abundance of scampi from 1993 to 1995 in SCI 1 and SCI 2, but were subsequently discontinued because it was inferred from the results that scampi catchability had varied among surveys. However, research trawling has continued for a variety of other purposes (although generally with fewer stations per survey), and time series are available for SCI 1 (1993–1996, 1998, 2000, and 2001–02) and for SCI 2 (1993–95, 1999, 2000, and 2002–06). Two surveys were also conducted in SCI 3 in 2001, although these are not considered sufficient for analysis. All surveys have followed a single phase random stratified design, and trawl stations considered for analysis were taken with a Florida Flyer trawl with body and wing mesh of 80 mm and codend mesh of 30 mm.

3.2.2. Chatham Rise hoki trawl surveys

Trawl surveys to monitor the relative abundance of hoki and other middle depth species on the Chatham Rise have been carried out annually in January since 1992 using RV *Tangaroa*, and were reviewed by Livingston (2002). Before the RV *Tangaroa* series, surveys covering the same core area were conducted from *Shinkai Maru* (1983 & 1986) and *Amaltal Explorer* (1989), although these surveys are not included in the fishery independent abundance indices due to concerns over gear and vessel effects. The core survey area has remained very consistent over time, although an additional deeper stratum was added in 2000. The survey follows a stratified random design, and the total number of stations, and stratification within the survey area have changed over time. All *Tangaroa* surveys have used the same middle depth species trawl design, with 60 mm codend mesh.

3.2.3. Southland and Sub-Antarctic trawl survey

Trawl surveys of the Southland and Sub-Antarctic region (known as the “Southern Plateau”) provide fishery independent abundance indices for hoki, hake, and ling. Two time series of trawl surveys have been carried out from *Tangaroa* in the area: a summer series in November–December 1991–93, and 2000–06; and an autumn series in March–June 1992, 1993, 1996, and 1998. Before the *Tangaroa* series, surveys covering the same core area were conducted from *Shinkai Maru* (1982, 1983, & 1986) and *Amaltal Explorer* (1989 & 1990), although these surveys are not included in the fishery independent abundance indices due to concerns over gear and vessel effects. The survey was reviewed by O’Driscoll & Bagley (2001). The core area of the survey has remained virtually unchanged over the time series, although additional strata have been added in some years. Most *Tangaroa* surveys (except 1993 and 1996) have followed a 2-phase stratified random design (Francis 1984), with station allocations on the basis of stratum area and previous target species catch rates. Phase 2 stations were allocated to improve the precision of biomass indices of target species. All *Tangaroa* surveys have used the same middle depth species trawl design, with 60 mm codend mesh.

3.3. Deepwater surveys

As with the middle depths surveys, deepwater surveys began after the declaration of a 200 n.mile EEZ in 1978. These surveys have targeted orange roughy and oreos on the Chatham Rise, Challenger Plateau, and off Southern New Zealand. While a large number of research voyages have been undertaken, many of these have not been consistent enough, or repeated enough, to generate a useful series for this study (M. Dunn, NIWA, pers. comm.).

3.3.1. Orange roughy on the Chatham Rise

Stratified random surveys for orange roughy during the spawning season on the Chatham Rise were started in 1984, and have been reviewed up to 1992 (Anderson & Fenaughty 1996). Surveys were conducted from two commercial vessels (FV *Otago Buccaneer* and FV *Cordella*) during the 1980s, and from *Tangaroa* since then. The surveys have generally targeted the spawning population, which concentrates in an area known as "the spawning box" in July, although some surveys have also fished in other areas. Trawl surveys have been conducted in 1984–90, 1992, and 1994, with acoustic survey approaches adopted after this (Dunn 2007).

3.3.2. Orange roughy on the Challenger Plateau

Trawl surveys for orange roughy on the Challenger Plateau began in 1984, and were conducted annually to 1990 (Clark & Tracey 1994). Over this period, three different commercial vessels were used, and survey designs changed, although surveys from 1987 to 1989 are considered to be fully comparable.

3.4. Survey series for examination of indicators

On the basis of preliminary examination of the data available and discussions at the stakeholder workshop it was decided to examine as wide a range of indicators as possible, for a limited set of trawl series, rather than a more limited suite of indicators for a wider range of data sets. None of the deepwater trawl survey series were considered to be consistent enough for useful examination at this time. To enable examination of the indicators over a range of habitats and communities, one inshore (Hauraki Gulf) and two middle depths (Chatham Rise and Southland / Sub-Antarctic) surveys were investigated.

3.5. Effort data

In evaluating the utility of the indicators to monitor the effects of fishing it is necessary to compare trends observed in indicators with patterns of fishing pressure. The current MFish project (BEN2006-01, Mapping the spatial and temporal extent of fishing in the EEZ), being conducted by NIWA, has compiled a database of the fishing activity by demersal gear type, over a 3 x 3 n.mile grid, from TCEPR trawl start and end positions and assumptions about the swept width of the gears concerned. For the three areas examined within this study, data were extracted from the "BEN200601" database constructed from the MFish "warehou" catch and effort database for fishing years 1989–90 to 2004–05. The gears considered were bottom trawl (all areas), bottom pair trawl (Hauraki Gulf), and midwater trawl within 1 m of the seafloor (Chatham Rise and Southland & Sub-Antarctic). The area fished in each year was summed within the survey strata and larger areas, and compared to the total area of the respective strata to provide an indicator of overall fishing intensity. Although the spatial patterns of the gears within areas differ, the overall level of effort by bottom trawl far exceeded that of the other gear considered in each area, and for simplicity a single combined figure (the two gears summed) has been used.

4. HAURAKI GULF SURVEYS

Seventeen spring/summer (October–December) trawl surveys have been conducted in the Hauraki Gulf from RV *Ikatere* (1964–80) and RV *Kaharoa* (later years), over 14 years between 1964 and 2000. These surveys had the primary purpose of providing an index of snapper and other inshore fish species. Stratification of the *Kaharoa* surveys has remained relatively consistent, on the basis of depth and area, and stations from the *Ikatere* surveys have been allocated to appropriate strata. Survey strata are shown in Figure 4, with numbers of stations by strata and year shown in Table 2. Analyses have been conducted on the basis of these survey strata, and also sediment type (sand or mud), and depth (less than 50 m or over 50 m), as these factors have previously been found the be influential in fish assemblage structure in the Hauraki Gulf (Kendrick & Francis 2002). The distribution of stations allocated to each of these four sediment/depth strata is shown in Figure 5. The numbers of stations by sediment/depth strata and year are shown in Table 3.

From the 17 voyages, 989 stations were extracted (where gear performance was considered suitable), listing 100 different species (870 stations within strata defined in Figure 4). Of these 100 species, 94 were fish or squid species, and were retained for the analysis, the others being excluded. For each station, numbers measured and weight caught by species were examined. Not all species were measured, and not all the species measured were always weighed (although this was less common). None of the species caught on the *Ikatere* surveys were weighed, as motion-compensating scales were not then available. For the *Ikatere* surveys, it is assumed that all catch was measured, since no other way of recording catch was available. Data sets were prepared for analysis on the basis of species catch weight by station, and species numbers at length by station. Catch weights and numbers were standardised to a 1 km tow (wing or door spread were not routinely measured on earlier surveys, to allow estimation of swept area). Although it has been assumed that the data from the *Ikatere* surveys is compatible with that for *Kaharoa*, this may not be the case, as the former vessel was smaller and towed a smaller trawl (although often for longer). The data are therefore examined over the whole time series, and just for the *Kaharoa* surveys.

For the catch weight by station data set, all 94 fish and squid species were included, and where weight was not recorded but numbers at length were, the catch weight was estimated from length-weight relationships either taken from the MFish *rdb* database, or the FishBase web site (http://filaman.ifm-geomar.de/home.htm) (Froese & Pauly 2000). Diet, mean trophic level, and environment (i.e., demersal, pelagic, etc) for each species (or closely related species) were also recorded from the FishBase web site. IUCN Red List status and the FishBase web site Resilience measure were taken as levels of concern in terms of endangered species. Resilience is based on the minimum population doubling time (on the basis of estimates of growth rate, age at maturity, and fecundity), and is split into four categories (High – less than 1.4 years minimum population doubling time; Medium - 1.4–4.4 years; Low - 4.5–14 years; Very low - over 14 years). Life history characteristics, including length weight parameters, habitat, feeding type, Red List and resilience status, trophic level, and taxonomy are provided by species in Appendix 1.

For the species numbers at length data set, 15 key species of fish were selected, being considered to be appropriately sampled by the gear and consistently measured. For these key species, if a station had a weight recorded but no numbers at length, then the station was excluded from the size based analysis. Excluding stations where these key species were caught but not measured left 691 stations for analysis. Weight at length for these species (for biomass size spectra) was estimated from length weight relationships described above.

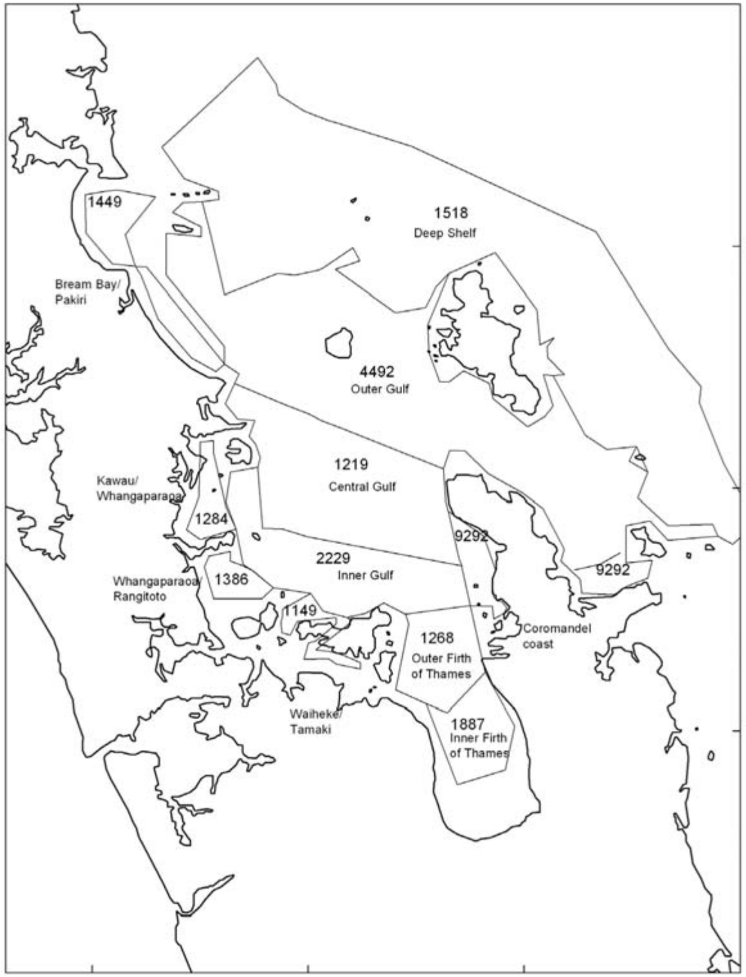


Figure 4: Survey area and stratum boundaries for Hauraki Gulf surveys. Stratum names referred to in text and tables.

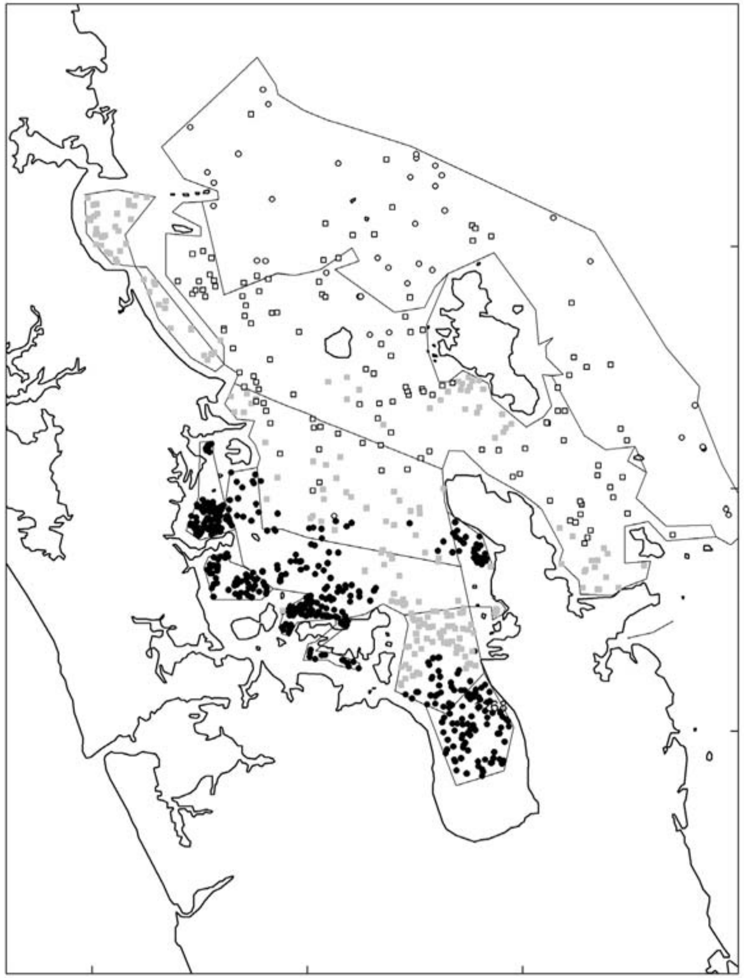


Figure 5: Station distribution by sediment and depth stratification. (– mud <50m, – mud >=50m, – sand <50m, – sand >=50m)

Taxonomic knowledge has consistently been good for inshore surveys, and all but the jack mackerel species are thought to have been identified consistently through the time series. For jack mackerel, three species have been recorded on Hauraki Gulf surveys, but before 1984, and for some surveys after, they were recorded as JMA rather than individual species (JMM, JMN, JMD). The sensitivity of the indices to pooling or exclusion of these species is examined.

The various indicators are calculated and analysed at the strata level, each tow within a stratum being weighted according to its catch. Data examined at the individual tow level tended to be very variable, and giving each tow equal weighting was not considered appropriate given the variability in catches (even within strata).

Table 2: Numbers of stations by survey stratum for each year. Numbers may not sum to station total in Appendix 2 as some stations are outside the standard strata.

															Survey year
Stratum	Name	1964	1965	1980	1984	1985	1986	1987	1988	1989	1990	1992	1994	1997	2000
1149	Waiheke/Tamaki	1	2	2	7	11	10	8	8	11	12	8	4	3	3
1219	Central Gulf	0	2	4	8	5	3	0	3	5	4	16	11	4	4
1268	Outer Thames	3	4	7	10	9	5	4	6	6	7	22	10	3	7
1284	Kawau/Whangaparaoa	0	1	2	9	8	7	6	13	12	6	12	4	3	4
1386	Whangaparaoa /Rangitoto	0	1	2	4	9	5	6	3	5	6	7	3	3	3
1449	Bream/Pakiri	0	1	2	4	4	2	4	4	3	5	8	3	3	3
1518	Deep shelf	0	0	0	7	6	2	2	4	4	7	9	4	5	3
1887	Inner Thames	4	3	6	3	7	5	4	11	5	5	16	9	3	5
2229	Inner Gulf	1	2	6	8	4	5	7	7	18	8	11	5	5	6
4492	Outer Gulf	8	8	15	20	12	7	1	6	6	10	26	12	14	7
9292	Coromandel	1	1	2	4	3	0	0	0	0	3	10	4	3	3
Total		18	25	48	84	78	51	42	65	75	73	145	69	49	48

Table 3: Numbers of stations by sediment/depth stratum for each year. Numbers may not sum to station total in Appendix 2 as some stations are outside the standard strata.

														Survey year
Stratum	1964	1965	1980	1984	1985	1986	1987	1988	1989	1990	1992	1994	1997	2000
mud<50 m	10	13	25	37	42	32	31	46	53	42	73	30	19	25
mud>=50 m	4	0	3	4	4	1	0	2	3	4	7	3	3	4
sand<50 m	1	7	12	28	23	12	9	10	15	20	36	19	14	15
sand>=50 m	3	4	8	14	9	6	2	7	4	7	29	17	13	4
Total	18	24	48	83	78	51	42	65	75	73	145	69	49	48

4.1. Analysis of catch weight by station

4.1.1. Species based indicators

4.1.1.1. Indicator / endangered species

Using the IUCN Red List, indicator species were taken as those listed within the threatened categories of vulnerable, near threatened, or of less concern. Species included in those considered threatened were the carpet shark, short-tailed black ray, rough skate, whiptail ray, eagle ray, bronze whaler shark, smooth skate, and school shark. The combined weight of these species was calculated for each tow, and examined as a proportion of total catch at the stratum level.

Over the whole time series, the two Firth of Thames strata (1268 and 1887) showed significant negative trends in the proportion of the catch classed as threatened, but no strata showed significant trends over the *Kaharoa* series (Figure 6 & Table 4). Examining the data over the sediment/depth strata (Figure 7 & Table 4), only the mud <50m area showed a significant trend in the proportion of threatened species (negative trend) over the whole time series, and there were no significant trends in the data since 1984.

Using low or very low resilience, indicator species included those identified as threatened in the Red List, but also others considered to have low resilience owing to life history characteristics. As with the Red List species, the Firth of Thames strata showed significant negative trends in resilient species over the whole time series, and the Central Gulf (1219) also showed a significant negative trend over more recent years (Figure 8 & Table 4). Both the shallower mud and sand strata showed negative trends over the whole time series (Figure 9 & Table 4).

Table 4: Slope and P value for linear regressions for each survey stratum of ratios of proportion threatened (left) and proportion with low or very low resilience (right) on year. Proportions were arcsin square root transformed. Regression parameters are presented for the whole series (solid lines in figures) and 1984 onwards (dashed lines) (RV *Kaharoa* data) for data averaged across a survey stratum for each year (upper table) and sediment/depth strata (lower table). Slopes significantly different from zero are in bold.

		Proportion threatened				Prop. L/VL resilience			
		All		1984 –2000		All		1984 –2000	
Strata	Name	slope	P	slope	P	slope	P	slope	P
1149	Waiheke/Tamaki	-0.0021	0.490	0.0056	0.246	-0.0025	0.256	0.0027	0.434
1219	Central Gulf	-0.0010	0.813	-0.0051	0.530	-0.0073	0.121	**-0.0207**	**0.009**
1268	Outer Thames	**-0.0075**	**0.002**	0.0005	0.868	**-0.0088**	**0.001**	0.0008	0.840
1284	Kawau/Whangaparaoa	0.0011	0.633	0.0062	0.120	0.0032	0.222	0.0060	0.216
1386	Whangaparaoa /Rangitoto	-0.0042	0.280	0.0044	0.196	-0.0021	0.607	0.0048	0.391
1449	Bream/Pakiri	0.0001	0.985	-0.0052	0.536	-0.0017	0.704	-0.0109	0.201
1518	Deep shelf	0.0177	0.109	0.0177	0.109	0.0130	0.083	0.0130	0.083
1887	Inner Thames	**-0.0158**	**0.004**	0.0015	0.852	**-0.0153**	**0.001**	-0.0029	0.590
2229	Inner Gulf	-0.0032	0.285	0.0002	0.914	-0.0001	0.985	-0.0073	0.274
4492	Outer Gulf	-0.0025	0.282	-0.0012	0.823	-0.0022	0.429	0.0084	0.112
9292	Coromandel	0.0009	0.125	0.0020	0.290	0.0027	0.070	0.0052	0.171
mud <50 m		**-0.0088**	**0.010**	0.0057	0.137	**-0.0092**	**0.008**	0.0051	0.138
mud >=50 m		0.0070	0.315	0.0210	0.144	0.0056	0.462	0.0061	0.683
sand <50 m		-0.0019	0.292	-0.0011	0.763	**-0.0055**	**0.009**	-0.0058	0.150
sand >=50 m		-0.0007	0.776	-0.0077	0.183	0.0000	0.996	0.0034	0.393

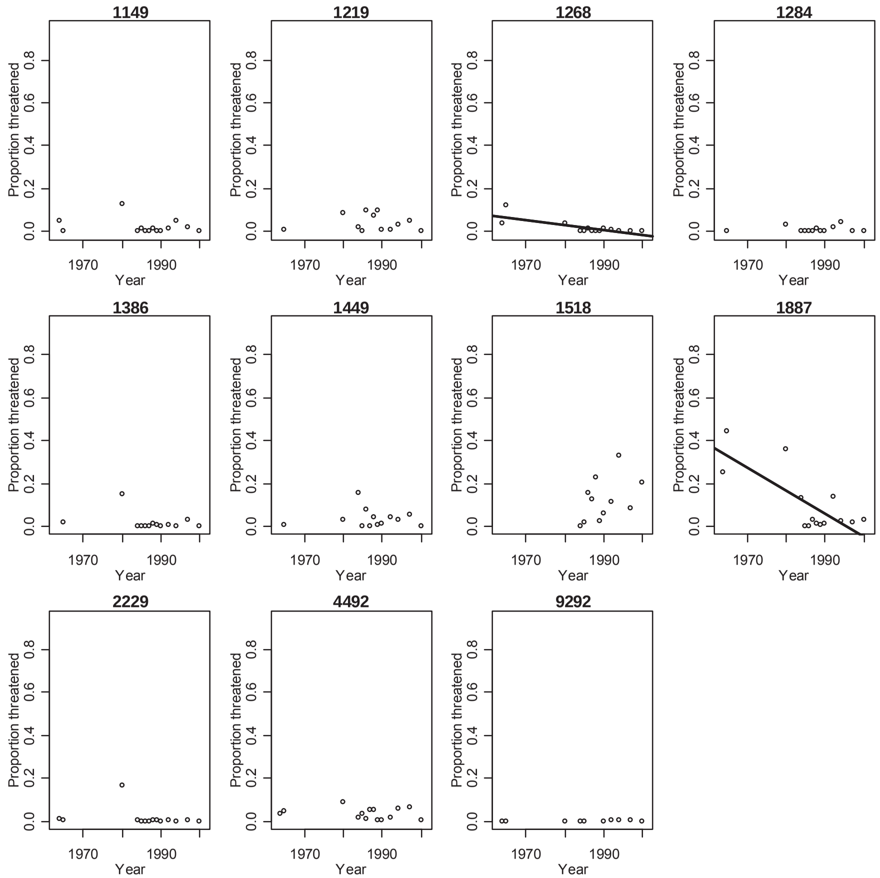


Figure 6: Plots of the proportion threatened (by weight) for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

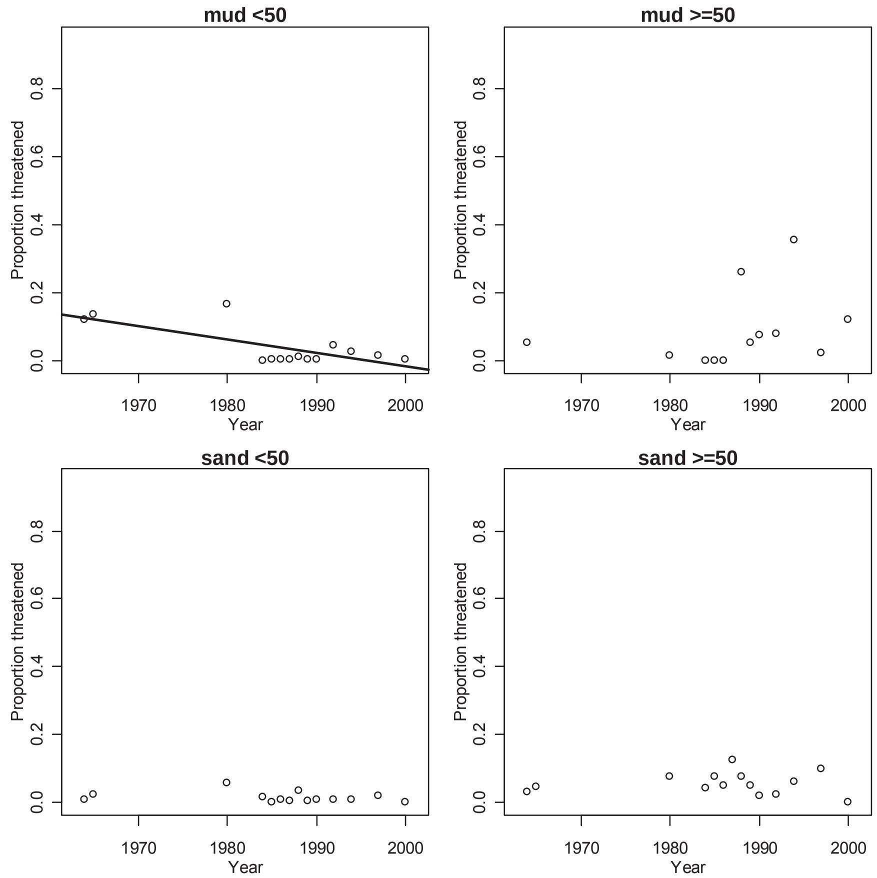


Figure 7: Plots of the proportion threatened (by weight) for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

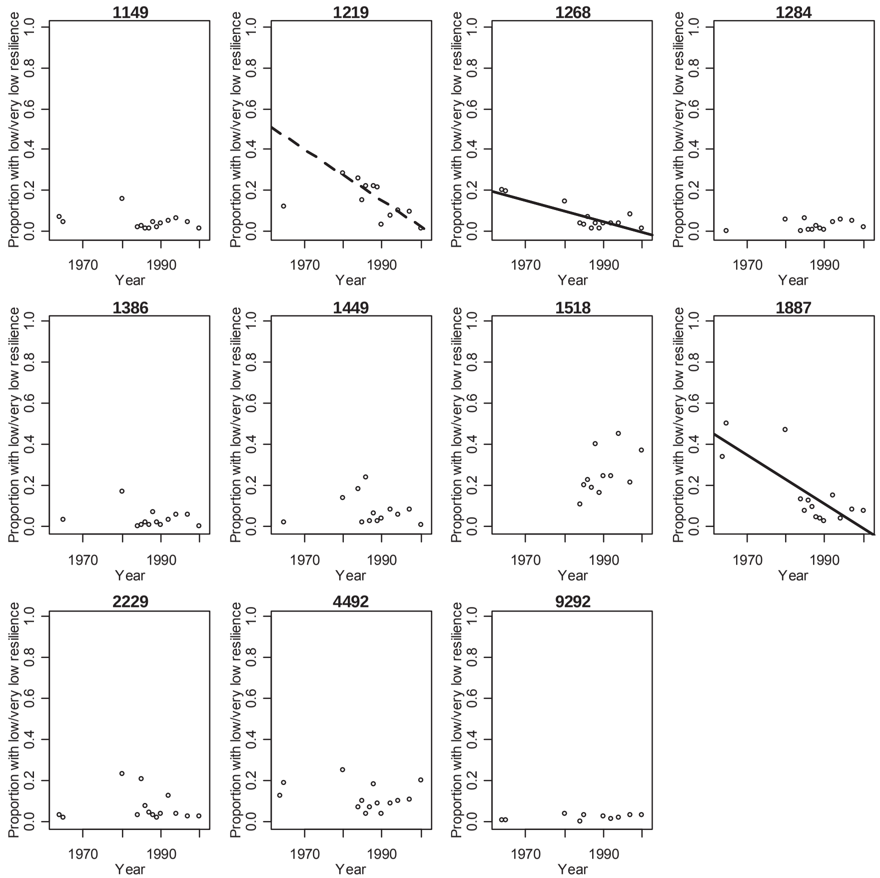


Figure 8: Plots of the proportion with low or very low resilience (by weight) for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

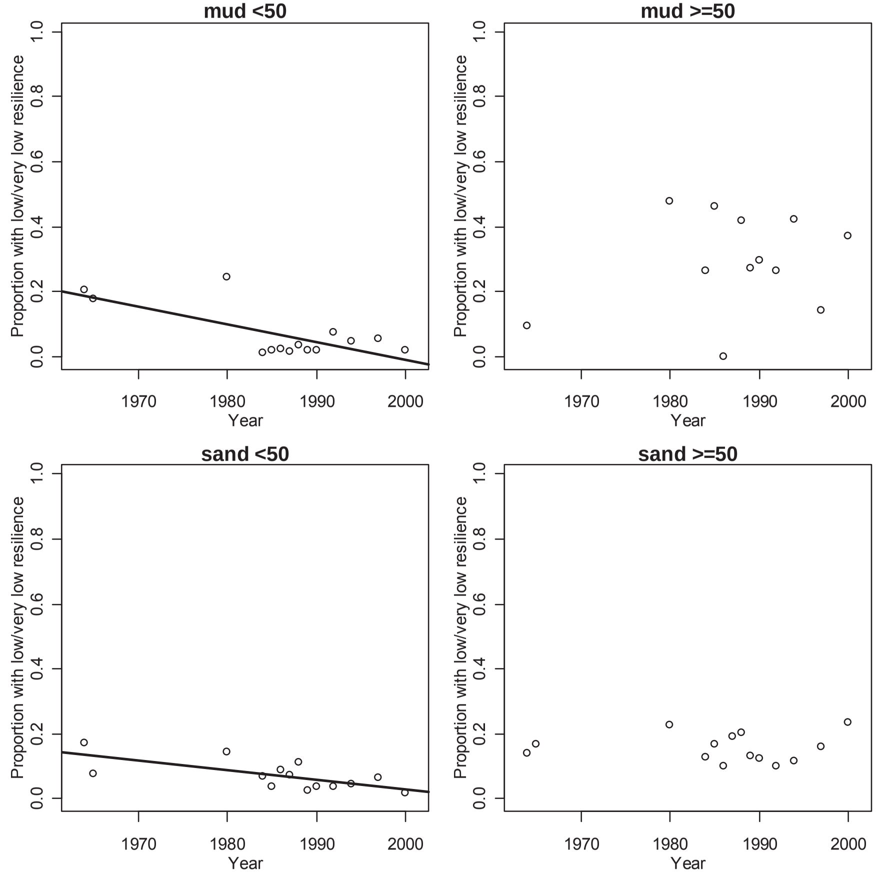


Figure 9: Plots of the proportion with low or very low resilience (by weight) for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

4.1.1.2. Species distribution index

The overall (across all surveys) ranked percentage of stations occupied by each species (Figure 10) declined exponentially from a maximum of 97% (snapper), with 29 species recorded at less than 1% of the stations. In examining the distribution of species, analysis was limited to species recorded at more than 10% of stations (20 species). Below this cut off point, annual as well as average estimates of distribution over the entire survey history are probably underestimated (Fisher & Frank 2004).

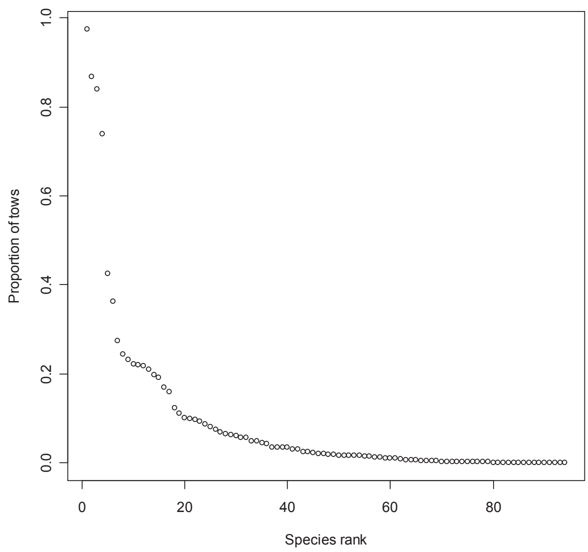


Figure 10: Ranked percentage of surveys occupied by each species.

Plots of the percentage of the survey area over which 90% of the abundance was distributed over time for the main species are shown in Figure 11. The combined jack mackerel species (JMA) and the eagle ray show significant increases in their distribution over the *Kaharoa* series, while lemon sole and kahawhai show significant decreases over the whole time series. Given that kahawhai catches are considered to be strongly influenced by hydrographic conditions, changes in this species should not necessarily be considered as a particularly appropriate indicator. Overall, this approach does not appear to suggest any consistent changes in species distribution trends.

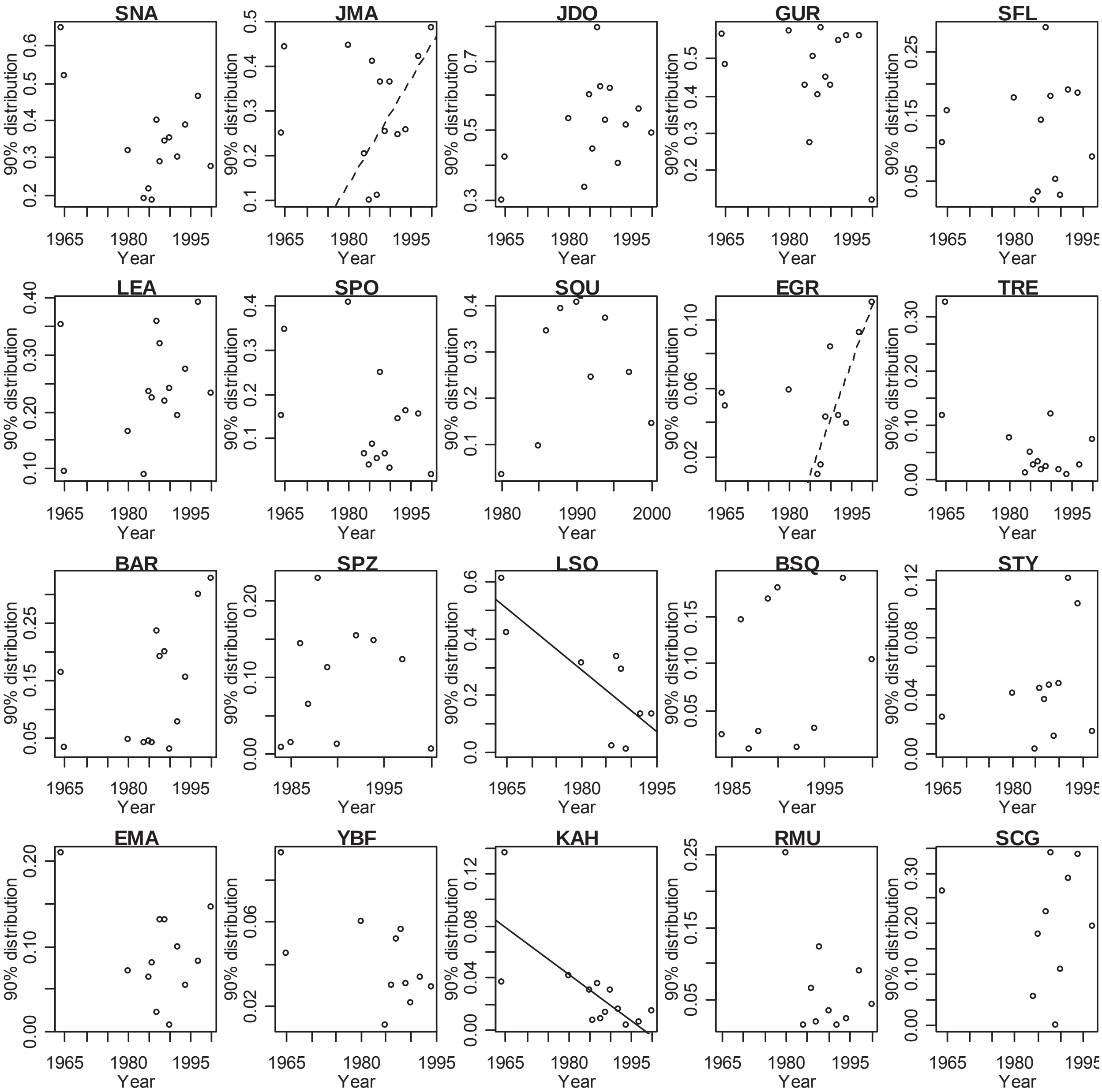


Figure 11: Plots of the percentage of the survey area over which 90% of the abundance (by weight) was distributed for the most frequently caught species. Weighted averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*). Key to species codes provided in Appendix 1.

4.1.1.3. Diversity indicators

Diversity parameters were calculated over the whole time series, and, given the influence a change in vessel may have had, for a subset of the data excluding voyages conducted by *Ikatere*. Various measures of diversity were calculated on different data sets derived from the species catch weight data. These data sets included a full data set with jack mackerel combined to a single group, a full data set with the jack mackerel excluded, a data set excluding pelagic species and a data set including only the key species as used for the numbers at length data set. The indicators are plotted only for the full data set, but trends are examined for each of the sets.

Hill’s N1 and N2 diversity indices showed very similar patterns on the full data set (Figures 12–15 and Table 5). Over the whole time series, both measures showed significant negative trends for the Firth of Thames strata (1268 and 1887). The mud <50 m strata also showed a negative trend over the whole series, but a positive trend over the more recent years.

Species richness did not show any significant trends over either time scale for the survey strata (Figures 16 & 17 and Table 6), but for the sediment/depth strata showed positive trends over time for the sand <50 m (whole series, and almost significant for more recent years) and sand >=50 m (more recent years). Margarlef’s d diversity parameter did not show significant trends over either time period or any scale examined (Figures 18 & 19 and Table 6).

Pielou’s evenness appeared more sensitive to apparent changes in the fish community over time (Figures 20 & 21 and Table 7), and showed a declining trend over time for the Outer Firth of Thames (1268) (whole series), Inner Firth of Thames (1887) (whole series and more recent years), and Outer Gulf (4492) (more recent years). For the sediment/depth strata, the mud <50 m stratum showed a negative trend over the whole series, but a positive trend over the more recent years. The Shannon-Weiner diversity parameter showed a negative trend over the whole series for the two Firth of Thames strata (1268 and 1887) (Figures 22 & 23 and Table 7). For the sediment/depth strata, the mud <50 m stratum showed a negative trend over the whole series, but a positive trend over the more recent years.

Average Taxonomic Distinctiveness increased over time for the Central (1219) and Inner Gulf (2229) over the whole time period (Figures 24 & 25 and Table 8), and for the sediment/depth strata, the mud <50 m stratum showed a positive trend over the whole time series. No strata showed a significant trend over the more recent years. The Variation in Taxonomic Distinctiveness showed a similar pattern (Figures 26 & 27 and Table 8), but in addition to positive trends over the whole time series for the Central (1219) and Inner (2229) Gulf and mud <50 m, the sand <50 m stratum also showed a significant increase over time.

4.1.1.4. Comparison across data sets

The comparison across data sets (full data set, jack mackerel excluded, pelagics excluded, key measured species only) has been made on the *Kaharoa* series, as this excludes any potential effects of vessel change. The data series were compared on the basis of the direction of any trend over time identified, and whether the trend was significant.

Examining the direction of trends over time, the patterns across strata while not identical, were generally similar for all four data sets, with the exclusion of the jack mackerel species having least influence (compared to the full data set), and limiting the analysis to the 15 measured species usually having the most. The diversity measures N1, N2, Species richness, and Pielou’s evenness appeared least sensitive to changes in the data set, while the levels of variability were greatest for the measures based on taxonomic distinctiveness.

There were few significant trends identified in the full data set. Over the larger sediment/depth areas the significant positive trends identified for N1, N2, Pielou’s evenness, Shannon-Weiner (mud <50m) and Species richness (sand >=50 m) were not identified in any of the other data sets, but other significant trends were identified in these data sets that were not recorded in the full data set. At the survey strata level, the only significant trends identified in the full data set were negative trends in Pielou’s evenness (Inner Firth of Thames and Outer Gulf). The negative trend was significant for the Outer Gulf (4492) in the data set excluding pelagics, and both were significant in the key species data set. Again, other significant trends (particularly in the measures based on taxonomic distinctiveness) were recorded in the reduced data sets that were not noted in the full data set.

Table 5: Slope and P value for linear regressions for each survey stratum of N1 (left) and N2 (right) on year. Regression parameters are presented for the whole series (solid lines in figures) and 1984 onwards (dashed lines) (RV *Kaharoa* data) for data averaged across a survey stratum for each year (upper table) and sediment/depth strata (lower table). Slopes significantly different from zero are in bold.

		N1				N2			
		All		1984 –2000		All		1984 –2000	
Stratum	Name	slope	P	slope	P	slope	P	slope	P
1149	Waiheke/Tamaki	0.020	0.555	0.086	0.341	0.020	0.453	0.061	0.382
1219	Central Gulf	-0.060	0.362	-0.084	0.518	-0.036	0.408	-0.048	0.552
1268	Outer Thames	**-0.147**	**0.000**	0.003	0.943	**-0.105**	**0.001**	-0.004	0.873
1284	Kawau/Whangaparaoa	0.021	0.106	0.029	0.264	0.013	0.122	0.021	0.211
1386	Whangaparaoa /Rangitoto	0.029	0.304	0.064	0.258	0.014	0.300	0.030	0.252
1449	Bream/Pakiri	0.066	0.233	-0.018	0.864	0.036	0.367	-0.043	0.573
1518	Deep shelf	-0.120	0.500	-0.120	0.500	-0.041	0.791	-0.041	0.791
1887	Inner Thames	**-0.133**	**0.002**	-0.032	0.581	**-0.108**	**0.000**	-0.027	0.473
2229	Inner Gulf	-0.014	0.465	0.023	0.537	-0.007	0.477	0.008	0.722
4492	Outer Gulf	-0.067	0.170	-0.096	0.295	-0.043	0.269	-0.117	0.099
9292	Coromandel	-0.037	0.178	0.020	0.330	-0.026	0.121	0.007	0.320
mud <50 m		**-0.105**	**0.008**	**0.081**	**0.009**	**-0.053**	**0.010**	**0.039**	**0.006**
mud >=50 m		0.074	0.308	0.053	0.734	0.035	0.530	-0.063	0.589
sand <50 m		-0.018	0.672	-0.008	0.932	-0.005	0.828	-0.012	0.833
sand >=50 m		0.056	0.350	0.061	0.676	0.023	0.611	-0.018	0.867

Table 6: Slope and P value for linear regressions for each survey stratum of Species richness (left) and Margarlef's d (right) on year. Regression parameters are presented for the whole series (solid lines in figures) and 1984 onwards (dashed lines) (RV *Kaharoa* data) for data averaged across a survey stratum for each year (upper table) and sediment/depth strata (lower table). Slopes significantly different from zero are in bold.

		Species Richness				Margarlef's d			
		All		1984 –2000		All		1984 –2000	
Strata	Name	slope	P	slope	P	slope	P	slope	P
1149	Waiheke/Tamaki	0.034	0.838	-0.105	0.798	0.009	0.778	-0.011	0.886
1219	Central Gulf	0.138	0.679	0.561	0.425	-0.081	0.347	-0.008	0.958
1268	Outer Thames	0.043	0.808	0.305	0.517	-0.024	0.474	0.050	0.555
1284	Kawau/Whangaparaoa	0.258	0.283	-0.225	0.612	0.037	0.327	-0.036	0.604
1386	Whangaparaoa /Rangitoto	0.259	0.248	-0.062	0.881	0.046	0.297	-0.003	0.974
1449	Bream/Pakiri	0.334	0.187	0.359	0.482	0.044	0.451	0.047	0.671
1518	Deep shelf	0.260	0.517	0.260	0.517	-0.038	0.682	-0.038	0.682
1887	Inner Thames	0.046	0.809	0.394	0.431	-0.016	0.625	0.022	0.792
2229	Inner Gulf	0.284	0.155	0.436	0.401	0.002	0.944	0.069	0.402
4492	Outer Gulf	-0.030	0.922	0.914	0.238	-0.152	0.074	0.112	0.464
9292	Coromandel	0.174	0.409	0.559	0.402	0.003	0.943	0.110	0.332
mud <50 m		-0.053	0.746	0.355	0.389	-0.059	0.085	0.056	0.407
mud >=50 m		-0.047	0.829	0.602	0.150	-0.135	0.107	0.064	0.572
sand <50 m		**0.414**	**0.042**	0.875	0.069	-0.001	0.988	0.130	0.219
sand >=50 m		0.273	0.285	**1.335**	**0.028**	-0.009	0.892	0.229	0.110

Table 7: Slope and P value for linear regressions for each survey stratum of Pielou's evenness (left) and Shannon-Weiner diversity (right) on year. Regression parameters are presented for the whole series (solid lines in figures) and 1984 onwards (dashed lines) (RV *Kaharoa* data) for data averaged across a survey stratum for each year (upper table) and sediment/depth strata (lower table). Slopes significantly different from zero are in bold.

		Pielou's evenness				Shannon-Weiner diversity			
			All	1984 –2000			All	1984 –2000	
Strata	Name	slope	P	slope	P	slope	P	slope	P
1149	Waiheke/Tamaki	0.001	0.807	0.010	0.320	0.004	0.749	0.029	0.331
1219	Central Gulf	-0.008	0.202	-0.018	0.146	-0.020	0.272	-0.027	0.452
1268	Outer Thames	**-0.013**	**0.001**	-0.002	0.777	**-0.038**	**0.002**	0.002	0.931
1284	Kawau/Whangaparaoa	0.004	0.167	0.007	0.226	0.013	0.100	0.016	0.305
1386	Whangaparaoa /Rangitoto	0.001	0.873	0.008	0.343	0.012	0.405	0.025	0.361
1449	Bream/Pakiri	0.005	0.394	-0.012	0.165	0.021	0.195	-0.012	0.675
1518	Deep shelf	-0.011	0.314	-0.011	0.314	-0.022	0.433	-0.022	0.433
1887	Inner Thames	**-0.012**	**0.000**	**-0.014**	**0.029**	**-0.032**	**0.005**	-0.009	0.664
2229	Inner Gulf	-0.005	0.103	-0.003	0.672	-0.006	0.454	0.009	0.569
4492	Outer Gulf	-0.004	0.173	**-0.013**	**0.036**	-0.014	0.151	-0.020	0.354
9292	Coromandel	-0.007	0.112	0.001	0.667	-0.014	0.226	0.014	0.298
mud <50 m		**-0.008**	**0.029**	**0.012**	**0.004**	**-0.027**	**0.029**	**0.041**	**0.007**
mud >=50 m		0.004	0.321	-0.011	0.084	0.010	0.401	0.009	0.735
sand <50 m		-0.004	0.215	-0.002	0.787	-0.006	0.630	0.004	0.887
sand >=50 m		0.002	0.504	-0.004	0.505	0.011	0.318	0.016	0.536

Table 8: Slope and P value for linear regressions for each survey stratum of Average Taxonomic distinctiveness (left) and Variation in Taxonomic Distinctiveness (right) on year. Regression parameters are presented for the whole series (solid lines in figures) and 1984 onwards (dashed lines) (RV *Kaharoa* data) for data averaged across a survey stratum for each year (upper table) and sediment/depth strata (lower table). Slopes significantly different from zero are in bold.

		Av. Taxonomic Distinctiveness				Var. Taxonomic Distinctiveness			
			All	1984 –2000			All	1984 –2000	
Strata	Name	slope	P	slope	P	slope	P	slope	P
1149	Waiheke/Tamaki	-0.010	0.904	0.027	0.902	3.304	0.217	-0.775	0.909
1219	Central Gulf	**0.261**	**0.046**	-0.055	0.764	**4.696**	**0.013**	5.302	0.085
1268	Outer Thames	0.063	0.461	0.253	0.254	0.672	0.621	-2.934	0.388
1284	Kawau/Whangaparaoa	0.159	0.172	0.043	0.848	-0.004	0.998	-5.208	0.059
1386	Whangaparaoa /Rangitoto	0.006	0.968	0.373	0.141	4.537	0.130	1.597	0.764
1449	Bream/Pakiri	0.111	0.180	0.149	0.344	4.369	0.076	7.737	0.083
1518	Deep shelf	0.084	0.609	0.084	0.609	0.249	0.939	0.249	0.939
1887	Inner Thames	0.013	0.906	-0.175	0.561	0.358	0.859	8.020	0.104
2229	Inner Gulf	**0.208**	**0.033**	0.388	0.109	**4.504**	**0.043**	7.127	0.203
4492	Outer Gulf	0.005	0.945	-0.216	0.289	2.462	0.166	1.119	0.808
9292	Coromandel	0.251	0.129	0.021	0.957	3.472	0.301	15.931	0.102
mud <50 m		**0.103**	**0.020**	0.179	0.078	**3.042**	**0.003**	-0.468	0.769
mud >=50 m		0.078	0.615	0.115	0.729	0.825	0.835	-7.600	0.337
sand <50 m		0.060	0.319	-0.037	0.797	**4.214**	**0.008**	-3.623	0.108
sand >=50 m		0.107	0.139	-0.122	0.444	2.626	0.124	-5.283	0.089

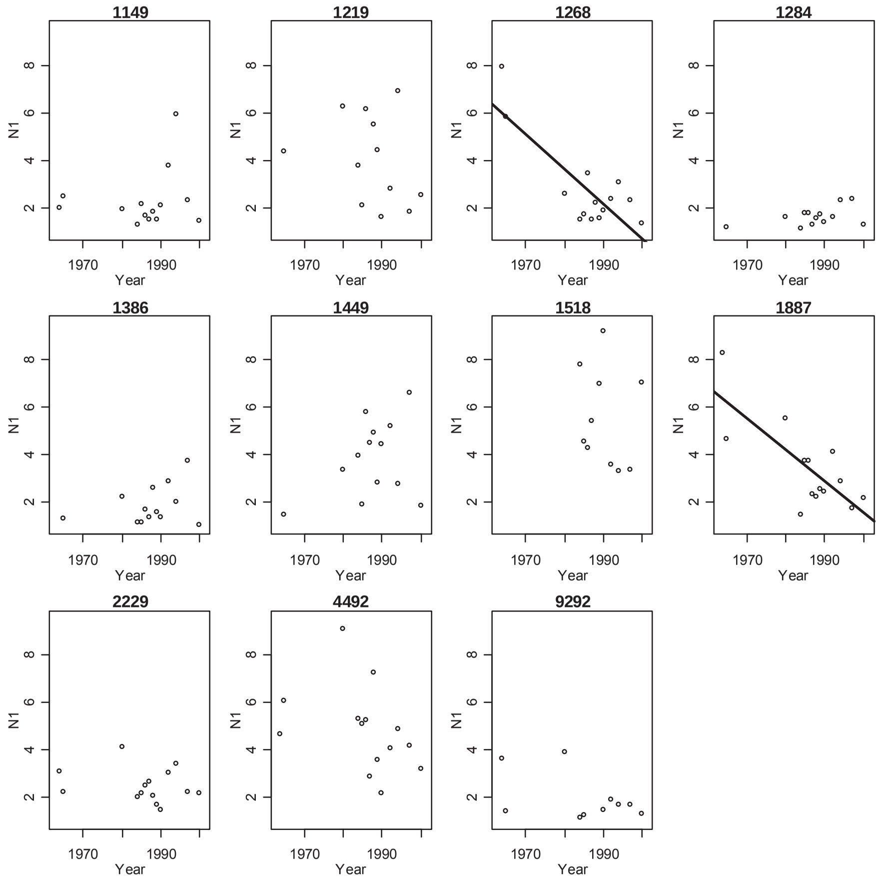


Figure 12: Plots of Hill's N1 diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

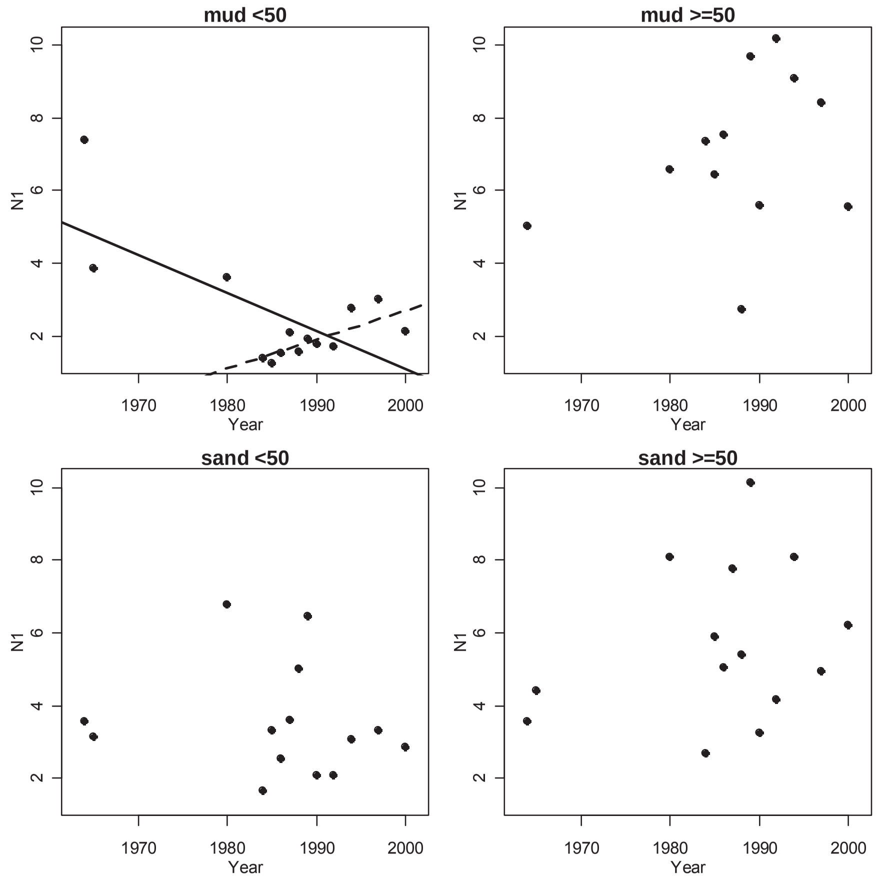


Figure 13: Plots of Hill's N1 diversity parameter for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

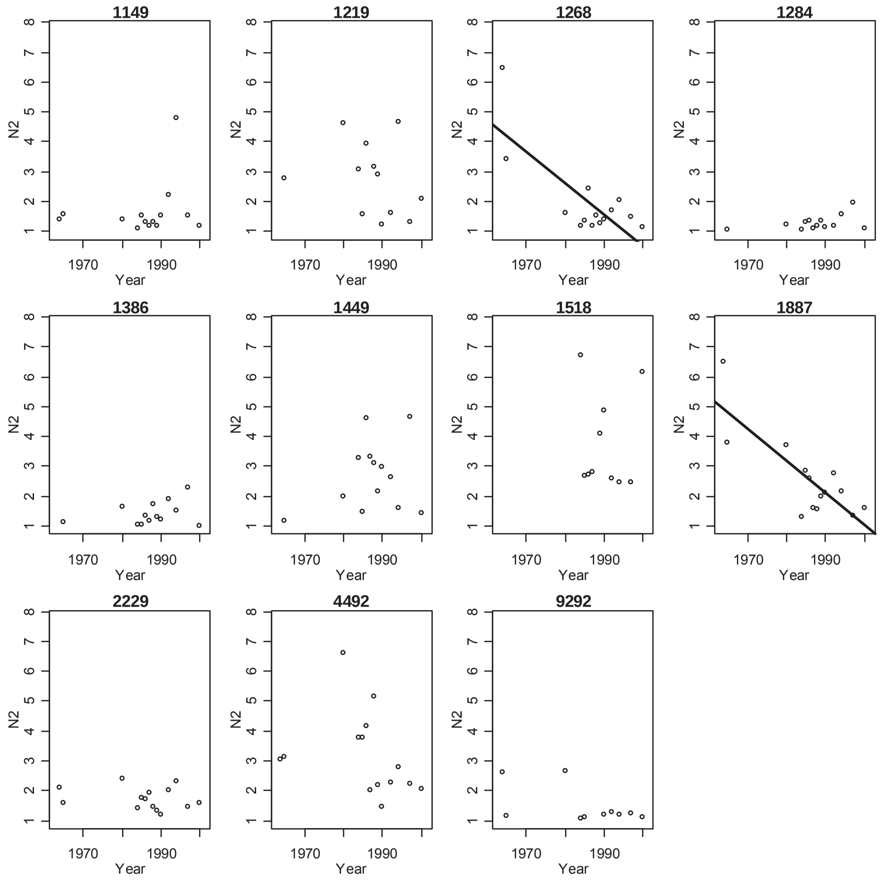


Figure 14: Plots of Hill's N2 diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

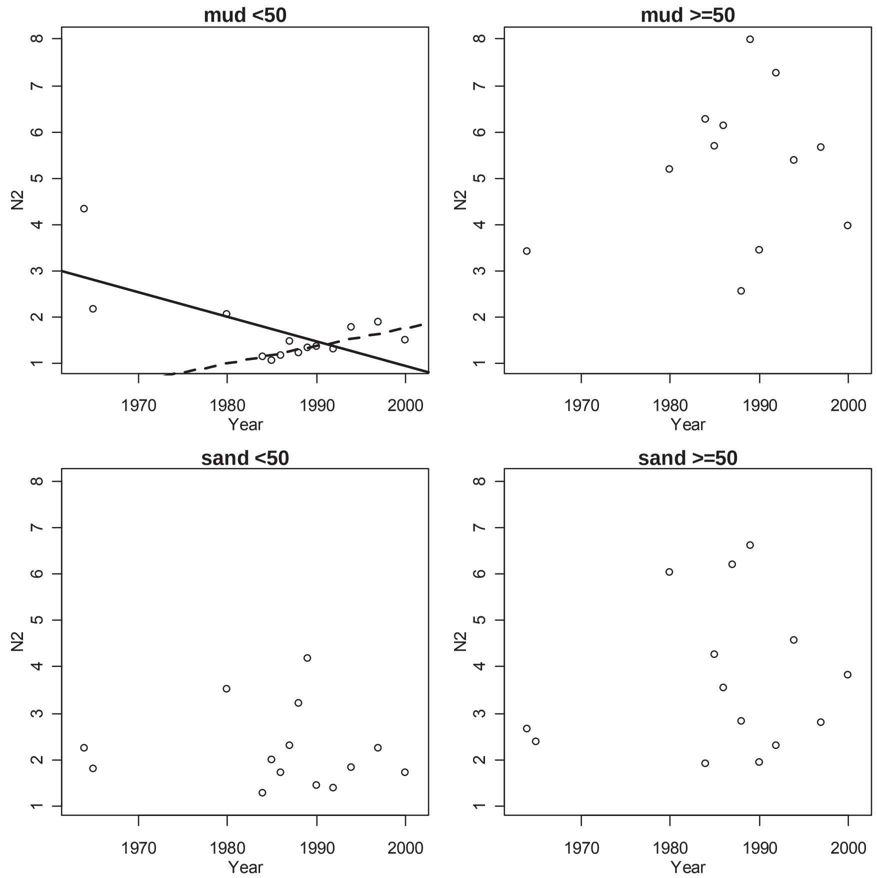


Figure 15: Plots of Hill's N2 diversity parameter for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

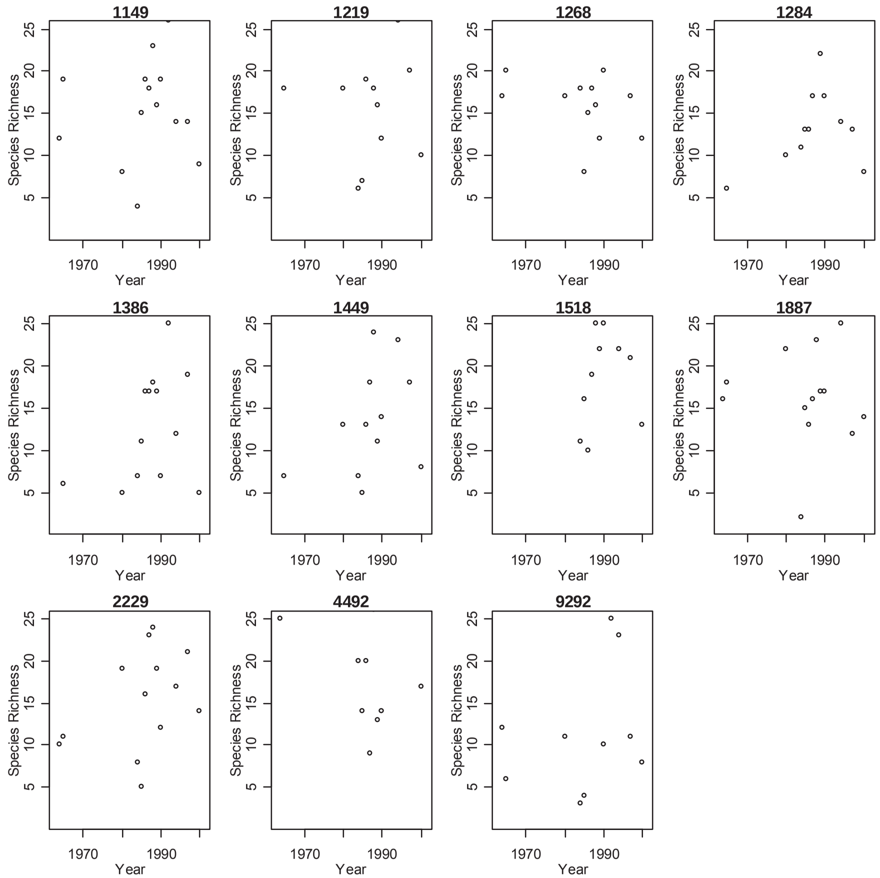


Figure 16: Plots of Species Richness for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

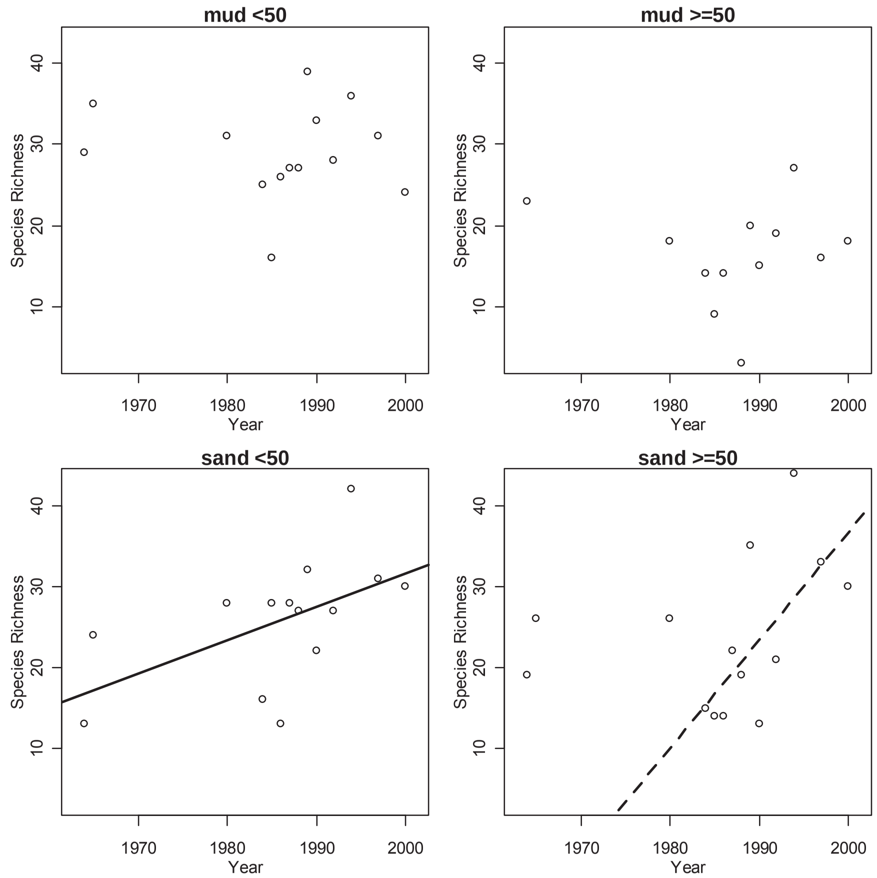


Figure 17: Plots of Species Richness for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

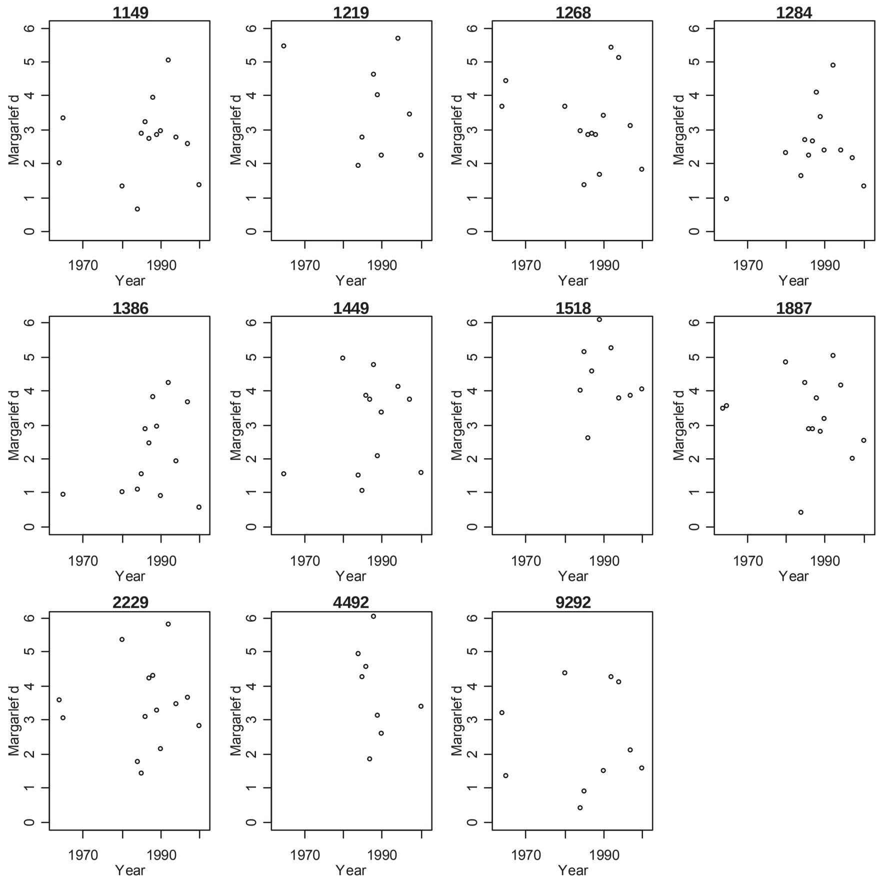


Figure 18: Plots of Margarlef's d diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

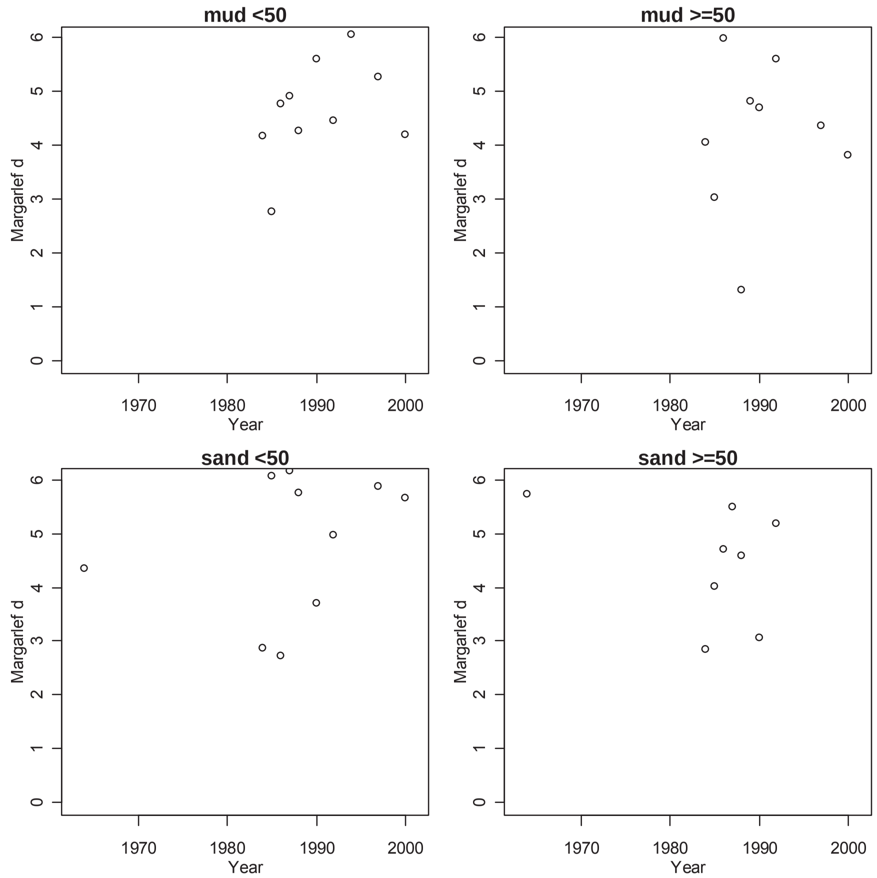


Figure 19: Plots of Margarlef's d diversity parameter for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

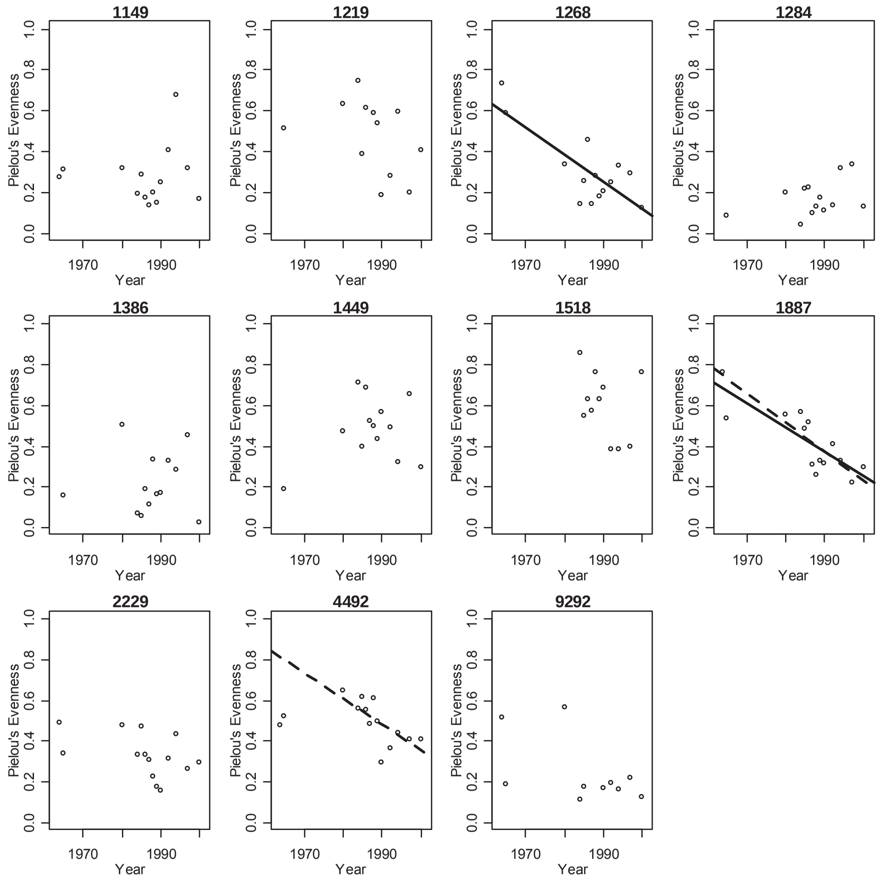


Figure 20: Plots of Pielou's evenness parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

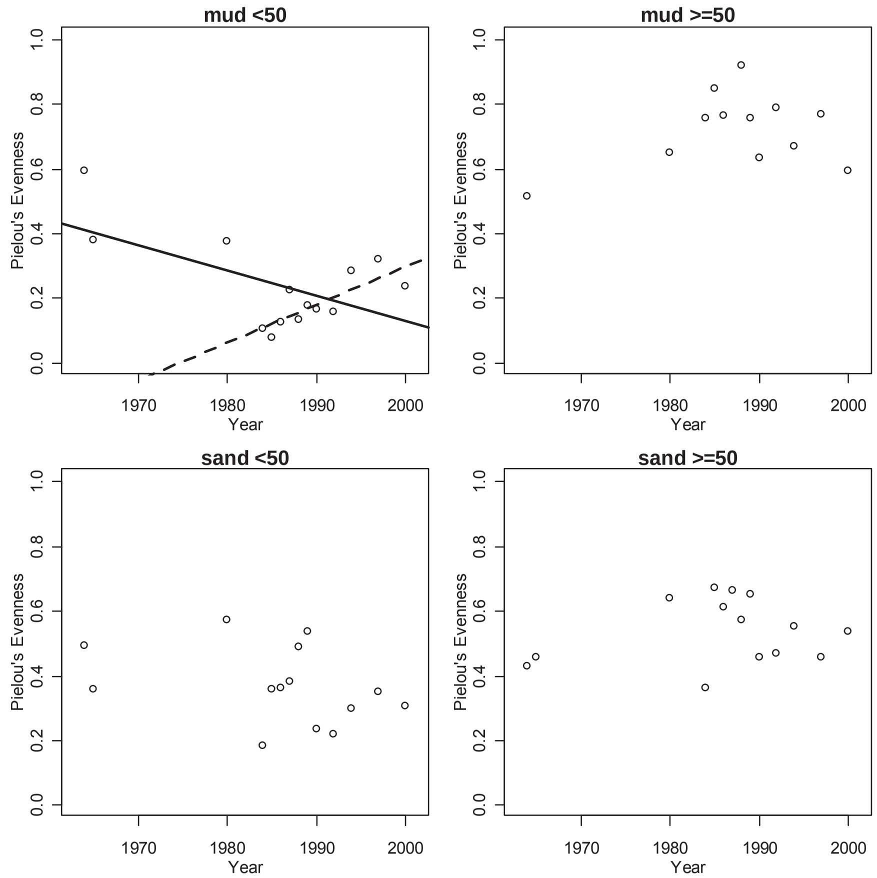


Figure 21: Plots of Pielou's evenness parameter for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

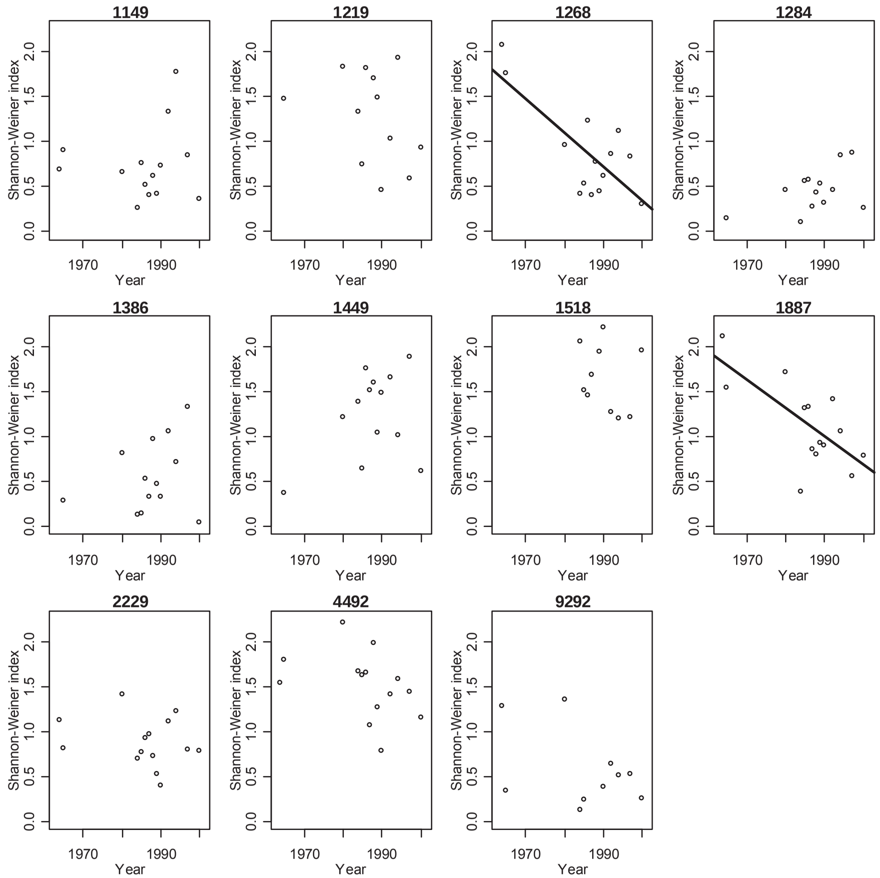


Figure 22: Plots of Shannon Weiner diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

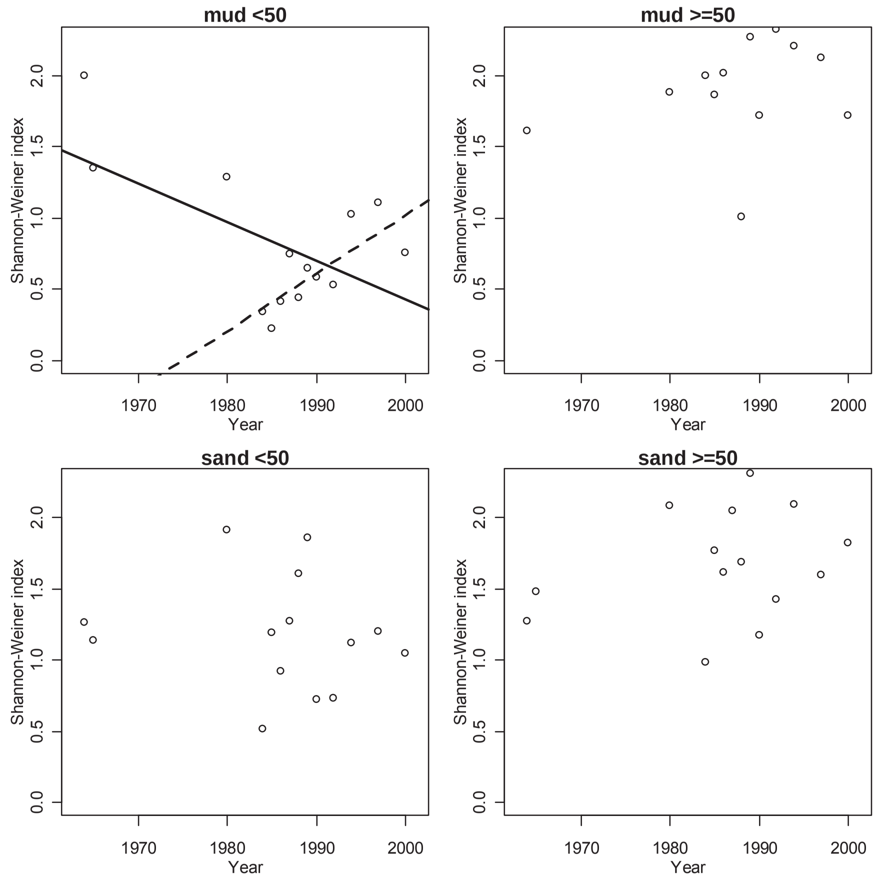


Figure 23: Plots of Shannon Weiner diversity parameter for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

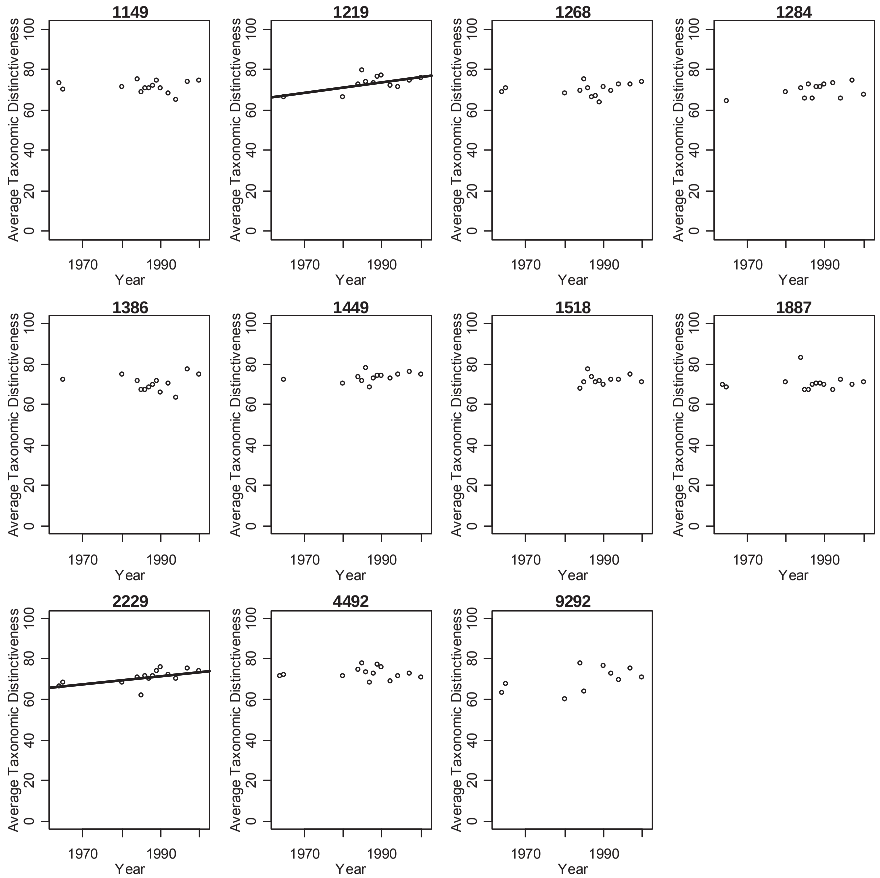


Figure 24: Plots of Average Taxonomic Distinctiveness parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

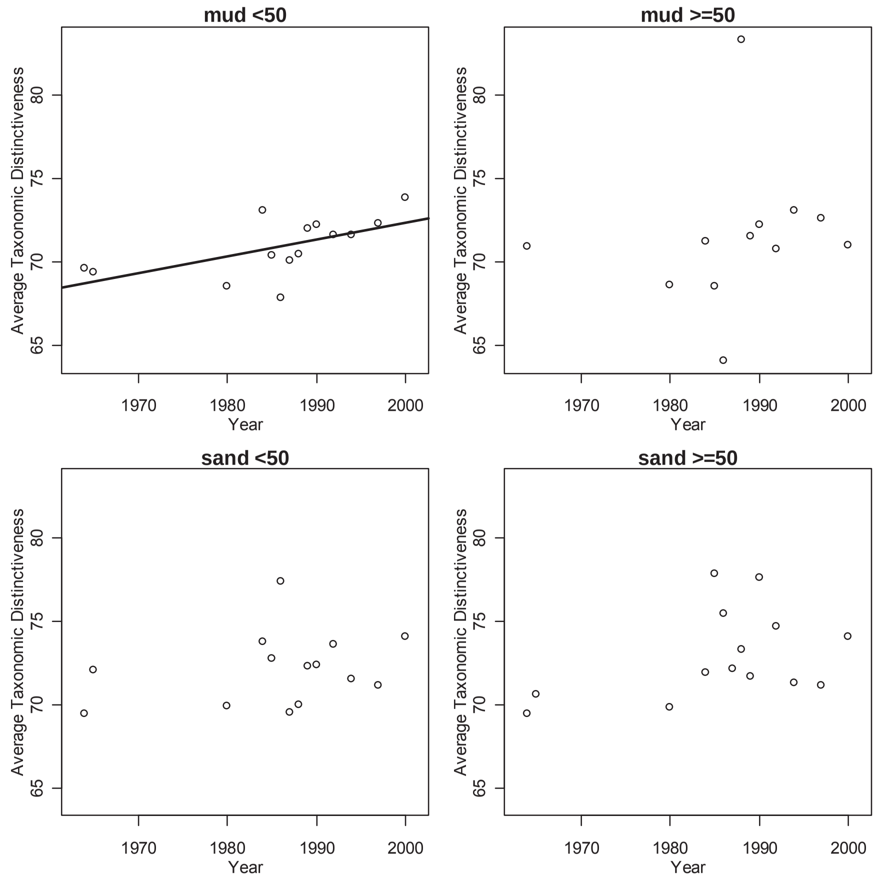


Figure 25: Plots of Average Taxonomic Distinctiveness parameter for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

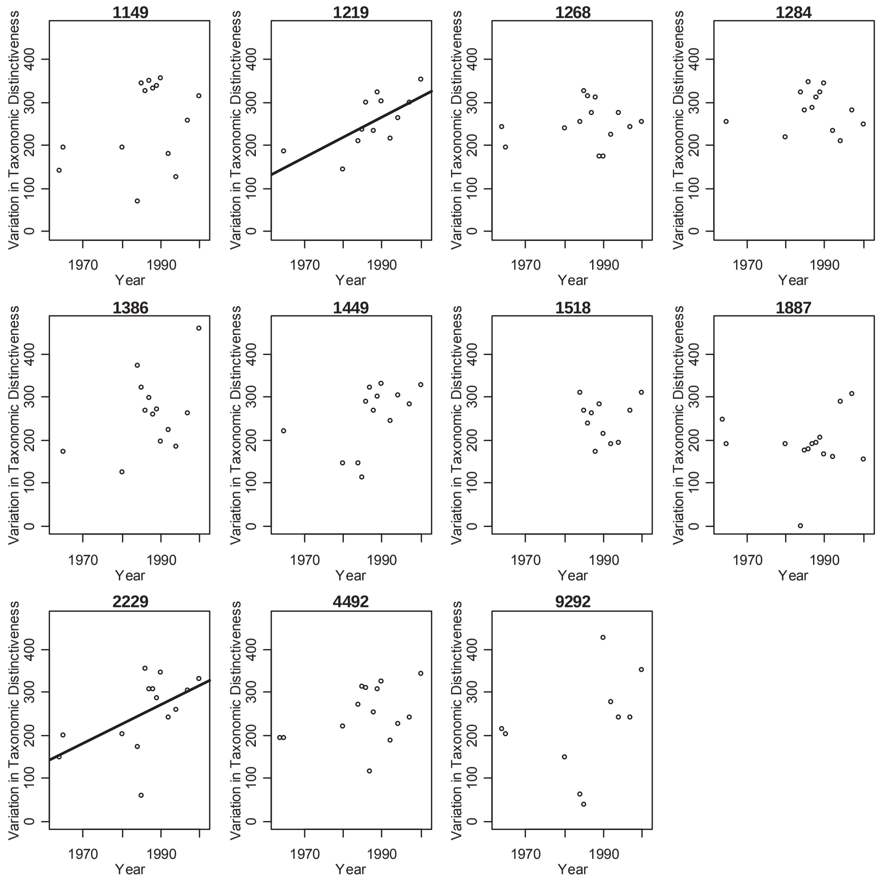


Figure 26: Plots of Variation in taxonomic distinctiveness parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

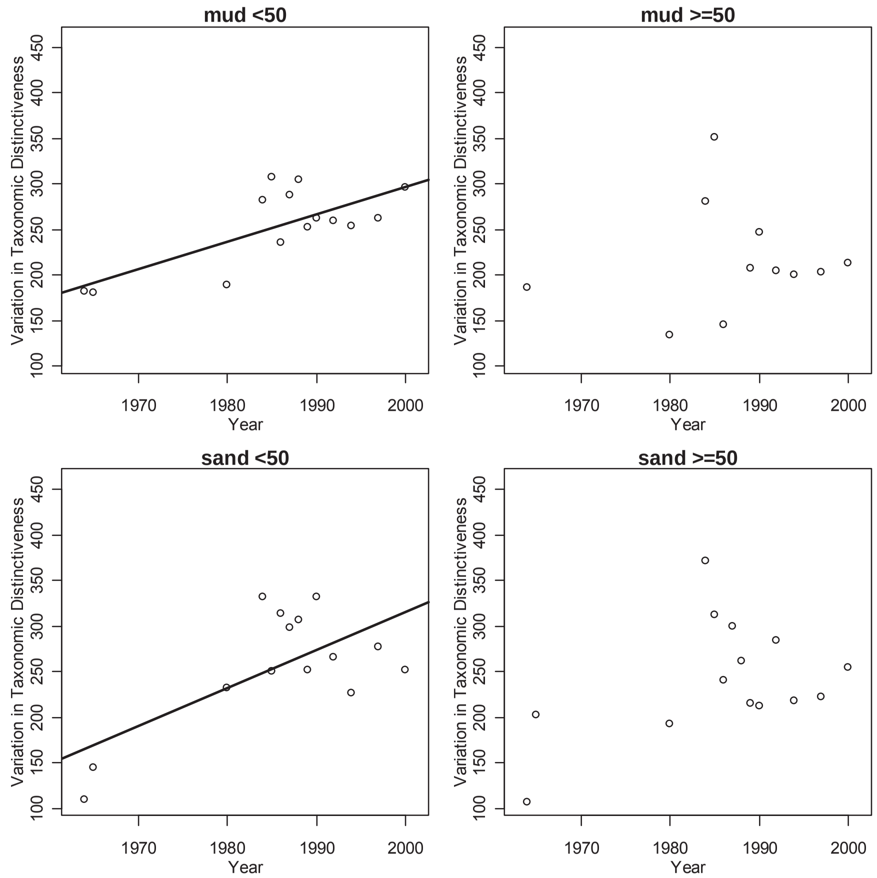


Figure 27; Plots of Variation in taxonomic distinctiveness parameter for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

4.1.2. Trophodynamic indicators

4.1.2.1. Biomass ratio

On the basis of life history knowledge for each species, the catch for each station was summed by main feeding group and environment. The ratio of Pisciverous:Total (Figures 28 & 29) and Demersal:Total (Figures 30 & 31) catch weight were examined over time for each stratum.

For the ratio of Pisciverous:Total catch weight, none of the strata showed a significant trend over time, either over the whole time series or the more recent data (Table 9).

For the ratio of Demersal:Total catch weight (Figure 30 & Table 9), the Waiheke/Tamaki (1149), Firth of Thames (1268 and 1887), Whangaparaoa/Rangitoto (1386), and Coromandel (9292) strata showed significant positive trends over time for the whole series, while the Outer Gulf (4492) showed a significant negative trend in the more recent data. The mud < 50 m and sand < 50 m areas both showed significant positive trends over the whole time series.

4.1.2.2. Trophic Level of the catch

The mean TL of the survey catch was examined over time for each stratum (Figure 32 & 33). None of the strata showed a significant trend over time for either the survey strata or larger sediment/depth areas.

4.1.2.3. Trophic spectra

Cumulative relative biomass trophic spectra are plotted for each year in each survey stratum in Figures 34 & 35.

Between-year pairs of cumulative relative biomass trophic spectra were compared using a Kolmogorov-Smirnov (KS) test to calculate the maximum proportional difference between the two curves (d statistic), and a bootstrap procedure to derive expected distributions of the d-statistic against which the observed d-statistic could be compared, based on a FORTRAN programme developed by Jeremy McKenzie (NIWA, pers. comm.). The standard KS test is typically too sensitive for fisheries data which generally have very large sample sizes and hence the test is prone to Type II error (falsely rejecting the null hypothesis). In the bootstrap process, two length frequency distributions were sampled from a combined distribution and a d-statistic derived. The bootstrap process was repeated 1000 times to generate an expected distribution for the d-statistic. The original d-statistic was then compared to generated distribution. The proportion of bootstrap d-statistic values less than the observed value was considered to represent the rejection probability of the null hypothesis (Type I rejection probability).

From the plots of cumulative relative biomass trophic level spectra (Figures 34 & 35) it can be seen that some strata and areas appear to have been more variable in their trophic spectra than others. The pairwise KS tests generated a triangular matrix of P values, which can be considered measures of similarity (the higher the P value, the more similar the pair of trophic spectra). Examination of patterns from the matrix is far from straightforward, and so the P values have been taken as measures of similarity and used to generate Multi Dimensional Scaling (MDS) plots to visualise how the patterns vary over time, and if there are any particular trends (i.e., samples becoming more different over time).

The MDS plots showing the changes in relative similarity in trophic spectra over time are shown for the survey strata in Figure 36, and for the larger sediment/depth areas in Figure 37. Only data from the *Kaharoa* survey series has been considered. Some individual years appear quite different from the rest (e.g., 1984 for survey the Waiheke/Tamaki (1149), Kawau/Whangaparaoa (1284) and Coromandel (9292) strata, and the larger mud < 50 m area), but there does not appear to be any evidence of a general shift in the trophic spectra over time.

Table 9: Slope and P value for linear regressions for each survey stratum of Pisciverous fish:Total fish catch (left), Demersal fish:Total fish catch (middle) and Mean TL (trophic level) (right) on year. Proportions were arcsin square root transformed. Regression parameters are presented for the whole series (solid lines in figures) and 1984 onwards (dashed lines) (RV *Kaharoa* data) for data averaged across a survey stratum for each year (upper table) and sediment/depth strata (lower table). Slopes significantly different from zero are in bold.

		Pisciverous:Total				Demersal:Total				Mean TL			
		All		1984 –2000		All		1984 –2000		All		1984 –2000	
Strata	Name	slope	P	slope	P	slope	P	slope	P	slope	P	slope	P
1149	Waiheke/Tamaki	0.0051	0.270	0.0162	0.152	**0.0057**	**0.014**	0.0038	0.382	0.0018	0.332	0.0064	0.183
1219	Central Gulf	0.0030	0.534	0.0067	0.518	0.0053	0.240	-0.0054	0.490	-0.0010	0.830	-0.0104	0.270
1268	Outer Thames	0.0032	0.348	-0.0020	0.807	**0.0107**	**0.005**	0.0110	0.190	0.0007	0.657	-0.0001	0.978
1284	Kawau/Whangaparaoa	0.0049	0.225	0.0037	0.646	0.0007	0.475	0.0012	0.521	0.0020	0.266	0.0019	0.603
1386	Whangaparaoa /Rangitoto	0.0054	0.563	-0.0061	0.742	**0.0023**	**0.038**	-0.0004	0.738	0.0024	0.618	-0.0022	0.820
1449	Bream/Pakiri	0.0059	0.502	-0.0066	0.705	-0.0003	0.975	0.0225	0.268	0.0002	0.948	-0.0120	0.062
1518	Deep shelf	0.0031	0.849	0.0031	0.849	0.0001	0.991	0.0001	0.991	0.0033	0.738	0.0033	0.738
1887	Inner Thames	0.0031	0.411	-0.0056	0.554	**0.0088**	**0.002**	0.0058	0.300	-0.0023	0.285	-0.0019	0.697
2229	Inner Gulf	0.0065	0.132	0.0019	0.854	-0.0003	0.938	-0.0060	0.491	0.0021	0.435	-0.0038	0.572
4492	Outer Gulf	0.0072	0.242	0.0012	0.936	0.0005	0.876	**-0.0151**	**0.023**	0.0015	0.701	0.0003	0.973
9292	Coromandel	-0.0031	0.320	0.0081	0.265	**0.0070**	**0.006**	0.0018	0.622	-0.0006	0.436	0.0013	0.345
mud <50		0.0024	0.338	0.0070	0.288	**0.0072**	**0.000**	0.0034	0.240	-0.0004	0.720	0.0033	0.230
mud >=50		0.0135	0.058	0.0044	0.744	-0.0026	0.682	0.0170	0.119	0.0045	0.342	0.0067	0.452
sand <50		0.0029	0.346	-0.0061	0.366	**0.0064**	**0.001**	0.0078	0.051	0.0009	0.671	-0.0053	0.281
sand >=50		0.0095	0.199	-0.0163	0.321	-0.0023	0.697	-0.0084	0.595	0.0020	0.588	-0.0081	0.354

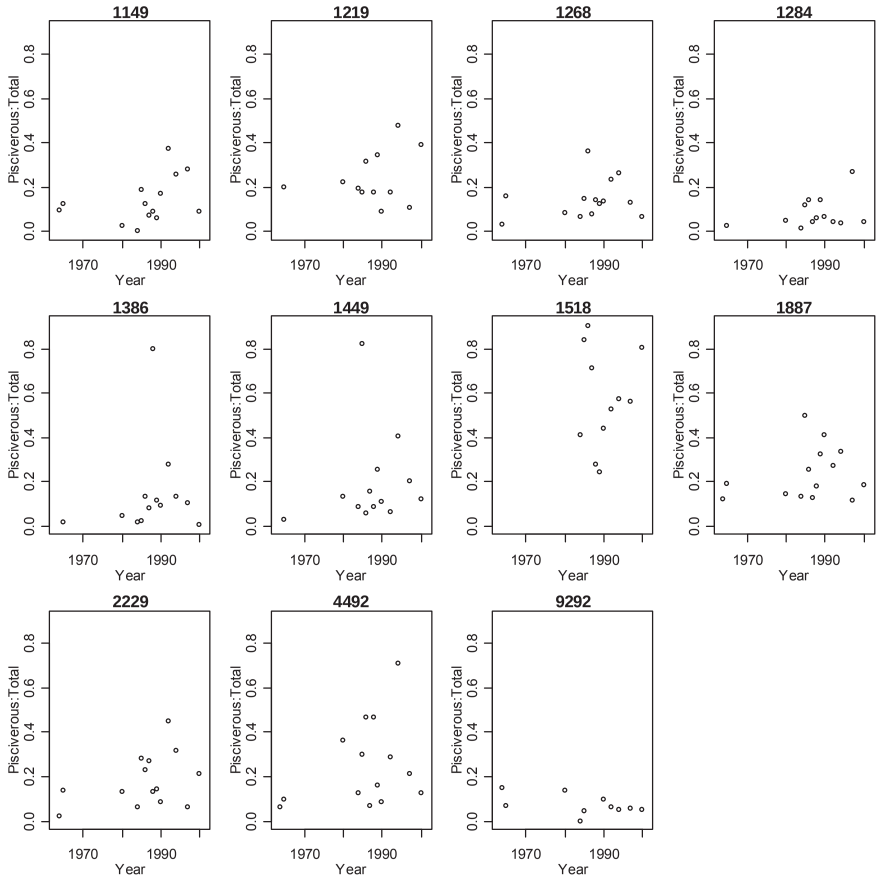


Figure 28: Plots of the Pisciverous:Total catch weight ratio for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

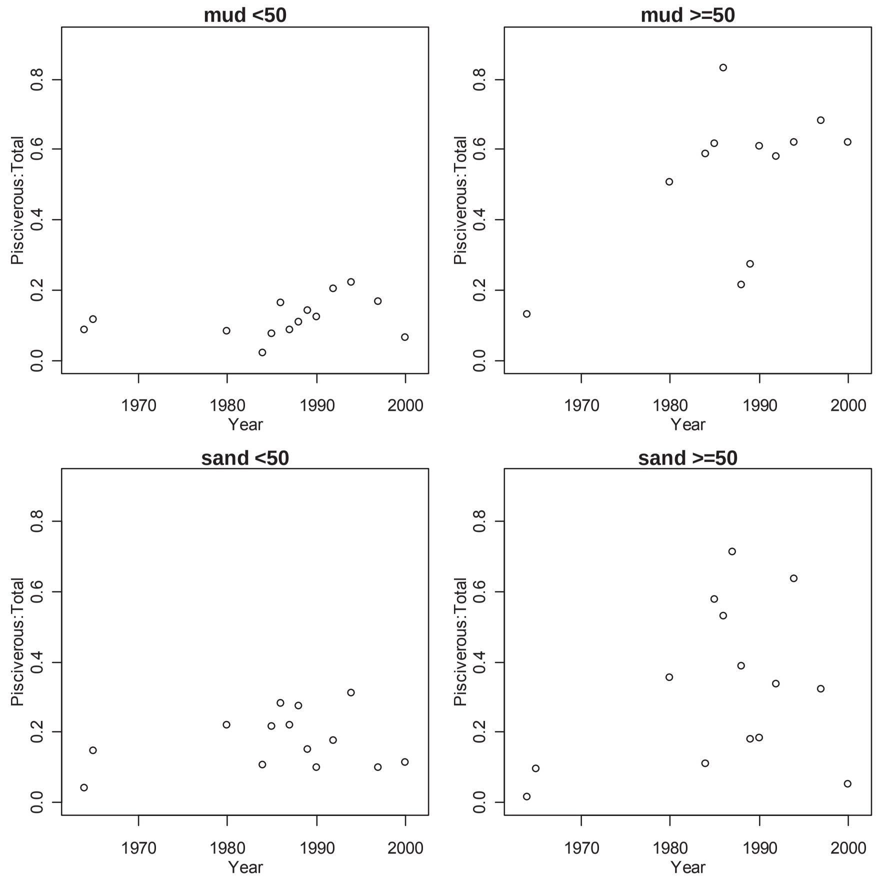


Figure 29: Plots of the Pisciverous:Total catch weight ratio for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

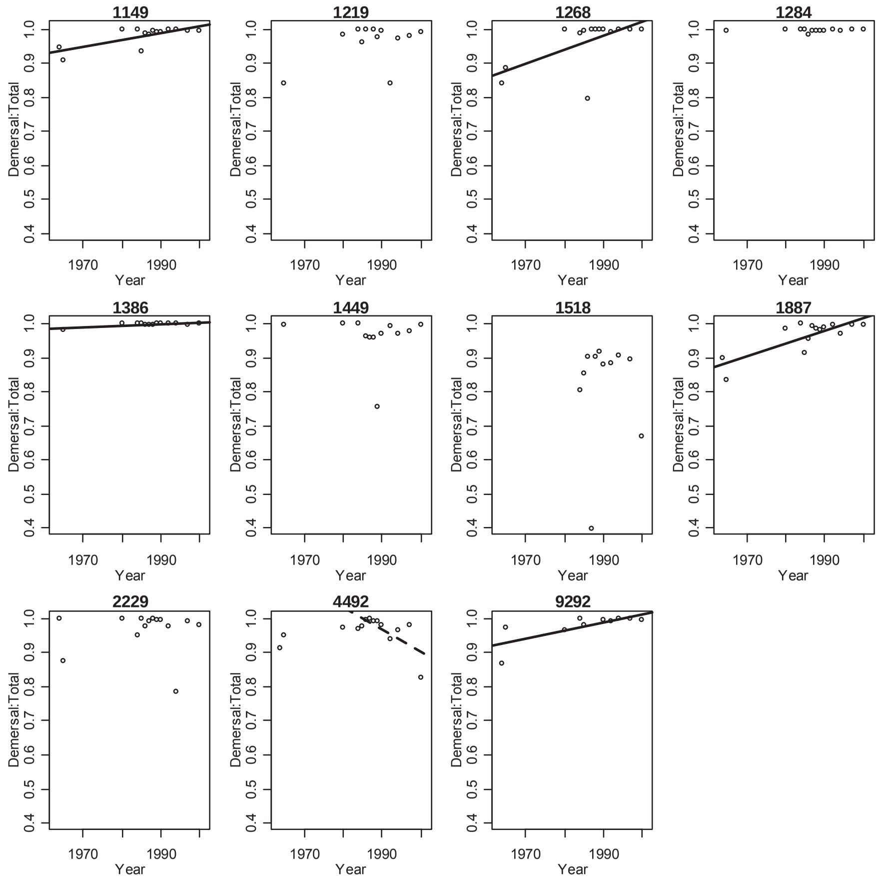


Figure 30: Plots of the Demersal:Total catch weight ratio for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

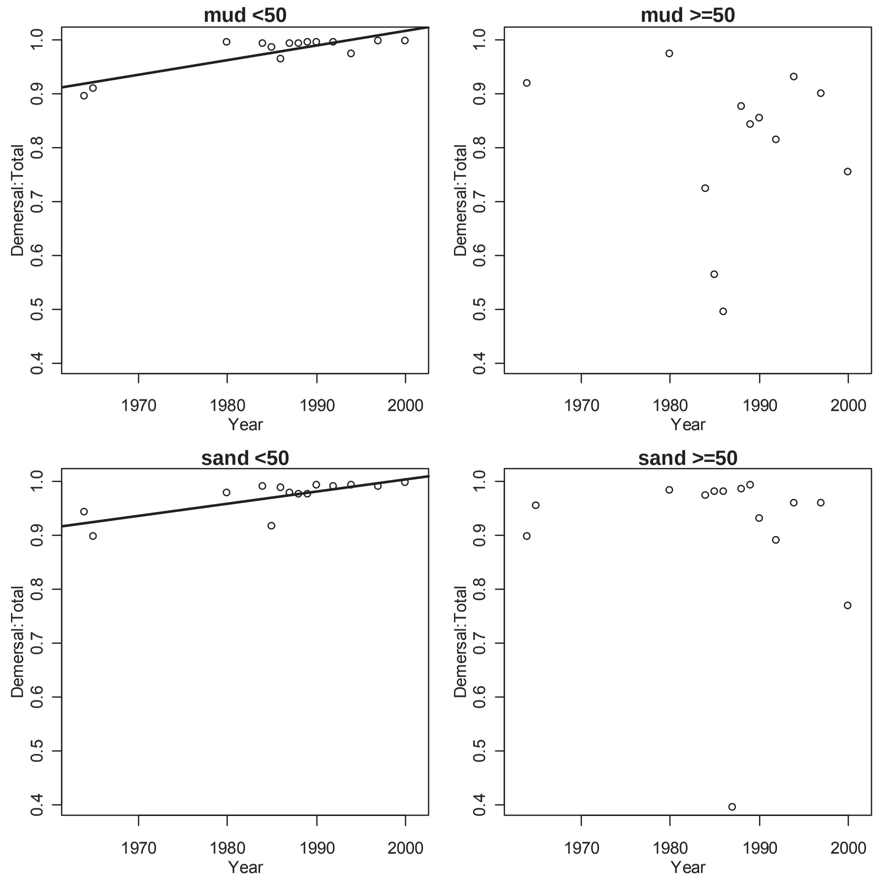


Figure 31: Plots of the Demersal:Total catch weight ratio for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

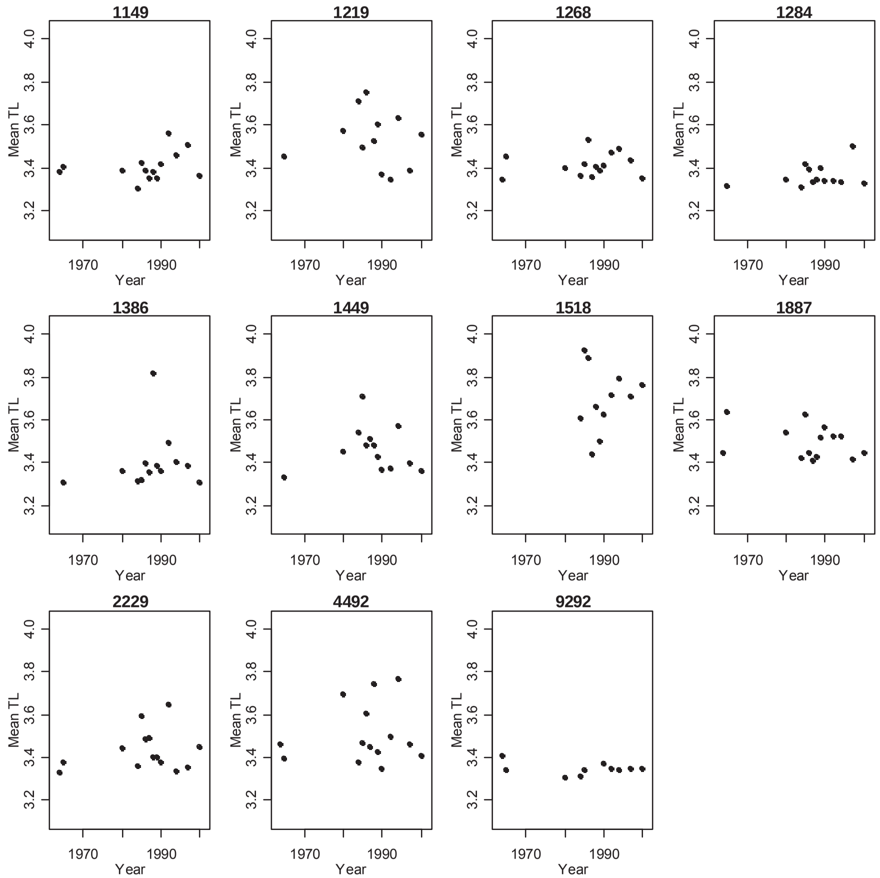


Figure 32: Plots of Mean TL for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

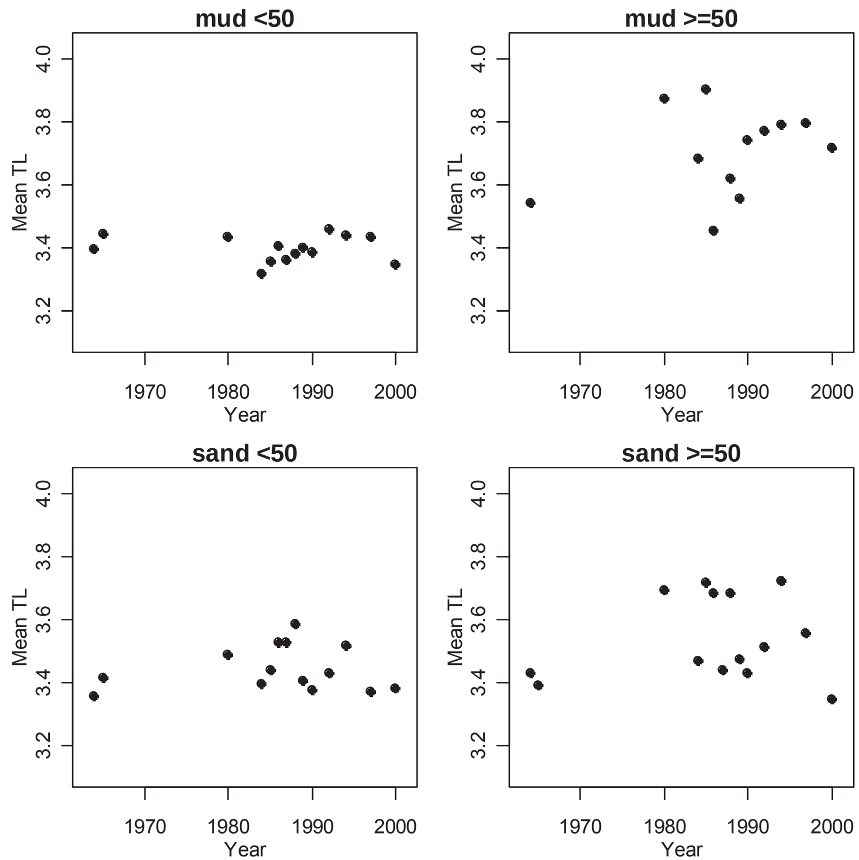


Figure 33: Plots of Mean TL for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

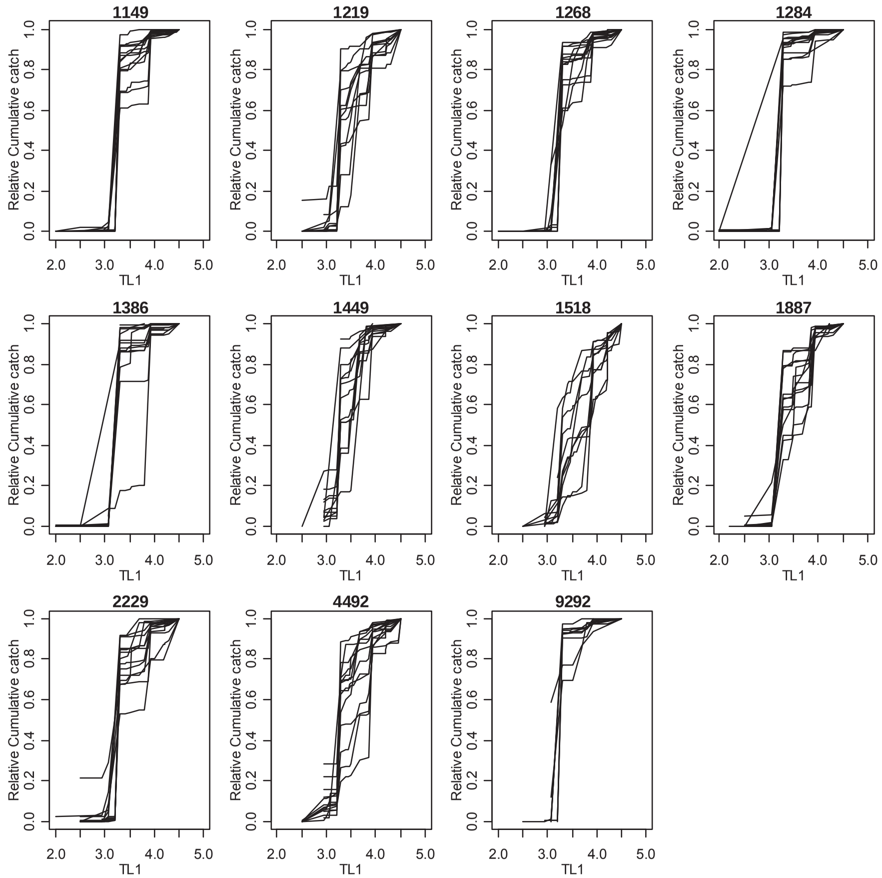


Figure 34: Plots of cumulative relative biomass trophic level spectra for each survey stratum.

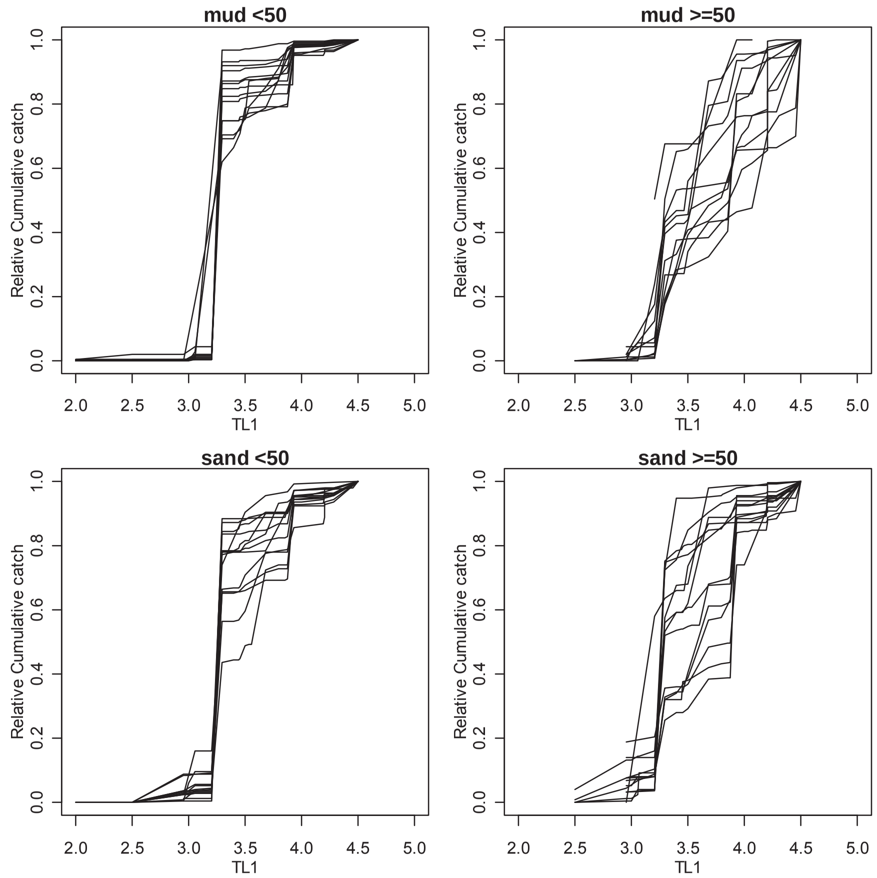


Figure 35: Plots of cumulative relative biomass trophic level spectra for each sediment/depth stratum.

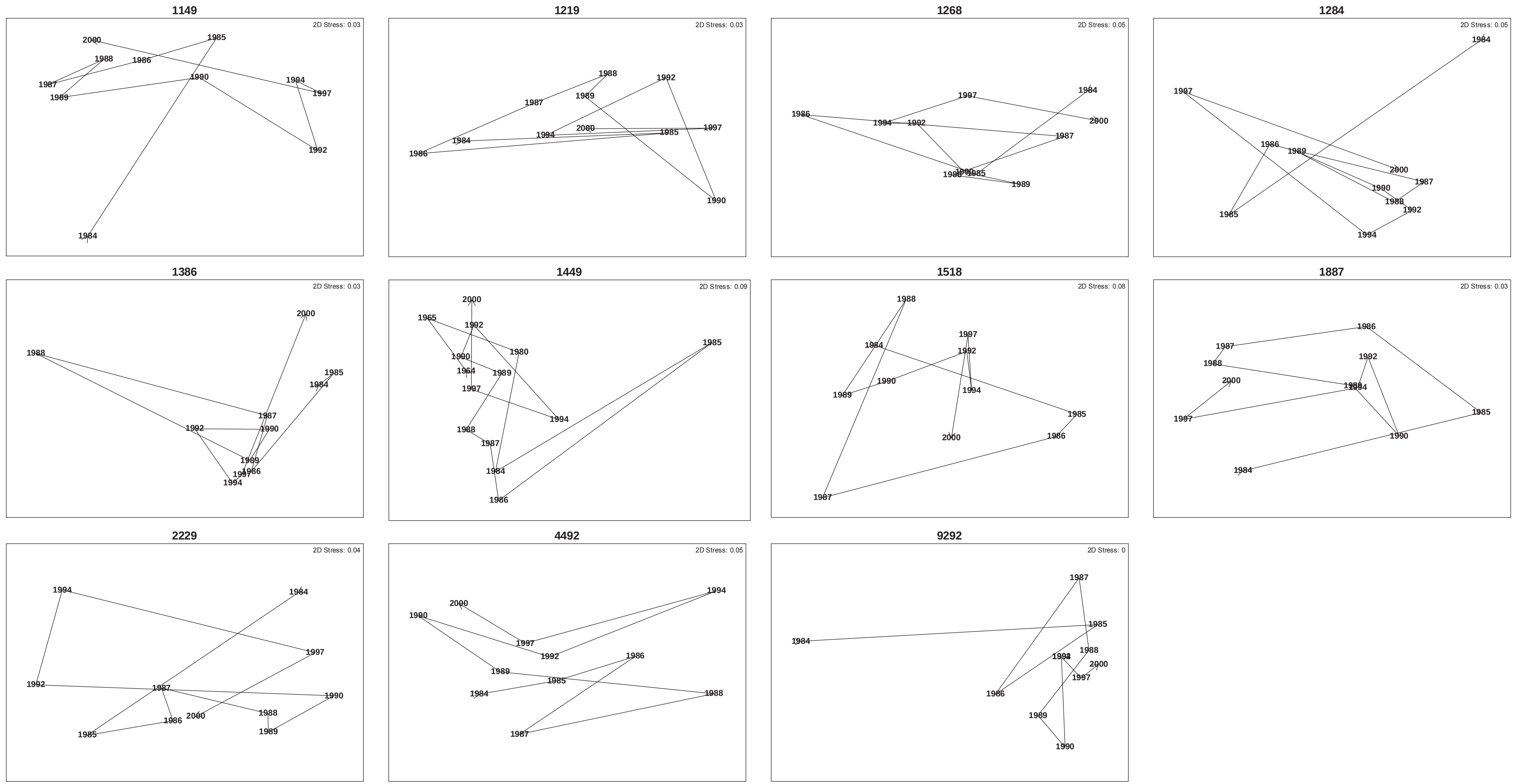


Figure 36: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of relative biomass trophic spectra over time for each survey stratum.

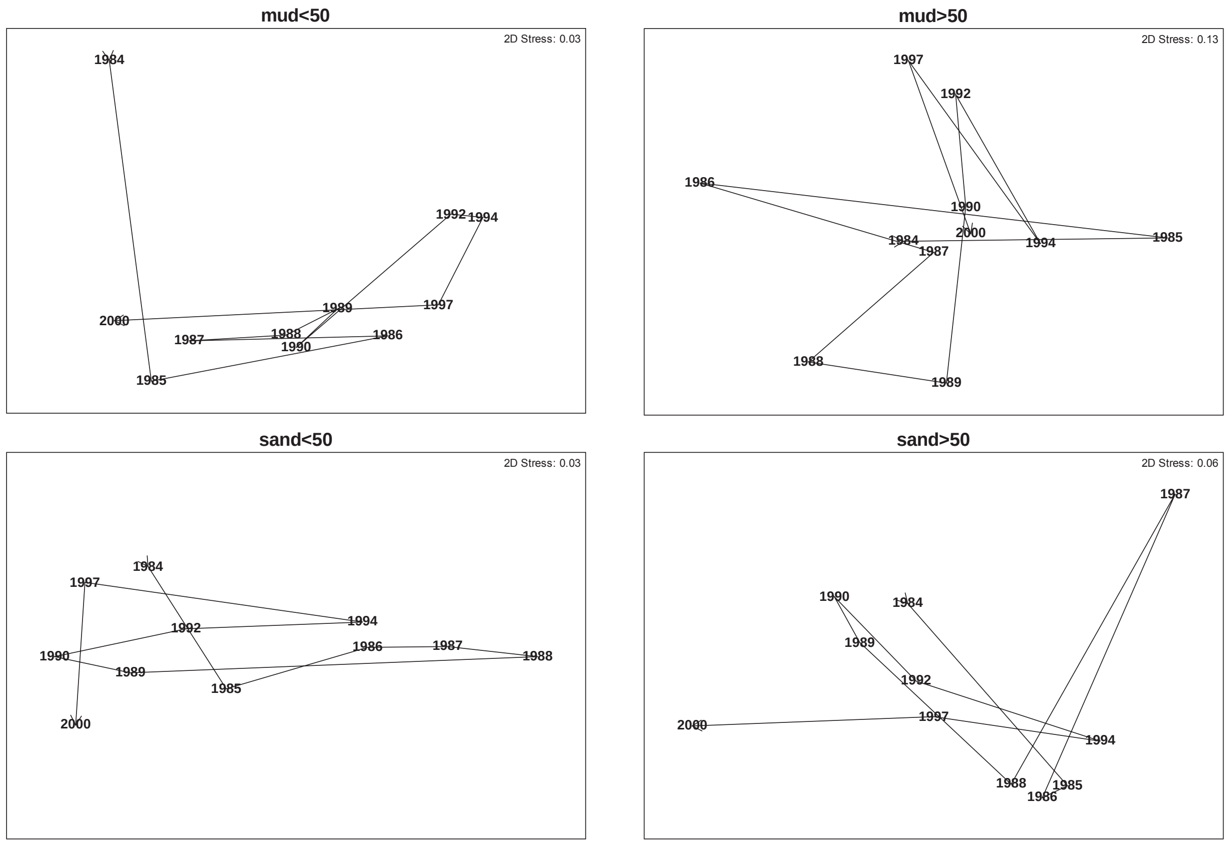


Figure 37: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of relative biomass trophic spectra over time for each of the sediment/depth stratum.

4.2. Analysis of catch numbers at length by station

Not all species caught during a tow are measured, and so for examination of size based indicators, a set of 15 species was selected, being considered to be appropriately sampled by the gear and consistently measured. Only tows in which all the species were measured (assuming they were caught) were included in the analysis. Indicators were calculated for the full combined length frequency distribution of the 15 species. The species were barracouta, blue mackerel, New Zealand sole, gurnard, John dory, jack mackerel (all species combined), leatherjacket, lemon sole, school shark, sand flounder, snapper, rig, spotted stargazer, witch, and yellow-belly founder.

4.2.1. Median and L95 size

Median length showed a significant trend (negative) only for the Central Gulf (1219) (over the whole time series) (Figures 38 & 39 and Table 10). For the Inner Firth of Thames (1887) there was an almost significant negative trend over the more recent years.

The L95 length (95th percentile of length distribution) appeared more sensitive to changes in the fish community length structure over time, with negative trends identified for the Central Gulf (1219) (whole series and more recent years) and the Firth of Thames (1268 and 1887) and the Outer Gulf (4492) (whole series) (Figures 40 & 41 and Table 10). Over the larger sediment/depth strata, negative trends were identified for mud <50 m (more recent years) and both sand strata (whole series).

4.2.2. Proportion of large individuals

The proportion (by number) of the catch under 30 cm shows a negative trend for the Central Gulf (1219) (whole series and more recent years), the Inner Firth of Thames (1887) for the more recent years and Outer Gulf (4492) for the whole series (Figures 42 & 43 and Table 11). Of the sediment/depth strata, only the sand >=50 m shows a negative trend (over the whole series).

4.2.3. W statistic

Overall, the W statistic values were generally scattered around zero, suggesting the group of measured species made up a moderately disturbed community. The Waiheke/Tamaki (1149) and Kawau/Whangaparaoa (1284) strata had positive trends (over more recent years), while stratum 1518 had a negative trend (stratum only surveyed in more recent years) (Figures 44 & 45 and Table 11). None of the sediment/depth strata showed significant trends, although a positive trend for sand <50 m was almost significant.

Table 10: Slope and P value for linear regressions for each survey stratum of Median length (left) and L95 length (right) on year. Regression parameters are presented for the whole series (solid lines in figures) and 1984 onwards (dashed lines) (RV *Kaharoa* data) for data averaged across a survey stratum for each year (upper table) and sediment/depth strata (lower table). Slopes significantly different from zero are in bold.

		Median length				L95			
		All		1984 –2000		All		1984 –2000	
Strata	Name	slope	P	slope	P	slope	P	slope	P
1149	Waiheke/Tamaki	-0.1360	0.073	-0.1926	0.254	-0.2057	0.115	-0.3263	0.336
1219	Central Gulf	**-0.3975**	**0.001**	-0.2591	0.204	**-0.4909**	**0.013**	**-0.6763**	**0.023**
1268	Outer Thames	-0.0256	0.749	-0.2143	0.227	**-0.2494**	**0.007**	-0.1621	0.386
1284	Kawau/Whangaparaoa	-0.0851	0.503	0.0264	0.920	0.0224	0.909	-0.2038	0.631
1386	Whangaparaoa /Rangitoto	0.0021	0.988	0.1068	0.711	0.0481	0.834	-0.2658	0.562
1449	Bream/Pakiri	-0.1914	0.129	-0.3165	0.238	-0.2791	0.174	-0.5812	0.170
1518	Deep shelf	-0.1691	0.569	-0.1691	0.569	0.3366	0.540	0.3366	0.540
1887	Inner Thames	-0.0865	0.292	-0.3610	0.061	**-0.3800**	**0.048**	-0.7356	0.109
2229	Inner Gulf	-0.1710	0.079	-0.3081	0.177	-0.1017	0.467	-0.6056	0.081
4492	Outer Gulf	-0.2114	0.091	-0.2153	0.483	**-0.3402**	**0.034**	-0.4538	0.251
9292	Coromandel	-0.1183	0.125	0.0996	0.622	-0.0298	0.620	0.2005	0.221
mud <50 m		-0.0784	0.208	-0.1978	0.207	-0.1442	0.121	**-0.5403**	**0.015**
mud >=50 m		-0.1665	0.280	-0.2753	0.415	-0.0562	0.836	-0.0946	0.868
sand <50 m		-0.1317	0.064	-0.2048	0.233	**-0.2363**	**0.006**	-0.2511	0.199
sand >=50 m		-0.2142	0.135	-0.1604	0.642	**-0.3453**	**0.016**	-0.2762	0.418

Table 11: Slope and P value for linear regressions for each survey stratum of proportion > 30cm (left) and W statistic (right) on year. Proportion data arcsine square root transformed. Regression parameters are presented for the whole series (solid lines in figures) and 1984 onwards (dashed lines) (RV *Kaharoa* data) for data averaged across a survey stratum for each year (upper table) and sediment/depth stratum (lower table). Slopes significantly different from zero are in bold.

		Proportion > 30cm				W statistic			
		All		1984 –2000		All		1984 –2000	
Strata	Name	slope	P	slope	P	slope	P	slope	P
1149	Waiheke/Tamaki	-0.0056	0.104	-0.0065	0.430	0.0014	0.285	**0.0069**	**0.024**
1219	Central Gulf	**-0.0097**	**0.004**	**-0.0129**	**0.030**	-0.0031	0.233	0.0025	0.635
1268	Outer Thames	-0.0055	0.139	-0.0088	0.307	0.0005	0.684	0.0008	0.472
1284	Kawau/Whangaparaoa	0.0000	0.997	-0.0006	0.960	0.0056	0.166	**0.0198**	**0.008**
1386	Whangaparaoa /Rangitoto	0.0043	0.573	0.0008	0.959	0.0001	0.947	-0.0018	0.379
1449	Bream/Pakiri	-0.0054	0.292	-0.0115	0.293	0.0043	0.217	0.0123	0.087
1518	Deep shelf	-0.0032	0.776	-0.0032	0.776	**-0.0200**	**0.015**	**-0.0200**	**0.015**
1887	Inner Thames	-0.0050	0.140	**-0.0157**	**0.034**	-0.0004	0.660	0.0030	0.147
2229	Inner Gulf	-0.0045	0.278	-0.0171	0.088	-0.0008	0.663	0.0015	0.701
4492	Outer Gulf	**-0.0078**	**0.015**	-0.0057	0.449	-0.0034	0.298	0.0005	0.952
9292	Coromandel	-0.0006	0.747	0.0061	0.228	-0.0015	0.055	0.0005	0.676
mud <50 m		-0.0029	0.300	-0.0122	0.083	-0.0007	0.163	0.0015	0.057
mud >=50 m		-0.0035	0.621	-0.0128	0.401	-0.0051	0.439	-0.0001	0.995
sand <50 m		-0.0036	0.177	-0.0064	0.350	-0.0021	0.112	0.0027	0.070
sand >=50 m		**-0.0096**	**0.018**	-0.0029	0.748	-0.0034	0.194	-0.0008	0.893

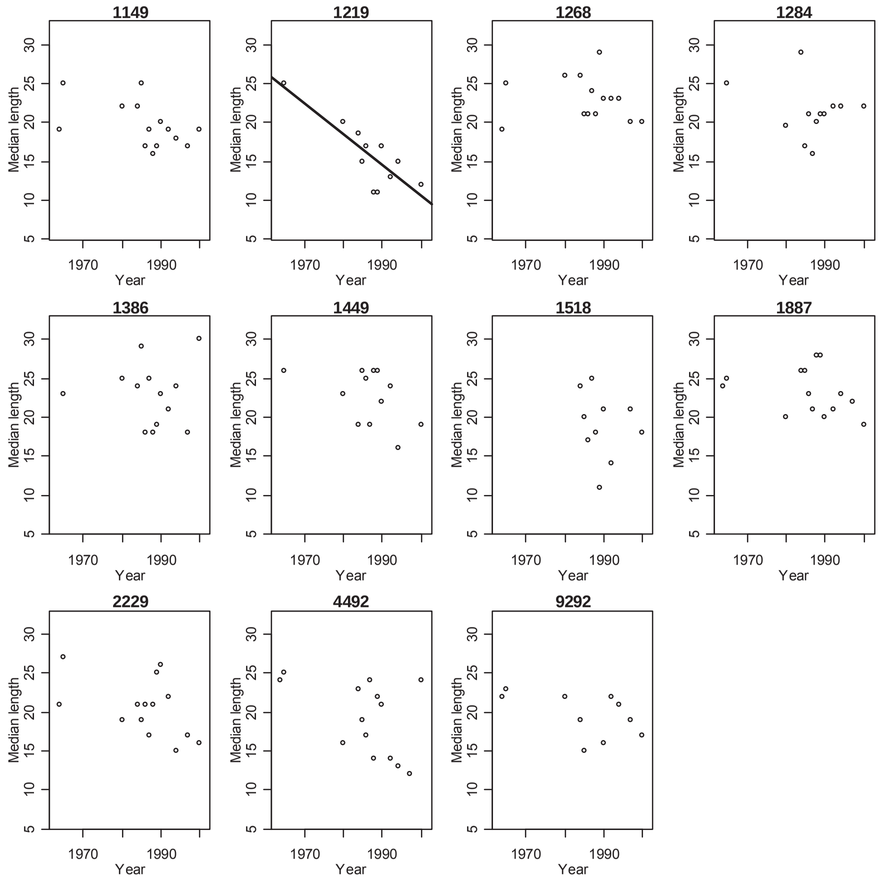


Figure 38: Plots of the Median length for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

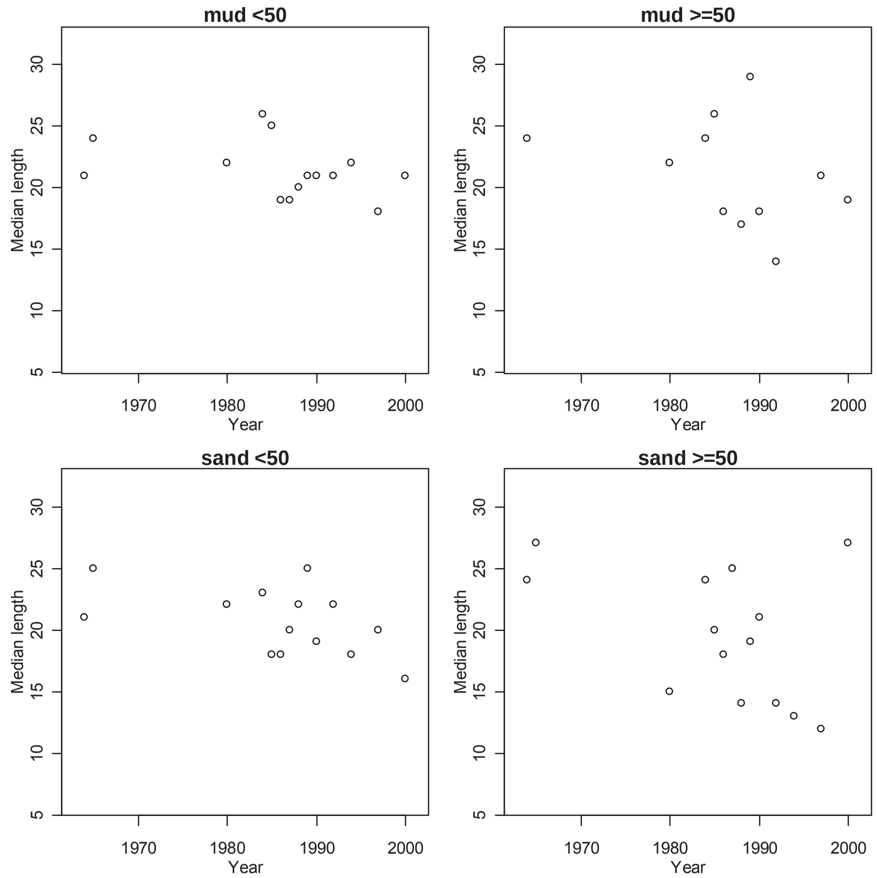


Figure 39: Plots of the Median length for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

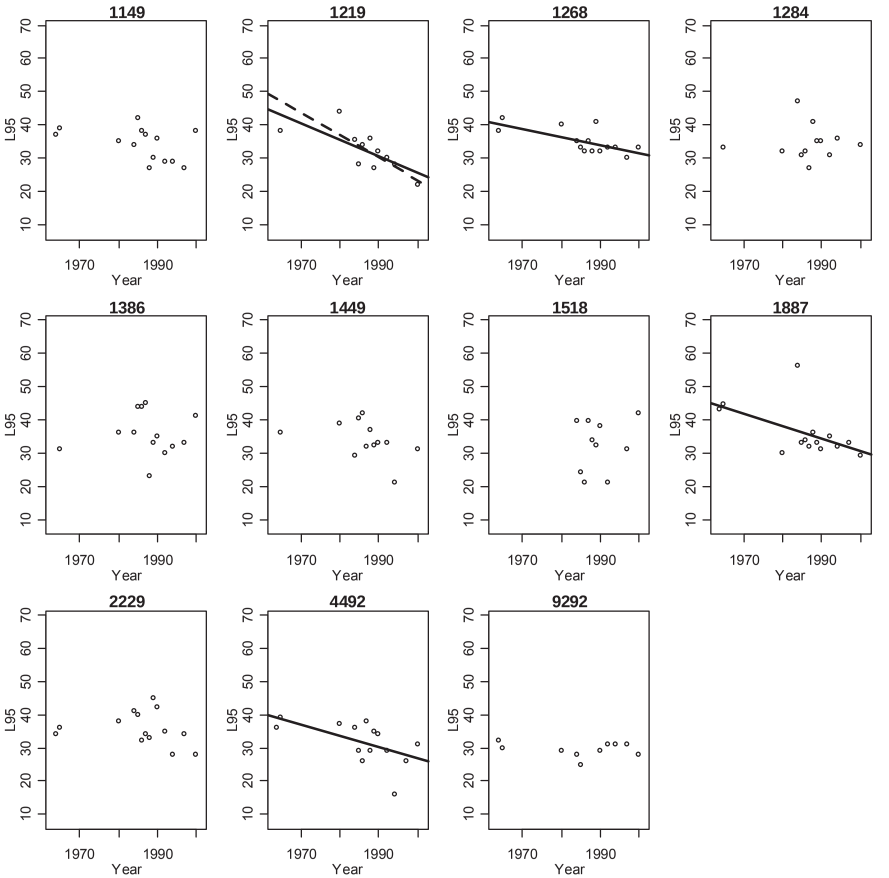


Figure 40: Plots of L95 for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

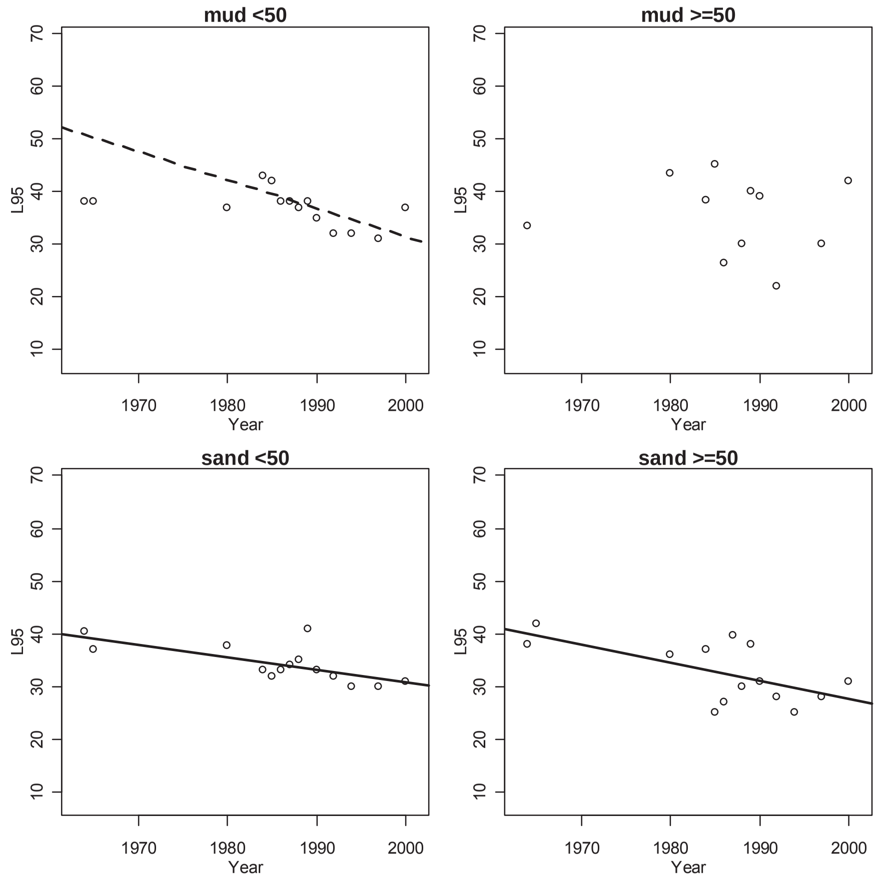


Figure 41: Plots of L95 for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

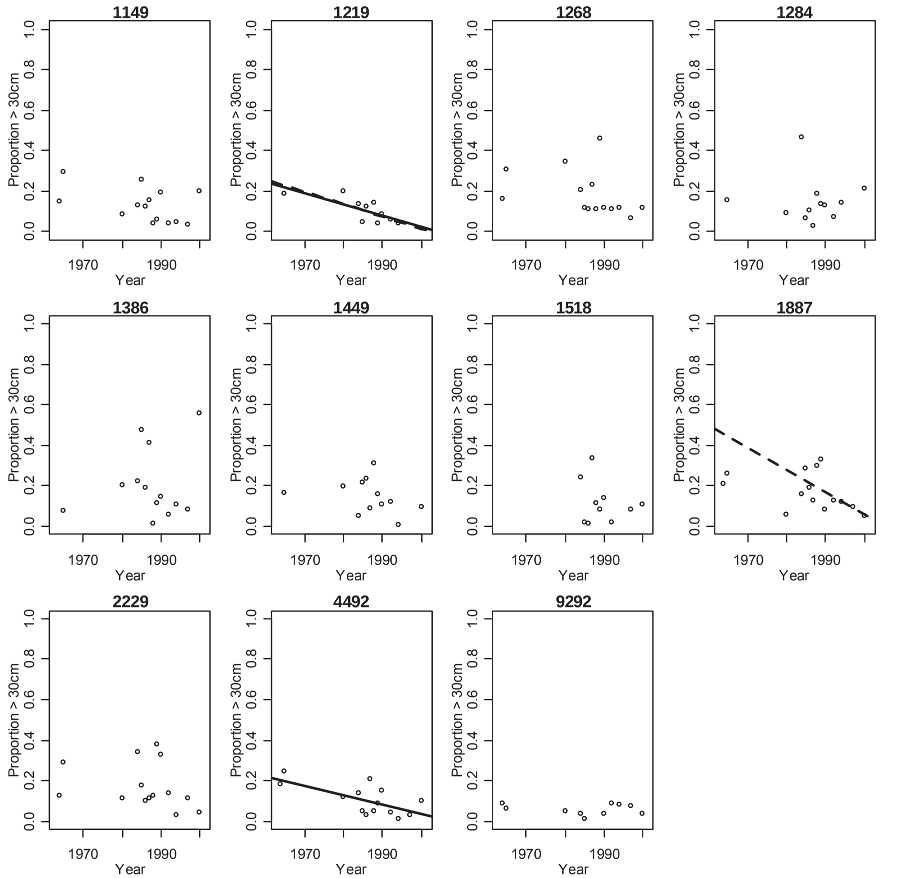


Figure 42: Plots of the proportion >30 cm length for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

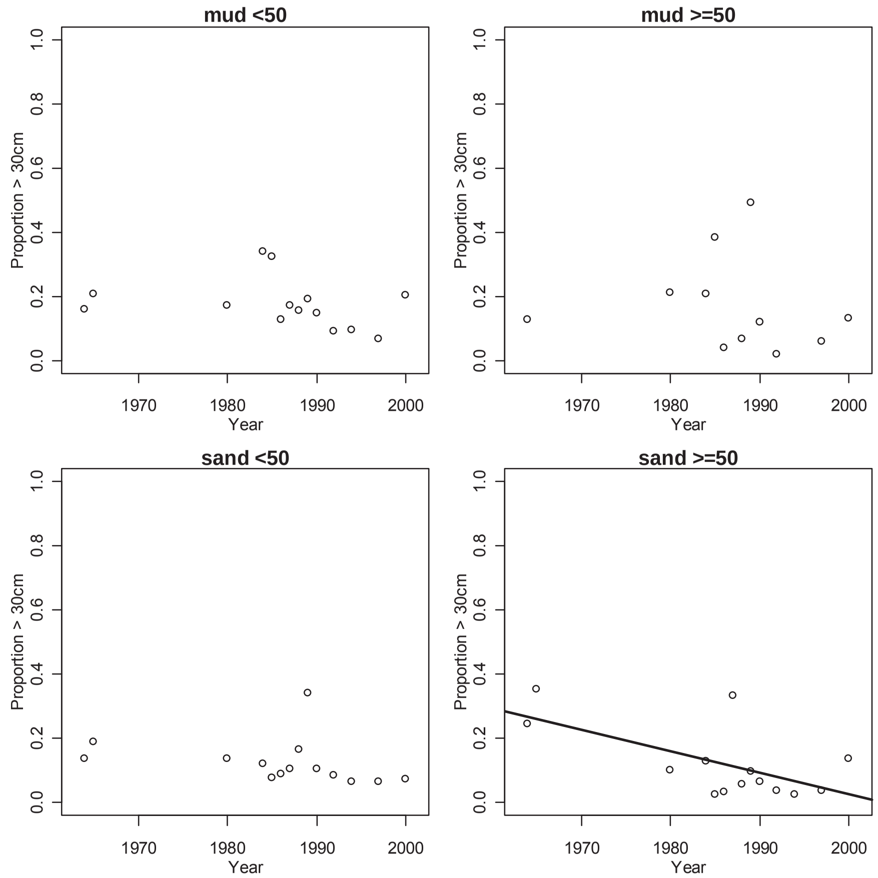


Figure 43: Plots of the proportion >30 cm length for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

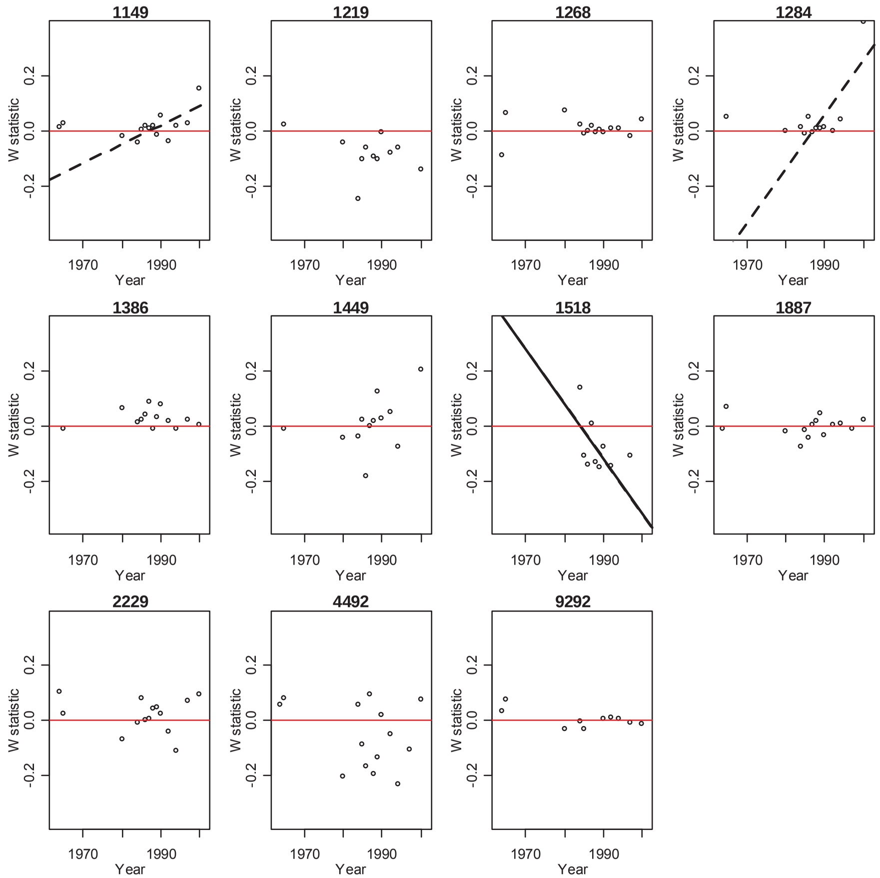


Figure 44: Plots of the W statistic for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

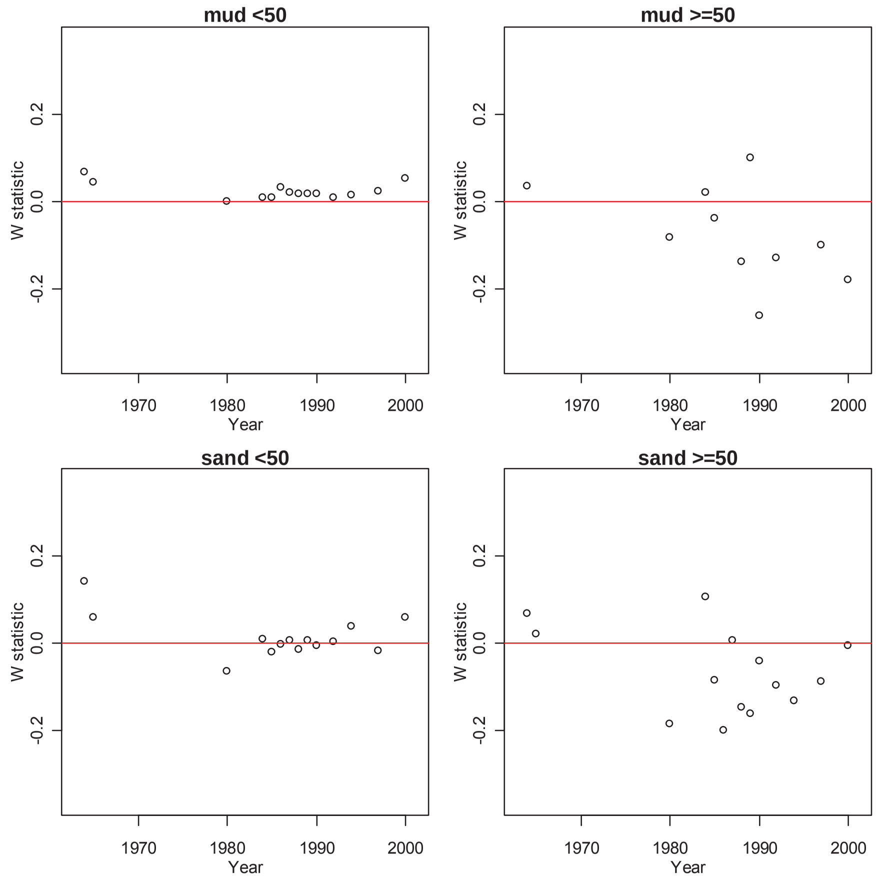


Figure 45: Plots of the W statistic for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

4.2.4. Abundance and biomass size spectra

Abundance and biomass size spectra were calculated for the combined set of the same 15 species, and changes in the spectra were examined over time for each stratum.

The slope of the size spectra showed a negative trend for the Central Gulf (1219) (whole series and more recent years), Outer Firth of Thames (1268) and Whangaparaoa/Rangitoto (1386) (whole series), and Inner Firth of Thames (1887) and Inner Gulf (2229) (more recent years) (Figures 46 & 47 and Table 12). Over the sediment/depth strata, the mud < 50 m showed a negative trend (whole series and more recent years), while the sand < 50 m had a negative trend over the whole series (negative trend over recent years almost significant).

The intercept of the size spectra appeared to be less sensitive than the slope, and significant trends were identified only for the Outer Firth of Thames (1268) (negative over whole series) and sediment/depth stratum mud < 50 m (negative over whole series and more recent years) (Figures 48 & 49 and Table 12).

From the analysis of the biomass size spectra, both positive and negative trends in curvature were identified over time. The Outer Firth of Thames (1268) (whole series), Whangaparaoa/Rangitoto (1386), Coromandel (9292) (more recent years), and Inner Firth of Thames (1887) (whole series and more recent years) had negative trends while Waiheke/Tamaki (1449) and Inner Gulf (2229) (whole series) had positive trends. For the sediment/depth strata, the mud < 50 m showed a negative trend (whole series and more recent years) (Figures 50 & 51 and Table 13).

For the biomass spectra x vertex, all the significant trends identified were negative. The Waiheke/Tamaki (1449) and Central Gulf (1219) strata had negative trends over the whole time series, while the Inner Firth of Thames (1887) had a negative trend over both the whole series and more recent years. For the sediment/depth strata, the mud <50 m showed a negative trend over more recent years while sand >= 50 m showed a negative trend over the whole series (Figure 52 & 53 and Table 13).

For the biomass spectra y vertex, all the significant trends identified were positive. The Central Gulf (1219) had a positive trend over more recent years, while the Outer Firth of Thames (1286) had a positive trend over the whole series. For the sediment/depth strata, mud < 50 m and sand < 50 m showed positive trends over the whole series while mud >= 50 m showed a positive trend over more recent years (Figure 54 & 55 and Table 13).

Table 12: Slope and P value for linear regressions for each survey stratum of Size Spectra slope (left) and intercept (right) on year. Regression parameters are presented for the whole series (solid lines in figures) and 1984 onwards (dashed lines) (RV *Kaharoa* data) for data averaged across a survey strata for each year (upper table) and sediment/depth strata (lower table). Slopes significantly different from zero are in bold.

		Size spectra slope				Size spectra intercept			
		All		1984 –2000		All		1984 –2000	
Strata	Name	slope	P	slope	P	slope	P	slope	P
1149	Waiheke/Tamaki	-0.0022	0.096	-0.0040	0.248	-0.0678	0.266	-0.1927	0.223
1219	Central Gulf	**-0.0029**	**0.015**	**-0.0054**	**0.023**	-0.0996	0.051	-0.1346	0.202
1268	Outer Thames	**-0.0022**	**0.006**	-0.0018	0.337	**-0.0623**	**0.001**	-0.0263	0.422
1284	Kawau/Whangaparaoa	0.0026	0.158	-0.0003	0.929	0.1576	0.167	-0.1142	0.579
1386	Whangaparaoa /Rangitoto	**-0.0030**	**0.033**	-0.0019	0.445	-0.0650	0.381	-0.0921	0.544
1449	Bream/Pakiri	-0.0034	0.097	-0.0057	0.151	-0.1431	0.079	-0.2248	0.162
1518	Deep shelf	0.0022	0.508	0.0022	0.508	0.1520	0.201	0.1520	0.201
1887	Inner Thames	-0.0016	0.093	**-0.0050**	**0.029**	-0.0522	0.067	-0.0806	0.260
2229	Inner Gulf	0.0001	0.876	**-0.0039**	**0.023**	0.0734	0.120	-0.1212	0.078
4492	Outer Gulf	-0.0001	0.886	0.0025	0.320	-0.0256	0.520	0.1134	0.221
9292	Coromandel	0.0016	0.164	0.0015	0.560	0.1219	0.104	0.1389	0.380
mud <50 m		**-0.0024**	**0.000**	**-0.0030**	**0.020**	**-0.0659**	**0.006**	**-0.1689**	**0.001**
mud >=50 m		0.0000	0.978	0.0017	0.644	-0.0320	0.679	0.2145	0.193
sand <50 m		**-0.0015**	**0.001**	-0.0018	0.053	0.0028	0.845	-0.0347	0.257
sand >=50 m		0.0010	0.392	0.0022	0.416	0.0275	0.585	0.1662	0.128

Table 13: Slope and P value for linear regressions for each survey stratum of Biomass spectra curvature (left), x vertex (middle) and y vertex (right) on year. Regression parameters are presented for the whole series (solid lines in figures) and 1984 onwards (dashed lines) (RV *Kaharoa* data) for data averaged across a survey strata for each year (upper table) and sediment/depth strata (lower table). Slopes significantly different from zero are in bold.

		Biomass spectra curvature				Biomass spectra x vertex				Biomass spectra y vertex			
		All		1984 –2000		All		1984 –2000		All		1984 –2000	
Strata	Name	slope	P	slope	P	slope	P	slope	P	slope	P	slope	P
1149	Waiheke/Tamaki	-0.0036	0.211	-0.0075	0.257	**-0.0209**	**0.014**	-0.0138	0.454	0.0301	0.188	-0.0116	0.805
1219	Central Gulf	-0.0036	0.429	-0.0029	0.767	**-0.0364**	**0.013**	-0.0241	0.318	0.0478	0.196	**0.1665**	**0.021**
1268	Outer Thames	**-0.0070**	**0.041**	-0.0005	0.950	-0.0114	0.118	-0.0118	0.527	**0.0426**	**0.026**	0.0462	0.334
1284	Kawau/Whangaparaoa	0.0060	0.168	-0.0013	0.873	0.0050	0.738	-0.0003	0.991	0.0425	0.347	-0.1183	0.088
1386	Whangaparaoa /Rangitoto	0.0086	0.365	**-0.0268**	**0.028**	0.0050	0.708	0.0068	0.803	0.0728	0.103	0.0287	0.683
1449	Bream/Pakiri	**0.0184**	**0.031**	0.0250	0.147	-0.0376	0.059	-0.0363	0.360	-0.0066	0.854	0.0469	0.542
1518	Deep shelf	0.0151	0.198	0.0151	0.198	0.0297	0.487	0.0297	0.487	0.0362	0.589	0.0362	0.589
1887	Inner Thames	**-0.0120**	**0.005**	**-0.0211**	**0.049**	**-0.0259**	**0.012**	**-0.0568**	**0.021**	0.0506	0.054	0.1215	0.092
2229	Inner Gulf	**0.0153**	**0.036**	-0.0143	0.070	-0.0059	0.701	-0.0552	0.131	0.0607	0.053	0.0727	0.344
4492	Outer Gulf	0.0004	0.935	0.0144	0.240	-0.0249	0.474	-0.0784	0.390	-0.0152	0.615	-0.0076	0.922
9292	Coromandel	-0.0035	0.573	**-0.0352**	**0.025**	0.0036	0.666	0.0339	0.141	0.0647	0.050	0.1079	0.249
mud <50 m		**-0.0073**	**0.014**	**-0.0185**	**0.004**	-0.0126	0.134	**-0.0517**	**0.007**	**0.0565**	**0.002**	0.0004	0.988
mud >=50 m		-0.0007	0.955	0.0249	0.285	-0.0076	0.804	-0.0361	0.593	0.0093	0.756	**0.1202**	**0.025**
sand <50 m		-0.0035	0.149	-0.0039	0.493	-0.0144	0.084	-0.0112	0.502	**0.0804**	**0.005**	0.0544	0.323
sand >=50 m		-0.0080	0.195	-0.0156	0.330	**-0.0414**	**0.003**	-0.0111	0.668	-0.0037	0.914	0.1122	0.164

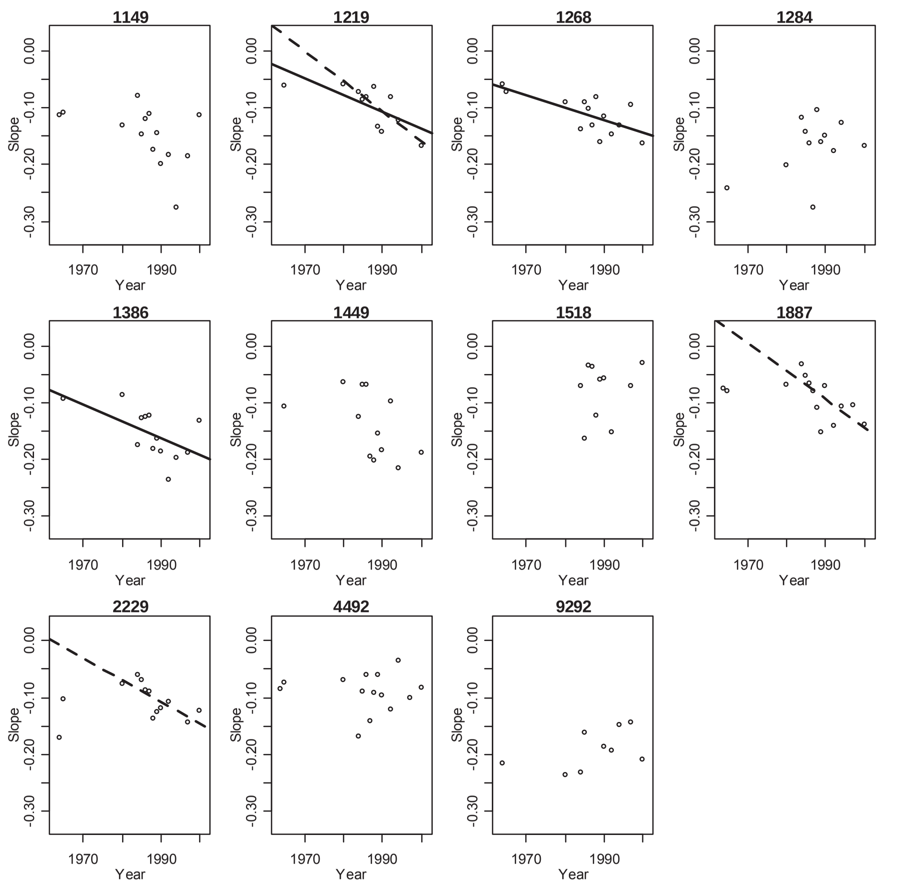


Figure 46: Plots of the Size spectra slope for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

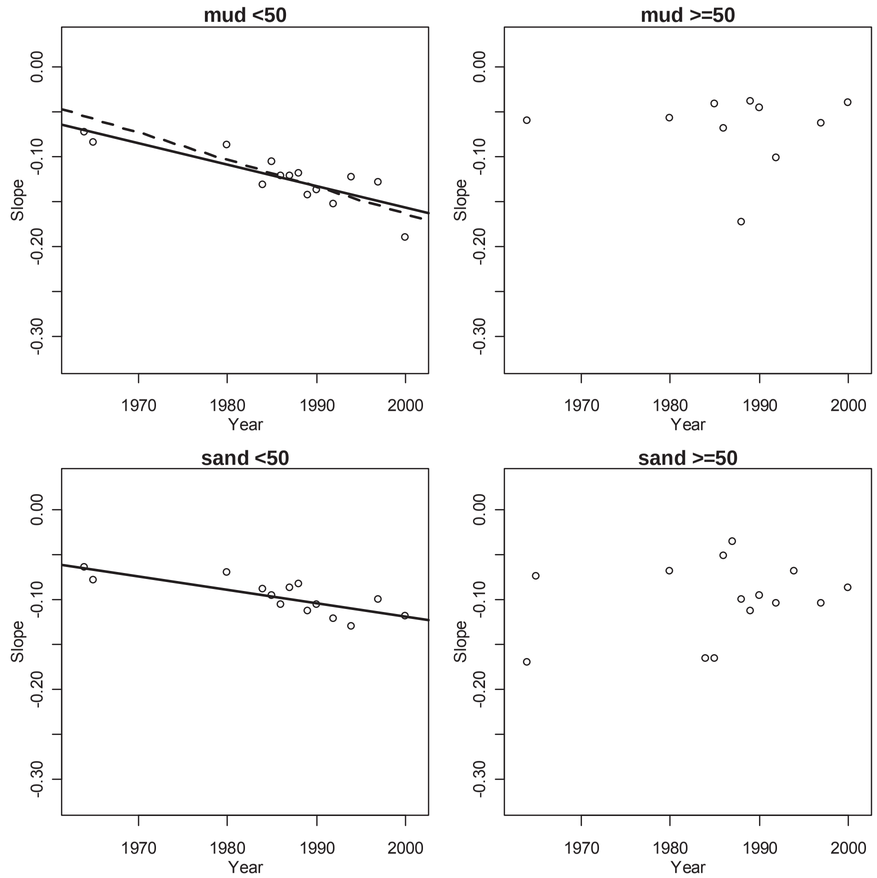


Figure 47: Plots of the Size spectra slope for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

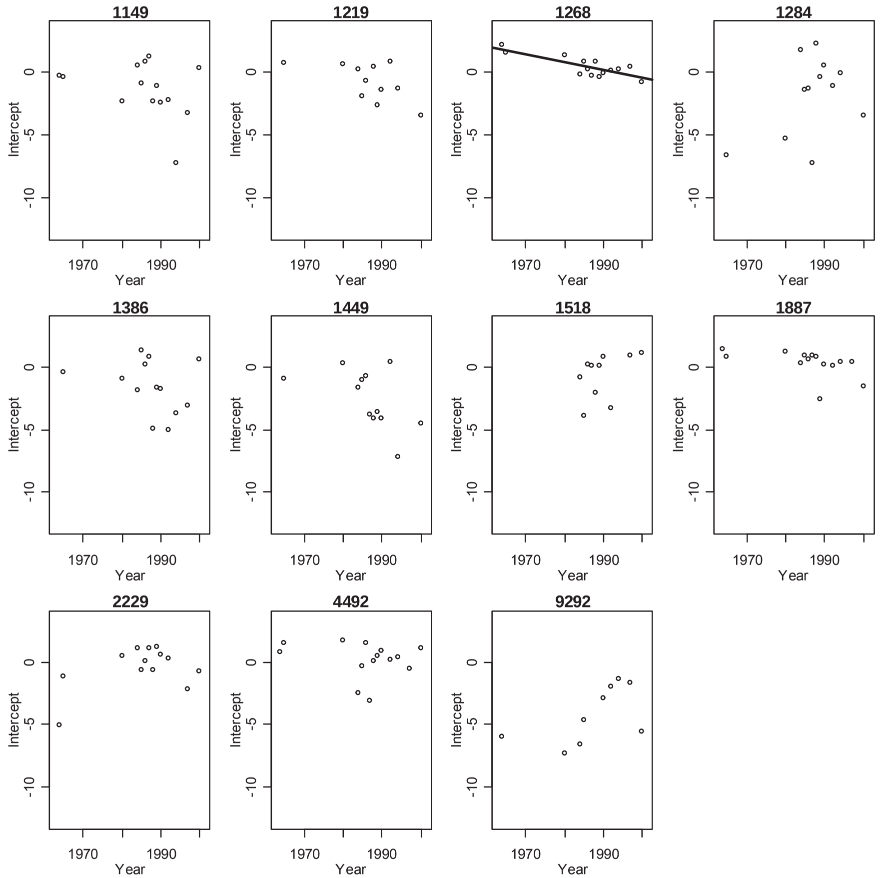


Figure 48: Plots of the Size spectra intercept for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

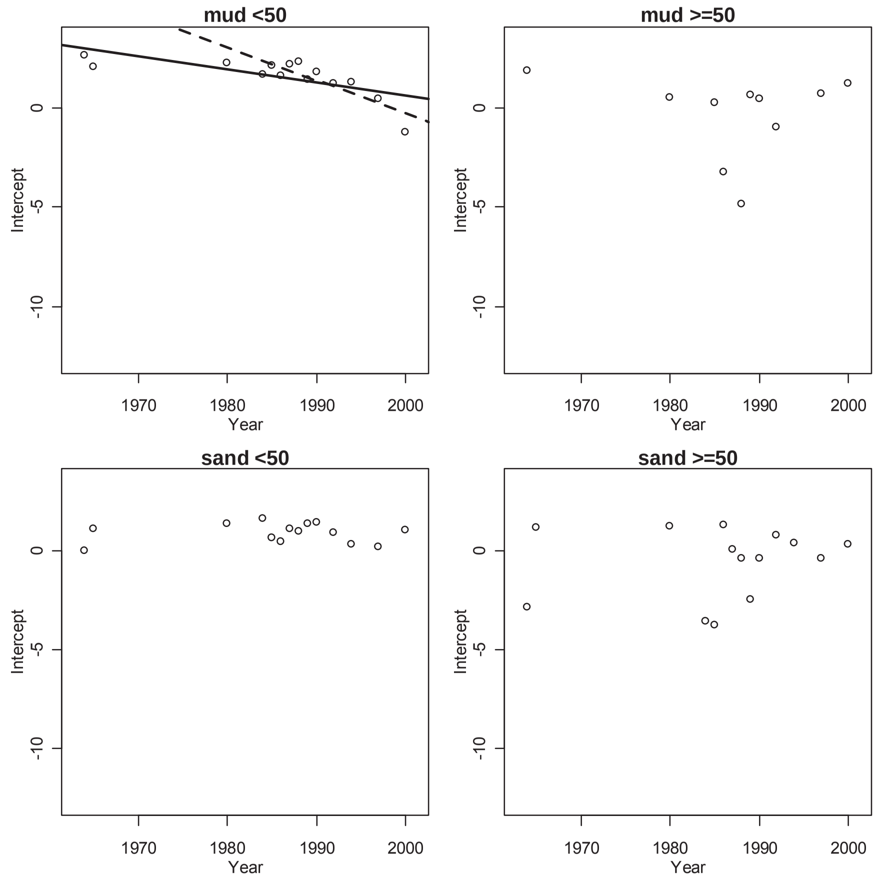


Figure 49: Plots of the Size spectra intercept for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

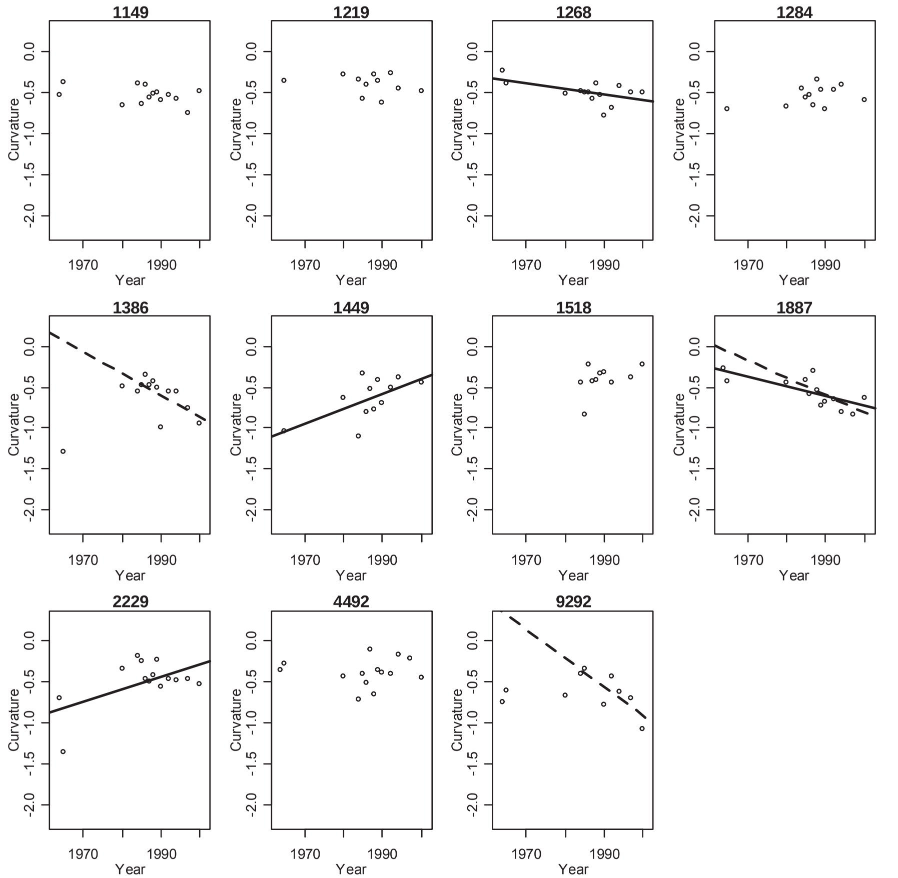


Figure 50: Plots of the Biomass spectra curvature for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

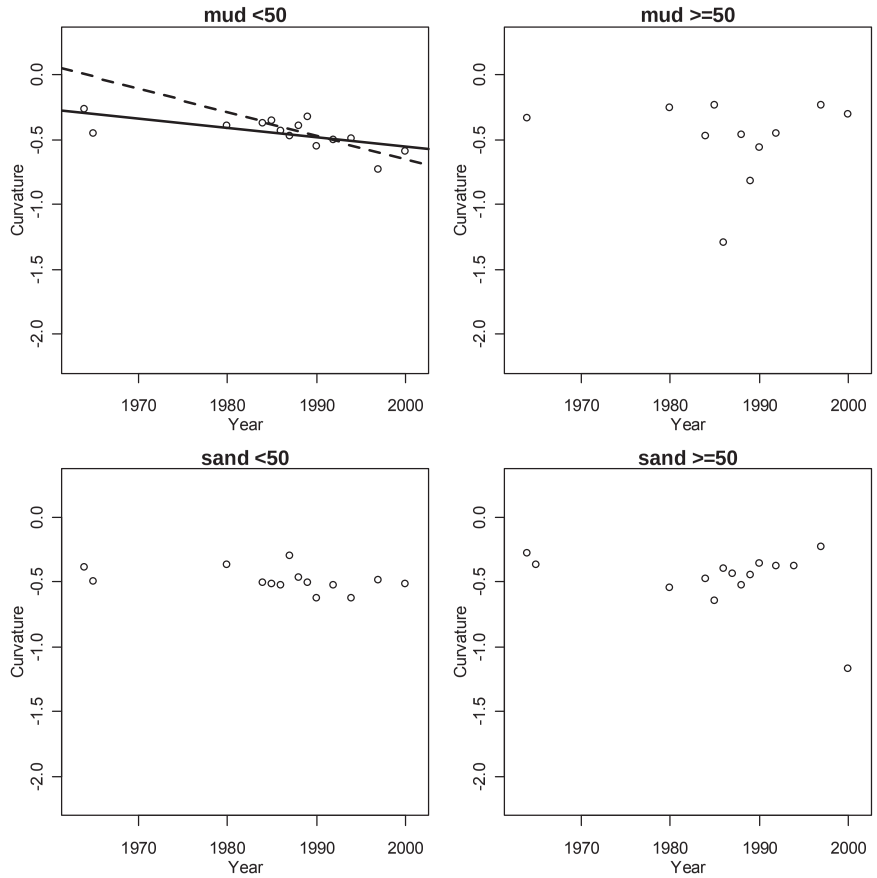


Figure 51: Plots of the Biomass spectra curvature for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

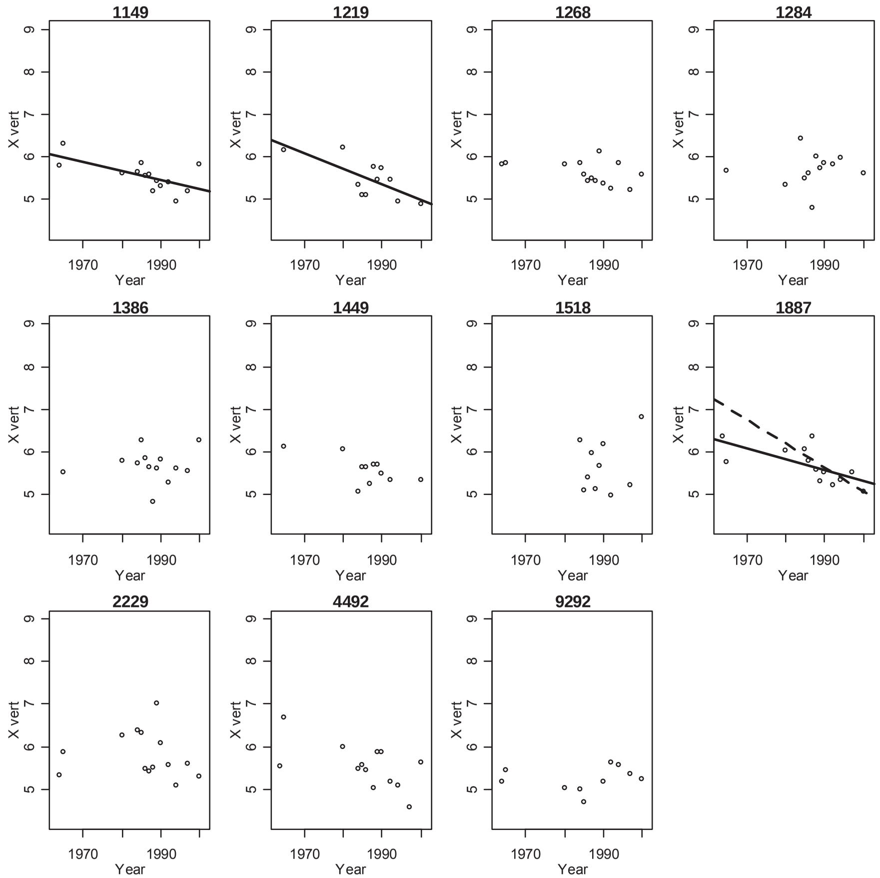


Figure 52: Plots of the Biomass spectra x vertex for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

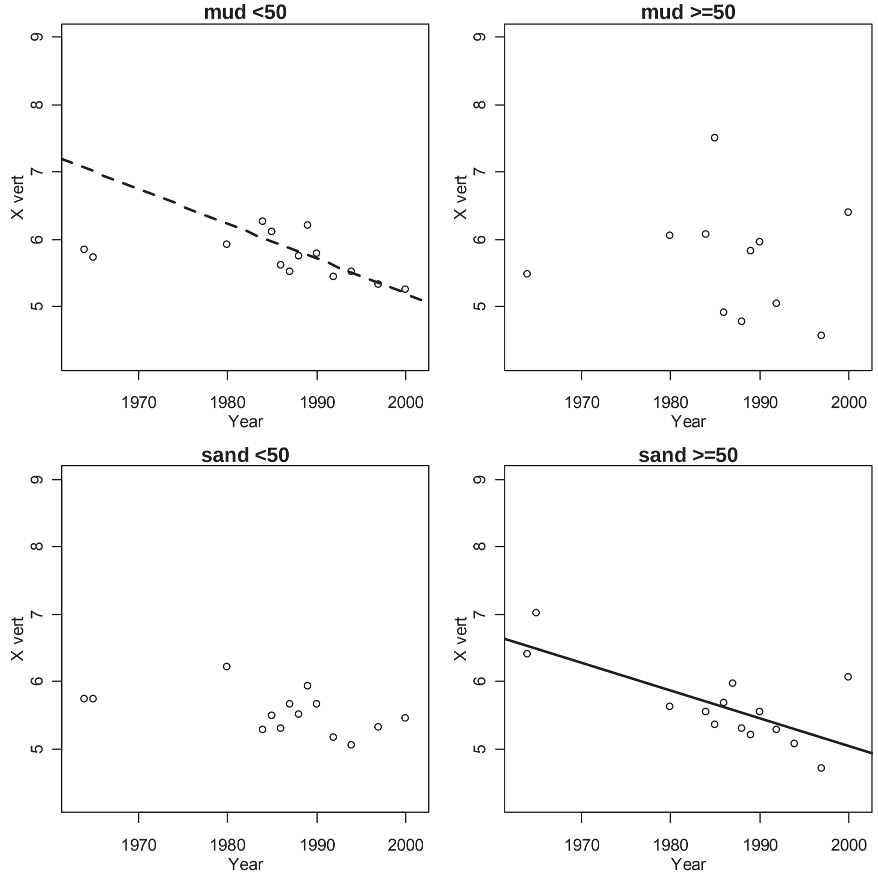


Figure 53: Plots of the Biomass spectra x vertex for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

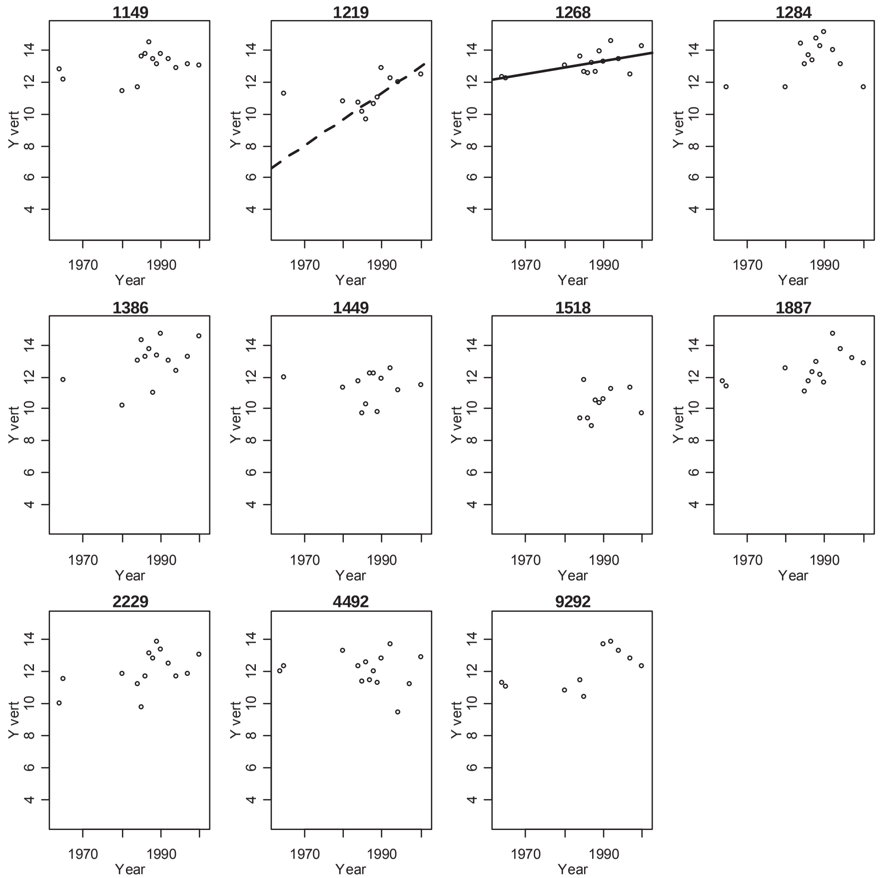


Figure 54: Plots of the Biomass spectra y vertex for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

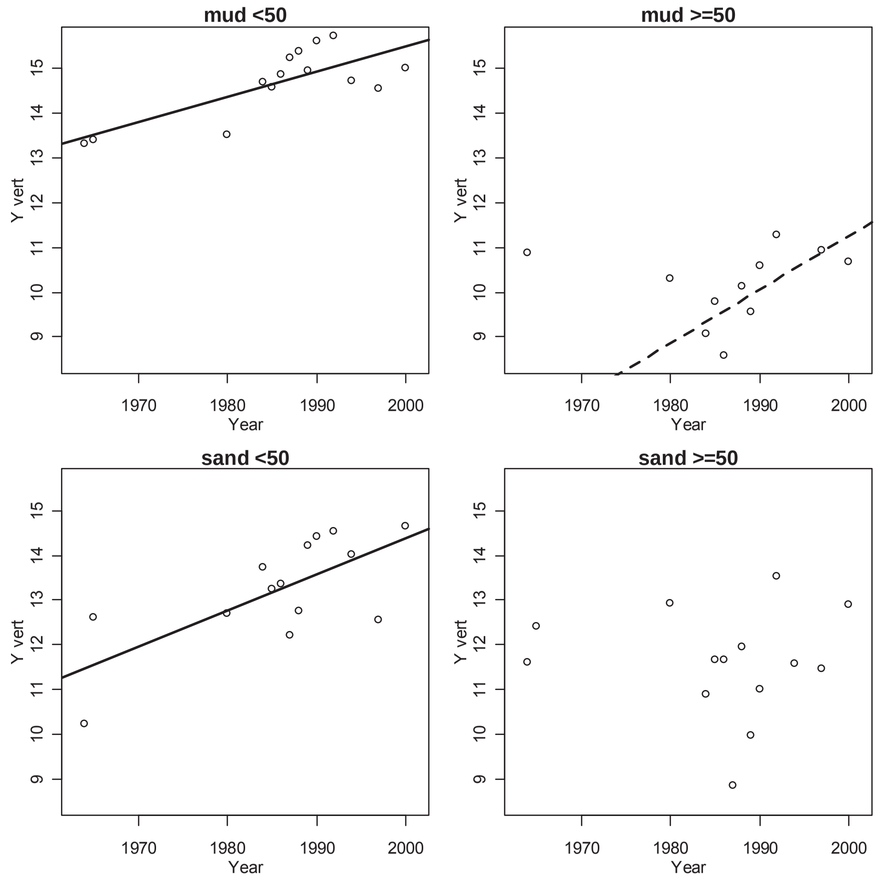


Figure 55: Plots of the Biomass spectra y vertex for each sediment/depth stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. The dashed line (where shown) represents a significant linear fit through the data from 1984 onwards (RV *Kaharoa*).

4.2.5. Diversity spectra

Diversity spectra have not been widely used in previous investigations, but where they have been applied, changes over time have been examined using similar approaches to size spectra (i.e. changes in slope and intercept of linear fit) (Rice & Gislason 1996). Preliminary examination of the diversity size spectra for the measured species within the Hauraki Gulf data set (Figures 56 & 57) suggests that fitting a linear relationship to the data above a standard length may not be the most appropriate approach (not all the spectra decline over the larger sizes, and where they do the size at which the decline starts varies between strata).

Therefore an alternative approach has been considered, comparing the relative cumulative diversity, in a similar way to that proposed for trophic spectra (Sosa-Lopez et al. 2005). The diversity spectra have been compared using the same Kolmogerov-Smirnov approach as the trophic spectra.

Some of the strata appear quite consistent over time in their diversity spectra (eg the Deep Shelf (1518) and mud >= 50m), while others are more variable (mud < 50 m and sand < 50 m) (Figures 58 & 59). MDS plots using P values from the pairwise KS tests as measures of similarity are shown in Figures 60 & 61. As with the trophic spectra, although some years stand out as appearing different from the rest, there is no evidence of a general shift in the diversity spectra over time.

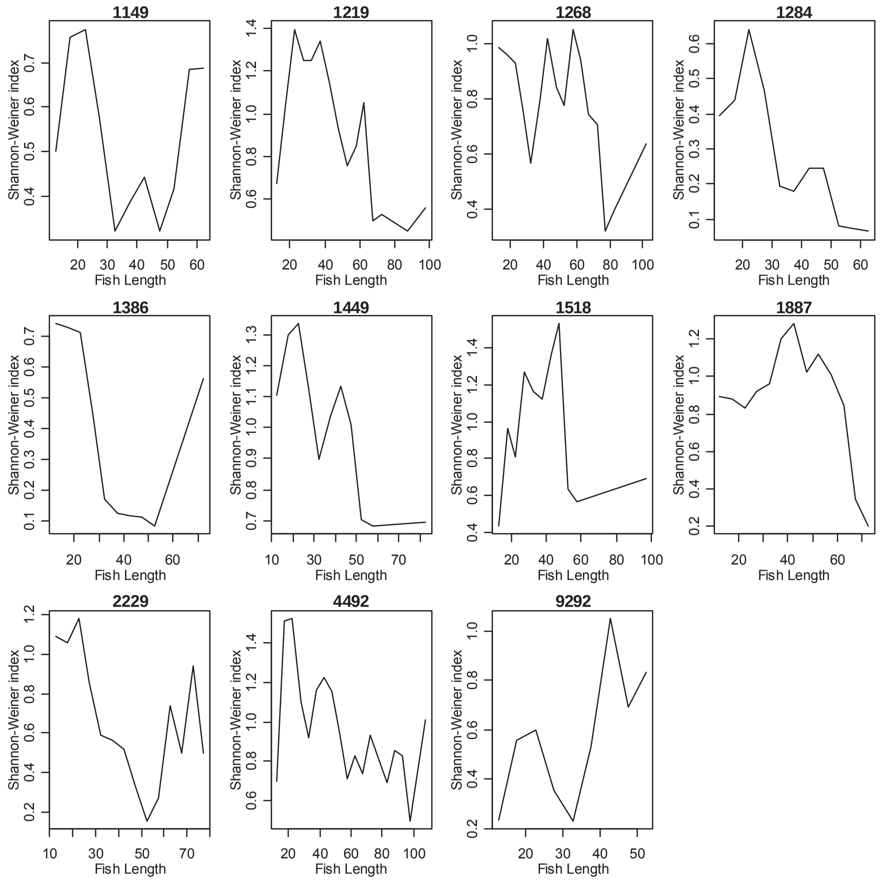


Figure 56: Plot of diversity (Shannon-Weiner index) size spectra for survey stratum (all years).

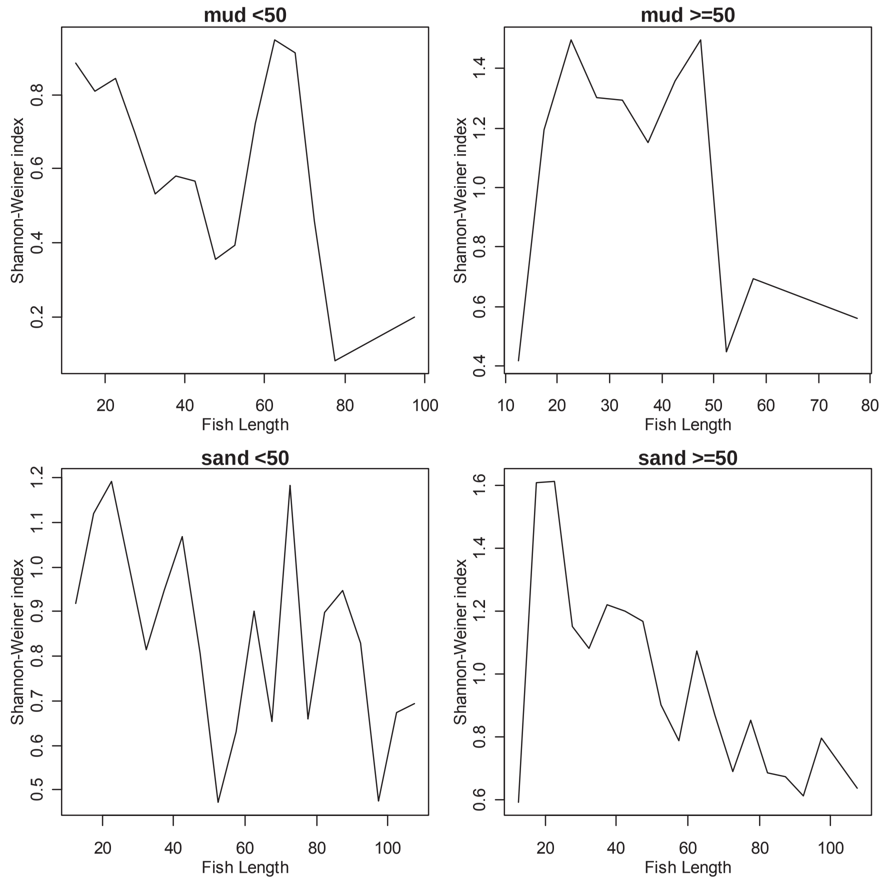


Figure 57: Plot of diversity (Shannon-Weiner index) size spectra for sediment/depth stratum (all years).

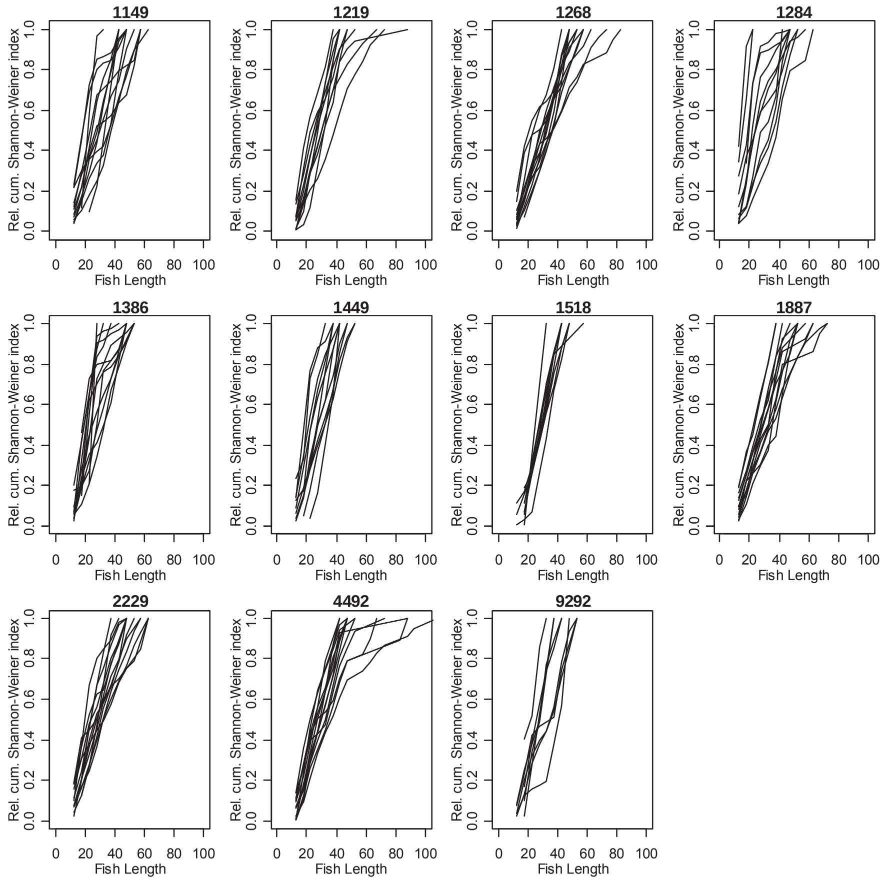


Figure 58: Plots of cumulative diversity spectra for each survey stratum.

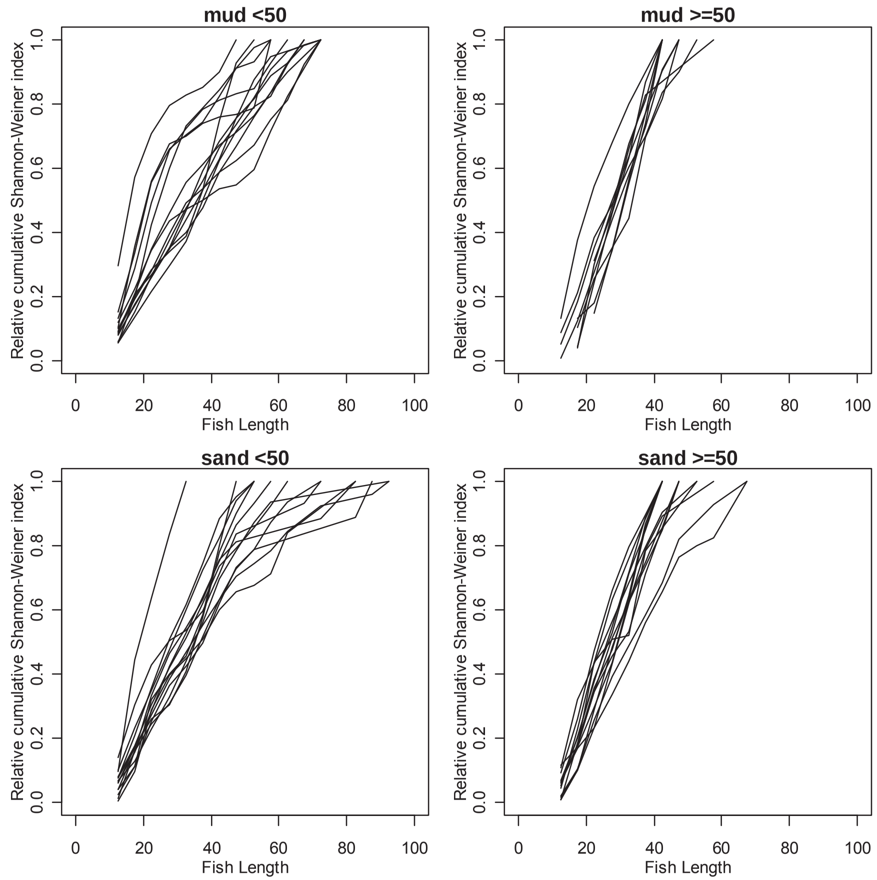


Figure 59: Plots of cumulative diversity spectra for each sediment/depth stratum.

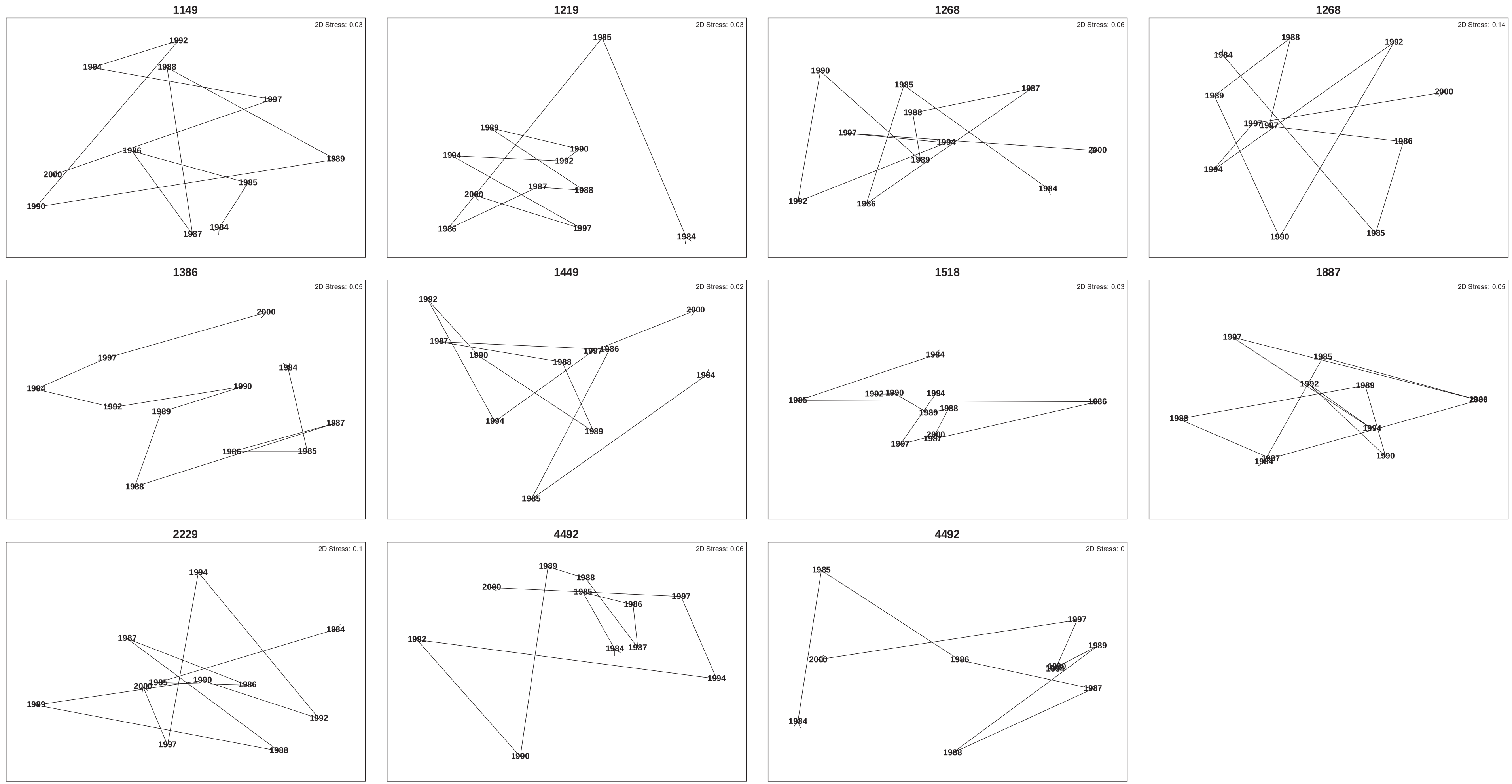


Figure 60: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of diversity spectra over time for each survey stratum.

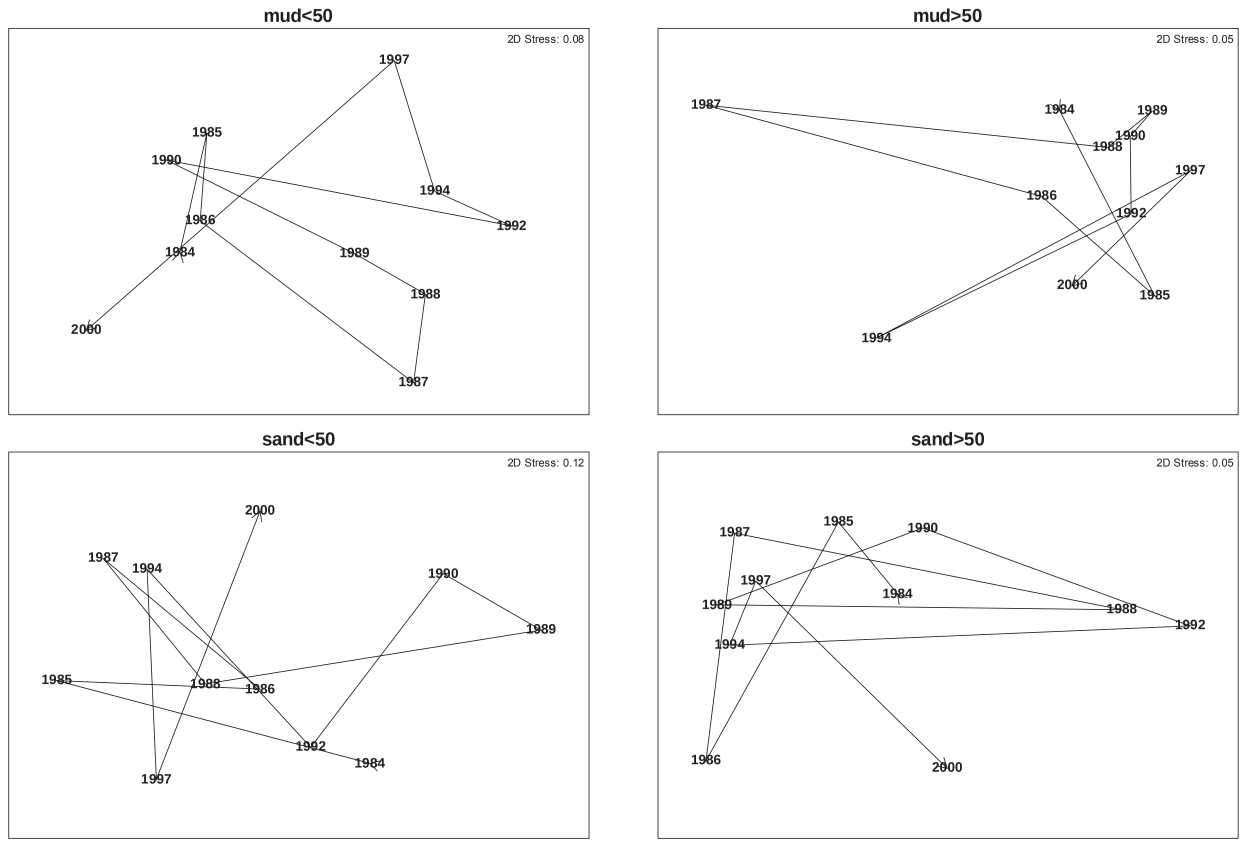


Figure 61: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of diversity spectra over time for each of the sediment/depth stratum.

4.3. Effort patterns

Trends in the cumulative area fished (as extracted from the BEN200601 database, based on TCEPR data) as a proportion of the stratum area for survey strata and the larger sediment/depth areas are shown in Figure 62. It can be seen that minimal data were available in the early 1990s, as the vessels active in this area were not required to use the TCEPR system, and recorded effort and landings to larger statistical areas rather than on an individual tow basis, recording start and end positions. Effort data are available before the early 1990s but only at the statistical area level. These statistical areas are generally defined by landmarks, and are not related to the survey strata, sediment, or depth information. However, examination of bottom trawl effort summed over all years by statistical area (from NABIS website) confirms the pattern observed from the TCEPR data for more recent years, that effort was lowest in the inner Hauraki Gulf (inside stratum 1219), and higher outside this. Given the area of the stratum, these data are consistent with our conclusion that the fishing intensity (cumulative area fished / strata area) is highest the Central Gulf (1219), followed by Outer Gulf (4492), Bream Bay/Pakiri (1449), Deep Shelf (1518) and Coromandel (9292), with other strata having very low levels of effort. Averaged over the period from 1995 (by which time most of the fleet were considered to be using TCEPR) to 2005, the ratios of cumulative area fished:strata area were 0.87, 0.58, 0.55, 0.38, and 0.15 for the Central Gulf, followed by Outer Gulf, Bream Bay/Pakiri, Deep Shelf, and Coromandel respectively.

For the larger sediment/depth area, the most intensively fished area appeared to be the sand >=50 m (average ratio 1995 to 2005 of 0.52), with the mud >= 50 m and sand < 50 m having a very similar fishing intensity (0.43), and the mud < 50 m being the least intensively fished (0.31).

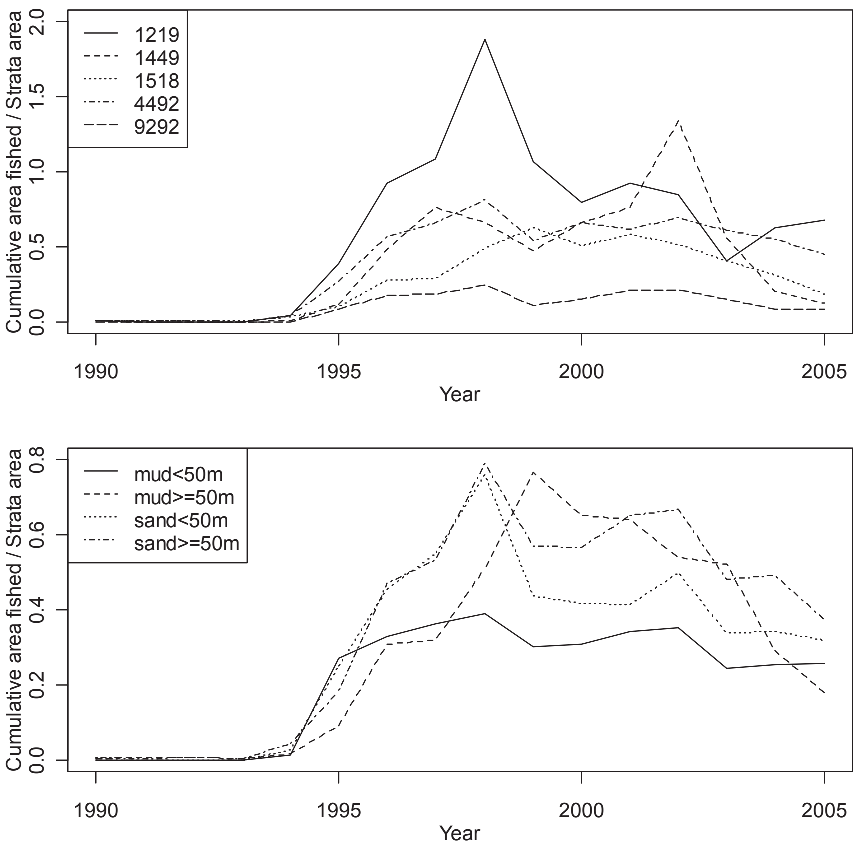


Figure 62: Plots of Cumulative area fished/Total strata area as estimated from data extracted from BEN200601 database for Hauraki Gulf survey strata (upper plot) and larger sediment/depth strata (lower plot). Survey strata not shown in the upper plot had minimal effort recorded (<2% of strata area in any year).

Table 14: Slope of linear relationships of parameters against year (RV *Kaharoa* series) for each survey strata and larger sediment/depth areas. To aid visualisation, significant relationships are in coloured font, with positive trends over time in green and negative trends over time in red. PT – proportion threatened; PLR – proportion with low or very low resilience; N1 – Hill's N1; N2 – Hill's N2; S – Species richness; d – Margarlef's d; J – Pielou's evenness; H – Shannon-Weiner diversity; Dist – average taxonomic distinctiveness; v Dist – variation in taxonomic distinctiveness; Pisc – Pisciverous:Total catch ratio; Dem – Demersal:Total catch ratio; TL – average trophic level; Med – median length; L95 – L95 length; PL – proportion of large fish; W – W statistic; SS – size spectra slope; SI – size spectra intercept; Curv – biomass spectra curvature; Xvert – biomass spectra x vertex; Yvert – biomass spectra y vertex.

		Life history based					Diversity based								Size based								
Strata	Name	PT	PLR	Pisc	Dem	TL	N1	N2	S	d	J	H	Dist	v Dist	Med	L95	PL	W	SS	SI	Curv	Xvert	Yvert
1149	Waiheke/Tamaki	0.006	0.003	0.016	0.004	0.006	0.086	0.061	-0.105	-0.011	0.010	0.029	0.027	-0.775	-0.193	-0.326	-0.007	**0.007**	-0.004	-0.193	-0.008	-0.014	-0.012
1219	Central Gulf	-0.005	**-0.021**	0.007	-0.005	-0.010	-0.084	-0.048	0.561	-0.008	-0.018	-0.027	-0.055	5.302	-0.259	**-0.676**	**-0.013**	0.003	**-0.005**	-0.135	-0.003	-0.024	**0.167**
1268	Outer Thames	0.001	0.001	-0.002	0.011	0.000	0.003	-0.004	0.305	0.050	-0.002	0.002	0.253	-2.934	-0.214	-0.162	-0.009	0.001	-0.002	-0.026	-0.001	-0.012	0.046
1284	Kawau/Whangaparaoa	0.006	0.006	0.004	0.001	0.002	0.029	0.021	-0.225	-0.036	0.007	0.016	0.043	-5.208	0.026	-0.204	-0.001	**0.020**	0.000	-0.114	-0.001	0.000	-0.118
1386	Whangaparaoa /Rangitoto	0.004	0.005	-0.006	0.000	-0.002	0.064	0.030	-0.062	-0.003	0.008	0.025	0.373	1.597	0.107	-0.266	0.001	-0.002	-0.002	-0.092	**-0.027**	0.007	0.029
1449	Bream/Pakiri	-0.005	-0.011	-0.007	0.023	-0.012	-0.018	-0.043	0.359	0.047	-0.012	-0.012	0.149	7.737	-0.317	-0.581	-0.012	0.012	-0.006	-0.225	0.025	-0.036	0.047
1518	Deep shelf	0.018	0.013	0.003	0.000	0.003	-0.120	-0.041	0.260	-0.038	-0.011	-0.022	0.084	0.249	-0.169	0.337	-0.003	**-0.020**	0.002	0.152	0.015	0.030	0.036
1887	Inner Thames	0.002	-0.003	-0.006	0.006	-0.002	-0.032	-0.027	0.394	0.022	**-0.014**	-0.009	-0.175	8.020	-0.361	-0.736	**-0.016**	0.003	**-0.005**	-0.081	**-0.021**	**-0.057**	0.122
2229	Inner Gulf	0.000	-0.007	0.002	-0.006	-0.004	0.023	0.008	0.436	0.069	-0.003	0.009	0.388	7.127	-0.308	-0.606	-0.017	0.002	**-0.004**	-0.121	-0.014	-0.055	0.073
4492	Outer Gulf	-0.001	0.008	0.001	**-0.015**	0.000	-0.096	-0.117	0.914	0.112	**-0.013**	-0.020	-0.216	1.119	-0.215	-0.454	-0.006	0.001	0.003	0.113	0.014	-0.078	-0.008
9292	Coromandel	0.002	0.005	0.008	0.002	0.001	0.020	0.007	0.559	0.110	0.001	0.014	0.021	15.931	0.100	0.201	0.006	0.001	0.002	0.139	**-0.035**	0.034	0.108
mud <50		0.006	0.005	0.007	0.003	0.003	**0.081**	**0.039**	0.355	0.056	**0.012**	**0.041**	0.179	-0.468	-0.198	**-0.540**	-0.012	0.002	**-0.003**	**-0.169**	**-0.019**	**-0.052**	0.000
mud >=50		0.021	0.006	0.004	0.017	0.007	0.053	-0.063	0.602	0.064	-0.011	0.009	0.115	-7.600	-0.275	-0.095	-0.013	0.000	0.002	0.215	0.025	-0.036	**0.120**
sand <50		-0.001	-0.006	-0.006	0.008	-0.005	-0.008	-0.012	0.875	0.130	-0.002	0.004	-0.037	-3.623	-0.205	-0.251	-0.006	0.003	-0.002	-0.035	-0.004	-0.011	0.054
sand >=50		-0.008	0.003	-0.016	-0.008	-0.008	0.061	-0.018	**1.335**	0.229	-0.004	0.016	-0.122	-5.283	-0.160	-0.276	-0.003	-0.001	0.002	0.166	-0.016	-0.011	0.112

4.4. Comparison across indicators and relationship with fishing effort

The slopes of the linear fits for each parameter for each strata are provided in Table 14, with significant trends over time colour coded to aid visualisation. There are relatively few significant trends identified, and it is difficult therefore to pick out consistent patterns. In Table 14 the indicators have been split into life history based (including species based and trophodynamic indicators), diversity based (all species based), and size-based indicators. The size-based indicators showed the greatest number of significant trends, but there were few consistent patterns. The Central Gulf (1219) shows significant negative trends in L95, the proportion of large fish, and the slope of the size spectra. Over the larger sediment/depth areas, the mud < 50 m area shows significant negative trends in L95 and the slope and intercept of the size spectra. This area also shows significant positive trends for the diversity measures N1, N2, J, and H. Neither the trophic or diversity spectra showed any consistent patterns of trends across strata.

To examine the trends in indicators in relation to fishing effort, the correlation (Spearman rank) between the strata slopes for each parameter (Table 14) and the average (1995–2005) ratio of area fished:total strata area (taken as a measure of overall fishing intensity) was examined for both survey strata and the larger sediment/depth areas (Table 15). Statistical significance was examined through comparing observed correlation with distribution of correlations calculated for each parameter with 1000 resampled effort data sets. Correlations were considered significant if the correlation coefficient was outside the 2.5 to 97.5 % quantiles of the correlations on the resampled effort data. At the survey strata level there were significant negative correlations between fishing intensity and the diversity measures N1, N2, Pielou's evenness, and the Shannon-Weiner index, but a positive correlation with species richness. Over the larger areas, significant positive correlations were identified between fishing intensity and species richness, Margalef's d parameter, the size spectra slope and the biomass spectra x vertex, and negative correlations were identified with average taxonomic distinctiveness and the proportion pisciverous.

Table 15: Summary of Spearman rank correlation tests between slopes of trends in indicator parameters over time and average (1995 to 2005) ratio of area fished:strata area. Correlation coefficient provided for rank correlations over survey strata and larger areas. Significant correlations (on basis of effort bootstraps) are in bold red (negative) and green (positive) font.

	Survey strata	Larger areas
PT	-0.537	-0.632
PLR	-0.057	-0.316
N1	**-0.724**	-0.316
N2	**-0.838**	-0.632
S	**0.634**	**0.949**
d	0.144	**0.949**
J	**-0.649**	-0.632
H	**-0.783**	-0.316
Dist	-0.461	**-0.949**
V Dist	0.258	-0.632
Pisc	0.070	**-0.949**
Dem	-0.306	-0.316
TL	-0.291	-0.632
Med	-0.203	0.316
L95	-0.109	0.316
PL	-0.005	0.632
W	-0.093	-0.632
SS	0.068	**0.949**
SI	0.059	0.632
Curv	0.472	0.316
Xvert	-0.154	**0.949**
Yvert	0.292	0.632

5. CHATHAM RISE MIDDLE DEPTHS SURVEYS

Sixteen summer (December–February) surveys have been conducted since 1992 on the Chatham Rise using RV *Tangaroa* to monitor the relative abundance of hoki and other middle depth species. Before 1992, surveys covering the same core area were conducted from *Shinkai Maru* (1983 & 1986) and *Amaltal Explorer* (1989), although these surveys are not included in the fishery-independent abundance indices due to concerns over gear and vessel effects, and have been excluded from this analysis for the same reasons, and concerns over changes in the level of taxonomic identification for some species groups in the early years (particularly rattails). The core survey area has remained constant over time, and all stations have been allocated to the strata as defined in the most recent surveys. Strata are defined on the basis of location and depth. The distribution of stations in relation to survey strata and also larger strata defined in a previous analysis of the fish communities in this area (Bull et al. 2001) is shown in Figure 63. Stratum region, depth ranges, and numbers of stations by strata and year are shown in Tables 16 & 17. Stratum names used in the data tables are derived from region and depth range and are modified from those defined on the surveys (Stevens & O'Driscoll 2007) to provide unique names for each stratum.

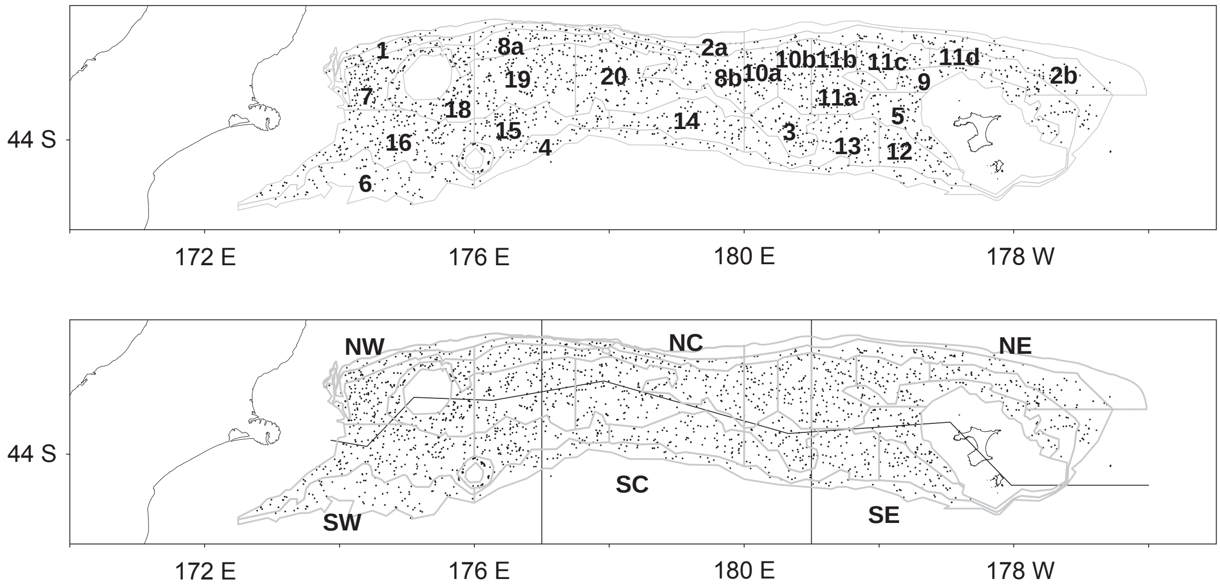


Figure 63: Survey area and stratum boundaries for Chatham Rise surveys (upper plot) and larger regions defined on basis of previous fish community analysis (Bull et al. 2001). Dots represent individual trawl stations.

From the 16 voyages, 2069 stations were extracted (where gear performance was considered suitable), listing a total of 508 species. Of these stations, 2053 were within the defined strata, and retaining only non-mesopelagic fish and squid species left 223 species for analysis. For each station, numbers measured and weight caught by species were examined. Not all species were measured on all occasions, but when a species was measured a weight was also recorded. Catch weights and numbers were standardised to a swept area of 1 km^2, using door spread data collected for each tow.

For the catch weight by station data set, all 223 fish and squid species were included. Diet, mean trophic level, and environment (i.e., demersal, pelagic, etc) for each species (or closely related species) were also recorded from the FishBase web site. IUCN Red List status and the FishBase web site Resilience measure were taken as levels of concern in terms of endangered species. Resilience is based on the minimum population doubling time (on the basis of estimates of growth rate, age at maturity and fecundity), and is split into four categories (High – less than1.4 years minimum population doubling time; Medium - 1.4–4.4 years; Low - 4.5–14 years; Very low - over 14 years). Life history characteristics, including length weight parameters, habitat, feeding type, Red List and resilience status, trophic level and taxonomy are provided by species in Appendix 1.

For the species numbers at length data set, 16 key species of fish were selected, being considered to be appropriately sampled by the gear and consistently measured. For these key species, if a station had a weight recorded but no numbers at length, then the station was excluded from the size-based analysis. Excluding stations where these key species were caught but not measured left 1527 stations for analysis. Weight at length for these species (for biomass size spectra), was estimated from length weight relationships either taken from the MFish *rdb* database, or the FishBase web site (http://filaman.ifm-geomar.de/home.htm) (Froese & Pauly 2000).

Table 16: Numbers of stations by survey stratum for each year. Numbers may not sum to station total in Appendix 1 as some stations are outside the standard strata.

			Survey year															
Stratum	Region	Depth m	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	NW Rise	600–800	3	3	2	3	2	3	3	2	2	4	4	3	3	3	4	7
2a	NC Rise	600–800	6	6	3	3	0	1	2	2	3	3	4	3	2	3	5	3
2b	NE Rise	600–800	6	5	5	7	3	4	1	2	7	5	3	3	6	7	8	13
3	Matheson	200–400	3	6	6	3	3	3	3	4	2	3	4	3	3	7	4	3
4	SC Rise	600–800	13	9	7	7	4	4	4	7	3	4	3	3	4	3	3	6
5	W Chatham	200–400	3	4	4	10	5	6	4	6	5	6	6	3	3	3	3	3
6	SW Rise	600–800	6	8	7	3	4	4	4	4	3	3	3	3	3	4	3	6
7	W Mernoo	400–600	9	6	12	11	8	7	7	10	8	9	9	6	6	13	6	7
8a	NW Reserve	400–600	7	5	5	3	2	2	4	2	3	3	4	3	3	3	4	3
8b	NE Reserve	400–600	6	9	7	4	3	5	3	5	9	5	5	4	6	7	5	3
9	N Chatham	200–400	4	3	4	3	3	4	3	6	8	7	3	6	4	4	3	3
10a	NW Matheson	400–600	4	3	2	4	2	2	1	3	4	3	2	3	5	5	2	3
10b	NC Matheson	400–600	4	4	3	2	1	4	2	1	5	6	3	3	5	3	3	4
11a	NE Matheson	400–600	1	2	3	2	2	2	1	0	6	4	3	3	7	5	5	4
11b	WW Chatham	400–600	2	5	2	1	1	0	3	0	2	2	3	3	4	3	3	3
11c	N Chatham	400–600	5	0	3	3	2	1	2	2	7	3	3	3	5	5	3	3
11d	NE Chatham	400–600	4	4	2	6	0	2	1	2	3	6	6	3	4	4	5	3
12	SW Chatham	400–600	9	6	4	7	4	5	3	6	3	3	5	4	3	4	3	3
13	Matheson	400–600	7	6	4	6	4	6	4	4	4	5	4	3	3	5	3	3
14	SE Reserve	400–600	8	6	5	6	4	5	3	2	4	3	4	3	3	4	5	3
15	SW Reserve	400–600	12	12	12	3	4	4	5	21	5	5	4	7	4	3	5	2
16	S Mernoo	400–600	25	24	20	7	8	8	9	9	9	18	14	6	7	3	6	6
17	Veryan	200–400	3	3	3	3	3	3	3	3	3	3	3	4	3	3	3	3
18	Mernoo	200–400	9	18	23	4	5	4	5	7	8	11	10	8	3	5	5	7
19	W Reserve	200–400	16	24	10	3	8	4	4	16	4	7	4	13	6	8	6	8
20	E Reserve	200–400	8	13	7	9	4	10	7	8	9	8	5	9	5	8	5	10
Total			184	194	165	123	89	103	91	135	132	139	123	117	110	125	110	129

Table 17: Numbers of stations by larger region strata for each year.

	Survey year															
Stratum	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
N_C	31	40	26	16	13	21	11	17	27	21	16	21	23	23	17	20
N_E	26	20	22	32	16	18	13	16	40	31	26	26	33	28	29	30
N_W	27	30	34	21	15	13	18	30	16	25	26	20	14	24	17	25
S_C	27	27	22	20	15	14	16	23	17	15	17	14	15	23	19	13
S_E	15	18	11	15	7	13	10	14	7	10	11	7	5	9	5	15
S_W	58	59	50	19	23	24	23	35	25	37	27	29	20	18	23	26
Total	184	194	165	123	89	103	91	135	132	139	123	117	110	125	110	129

The various indicators are calculated and analysed at the strata level, each tow within a stratum being weighted according to its catch. Data examined at the individual tow level tended to be very variable, and giving each tow equal weighting was not considered appropriate given the variability in catches (even within strata). Levels of sampling vary between strata (particularly before 2000), and only the 12 most frequently sampled survey strata are examined at the strata level.

5.1. Analysis of catch weight by station

5.1.1. Species-based indicators

5.1.1.1. Indicator / endangered species

Using the IUCN Red List, indicator species were taken as those listed within the threatened categories of the as vulnerable, near threatened or of less concern. Species included a range of sharks and rays and some chimaeras. The combined weight of these species was calculated for each tow, and examined as a proportion of total catch at the stratum level.

At the survey strata level, significant positive trends in the proportion of threatened species were identified for N and W Chatham 200–400 (9 and 5), NE Reserve 400–600 (8b) and W and S Mernoo 400–600 (7 and 16) (Figures 65 & 66 and Table 18). Over the larger areas, positive trends were identified for all three northern areas, and for the SW area.

Table 18: Slope and P value for linear regressions for each survey stratum of ratios of proportion threatened (left) and proportion with low or very low resilience (right) on year. Proportions were arcsin square root transformed. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		Proportion threatened		Prop. L/VL resilience	
Stratum	Name	slope	P	slope	P
2b	NE Rise 600–800	0.0072	0.327	0.0109	0.101
4	SC Rise 600–800	0.0045	0.325	**0.0303**	**0.001**
5	W Chatham 200–400	**0.0159**	**0.000**	0.0132	0.195
6	SW Rise 600–800	0.0010	0.852	**0.0334**	**0.001**
7	W Mernoo 400–600	**0.0106**	**0.045**	**0.0222**	**0.029**
8b	NE Reserve 400–600	**0.0109**	**0.002**	**0.0253**	**0.000**
9	N Chatham 200–400	**0.0173**	**0.012**	–0.0003	0.981
15	SW Reserve 400–600	0.0062	0.104	**0.0171**	**0.031**
16	S Mernoo 400–600	**0.0062**	**0.034**	**0.0191**	**0.002**
18	Mernoo 200–400	0.0067	0.186	0.0055	0.373
19	W Reserve 200–400	0.0012	0.692	0.0021	0.601
20	E Reserve 200–400	0.0023	0.322	0.0064	0.136
NW		**0.0083**	**0.024**	**0.0168**	**0.005**
NC		**0.0088**	**0.002**	**0.0220**	**0.000**
NE		**0.0087**	**0.003**	0.0018	0.695
SW		**0.0105**	**0.018**	**0.0175**	**0.004**
SC		0.0014	0.540	0.0063	0.269
SE		0.0025	0.486	**0.0195**	**0.010**

Using low or very low resilience as a measure, the Chatham Rise data series also showed positive trends in the proportion of catch over time (Figures 67 & 68 and Table 18). Positive trends were identified for SC and SW Rise 600–800 (4 and 6), NE and SW Reserve 400–600 (8b and 15) and W and S Mernoo 400–600 (7 and 16), and over the larger areas, for the NW, NC, SW and SE areas.

5.1.1.2. Species distribution index

The overall (across all surveys) ranked percentage of stations occupied by each species (Figure 64) declined exponentially from a maximum of 96% (hoki), with 115 species recorded at less than 1% of the stations. In examining the distribution of species, analysis was limited to species recorded at more than 10 % of stations (47 species). Below this cut off point, annual as well as average estimates of distribution over the entire survey history are probably underestimated (Fisher & Frank 2004).

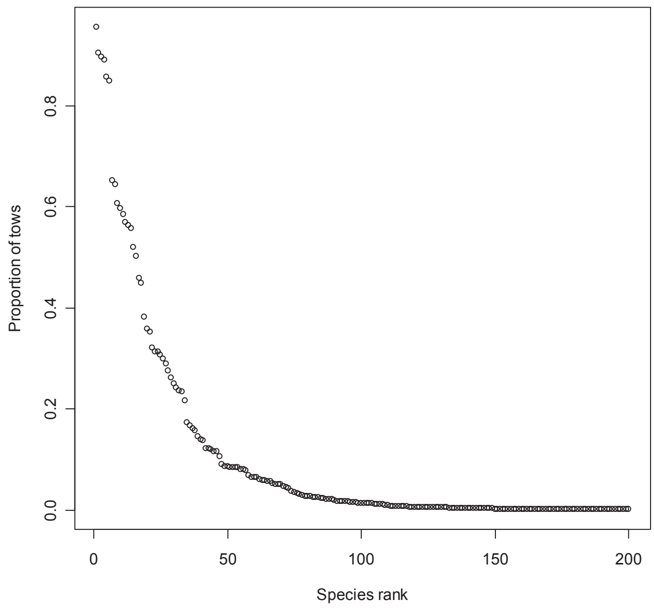


Figure 64: Ranked percentage of tows occupied by each species.

Plots of the percentage of the survey area over which 90% of the abundance was distributed over time for the main species are shown in Figures 69 & 70. Of this reduced species data set, for the most frequently occurring species, those that showed a significant trend over time in the area over which 90% of abundance was distributed tended to have declining trends (e.g., lookdown dory, ling, pale ghost shark, hake, Oliver's rattail, stargazer), while the slightly less common species showed both positive (ghost shark, deepsea flathead, smooth skate, silver roughy, silver dory, blackspot rattail, *Todarodes filoppovae*, small banded rattail) and negative (hairy conger, rudderfish) trends.

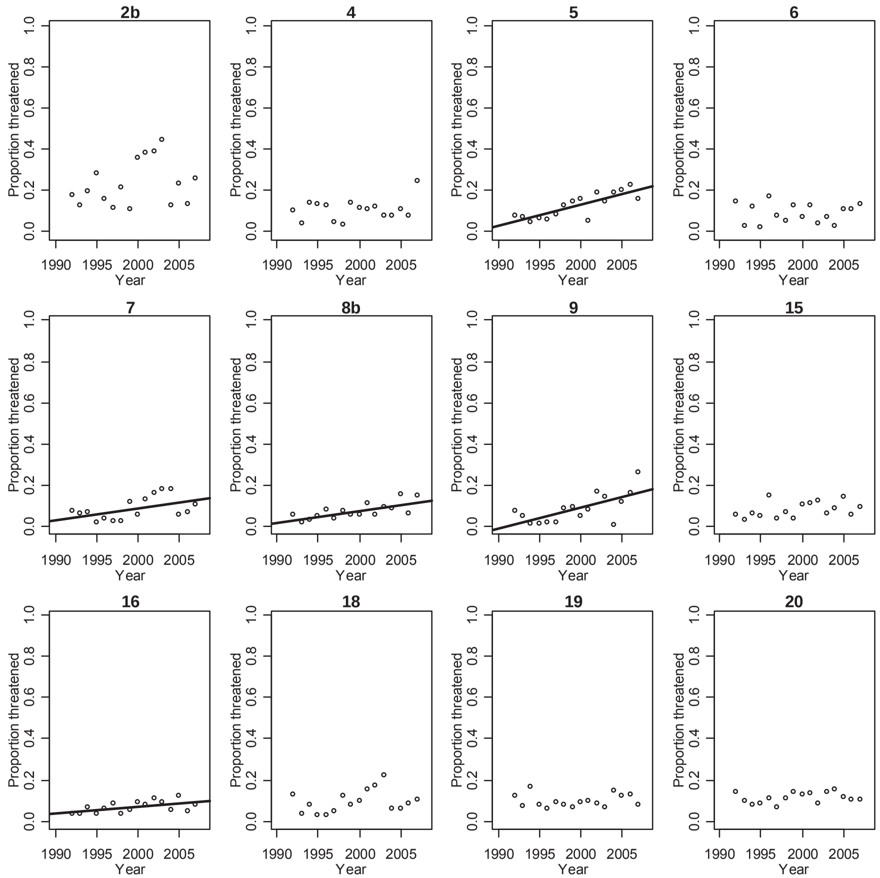


Figure 65: Plots of the proportion threatened (by weight) for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

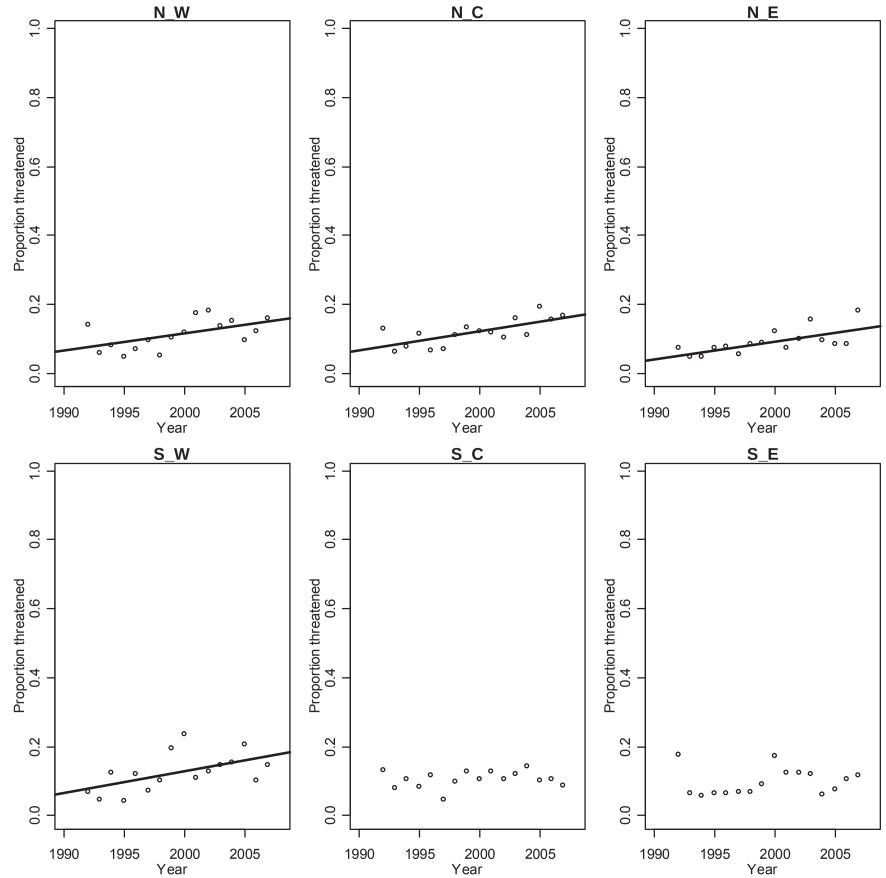


Figure 66: Plots of the proportion threatened (by weight) for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

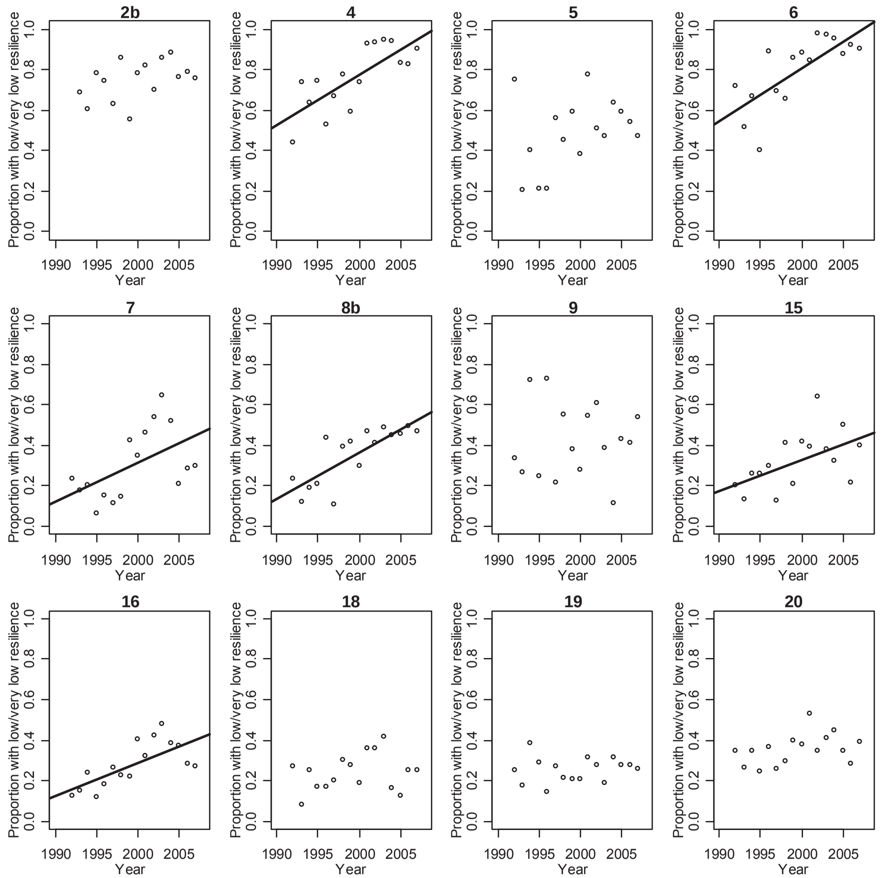


Figure 67: Plots of the proportion with low or very low resilience (by weight) for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

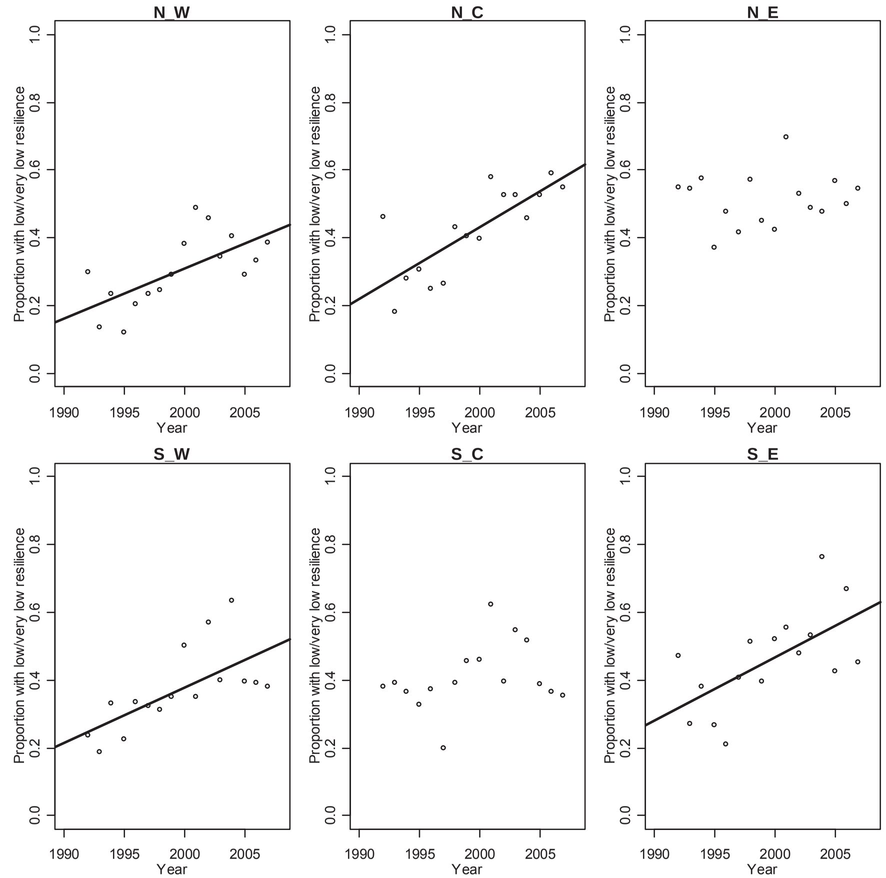


Figure 68: Plots of the proportion with low or very low resilience (by weight) for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

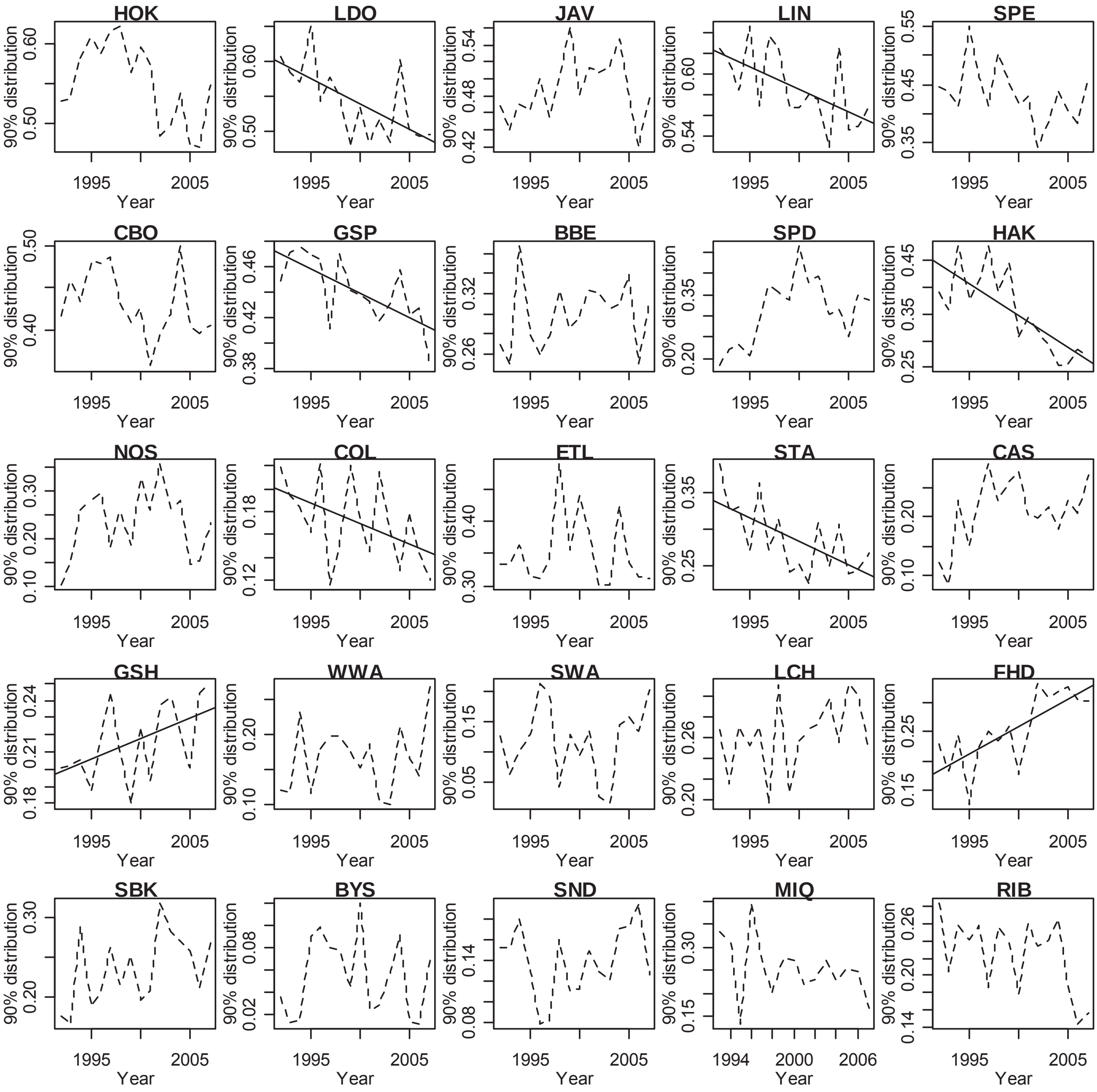


Figure 69: Plots of the percentage of the survey area over which 90% of the abundance (by weight) was distributed for the 20 most frequently caught species. Weighted averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. Key to species codes provided in Appendix 1.

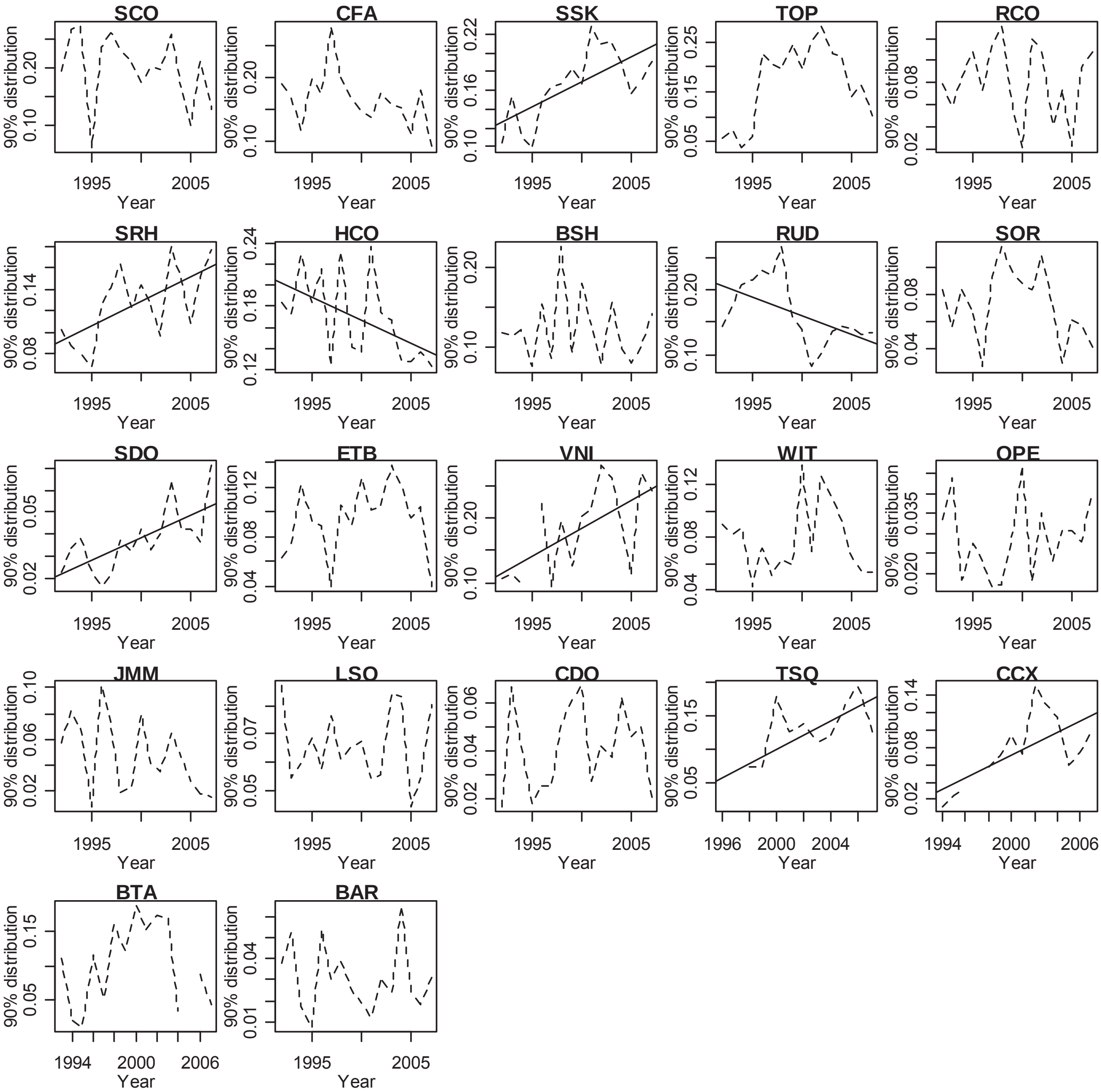


Figure 70: Plots of the percentage of the survey area over which 90% of the abundance (by weight) was distributed for the 21st to 47th most frequently caught species. Weighted averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series. Key to species codes provided in Appendix 1.

5.1.1.3. Diversity indices

As with the analysis of the Hauraki Gulf trawl series, a variety of measures of diversity were calculated on different data sets derived from the species catch weight data. These data sets included a full data set, a data set excluding pelagic species and a data set including only the key species, as used for the numbers at length data set. The indicators are plotted only for the full data set, but trends are examined for each of the sets.

Hill's N1 and N2 diversity indices showed similar patterns (Figures 71–74 and Table 19) with positive trends identified for W and S Mernoo 400–600 (7 (almost significant for N2) and 16), and NE and SW Reserve 400–600 (8b and 15), and larger regions NW, NC, SW and SE.

Species richness did not show any significant trends over either scale of area, although a positive trend for NE Reserve 400–600 (8b) was almost significant (Figures 75 & 76 and Table 19). Margarlef's d diversity parameter showed significant positive trends over time for NE Reserve 400–600 (8b) (and almost significant for W Mernoo 400–600 (7)), and for the larger NW area (Figures 77 & 78 and Table 19).

Pielou's evenness and the Shannon-Weiner diversity parameter showed similar patterns, with positive trends identified for W Chatham 200–400 (5), W and S Mernoo 400–600 (7 and 16), NE and SW Reserve 400–600, (8b and 15) and Mernoo 200–400 (18) (trends almost significant for Shannon-Weiner for 5 and 18), and for the larger NW, NC, SW, and SE areas (Figures 79–82 and Table 20).

Average Taxonomic Distinctiveness increased over time for W Mernoo 400–600 (7), but decreased for Mernoo 200–400 (18). Over the larger areas, a positive trend for the NE area was not quite significant at the 5% level (Figures 83 & 84 and Table 20). The Variation in Taxonomic Distinctiveness was more consistent, with SW Rise 600–800 (6), SW Reserve 400–600 (15), S Mernoo 400–600 (16) and the larger SW area showing significant increasing trends over time. The larger NW area showed an almost significant positive trend (Figures 85 & 86 and Table 20).

5.1.1.4. Comparison across data sets

Comparisons across data sets (full data set, pelagics excluded, key measured species only) have been made on the basis of the direction of any trend over time identified, and whether the trend was significant.

Examining the direction of trends over time, identical patterns were identified for some indicators (N1, N2, Pielou's evenness, and the Shannon-Weiner index) over the three data sets, while species richness and Margarlef's d were identical for the full and pelagics excluded data set, but showed some differences for the measured species data set. Average taxonomic distinctiveness showed some similarities between the full and pelagics excluded data sets, but the two indicators based on taxonomic distinctiveness showed far greater levels of variability between data sets than the other indicators.

Significant trends over time were identified for a number of the strata and indicators. For indicators N1, N2, Pielou's evenness, and the Shannon-Weiner index, identical patterns of significance were identified for the full and pelagics excluded data sets, with additional significant trends identified for the measured species data set. No significant trends were identified for species richness in the full data set, but a positive significant trend was identified in the pelagics excluded and measured species data sets for NE Reserve 400–600 (8b), the latter set also showing a negative trend for W Chatham 200–400 (5). For the Margarlef's d indicator, significant positive trends were identified in the full data set for stratum NE Reserve 400–600 (8b) and the larger NW area. While the trend in NE Reserve 400–600 (8b) was also significant in the other two data sets, the trend in the NW area was not, and an additional significant negative trend was identified in W Chatham 200–400 (5) for the measured species data set. Average taxonomic distinctiveness showed no consistency in significant trends between data sets, and although the variation in taxonomic distinctiveness was more consistent, it was less consistent than the other indicators.

Table 19: Slope and P value for linear regressions for each survey strata of N1 (set 1), N2 (set 2), Species Richness (set 3), and Margarlef d (set 4) on year. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		N1		N2		Species Richness		Margarlef's d	
Stratum	Name	slope	P	slope	P	slope	P	slope	P
2b	NE Rise 600–800	0.0545	0.704	0.0248	0.803	-0.0176	0.965	0.0360	0.575
4	SC Rise 600–800	-0.1193	0.365	-0.1314	0.128	-0.3500	0.226	-0.0395	0.379
5	W Chatham 200–400	0.2399	0.141	0.2043	0.096	-0.6044	0.065	-0.0589	0.135
6	SW Rise 600–800	-0.0931	0.314	-0.0736	0.188	-0.0868	0.770	-0.0026	0.956
7	W Mernoo 400–600	**0.4069**	**0.033**	0.2395	0.069	0.1147	0.613	0.0670	0.070
8b	NE Reserve 400–600	**0.4428**	**0.001**	**0.2381**	**0.001**	0.5426	0.053	**0.1175**	**0.010**
9	N Chatham 200–400	0.1760	0.315	0.1788	0.184	0.1368	0.649	0.0258	0.447
15	SW Reserve 400–600	**0.4123**	**0.003**	**0.3013**	**0.007**	-0.4912	0.128	-0.0393	0.306
16	S Mernoo 400–600	**0.4264**	**0.001**	**0.2739**	**0.004**	-0.5500	0.172	-0.0295	0.556
18	Mernoo 200–400	0.1722	0.114	0.1075	0.085	-0.5941	0.252	-0.0581	0.359
19	W Reserve 200–400	0.0446	0.658	0.0381	0.593	-0.2603	0.607	-0.0325	0.586
20	E Reserve 200–400	0.0509	0.684	0.0502	0.589	0.1029	0.758	0.0092	0.846
NW		**0.5037**	**0.016**	**0.2277**	**0.045**	0.5735	0.280	**0.1534**	**0.034**
NC		**0.5468**	**0.000**	**0.2996**	**0.000**	0.0353	0.935	0.0769	0.211
NE		0.2386	0.191	0.1995	0.105	0.3971	0.318	0.0953	0.095
SW		**0.4185**	**0.001**	**0.2415**	**0.003**	-0.0412	0.947	0.0147	0.844
SC		0.1728	0.315	0.1402	0.260	-0.3118	0.379	-0.0356	0.510
SE		**0.3438**	**0.033**	**0.2795**	**0.011**	0.1309	0.695	0.0236	0.626

Table 20: Slope and P value for linear regressions for each survey strata of Pielou's evenness (set 1), Shannon-Weiner (set 2), Av Taxonomic distinctiveness (set 3), and Var. Taxonomic distinctiveness (set 4) on year. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		Pielou's evenness		Shannon-Weiner		Av Tax dist		Var. Tax dist	
Stratum	Name	slope	P	slope	P	slope	P	slope	P
2b	NE Rise 600–800	0.0012	0.769	0.0049	0.762	0.0287	0.715	1.6300	0.502
4	SC Rise 600–800	-0.0044	0.421	-0.0204	0.342	0.0325	0.607	-0.0043	0.998
5	W Chatham 200–400	**0.0131**	**0.036**	0.0357	0.095	-0.1094	0.093	0.5678	0.532
6	SW Rise 600–800	-0.0067	0.233	-0.0240	0.262	-0.0142	0.796	**4.8909**	**0.005**
7	W Mernoo 400–600	**0.0196**	**0.024**	**0.0755**	**0.023**	**0.0953**	**0.023**	1.3723	0.250
8b	NE Reserve 400–600	**0.0201**	**0.002**	**0.0803**	**0.001**	-0.0737	0.250	0.7837	0.554
9	N Chatham 200–400	0.0047	0.465	0.0196	0.400	0.1075	0.145	1.2874	0.216
15	SW Reserve 400–600	**0.0208**	**0.002**	**0.0690**	**0.003**	0.0074	0.898	**2.4368**	**0.045**
16	S Mernoo 400–600	**0.0225**	**0.000**	**0.0771**	**0.001**	0.0506	0.094	**3.2063**	**0.033**
18	Mernoo 200–400	**0.0104**	**0.042**	0.0358	0.088	**-0.1272**	**0.031**	0.7914	0.625
19	W Reserve 200–400	0.0032	0.486	0.0116	0.497	-0.1169	0.183	-0.4416	0.743
20	E Reserve 200–400	0.0014	0.752	0.0075	0.672	0.0730	0.206	0.1996	0.861
NW		**0.0171**	**0.006**	**0.0769**	**0.006**	0.0179	0.672	1.6361	0.071
NC		**0.0155**	**0.001**	**0.0664**	**0.001**	0.0619	0.142	1.7513	0.190
NE		0.0033	0.324	0.0181	0.193	0.0564	0.063	0.9760	0.234
SW		**0.0120**	**0.001**	**0.0530**	**0.001**	0.0171	0.547	**2.0649**	**0.015**
SC		0.0060	0.191	0.0221	0.279	0.0180	0.749	0.8336	0.225
SE		**0.0111**	**0.032**	**0.0454**	**0.028**	-0.0080	0.853	0.9261	0.422

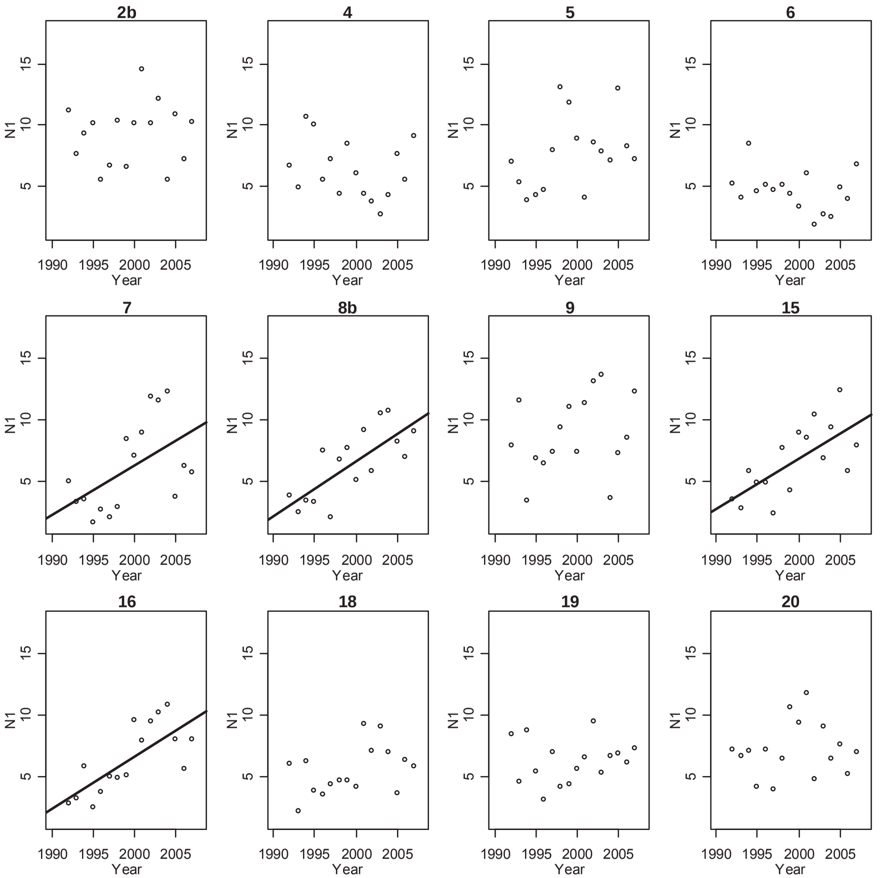


Figure 71: Plots of Hill's N1 diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

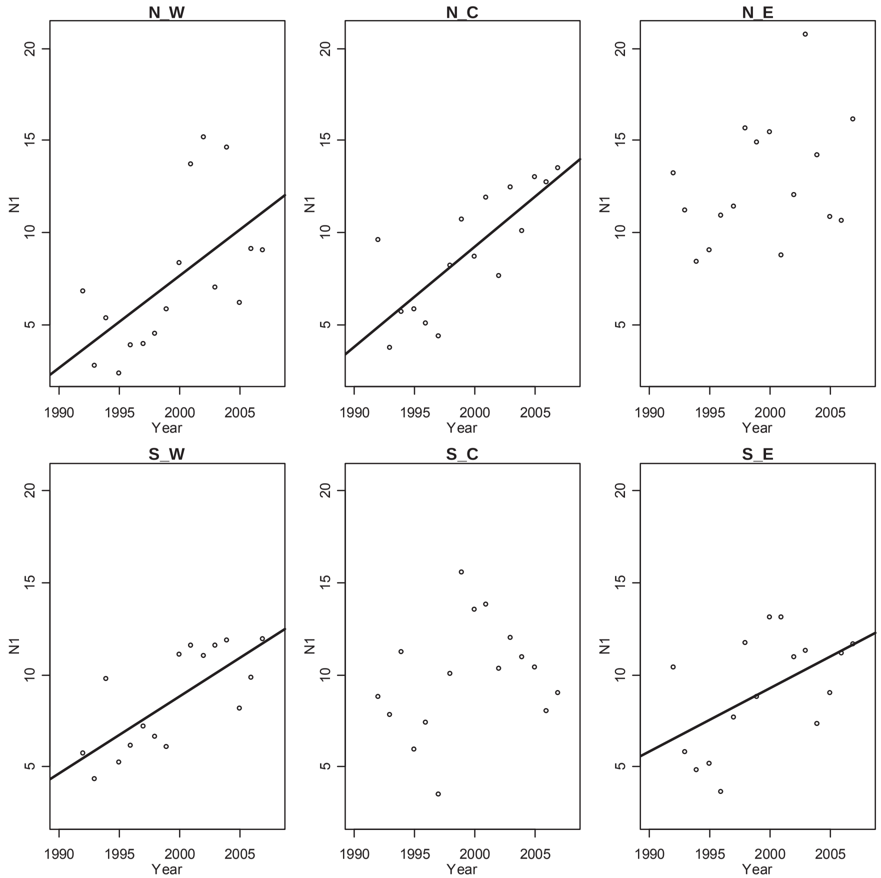


Figure 72: Plots of Hill's N1 diversity parameter for larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

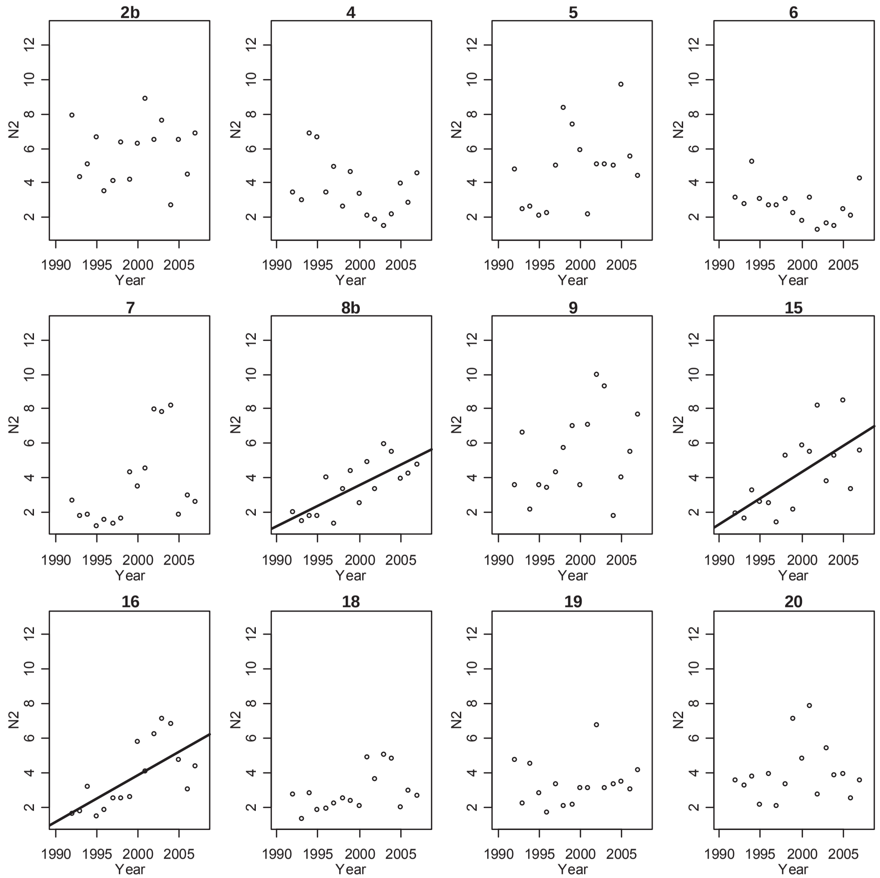


Figure 73: Plots of Hill's N2 diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

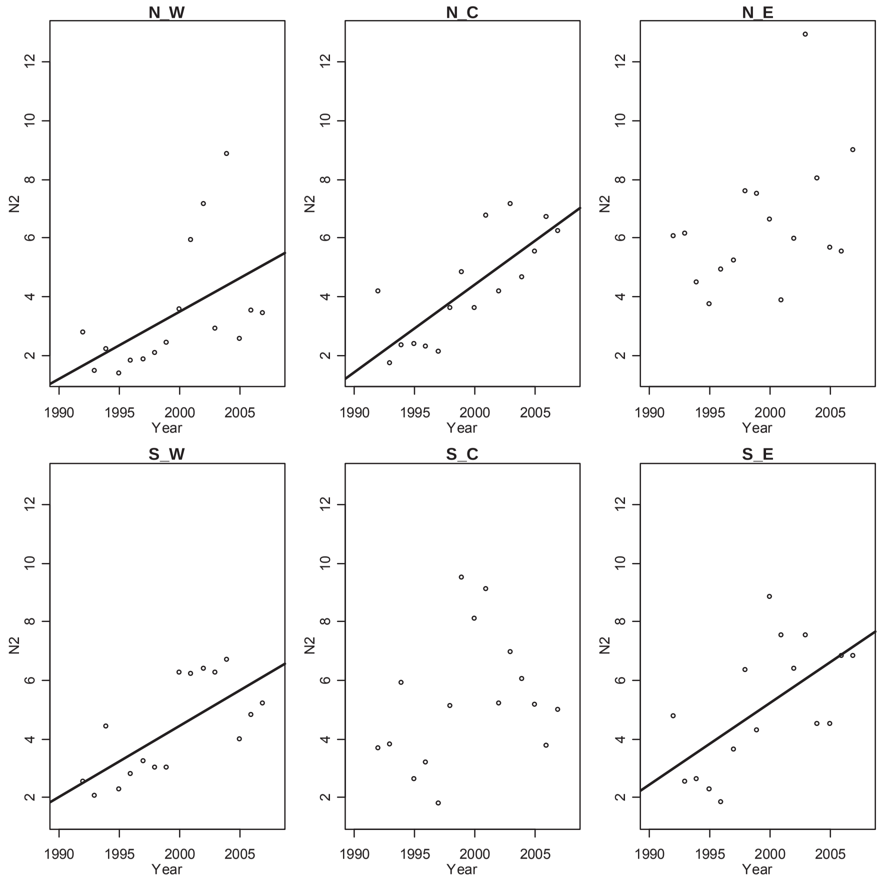


Figure 74: Plots of Hill's N2 diversity parameter for larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

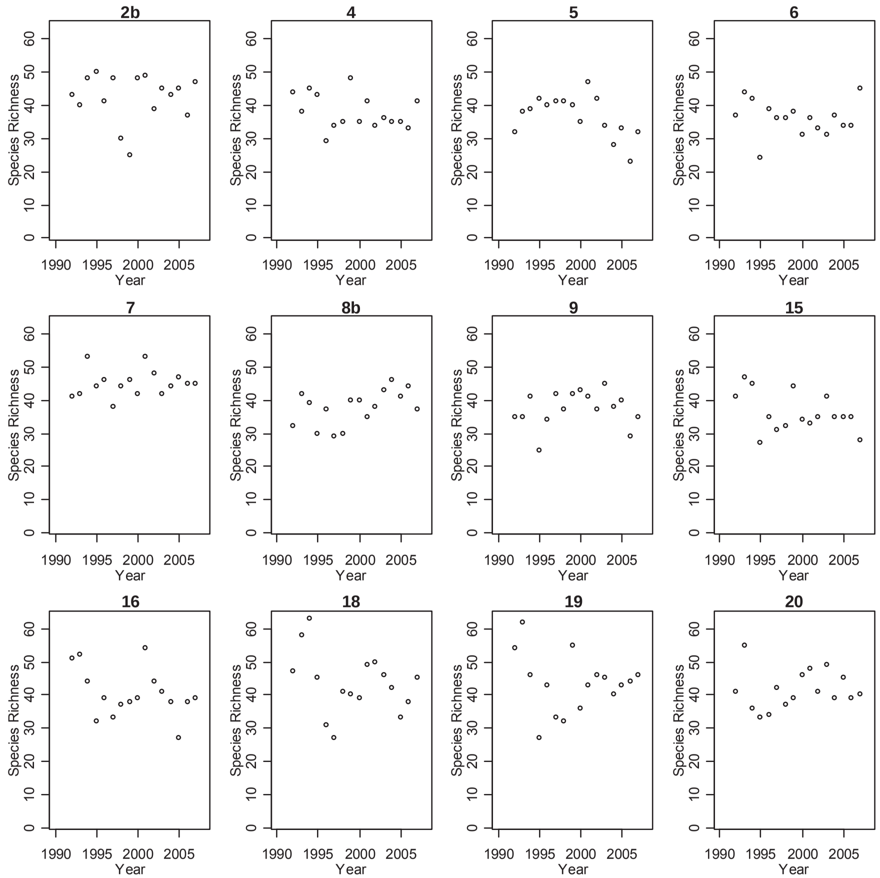


Figure 75: Plots of Species Richness for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

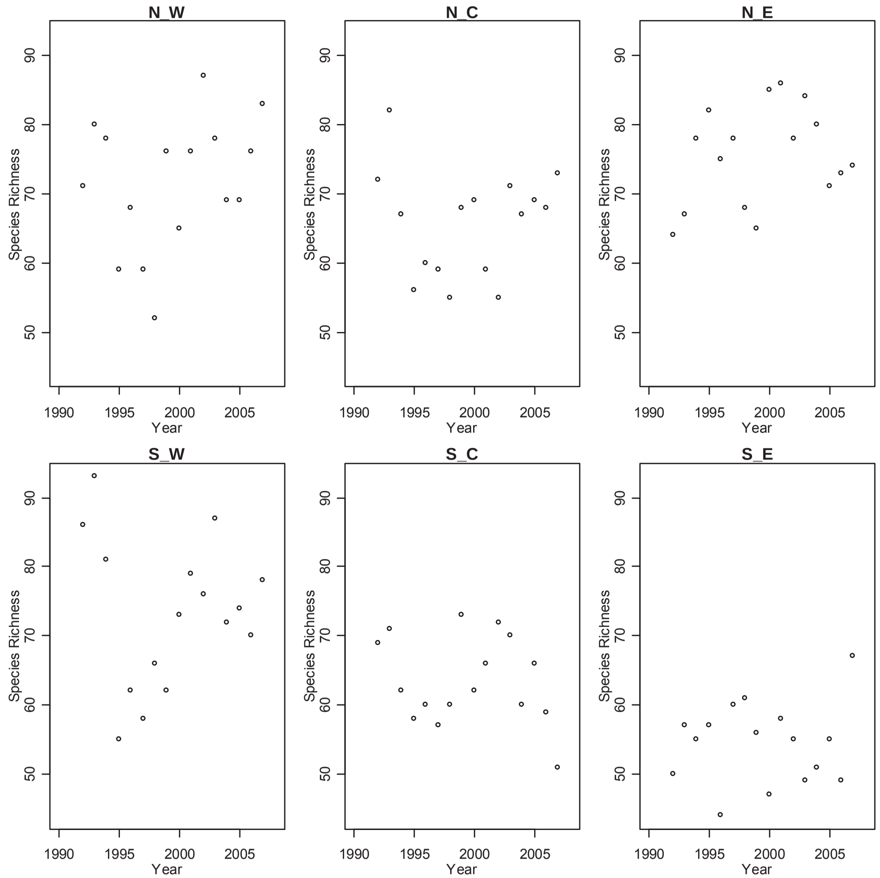


Figure 76: Plots of Species Richness for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

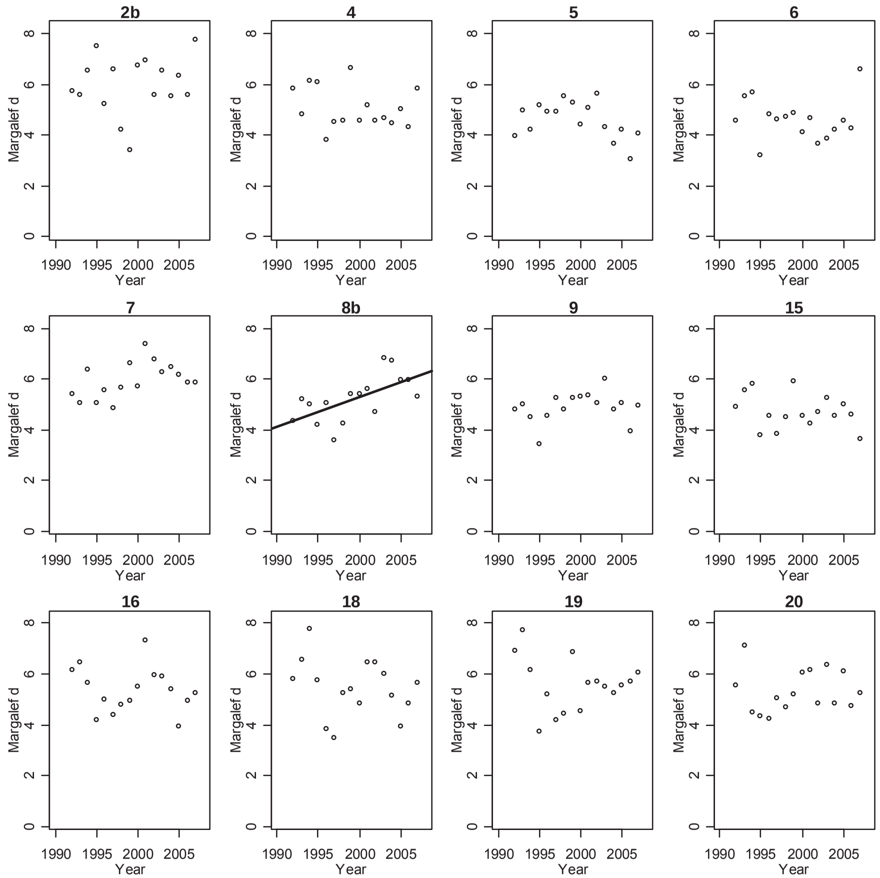


Figure 77: Plots of Margarlef's d diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

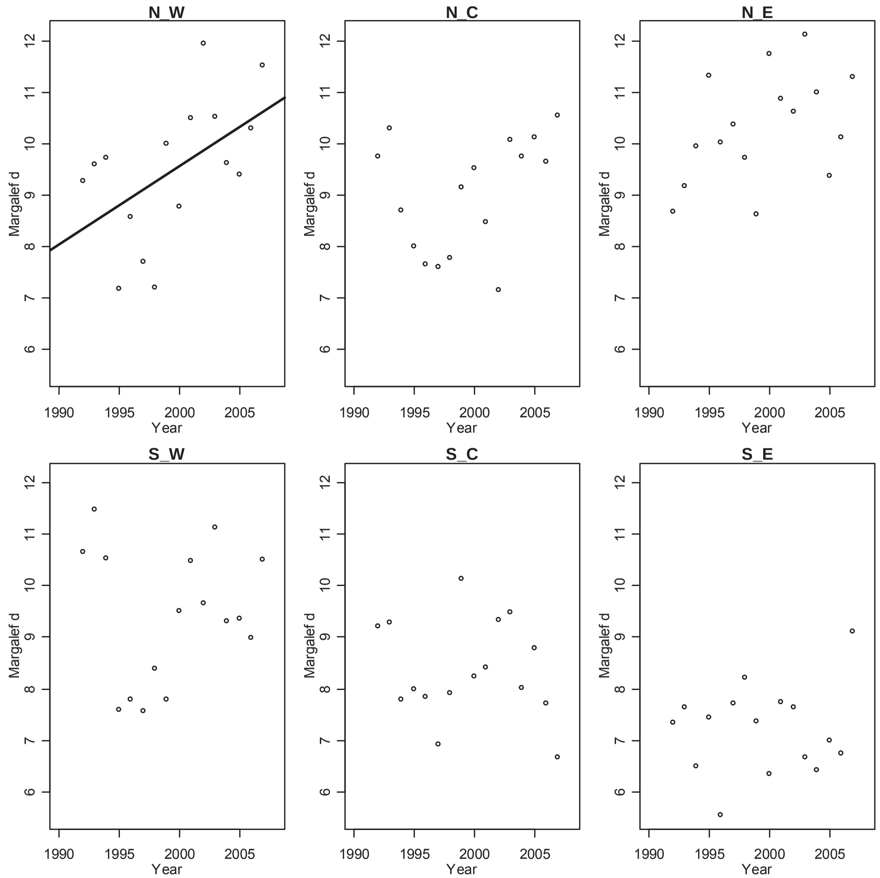


Figure 78: Plots of Margarlef's d diversity parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

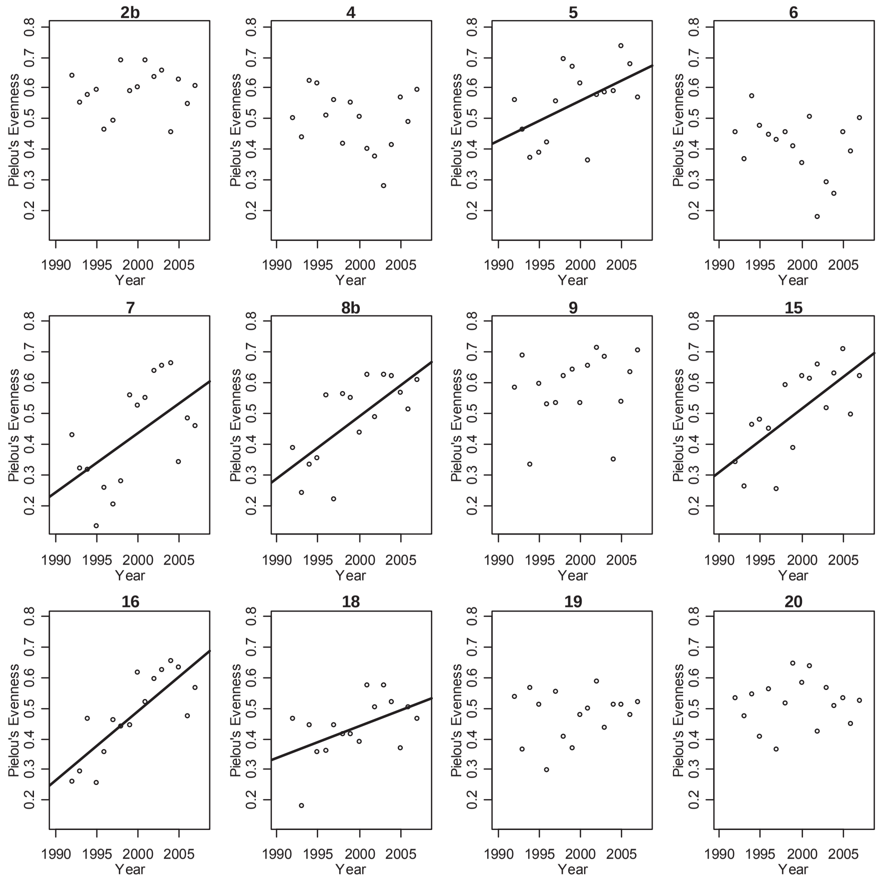


Figure 79: Plots of Pielou's evenness parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

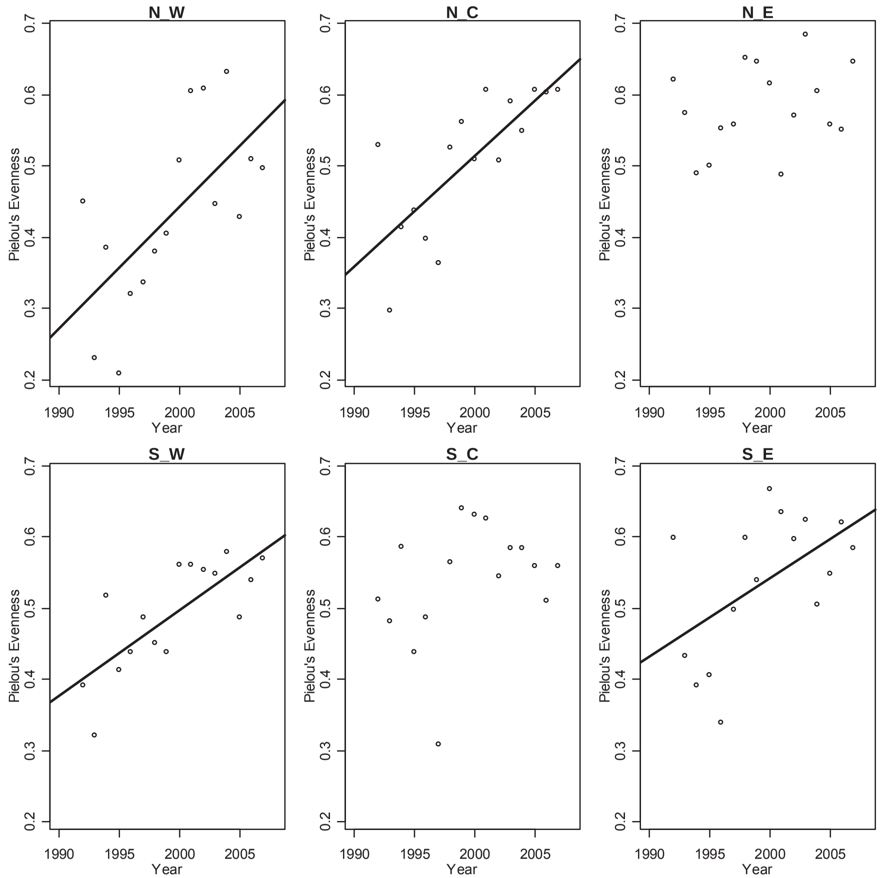


Figure 80: Plots of Pielou's evenness parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

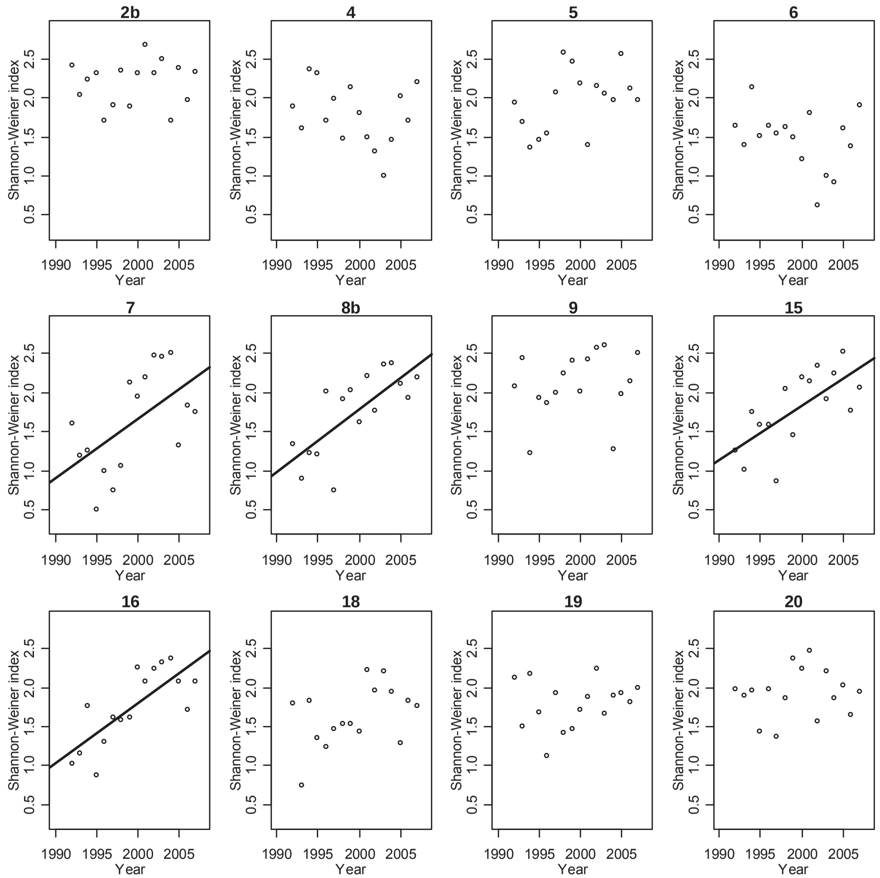


Figure 81: Plots of Shannon Weiner diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

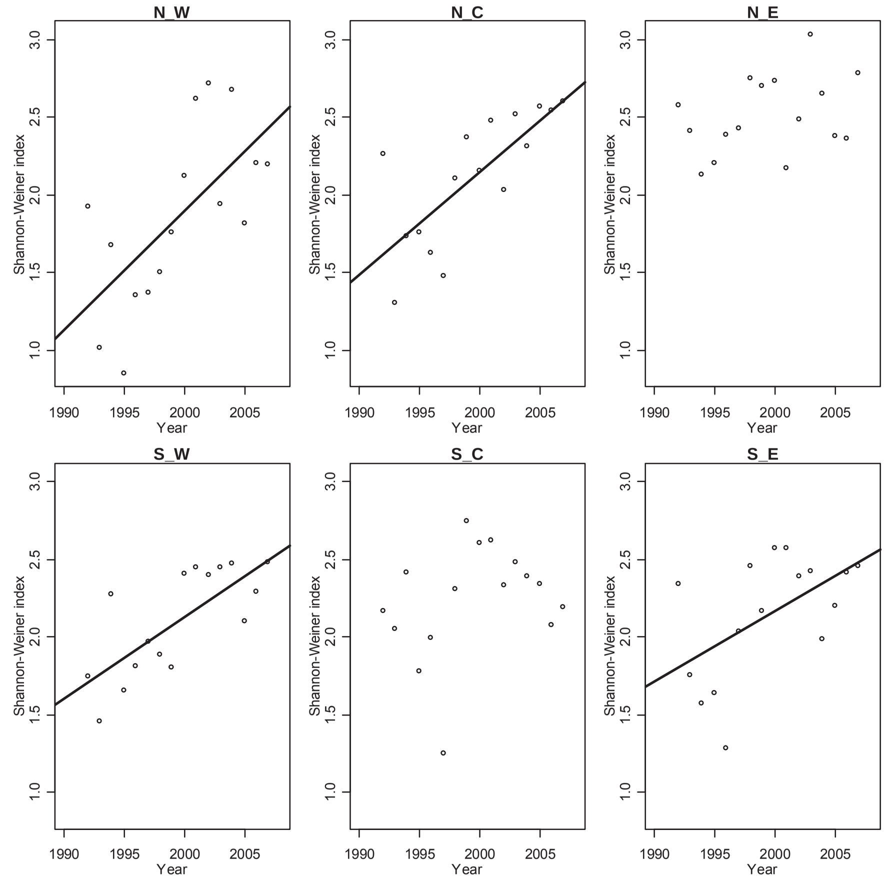


Figure 82: Plots of Shannon Weiner diversity parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

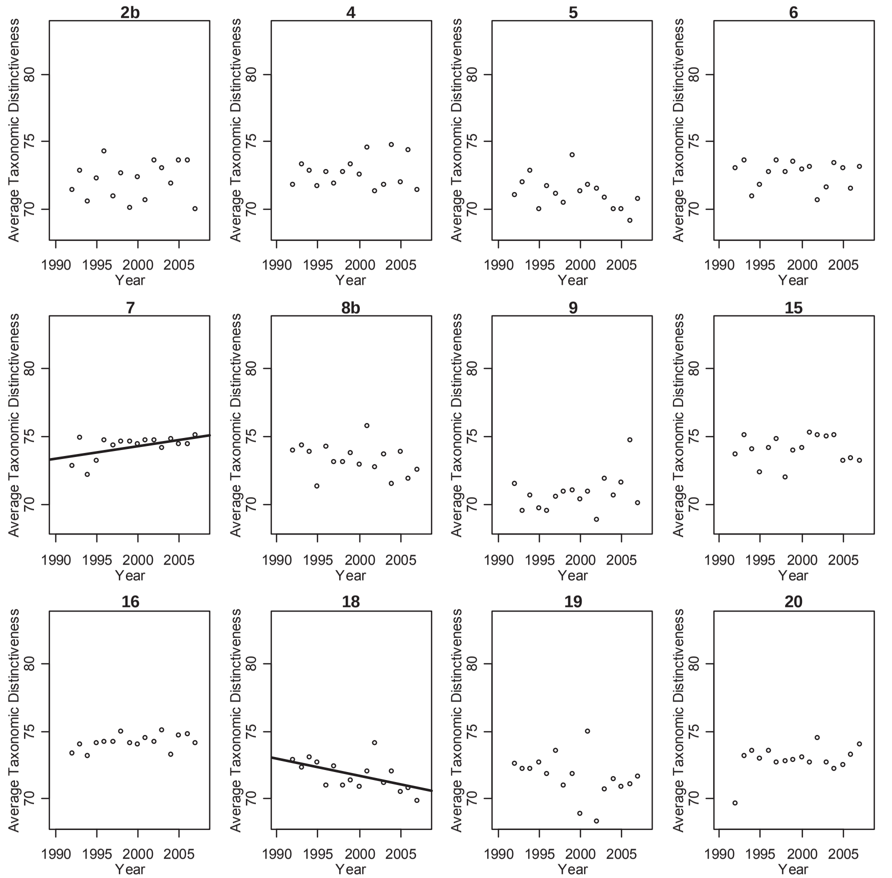


Figure 83: Plots of Average Taxonomic Distinctiveness parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

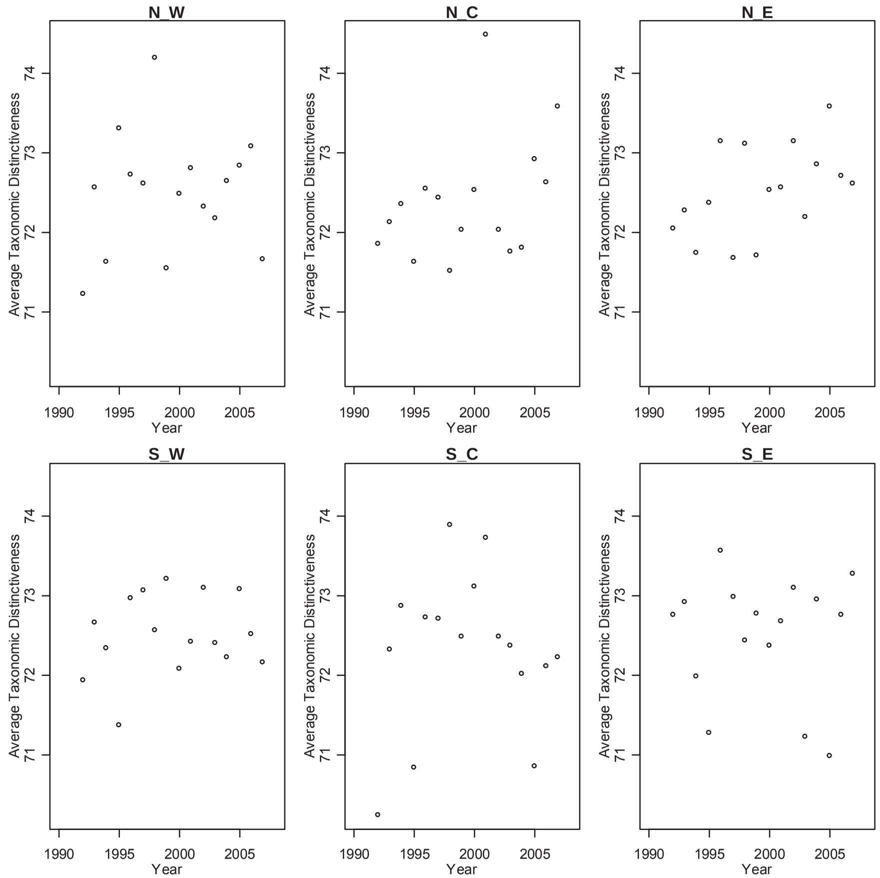


Figure 84: Plots of Average Taxonomic Distinctiveness parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

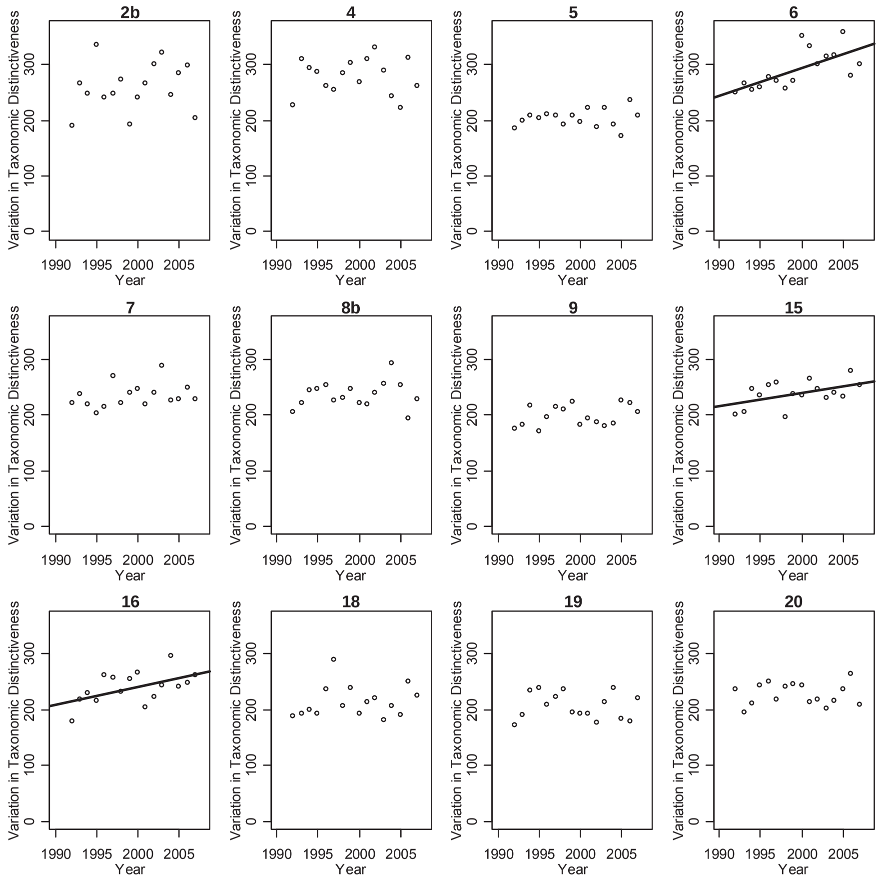


Figure 85: Plots of Variation in taxonomic distinctiveness parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

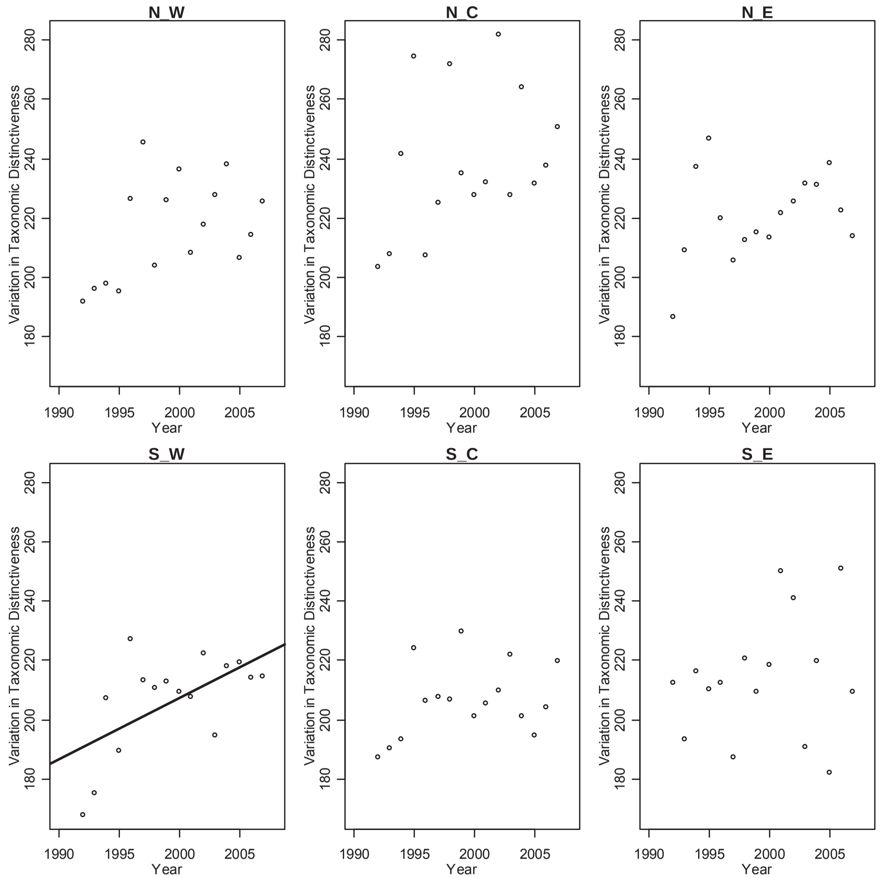


Figure 86: Plots of Variation in taxonomic distinctiveness parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

5.1.2. Trophodynamic indicators

5.1.2.1. Biomass ratio

On the basis of life history knowledge for each species, the catch for each station was summed by main feeding group and habitat. The ratio of Pisciverous:Total (Figures 87 & 88) and Demersal:Total (Figures 89 & 90) catch weight were examined over time for each stratum. The demersal species group was defined as those species within the working data set that were not pelagic or bathypelagic.

For the ratio of Pisciverous:Total catch weight, significant negative trends over time were identified for SC and SW Rise 600–800 (4 and 6), W Chatham 200–400 (5), NE and SW Reserve 400–600 (8b and 15) and W and S Mernoo 400–600 (7 and 16), with other strata showing almost significant trends. Over the larger areas, negative trends were identified for the NW, NC, SW, and SE areas (Table 21).

The ratio of Demersal : Total catch weight appeared less sensitive to changes in the fish community, but significant negative trends were identified for SC and SW Rise 600–800 (4 and 6), and W Mernoo 400–600 (7), and the NW and NC larger areas (Table 21).

Table 21: Slope and P value for linear regressions for each survey strata of Pisciverous:Total (left), Demersal:Total (centre) and Mean TL (right) on year. Proportions were arcsin square root transformed. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		Pisciverous:Total		Demersal:Total		Mean TL	
Strata	Name	slope	P	slope	P	slope	P
2b	NE Rise 600–800	-0.0053	0.485	-0.0036	0.651	-0.0073	0.148
4	SC Rise 600–800	**-0.0250**	**0.013**	**-0.0235**	**0.013**	**-0.0256**	**0.005**
5	W Chatham 200–400	**-0.0232**	**0.007**	0.0159	0.227	**-0.0169**	**0.018**
6	SW Rise 600–800	**-0.0322**	**0.001**	**-0.0197**	**0.045**	**-0.0272**	**0.001**
7	W Mernoo 400–600	**-0.0123**	**0.015**	**-0.0063**	**0.015**	**-0.0111**	**0.046**
8b	NE Reserve 400–600	**-0.0145**	**0.001**	-0.0045	0.098	**-0.0143**	**0.000**
9	N Chatham 200–400	-0.0228	0.063	0.0052	0.541	-0.0195	0.080
15	SW Reserve 400–600	**-0.0169**	**0.002**	-0.0056	0.127	**-0.0175**	**0.000**
16	S Mernoo 400–600	**-0.0110**	**0.002**	-0.0037	0.164	**-0.0137**	**0.001**
18	Mernoo 200–400	-0.0156	0.062	-0.0078	0.183	**-0.0148**	**0.048**
19	W Reserve 200–400	-0.0133	0.095	-0.0052	0.329	-0.0104	0.186
20	E Reserve 200–400	-0.0040	0.412	-0.0048	0.196	-0.0027	0.560
NW		**-0.0143**	**0.018**	**-0.0103**	**0.022**	**-0.0132**	**0.021**
NC		**-0.0110**	**0.001**	**-0.0066**	**0.033**	**-0.0121**	**0.000**
NE		-0.0078	0.240	0.0020	0.791	-0.0087	0.094
SW		**-0.0228**	**0.001**	-0.0114	0.058	**-0.0210**	**0.002**
SC		-0.0058	0.330	0.0021	0.731	-0.0058	0.331
SE		**-0.0249**	**0.002**	-0.0131	0.209	**-0.0210**	**0.002**

5.1.2.2. Trophic level of catch

The mean TL of the survey catch was examined over time for each stratum (Figures 91 & 92 and Table 21). The data showed a very similar pattern to the ratio of Pisciverous:Total catch weight. Significant negative trends over time were identified for SC and SW Rise 600–800 (4 and 6), W Chathan 200–400

(5), NE and SW Reserve 400–600 (8b and 15), W and S Mernoo 400–600 (7 and 16), and Mernoo 200–400 (18), with other strata showing almost significant trends. Over the larger areas, negative trends were identified for the NW, NC, SW and SE areas (Figure 92).

5.1.2.3. Trophic spectra

Cumulative relative biomass trophic spectra are plotted for each year in each survey strata in Figures 93 & 94.

Between-year pairs of cumulative relative biomass spectra were compared using a Kolmogorov-Smirnov test as described for the Hauraki Gulf dataset.

The MDS plots showing the changes in relative similarity in trophic spectra over time are shown for the survey strata in Figure 95, and for the larger sediment/depth areas in Figure 96. Although all the plots show a certain degree of scatter, some also show evidence of a more linear pattern, which may imply a trend in the trophic spectra over time. For NE and SW Reserve 400–600 (8b and 15) and W and S Mernoo 400–600 (7 and 16), the data points from the 1990s tend to be separated from those from the 2000s, suggesting that the trophic spectra may have changed between these periods. Examining the data over the larger areas, the MDS plots show a similar split between the 1990s and 2000s for the NW and SW area. The NC and SC areas also show some evidence of a split between the two time periods, while the data from the NE and SE areas are more scattered, and show no real trend.

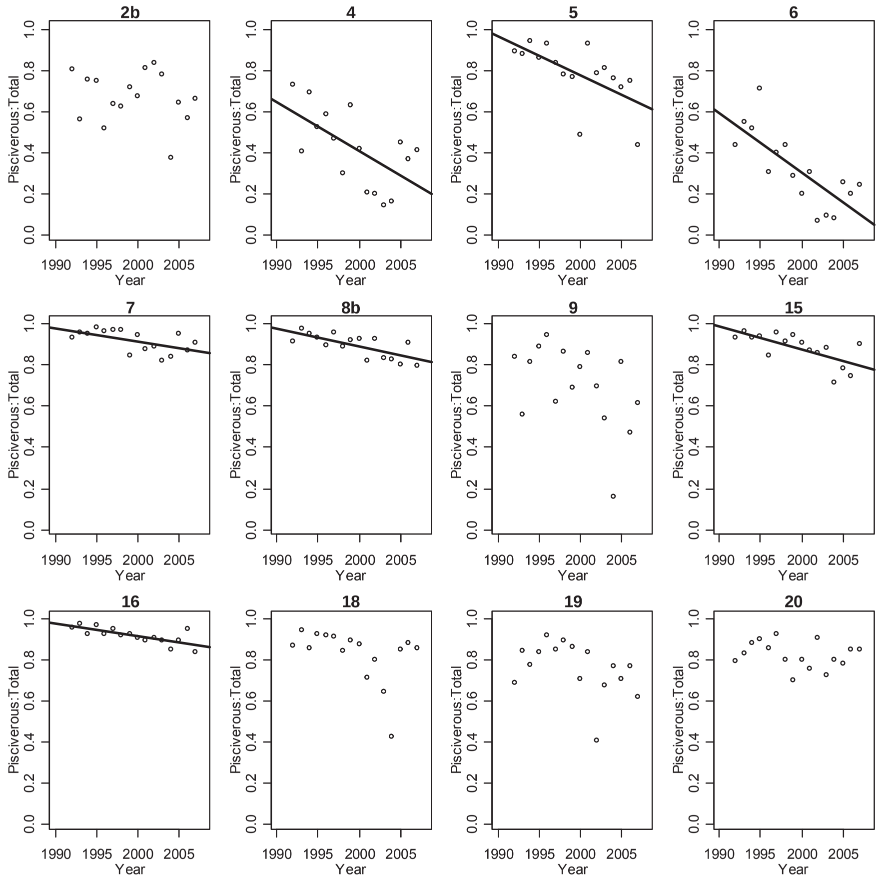


Figure 87: Plots of the Pisciverous:Total catch weight ratio for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

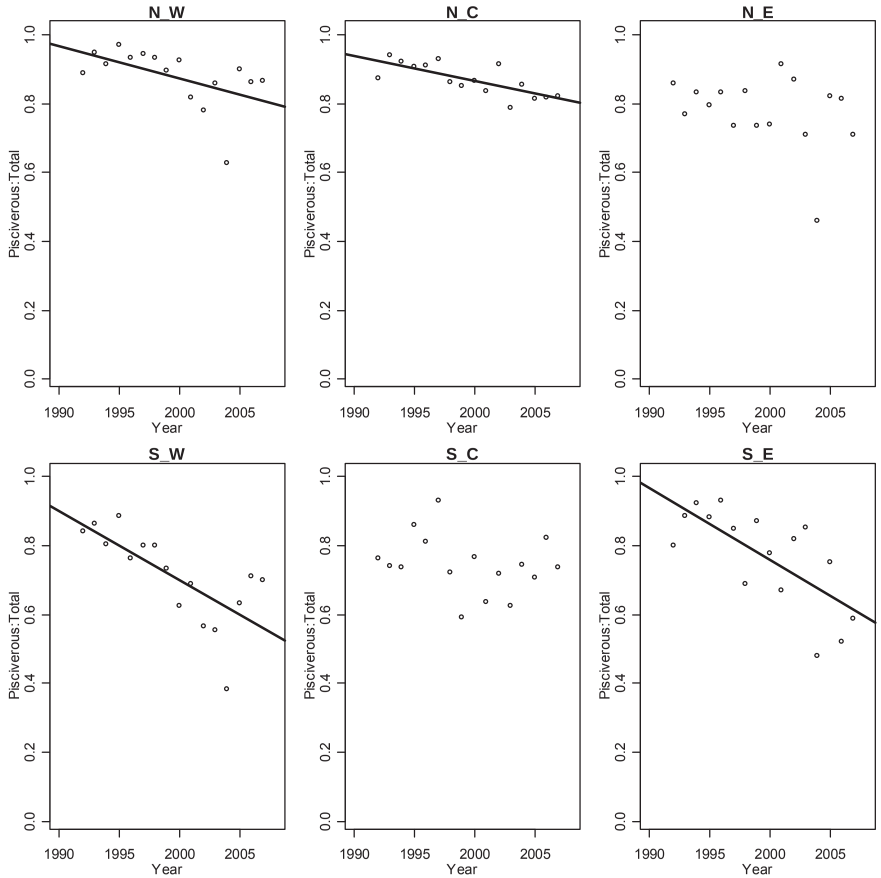


Figure 88: Plots of the Pisciverous:Total catch weight ratio for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

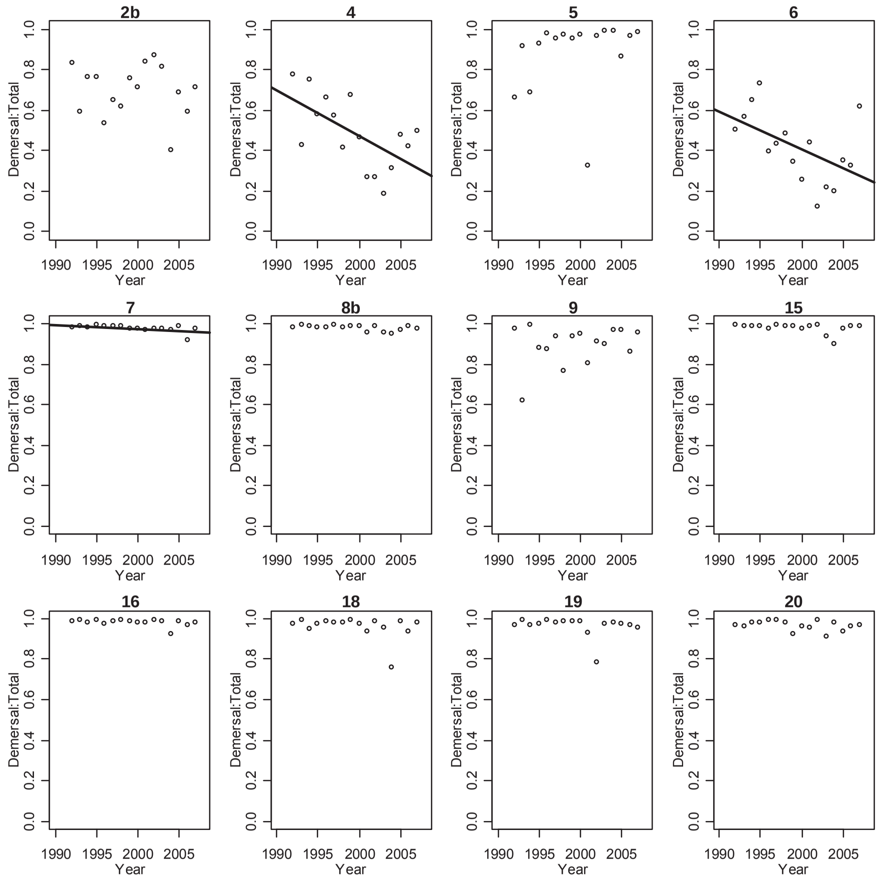


Figure 89: Plots of the Demersal:Total catch weight ratio for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

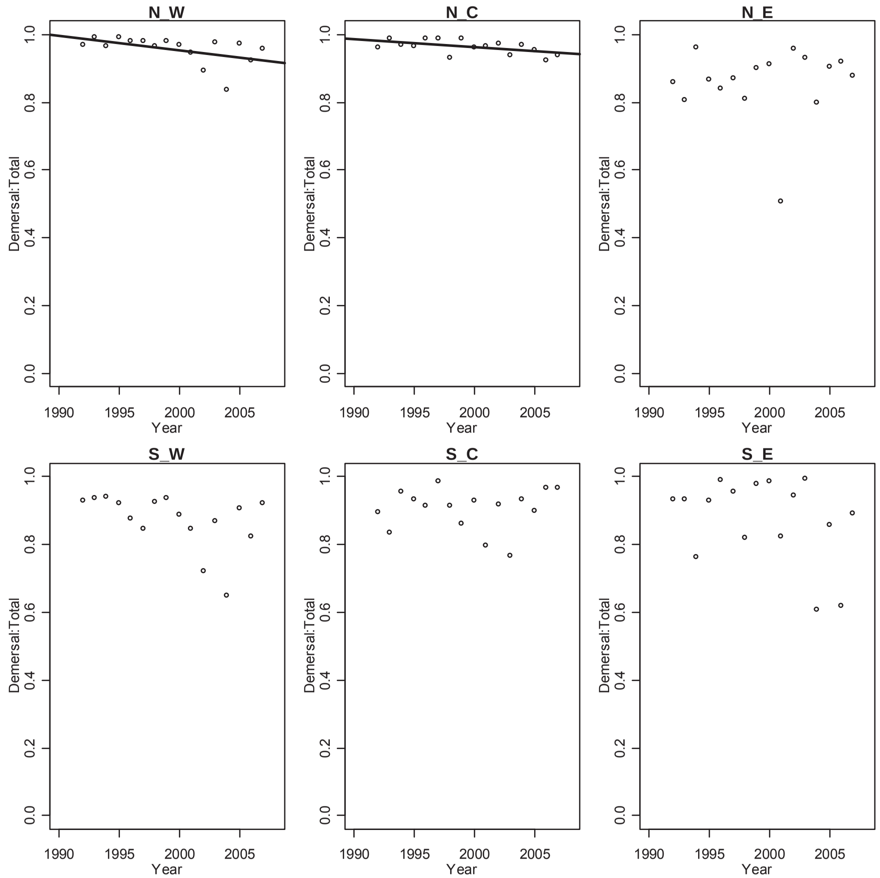


Figure 90: Plots of the Demersal:Total catch weight ratio for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

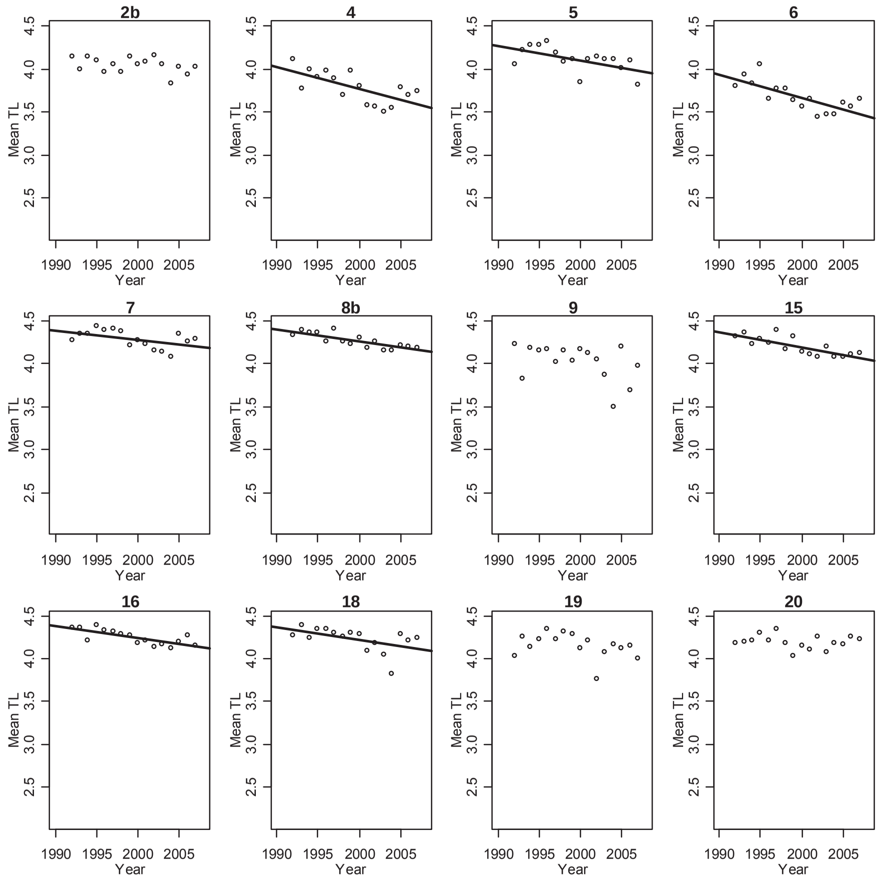


Figure 91: Plots of Mean TL for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

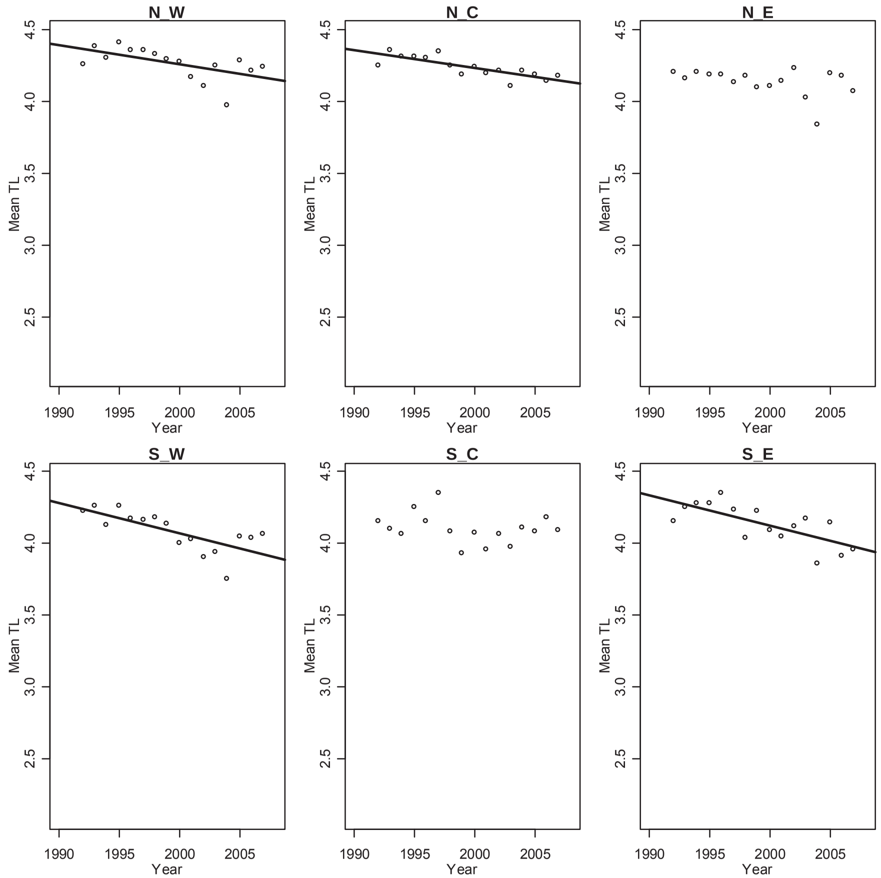


Figure 92: Plots of Mean TL for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

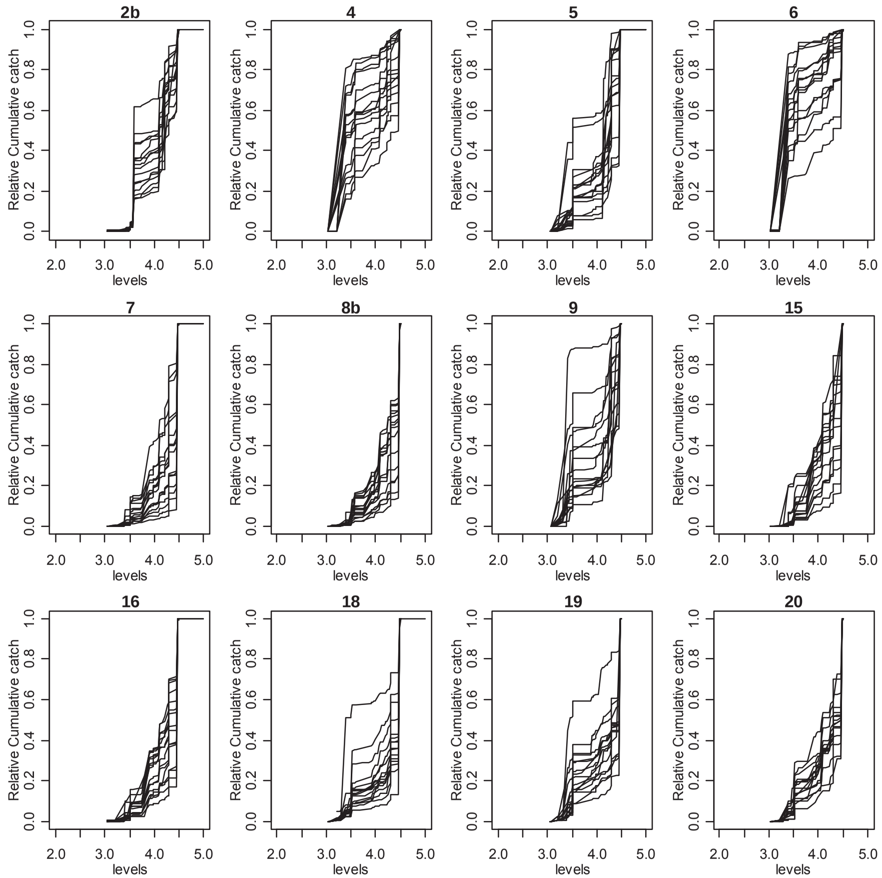


Figure 93: Plots of cumulative relative biomass trophic level spectra for each survey stratum.

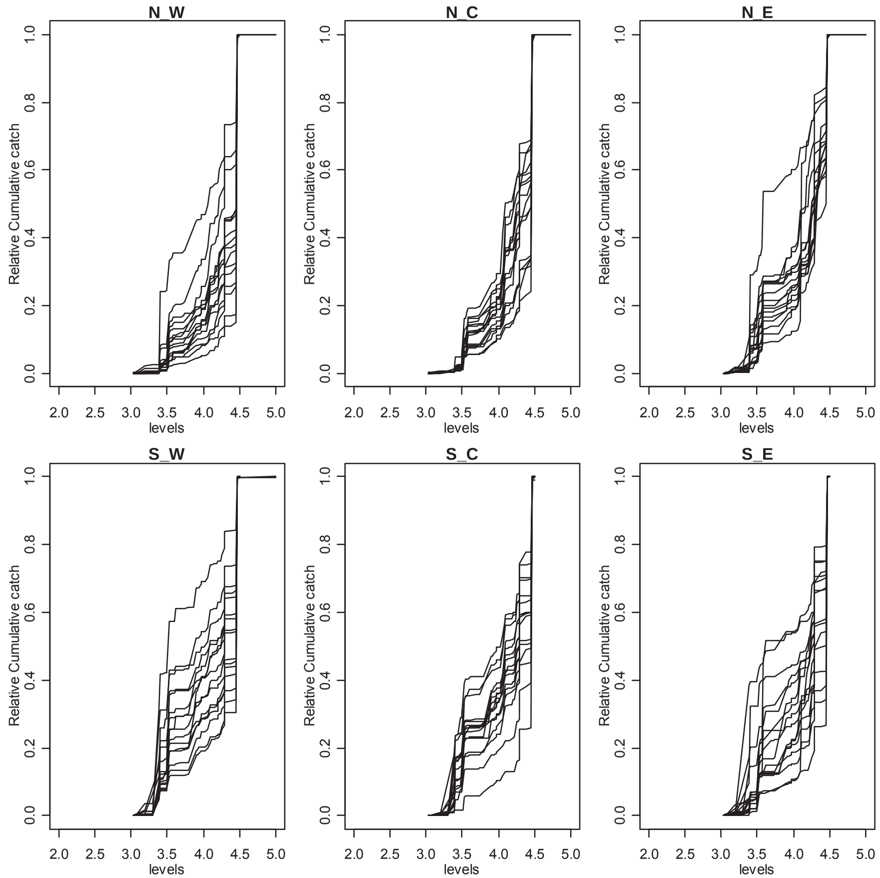


Figure 94: Plots of cumulative relative biomass trophic level spectra for each larger region stratum.

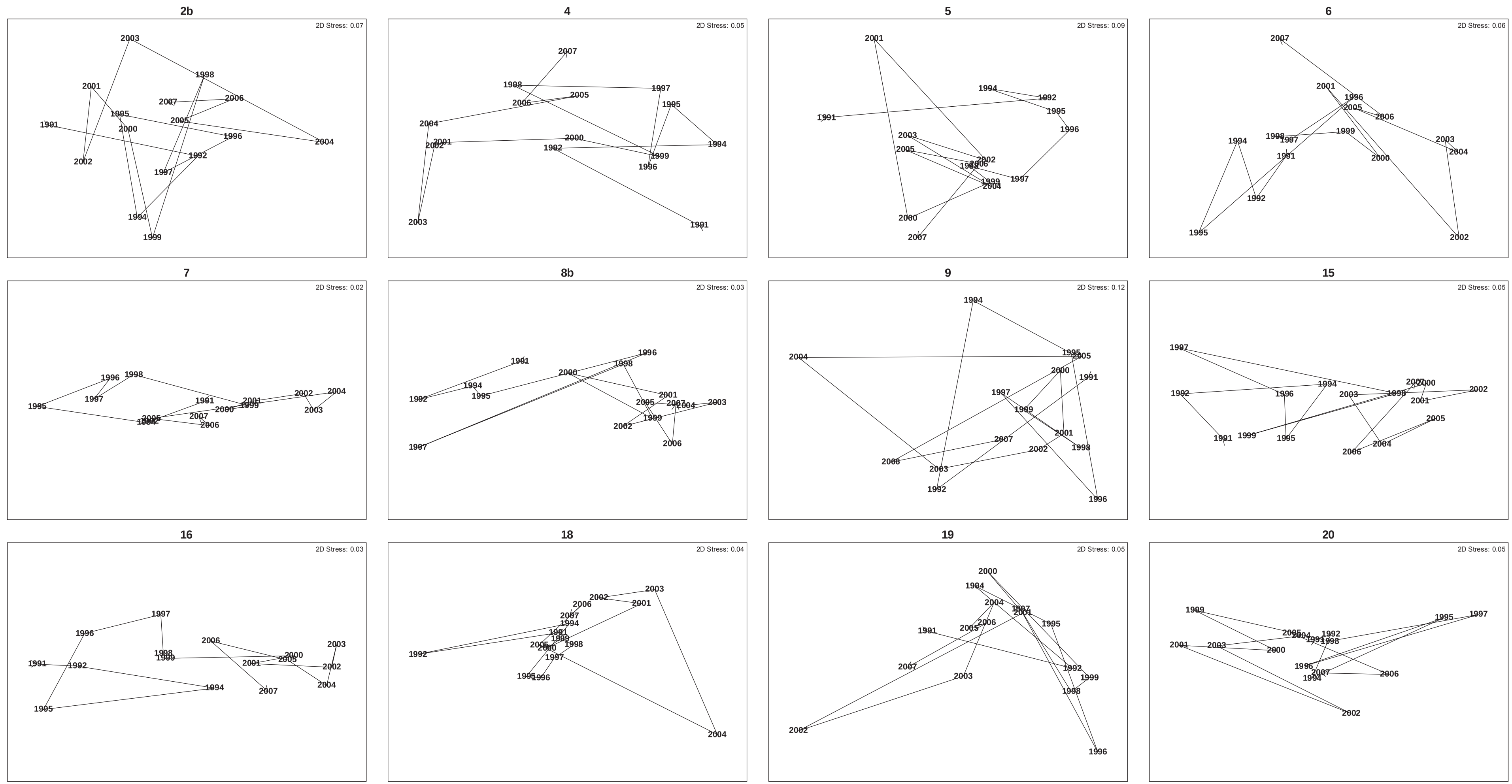


Figure 95: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of relative biomass trophic spectra over time for each survey stratum.

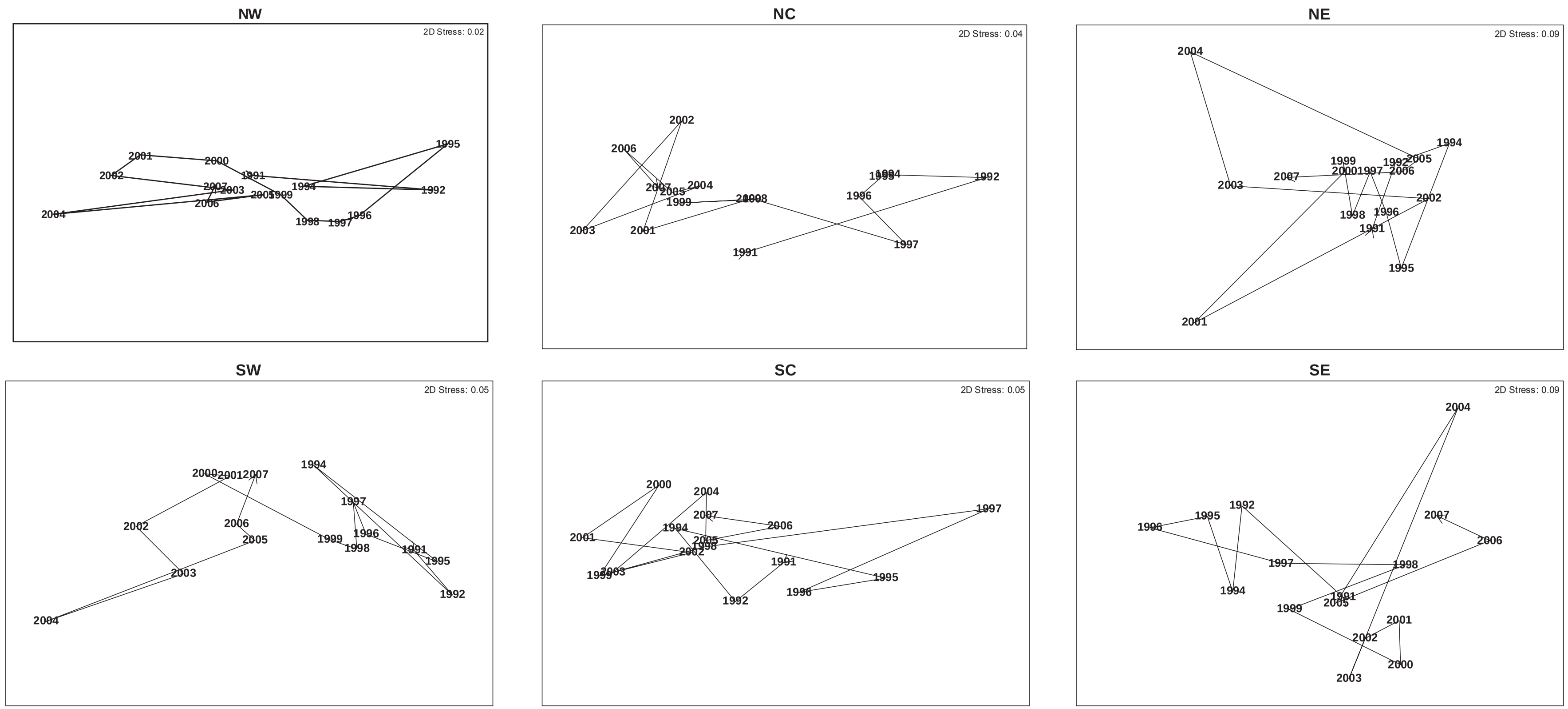


Figure 96: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of relative biomass trophic spectra over time for each of the larger area stratum.

5.2. Analysis of catch numbers at length by station

Not all species caught during a tow are measured, and so for examination of size-based indicators, a set of 15 species was selected, being considered to be appropriately sampled by the gear and consistently measured. Only tows in which all the species were measured (assuming they were caught) were included in the analysis. Indicators were calculated for the full combined length frequency distribution of the 15 species. The species were barracouta, black oreo, alfonsino, ghost shark, pale ghost shark, hake, hoki, lookdown dory, ling, orange roughy, red cod, spiny dogfish, smooth oreo, silver warehou, and white warehou.

5.2.1. Median and L95 size

Median length did not show any significant trends over time at the survey strata level, but did show a negative trend over the larger SE area (Figures 97 & 98 and Table 22).

The L95 length appeared more sensitive to changes in the fish community length structure over time, with NE Rise 600–800 (2b) showing a positive trend, and SC and SW Rise 600–800 (4 and 6) and W Reserve 200–400 (19) showing negative trends. The larger SW area also showed a negative trend (Figures 99 & 100 and Table 22).

5.2.2. Proportion of large individuals

The proportion (by number) of the catch under 30 cm shows a negative trend for W Chatham 200–400 (5), NE Reserve 400–600 (8b), W and S Mernoo 400–600 (7 and 16) and Mernoo 200–400 (18), with almost significant trends identified for SW Reserve 400–600 (15) (-ve) and W Reserve 200–400 (19) (+ve). Over the larger area, the NW and NE areas showed negative trends (Figures 101 & 102 and Table 22).

5.2.3. W statistic

Overall, the W statistic values were generally negative, suggesting the group of measured species is made up of a disturbed community. At the level of the survey strata, only W Chatham 200–400 (5) showed a significant trend (+ve), but over the larger area, both the NW and SW areas showed negative trends (Figures 103 & 104 and Table 22).

Table 22: Slope and P value for linear regressions for each survey stratum of Median length (set 1), L95 (set 2), Proportion > 30cm (set 3), and W statistic (set 4) on year. Proportions were arcsin square root transformed. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey stratum for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		Median length		L95		Proportion > 30 cm		W statistic	
Strata	Name	slope	P	slope	P	slope	P	slope	P
2b	NE Rise 600–800	-0.3696	0.598	**0.4727**	**0.011**	-0.0073	0.306	0.0007	0.790
4	SC Rise 600–800	-0.1500	0.220	**-2.4929**	**0.033**	-0.0112	0.218	0.0004	0.871
5	W Chatham 200–400	-0.5297	0.279	-0.1538	0.600	**-0.0304**	**0.000**	**0.0099**	**0.037**
6	SW Rise 600–800	-0.1286	0.143	**-2.5071**	**0.008**	-0.0084	0.361	-0.0030	0.344
7	W Mernoo 400–600	-0.3464	0.452	-0.1761	0.765	**-0.0109**	**0.014**	-0.0008	0.832
8b	NE Reserve 400–600	-0.2500	0.344	-0.0132	0.943	**-0.0145**	**0.011**	-0.0039	0.069
9	N Chatham 200–400	-0.3362	0.576	-0.5930	0.198	-0.0172	0.098	0.0081	0.229
15	SW Reserve 400–600	0.3250	0.405	0.1964	0.385	-0.0117	0.059	-0.0019	0.294
16	S Mernoo 400–600	-0.0393	0.902	0.0679	0.804	**-0.0079**	**0.011**	-0.0051	0.054
18	Mernoo 200–400	0.3857	0.309	-0.1679	0.515	**-0.0063**	**0.004**	-0.0039	0.064
19	W Reserve 200–400	0.3107	0.422	**-0.7607**	**0.009**	0.0094	0.061	-0.0003	0.873
20	E Reserve 200–400	0.1214	0.775	-0.3000	0.156	-0.0005	0.946	0.0022	0.381
NW		0.2286	0.562	-0.0357	0.903	**-0.0081**	**0.003**	**-0.0073**	**0.001**
NC		0.5132	0.338	0.0985	0.647	-0.0098	0.103	-0.0027	0.105
NE		-0.5429	0.298	-0.0679	0.670	**-0.0176**	**0.012**	0.0008	0.780
SW		-0.4321	0.249	**-0.6429**	**0.009**	-0.0062	0.258	**-0.0052**	**0.005**
SC		0.4893	0.347	-0.2107	0.187	0.0012	0.907	0.0010	0.636
SE		**-1.4786**	**0.031**	-0.2143	0.152	-0.0143	0.211	-0.0005	0.759

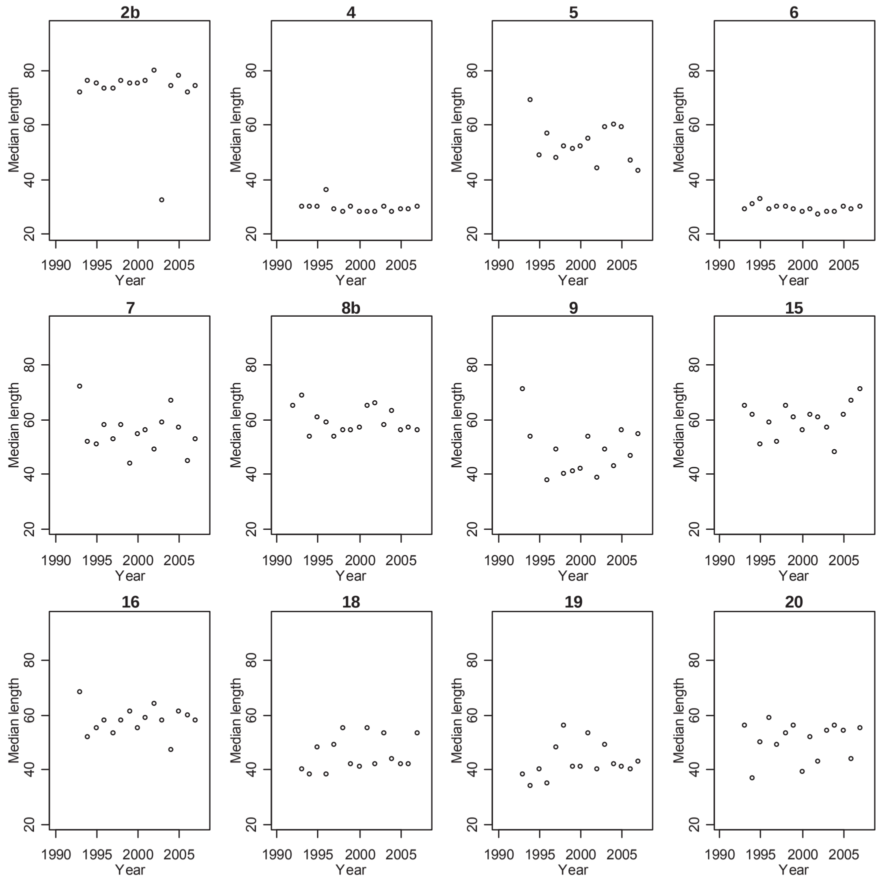


Figure 97; Plots of the Median length for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

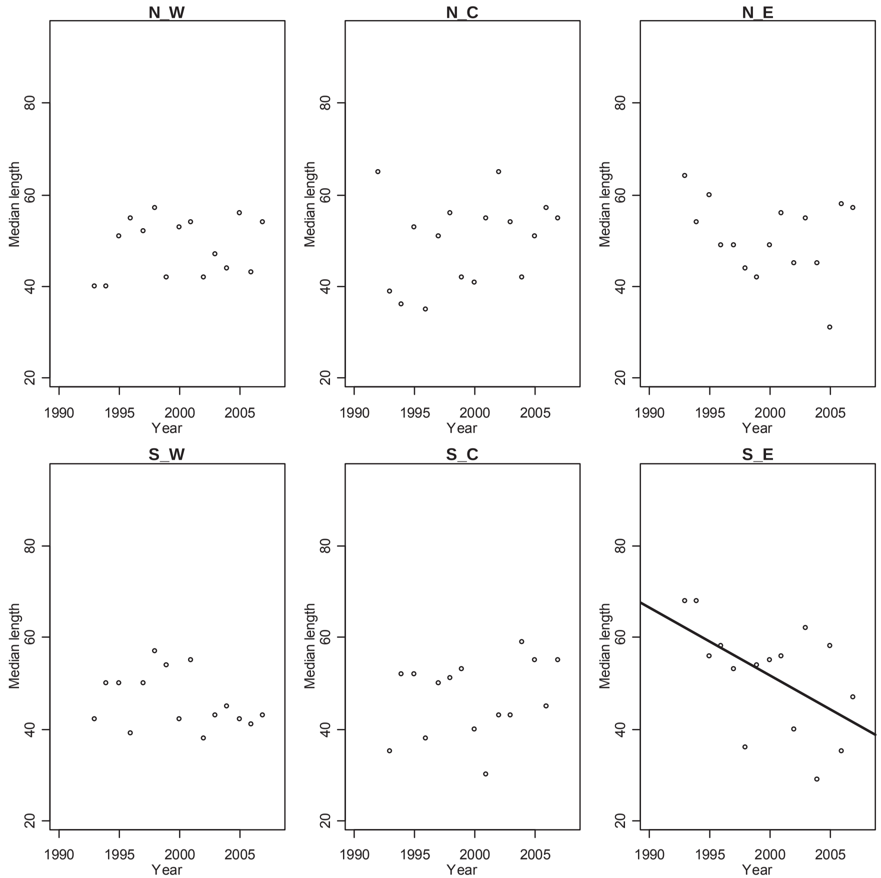


Figure 98: Plots of the Median length for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

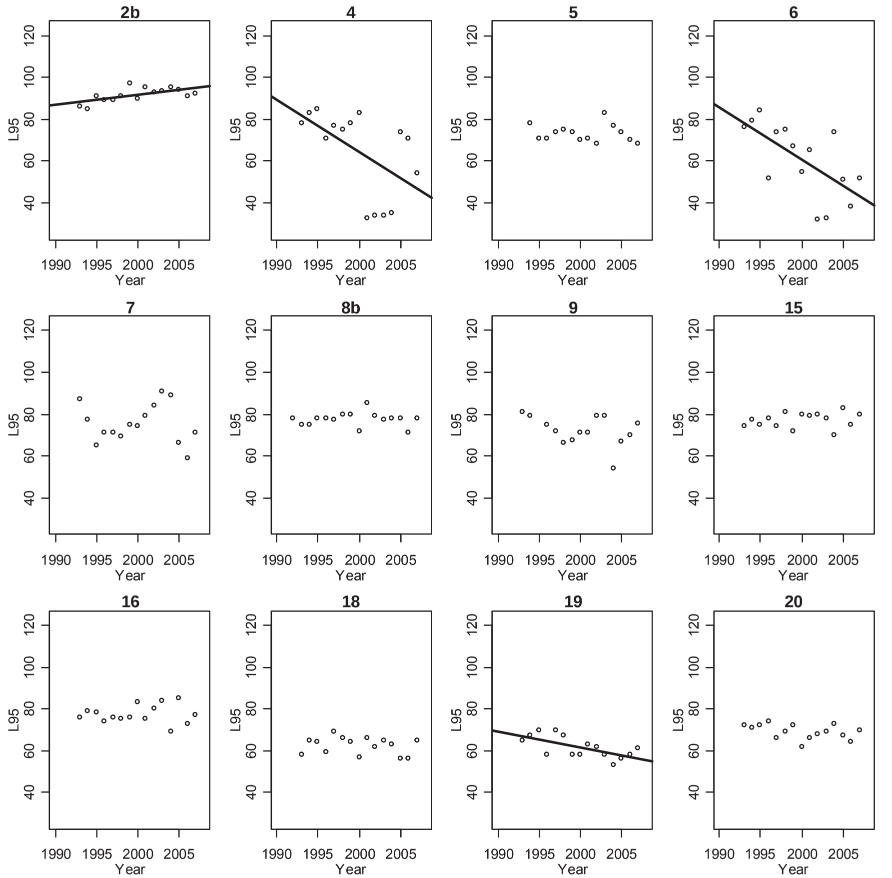


Figure 99: Plots of L95 for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

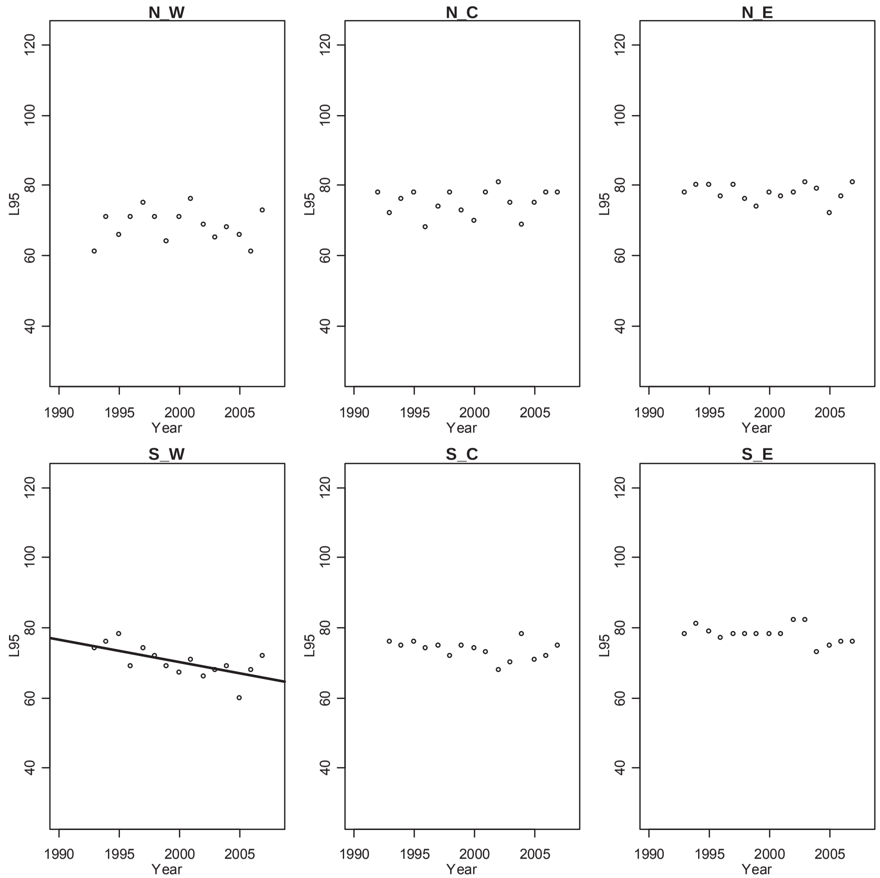


Figure 100; Plots of L95 for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

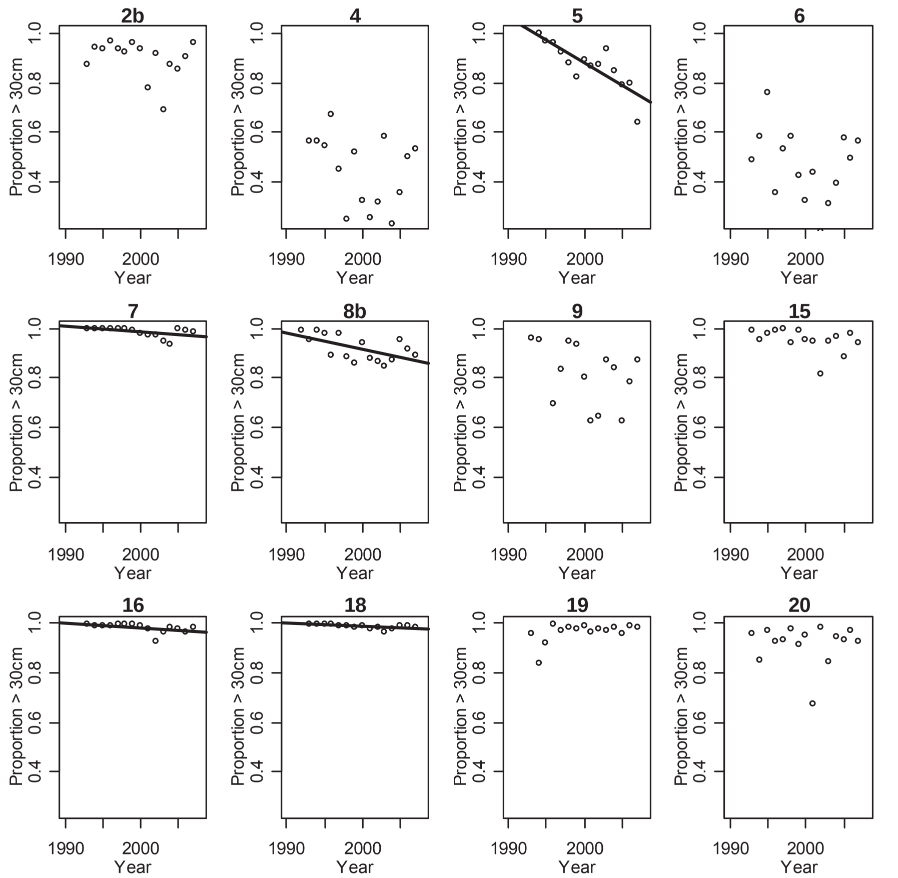


Figure 101: Plots of the Proportion >30 cm length for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

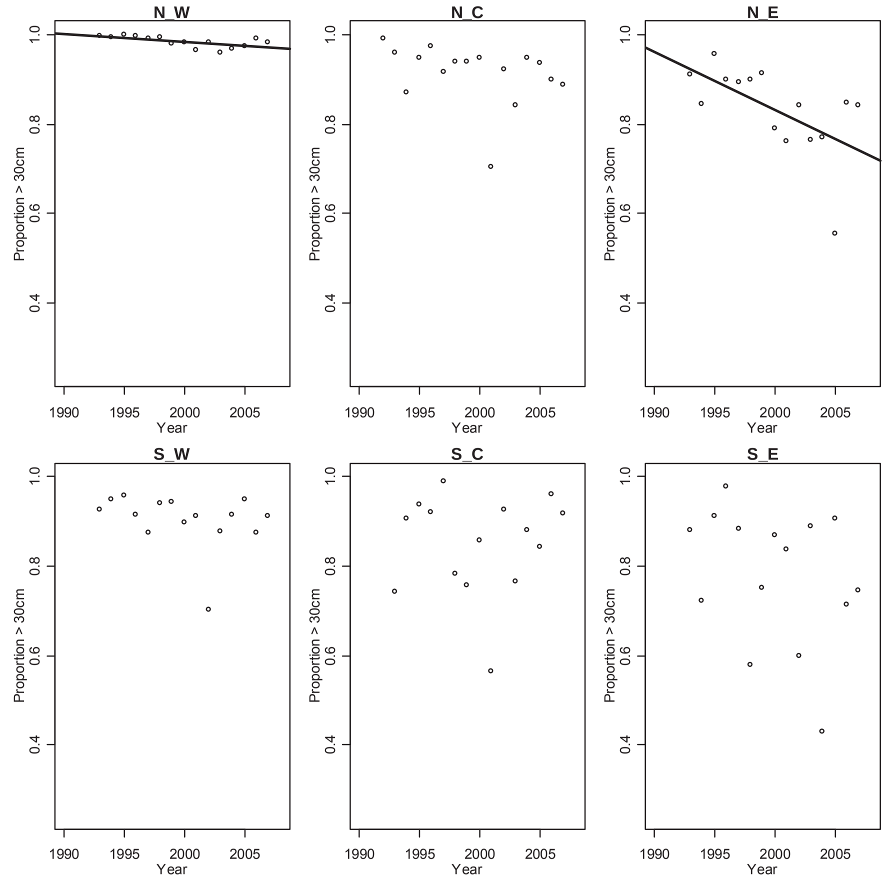


Figure 102: Plots of the Proportion >30 cm length for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

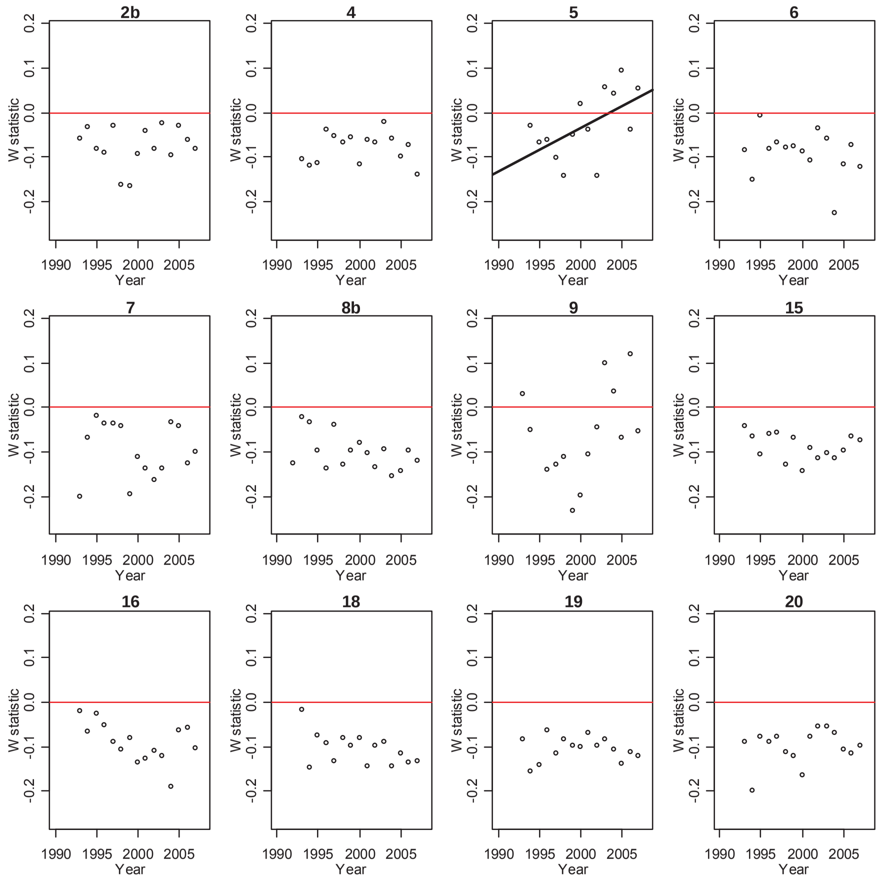


Figure 103: Plots of the W statistic for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

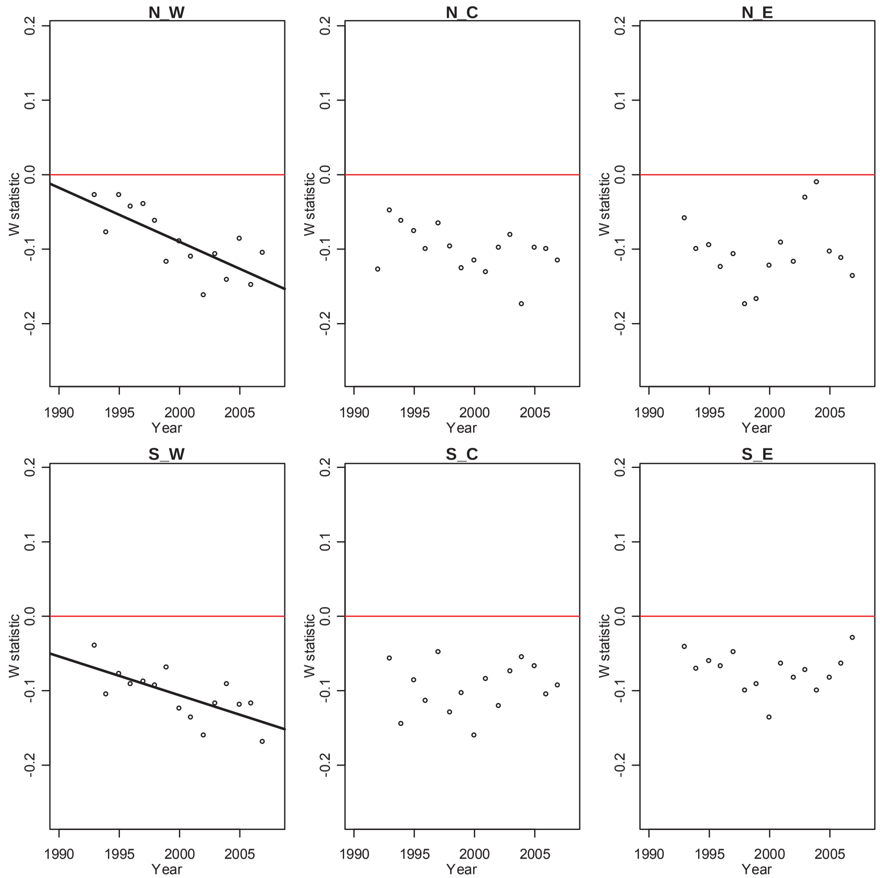


Figure 104: Plots of the W statistic for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

5.2.4. Abundance and biomass size spectra

Abundance and biomass size spectra were calculated for the combined set of the same 15 species, and changes in the spectra were examined over time for each stratum.

The slope of the size spectra showed a significant trend only for SW Reserve 400–600 (15) (+ve), although a positive trend for NE Rise 600–800 (2b) and a negative trend for the larger SW area were almost significant (Figures 105 & 106 and Table 23).

The intercept of the size spectra appeared more sensitive to any trends in the length composition, with negative trends identified for SW Rise 600–800 (6), S Mernoo 400–600 (16), Mernoo 200–400 (18), and W Reserve 200–400 (19), and the larger SW area (Figures 107 & 108 and Table 23).

From the analysis of the biomass size spectra, significant positive trends were identified in curvature over time for N Chatham 200–400 (9) and the larger SE area, but SW Reserve 400–600 (15) had an almost significant negative trend (Figures 109 & 100 and Table 24).

For the biomass spectra x vertex, no significant trends were identified, although a positive trend for the larger NW area was almost significant (Figures 111 & 112 and Table 24).

For the biomass spectra x vertex, negative trends were identified for SW Reserve 400–600 (15) and S Mernoo 400–600 (16), and a negative trend for the larger NW area was almost significant (Figures 113 & 114 and Table 24).

Table 23: Slope and P value for linear regressions for each survey stratum Size spectra slope (left) and intercept (right) on year. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		Size spectra slope		Size spectra intercept	
Stratum	Name	slope	P	slope	P
2b	NE Rise 600–800	0.0015	0.054	0.0192	0.554
4	SC Rise 600–800	0.0013	0.286	-0.0621	0.062
5	W Chatham 200–400	-0.0003	0.785	-0.0400	0.106
6	SW Rise 600–800	0.0006	0.623	**-0.0652**	**0.031**
7	W Mernoo 400–600	-0.0002	0.852	-0.0225	0.534
8b	NE Reserve 400–600	0.0007	0.399	-0.0067	0.784
9	N Chatham 200–400	-0.0023	0.076	-0.0009	0.978
15	SW Reserve 400–600	**0.0029**	**0.010**	-0.0473	0.149
16	S Mernoo 400–600	0.0012	0.091	**-0.0663**	**0.017**
18	Mernoo 200–400	-0.0005	0.554	**-0.0624**	**0.018**
19	W Reserve 200–400	-0.0016	0.079	**-0.0927**	**0.011**
20	E Reserve 200–400	-0.0013	0.169	-0.0017	0.939
NW		0.0003	0.442	-0.0370	0.085
NC		0.0003	0.400	0.0209	0.503
NE		-0.0008	0.139	0.0112	0.447
SW		-0.0010	0.063	**-0.0701**	**0.008**
SC		-0.0012	0.103	-0.0187	0.344
SE		-0.0002	0.813	-0.0112	0.658

Table 24: Slope and P value for linear regressions for each survey stratum of Biomass spectra curvature (left), x vertex (middle) and y vertex (right) on year. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold font.

		Biomass spectra curvature		Biomass spectra x vertex		Biomass spectra y vertex	
Strata	Name	slope	P	slope	P	slope	P
2b	NE Rise 600–800	-0.0022	0.716	-0.0070	0.490	-0.0175	0.700
4	SC Rise 600–800	-0.0170	0.321	-0.0201	0.416	-0.0203	0.505
5	W Chatham 200–400	0.0023	0.867	-0.0088	0.602	-0.0320	0.528
6	SW Rise 600–800	-0.0317	0.156	-0.0023	0.858	0.0041	0.904
7	W Mernoo 400–600	-0.0297	0.157	0.3177	0.213	-0.1405	0.357
8b	NE Reserve 400–600	0.0055	0.488	-0.0100	0.360	-0.0288	0.565
9	N Chatham 200–400	**0.0377**	**0.041**	0.0160	0.534	0.0452	0.501
15	SW Reserve 400–600	-0.0309	0.053	0.0281	0.146	**-0.1024**	**0.014**
16	S Mernoo 400–600	-0.0088	0.474	0.0095	0.691	**-0.1071**	**0.009**
18	Mernoo 200–400	-0.0147	0.145	0.0299	0.136	-0.0487	0.131
19	W Reserve 200–400	-0.0152	0.143	0.0039	0.774	-0.0319	0.607
20	E Reserve 200–400	-0.0081	0.375	-0.0039	0.667	0.0271	0.320
NW		0.0043	0.667	0.0222	0.066	-0.0804	0.050
NC		0.0099	0.081	0.0067	0.620	-0.0118	0.838
NE		0.0020	0.743	-0.0150	0.154	0.0272	0.341
SW		-0.0135	0.206	-0.0049	0.776	-0.0154	0.685
SC		-0.0019	0.764	-0.0088	0.205	0.0015	0.952
SE		**0.0101**	**0.028**	-0.0014	0.853	-0.0359	0.379

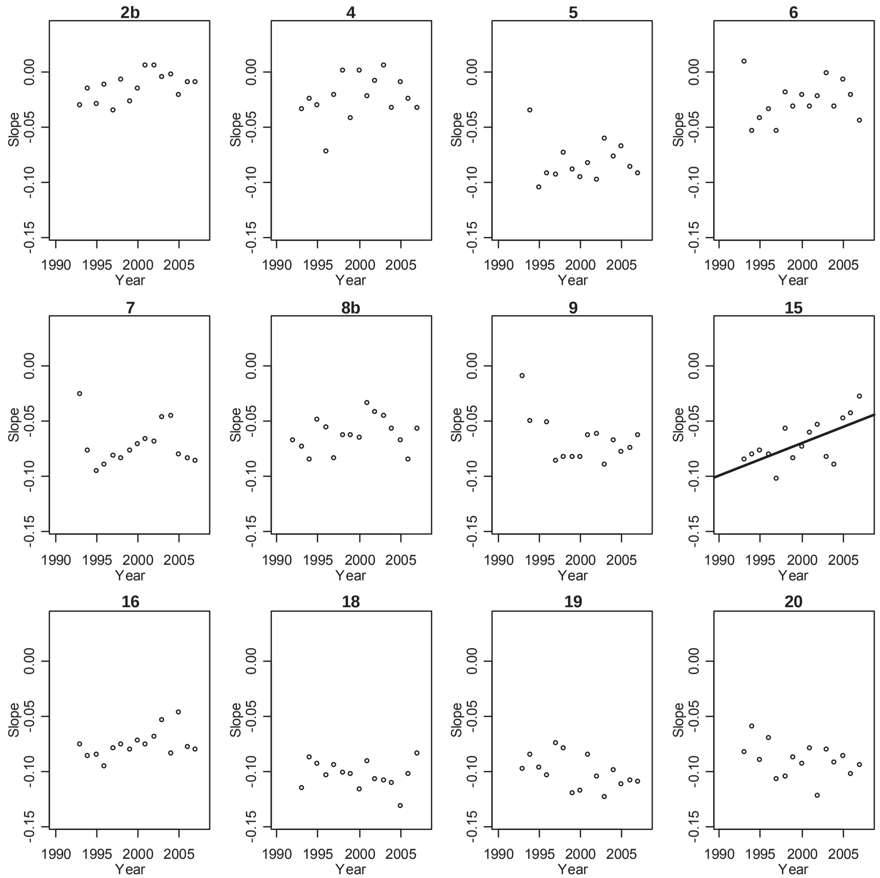


Figure 105: Plots of the Size spectra slope for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

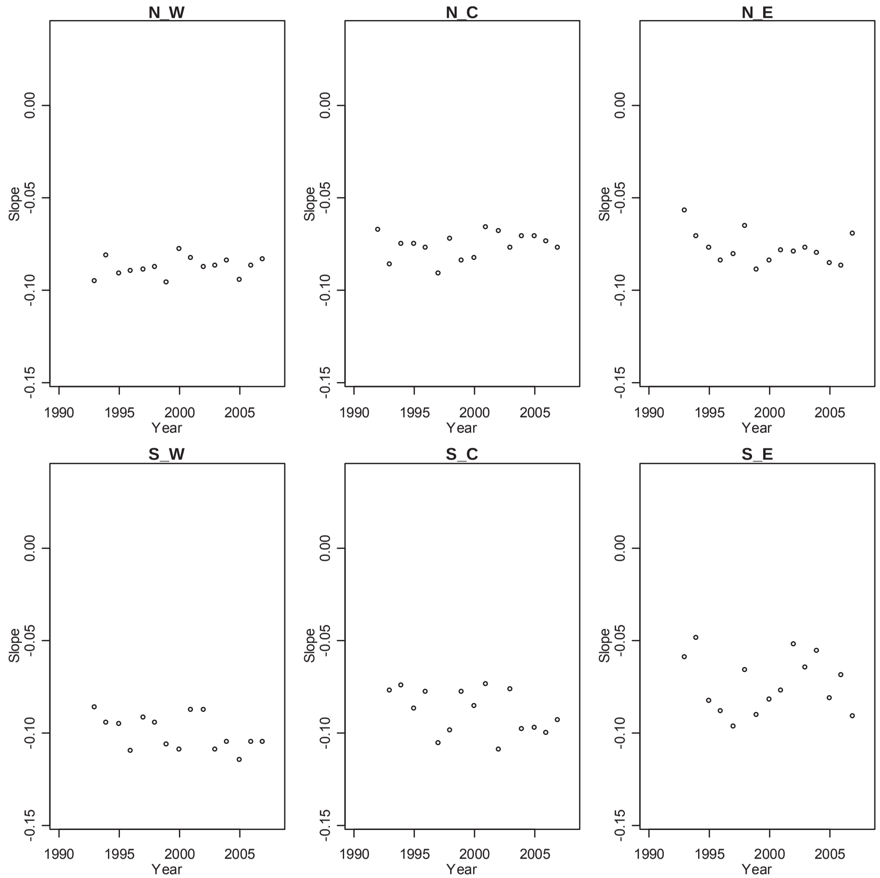


Figure 106: Plots of the Size spectra slope for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

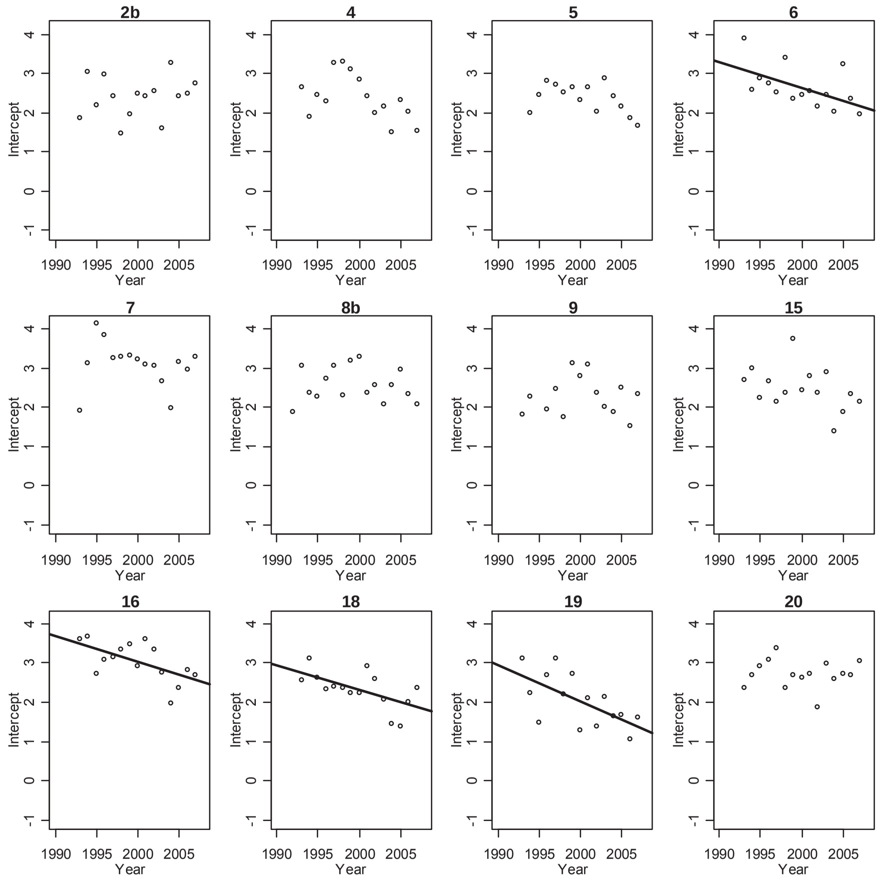


Figure 107: Plots of the Size spectra intercept for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

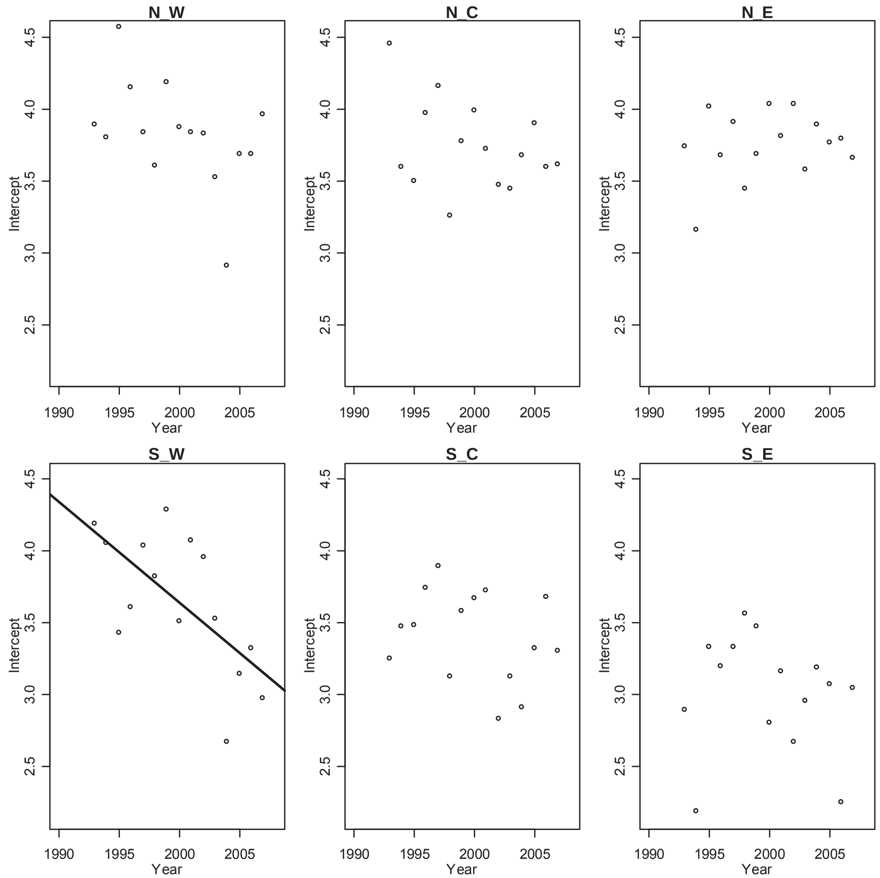


Figure 108: Plots of the Size spectra intercept for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

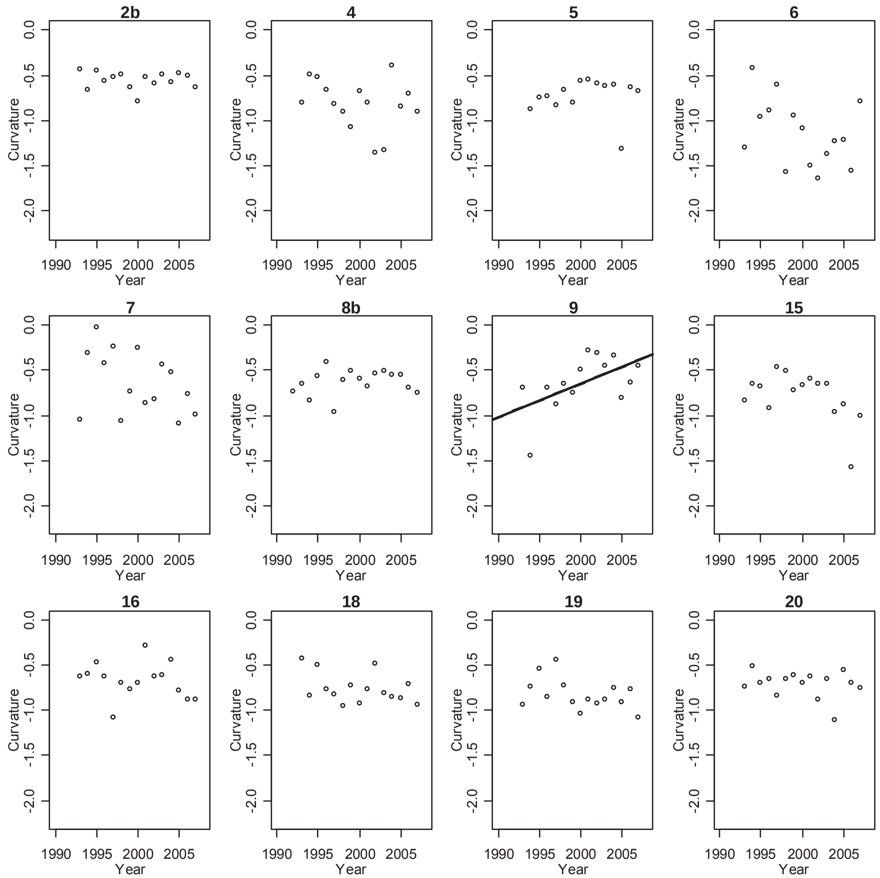


Figure 109: Plots of the Biomass spectra curvature for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

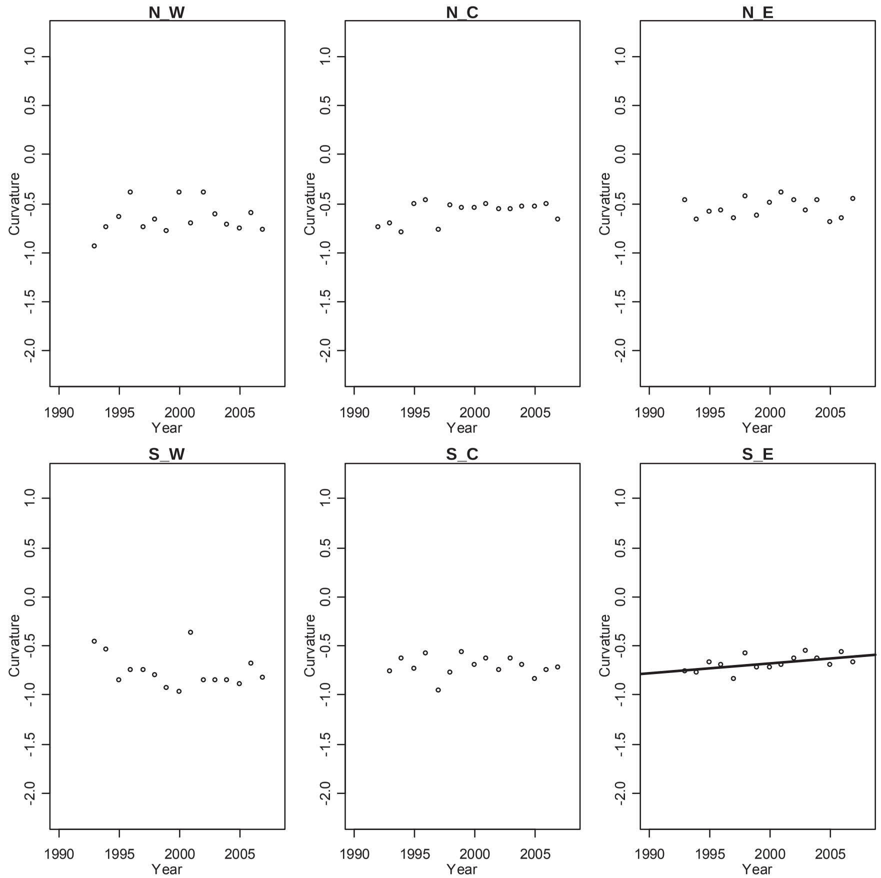


Figure 110: Plots of the Biomass spectra curvature for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

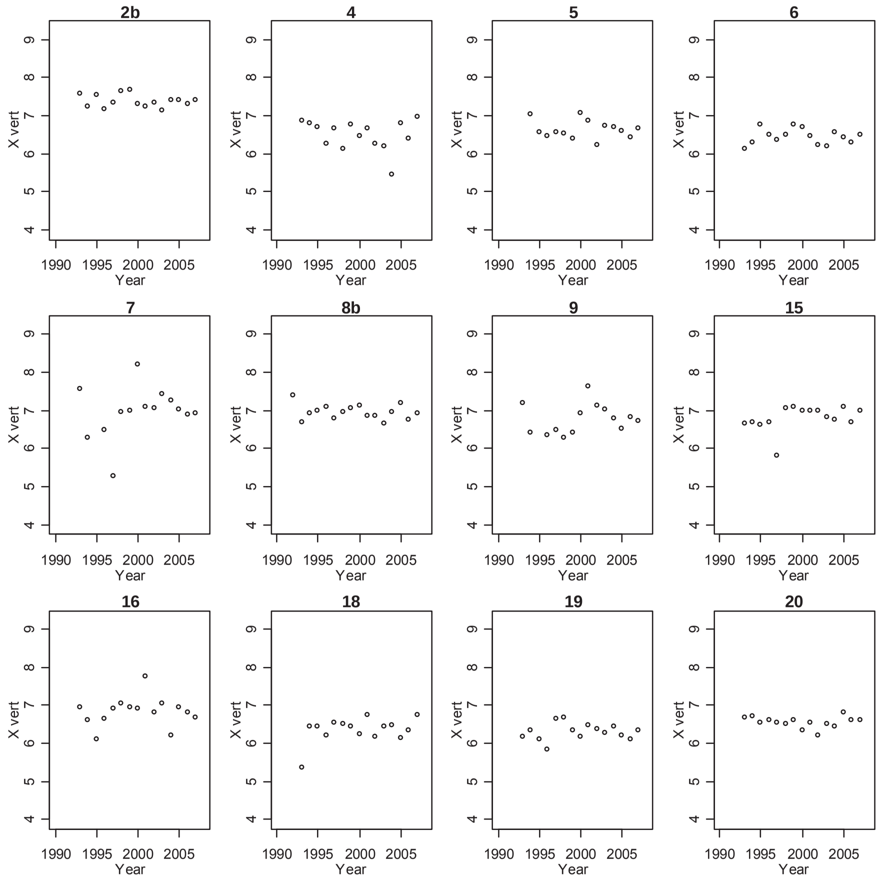


Figure 111: Plots of the Biomass spectra x vertex for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

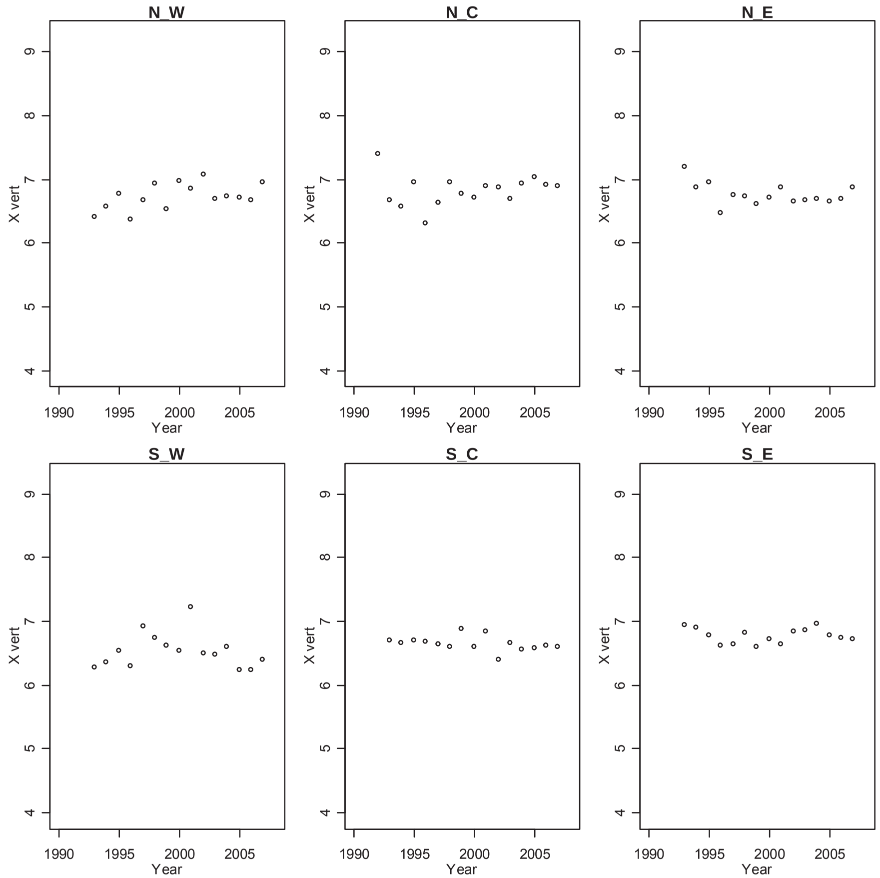


Figure 112: Plots of the Biomass spectra x vertex for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

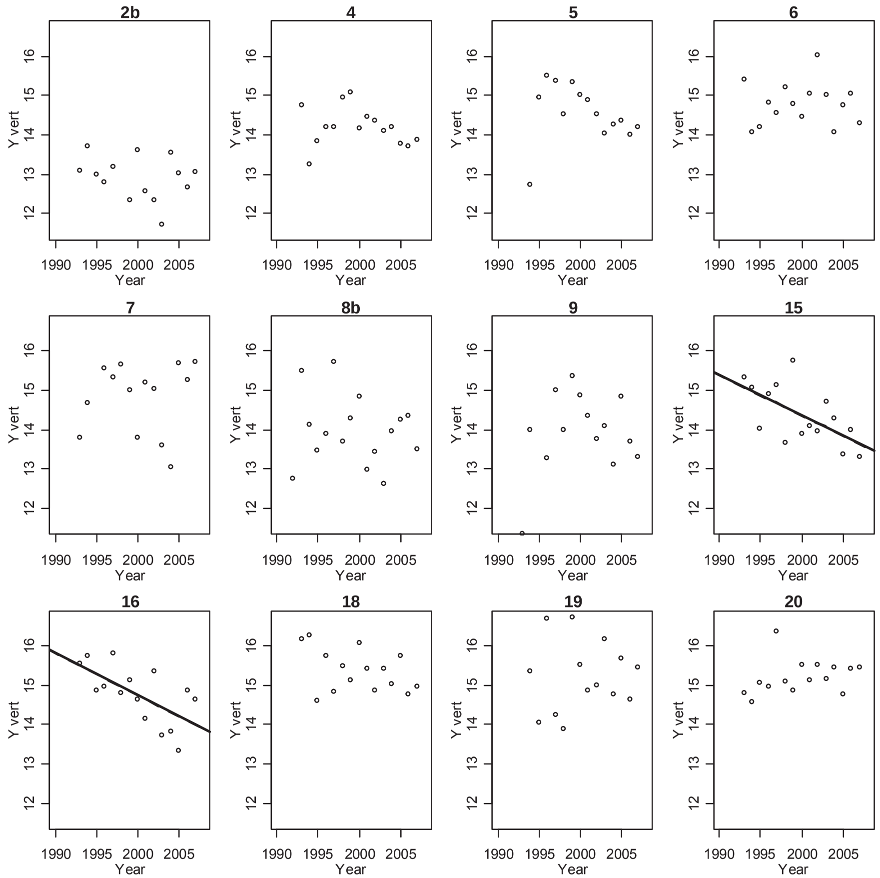


Figure 113: Plots of the Biomass spectra y vertex for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

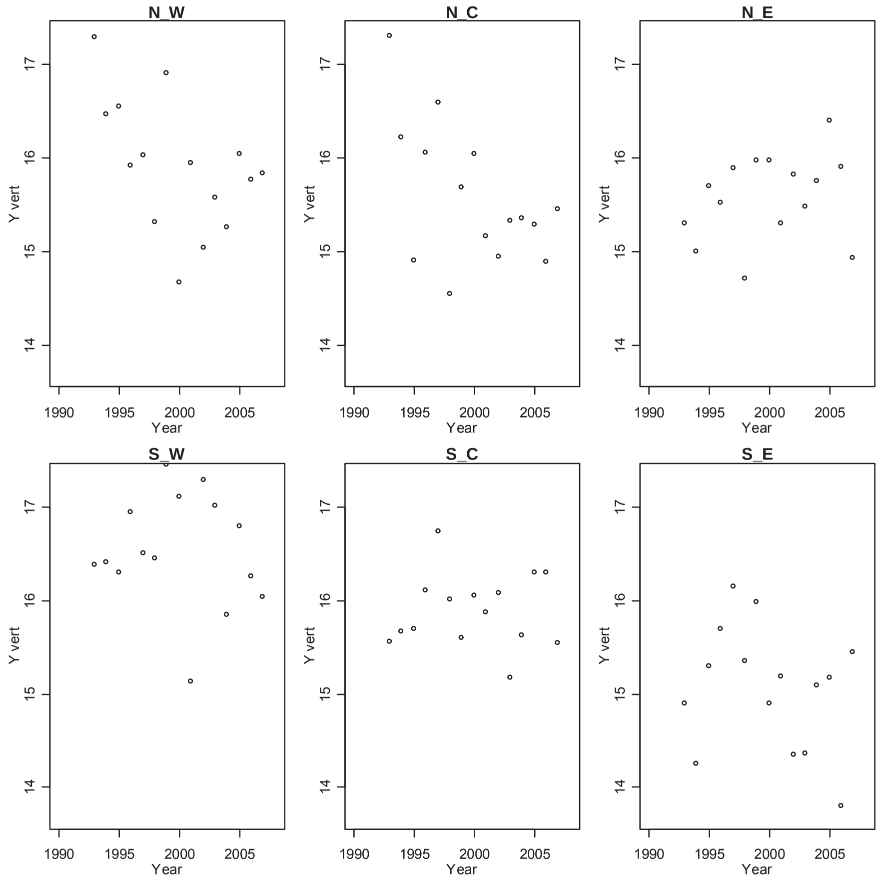


Figure 114: Plots of the Biomass spectra y vertex for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

5.2.5. Diversity spectra

As with the Hauraki Gulf data, preliminary examination of the diversity size spectra for the measured species within the Chatham Rise data set (Figures 115 & 116) suggests that fitting a linear relationship to the data above a standard length may not be the most appropriate approach (the diversity spectra were generally bimodal).

As described for the Hauraki Gulf dataset, an alternative approach comparing the cumulative relative diversity has been considered. Plots of the cumulative relative diversity for each stratum and larger area are shown in Figures 117 & 118. The diversity spectra have been compared using the same Kolmogerov-Smirnov approach as the trophic spectra.

MDS plots of the pairwise P values are shown for the survey strata in Figure 119, and for the larger areas in Figure 120. The plots are quite scattered, but while some strata or areas show no evidence of any trend over time (e.g., SC Rise 600–800 (4) or the larger NE area), others show some suggestion that the early years are separated from the later years (e.g., NE and SW Reserve 400–600 (8b and 15), S Mernoo 400–600 (16) or W Reserve 200–400 (19)), and the diversity spectra may have changed over time.

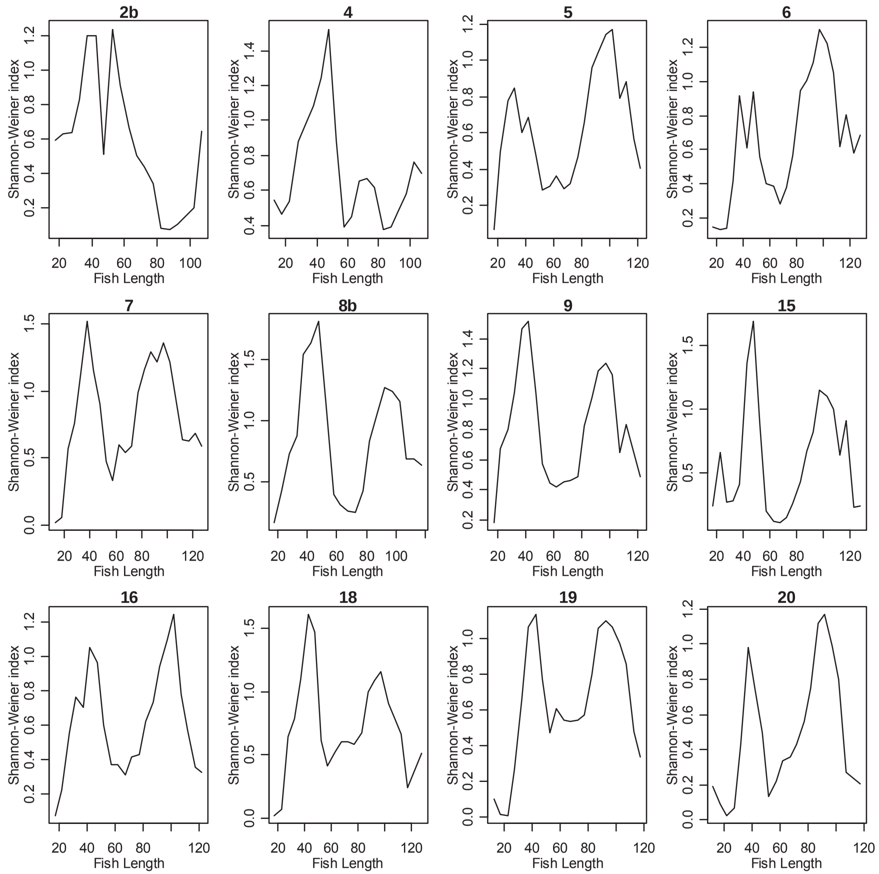


Figure 115: Plot of diversity (Shannon-Weiner index) size spectra for survey stratum (all years).

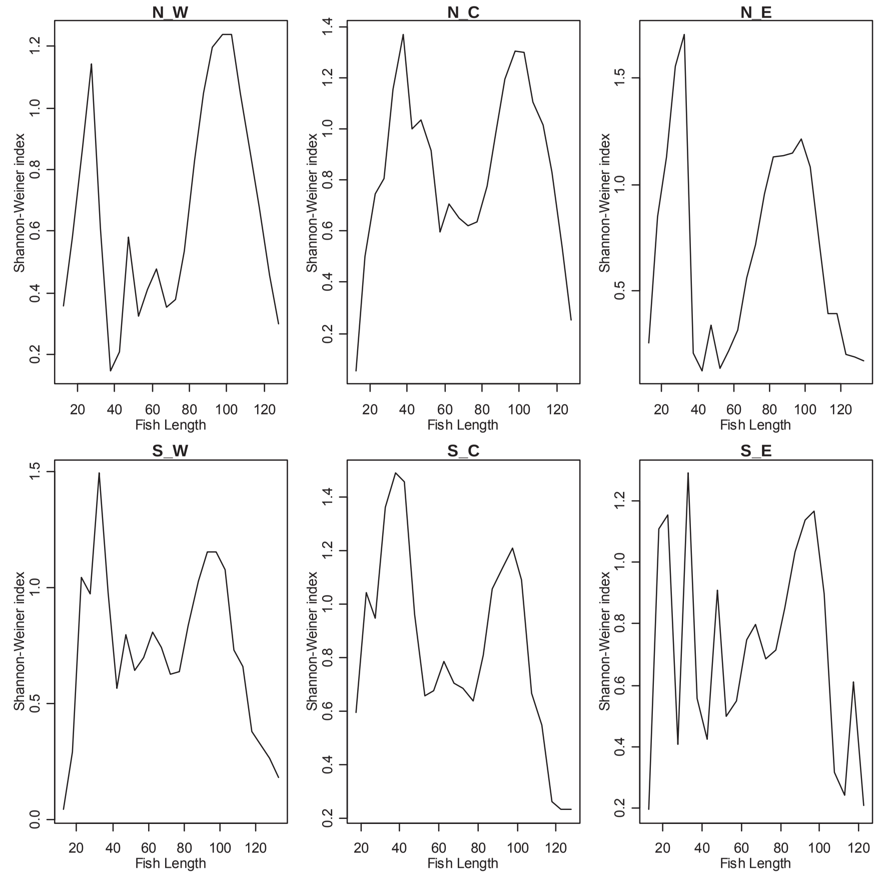


Figure 116: Plot of diversity (Shannon-Weiner index) size spectra for larger region stratum (all years).

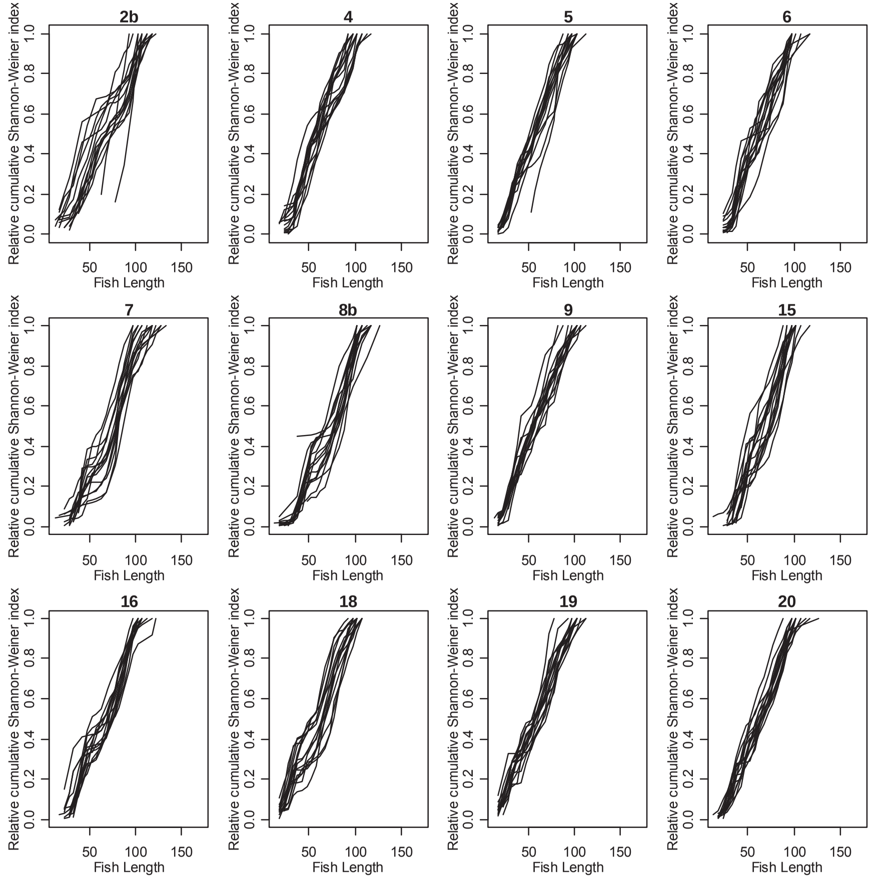


Figure 117: Plots of cumulative diversity spectra for each survey stratum.

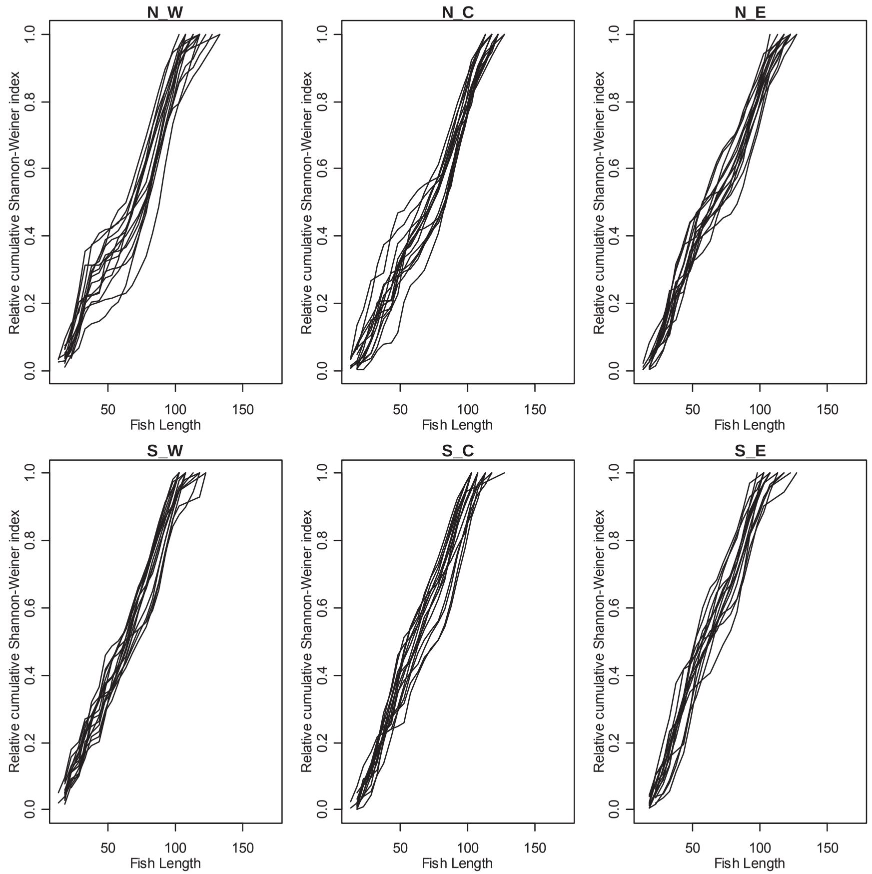


Figure 118: Plots of cumulative diversity spectra for each larger region stratum.

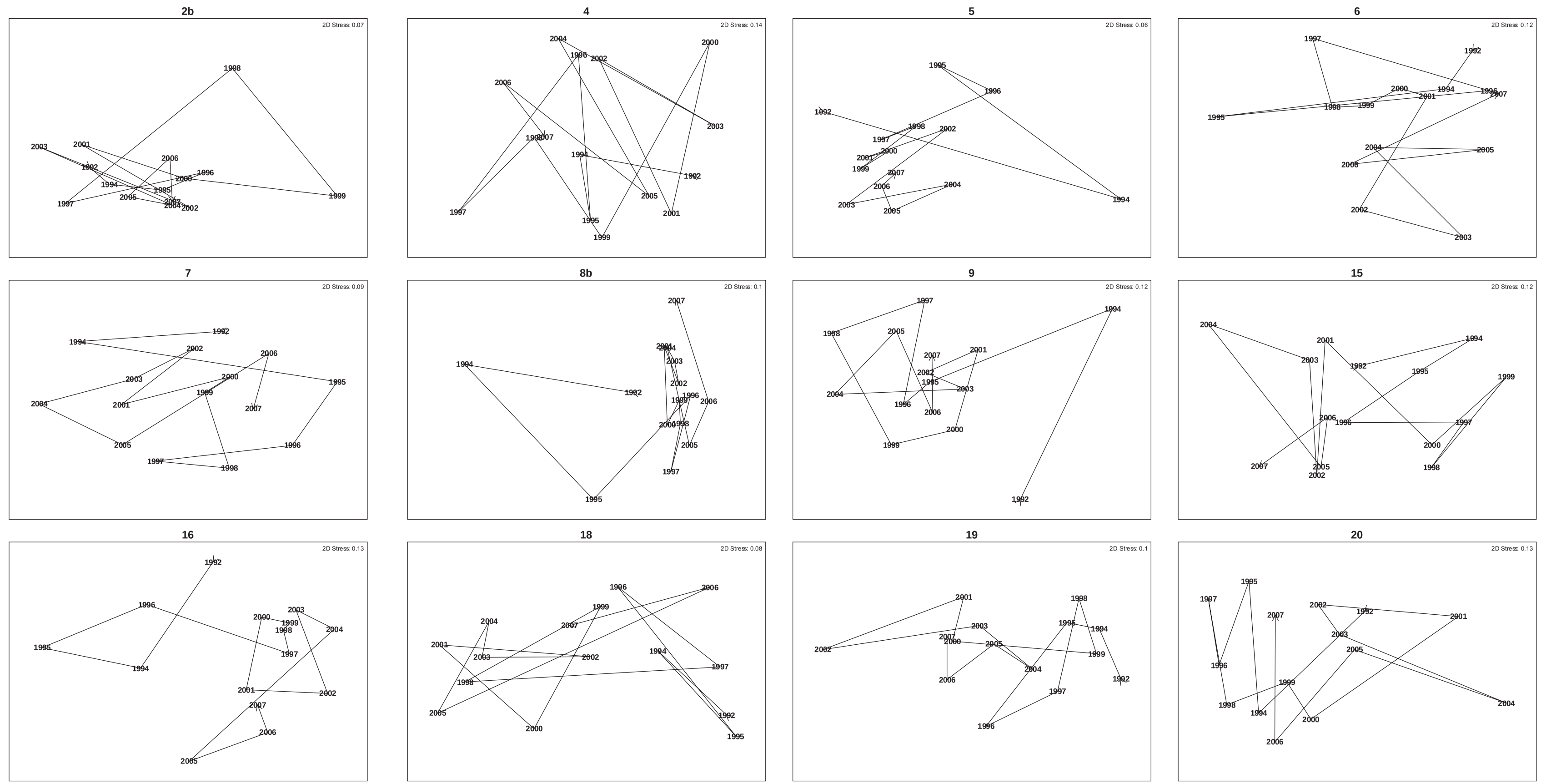


Figure 119: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of diversity spectra over time for each of the survey stratum.

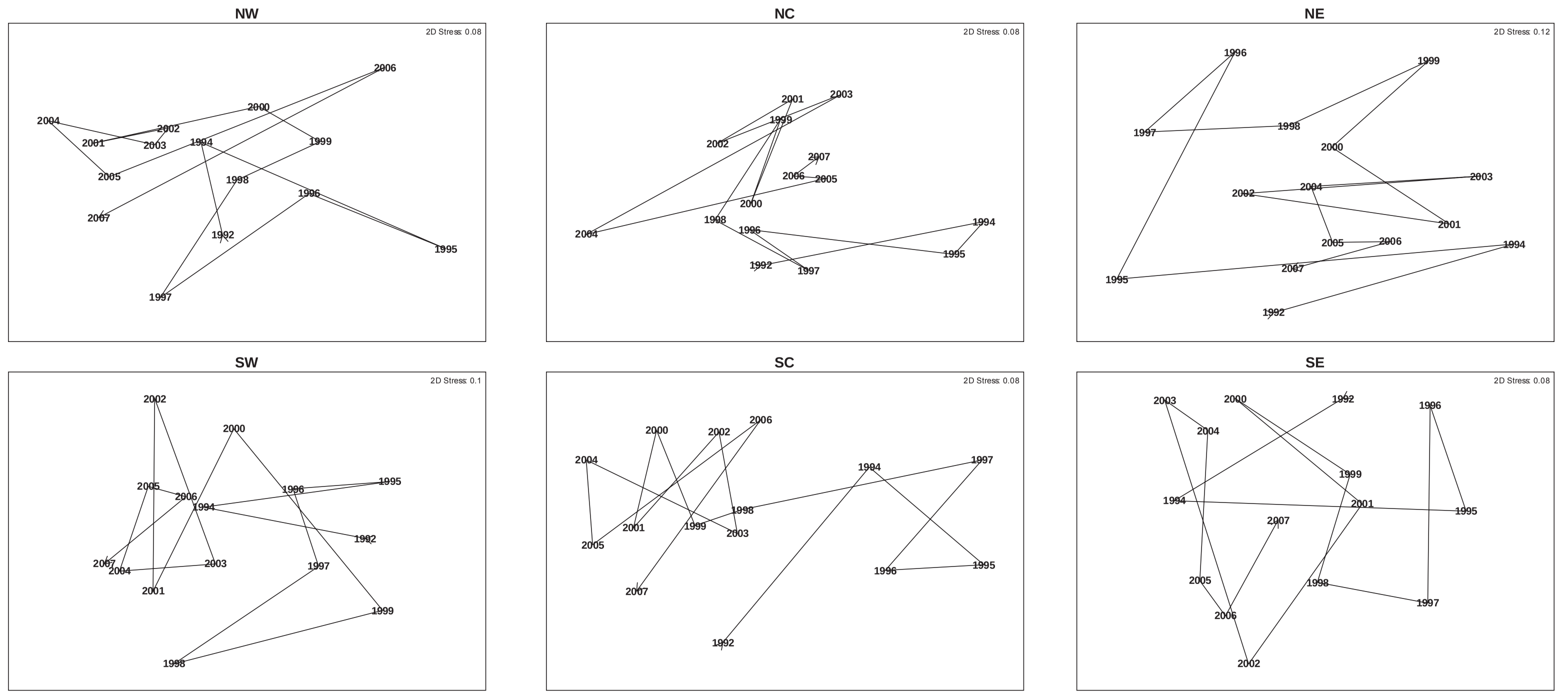


Figure 120: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of diversity spectra over time for each of the larger areas.

5.3. Effort patterns

Trends in the cumulative area fished (as extracted from the BEN200601 database, based on TCEPR data) as a proportion of the strata area for survey strata and the larger sediment/depth areas are shown in **Error! Reference source not found.**. For this offshore fishery, vessels have been required to use the TCEPR system from its onset, and data goes back to the 1989–90 fishing year. As might be expected over such a large area, the level of fishing has varied markedly, with the western end of the Rise (which is closest to land) being fished most often. For the most intensively fished of the 12 strata examined, averaged over the full effort series, the ratios of cumulative area fished:strata area were 1.31, 0.90, 0.48, 0.36, 0.34, 0.22, 0.16, and 0.13 for W and S Mernoo 400–600 (7 and 16), SW Reserve 400–600 (15), Mernoo 200–400 (18), NE Reserve 400–600 (8b), SC and SW Rise 600–800 (4and 6), and W Reserve 200–400 (19), respectively. The other strata had on average less than 10% of their area fished.

For the larger areas, the most intensively fished area appeared to be the NW (average ratio 1990–2005 of 0.70), followed by the SW (0.42), NC (0.30), SC (0.25), and SE (0.19) with the NE very lightly fished (0.07).

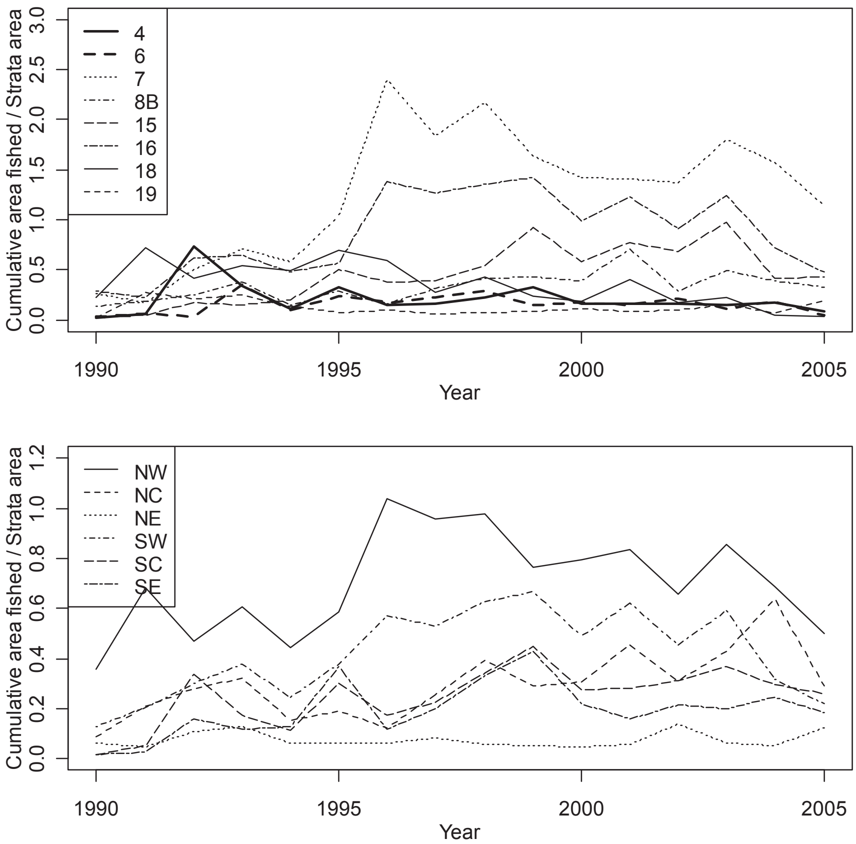


Figure 121: Plots of Cumulative area fished:Total strata area as estimated from data extracted from BEN200601 database for Chatham Rise survey strata (upper plot) and larger areas (lower plot). Survey strata not shown in the upper plot had low average effort recorded (average <10% of strata area).

Table 25: Slope of linear relationships of parameters against year for each survey strata and larger areas. To aid visualisation, significant relationships are in coloured font, with positive trends over time in green and negative trends over time in red. PT – proportion threatened; PLR – proportion with low or very low resilience; N1 – Hill's N1; N2 – Hill's N2; S – Species richness; d – Margarlef's d; J – Pielou's evenness; H – Shannon-Weiner diversity; Dist – average taxonomic distinctiveness; v Dist – variation in taxonomic distinctiveness; Pisc – Pisciverous:Total catch ratio; Dem – Demersal:Total catch ratio; TL – average trophic level; Med – median length; L95 – L95 length; PL – proportion of large fish; W – W statistic; SS – size spectra slope; SI – size spectra intercept; Curv – biomass spectra curvature; Xvert – biomass spectra x vertex; Yvert – biomass spectra y vertex.

		Life history based					Diversity based								Size based								
Stratum	Name	PT	PLR	Pisc	Dem	TL	N1	N2	S	d	J	H	Dist	v Dist	Med	L95	PL	W	SS	SI	Curv	Xvert	Yvert
2b	NE Rise 600–800	0.0072	0.0109	-0.0053	-0.0036	-0.0073	0.0545	0.0248	-0.0176	0.0360	0.0012	0.0049	0.0287	1.6300	-0.3696	**0.4727**	-0.0073	0.0007	0.0015	0.0192	-0.0022	-0.0070	-0.0175
4	SC Rise 600–800	0.0045	**0.0303**	**-0.0250**	**-0.0235**	**-0.0256**	-0.1193	-0.1314	-0.3500	-0.0395	-0.0044	-0.0204	0.0325	-0.0043	-0.1500	**-2.4929**	-0.0112	0.0004	0.0013	-0.0621	-0.0170	-0.0201	-0.0203
5	W Chatham 200–400	**0.0159**	0.0132	**-0.0232**	0.0159	**-0.0169**	0.2399	0.2043	-0.6044	-0.0589	**0.0131**	0.0357	-0.1094	0.5678	-0.5297	-0.1538	**-0.0304**	**0.0099**	-0.0003	-0.0400	0.0023	-0.0088	-0.0320
6	SW Rise 600–800	0.0010	**0.0334**	**-0.0322**	**-0.0197**	**-0.0272**	-0.0931	-0.0736	-0.0868	-0.0026	-0.0067	-0.0240	-0.0142	**4.8909**	-0.1286	**-2.5071**	-0.0084	-0.0030	0.0006	**-0.0652**	-0.0317	-0.0023	0.0041
7	W Mernoo 400–600	**0.0106**	**0.0222**	**-0.0123**	**-0.0063**	**-0.0111**	**0.4069**	0.2395	0.1147	0.0670	**0.0196**	**0.0755**	**0.0953**	1.3723	-0.3464	-0.1761	**-0.0109**	-0.0008	-0.0002	-0.0225	-0.0297	0.3177	-0.1405
8b	NE Reserve 400–600	**0.0109**	**0.0253**	**-0.0145**	-0.0045	**-0.0143**	**0.4428**	**0.2381**	0.5426	**0.1175**	**0.0201**	**0.0803**	-0.0737	0.7837	-0.2500	-0.0132	**-0.0145**	-0.0039	0.0007	-0.0067	0.0055	-0.0100	-0.0288
9	N Chatham 200–400	**0.0173**	-0.0003	-0.0228	0.0052	-0.0195	0.1760	0.1788	0.1368	0.0258	0.0047	0.0196	0.1075	1.2874	-0.3362	-0.5930	-0.0172	0.0081	-0.0023	-0.0009	**0.0377**	0.0160	0.0452
15	SW Reserve 400–600	0.0062	**0.0171**	**-0.0169**	-0.0056	**-0.0175**	**0.4123**	**0.3013**	-0.4912	-0.0393	**0.0208**	**0.0690**	0.0074	**2.4368**	0.3250	0.1964	-0.0117	-0.0019	**0.0029**	-0.0473	-0.0309	0.0281	**-0.1024**
16	S Mernoo 400–600	**0.0062**	**0.0191**	**-0.0110**	-0.0037	**-0.0137**	**0.4264**	**0.2739**	-0.5500	-0.0295	**0.0225**	**0.0771**	0.0506	**3.2063**	-0.0393	0.0679	**-0.0079**	-0.0051	0.0012	**-0.0663**	-0.0088	0.0095	**-0.1071**
18	Mernoo 200–400	0.0067	0.0055	-0.0156	-0.0078	**-0.0148**	0.1722	0.1075	-0.5941	-0.0581	**0.0104**	0.0358	**-0.1272**	0.7914	0.3857	-0.1679	**-0.0063**	-0.0039	-0.0005	**-0.0624**	-0.0147	0.0299	-0.0487
19	W Reserve 200–400	0.0012	0.0021	-0.0133	-0.0052	-0.0104	0.0446	0.0381	-0.2603	-0.0325	0.0032	0.0116	-0.1169	-0.4416	0.3107	**-0.7607**	0.0094	-0.0003	-0.0016	**-0.0927**	-0.0152	0.0039	-0.0319
20	E Reserve 200–400	0.0023	0.0064	-0.0040	-0.0048	-0.0027	0.0509	0.0502	0.1029	0.0092	0.0014	0.0075	0.0730	0.1996	0.1214	-0.3000	-0.0005	0.0022	-0.0013	-0.0017	-0.0081	-0.0039	0.0271
NW		**0.0083**	**0.0168**	**-0.0143**	**-0.0103**	**-0.0132**	**0.5037**	**0.2277**	0.5735	**0.1534**	**0.0171**	**0.0769**	0.0179	1.6361	0.2286	-0.0357	**-0.0081**	**-0.0073**	0.0003	-0.0370	0.0043	0.0222	-0.0804
NC		**0.0088**	**0.0220**	**-0.0110**	**-0.0066**	**-0.0121**	**0.5468**	**0.2996**	0.0353	0.0769	**0.0155**	**0.0664**	0.0619	1.7513	0.5132	0.0985	-0.0098	-0.0027	0.0003	0.0209	0.0099	0.0067	-0.0118
NE		**0.0087**	0.0018	-0.0078	0.0020	-0.0087	0.2386	0.1995	0.3971	0.0953	0.0033	0.0181	0.0564	0.9760	-0.5429	-0.0679	**-0.0176**	0.0008	-0.0008	0.0112	0.0020	-0.0150	0.0272
SW		**0.0105**	**0.0175**	**-0.0228**	-0.0114	**-0.0210**	**0.4185**	**0.2415**	-0.0412	0.0147	**0.0120**	**0.0530**	0.0171	**2.0649**	-0.4321	**-0.6429**	-0.0062	**-0.0052**	-0.0010	**-0.0701**	-0.0135	-0.0049	-0.0154
SC		0.0014	0.0063	-0.0058	0.0021	-0.0058	0.1728	0.1402	-0.3118	-0.0356	0.0060	0.0221	0.0180	0.8336	0.4893	-0.2107	0.0012	0.0010	-0.0012	-0.0187	-0.0019	-0.0088	0.0015
SE		0.0025	**0.0195**	**-0.0249**	-0.0131	**-0.0210**	**0.3438**	**0.2795**	0.1309	0.0236	**0.0111**	**0.0454**	-0.0080	0.9261	**-1.4786**	-0.2143	-0.0143	-0.0005	-0.0002	-0.0112	**0.0101**	-0.0014	-0.0359

5.4. Comparison across indicators and relationship with fishing effort

The slopes of the linear fits for each parameter for each strata are provided in Table 25, with significant trends over time colour coded to aid visualisation. There were markedly more significant trends identified from the Chatham Rise data set than for the Hauraki Gulf. In Table 25 the indicators have been split into life history based (including species-based and trophodynamic indicators), diversity-based (all species based) and size-based indicators. The life history based indicators showed both positive and negative significant trends, but were consistent within indicator. The significant trends for the diversity-based indicators were generally positive, while the significant trends for the size-based indicators were generally negative. The proportion threatened and proportion with low or very low resilience both showed significant positive trends for NE Reserve 400–600 (8b) and W and S Mernoo 400–600 (7 and 16), and for the larger NW, NC, and SW areas. Other strata showed positive trends in both indicators, but not always significantly. The proportion pisciverous and mean trophic level showed significant negative trends in the same strata and areas mentioned above, and W Chatham 200–400 (5), NE and SW Reserve 400–600 (8b and 15) and the SE area. The proportion demersal showed similar patterns, but was less consistently significant. The trophic spectra also showed evidence of change over time for W and S Mernoo 400–600 (7 and 16) and NE and SW Reserve 400–600 (8b and 15), and the larger NW and SW areas.

Of the diversity indicators, Hill's N1 and N2, Pielou's evenness, and the Shannon-Weiner index generally showed similar patterns, and had significant positive trends for W and S Mernoo 400–600 (7 and 16) and NE and SW Reserve 400–600 (8b and 15), and the NW, NC, SW, and SE larger areas. Although a number of significant (mostly negative) relationships were identified for the size-based indicators, there were few consistent patterns with the same groups of indicators showing significant trends for different strata or areas. The diversity spectra showed some distinction between the 1990s and 2000s for SW Reserve 400–600 (15), S Mernoo 400–600 (16), and W Reserve 200–400 (19).

To examine the trends in indicators in relation to fishing effort, the correlation (Spearman rank) between the strata slopes for each parameter (Table 26) and the average ratio of area fished:total strata area (taken as a measure of overall fishing intensity) was examined for both survey strata and the larger sediment/depth areas (Table 26). Statistical significance was examined through comparing observed correlation with distribution of correlations calculated for each parameter with 1000 resampled effort data sets. Correlations were considered significant if the correlation coefficient was outside the 2.5 to 97.5% quantiles of the correlations on the resampled effort data. At the survey strata level there were significant positive correlations between fishing intensity and Pielou's evenness and the Shannon-Weiner index, but a significant negative correlation with the W statistic and the Y vertex of the biomass spectra. Over the larger areas, the same significant correlations were identified between fishing intensity and Pielou's evenness, the Shannon-Weiner index, and the W statistic. Although there were a number of significant (mostly negative) trends identified for size-based indicators over time, the pattern among strata is not significantly correlated with the fishing intensity data.

The distinction between time periods in the trophic and diversity spectra has only been judged "by eye", but those strata and areas showing most evidence of a change between the 1990s and 2000s (particularly for the trophic spectra) were the areas with the highest measures of fishing intensity, and this approach may warrant further investigation as an indicator.

Table 26: Summary of Spearman rank correlation tests between slopes of trends in indicator parameters over time and average ratio of area fished:strata area. Correlation coefficient provided for rank correlations over survey strata and larger areas. Significant correlations (on basis of effort bootstraps) are in bold red (negative) and green (positive) font.

	Survey strata	Larger areas
PT	-0.007	0.3143
PLR	0.420	0.3143
N1	0.497	0.6571
N2	0.587	0.2000
S	-0.140	0.0286
d	-0.014	0.1429
J	**0.629**	**0.8857**
H	**0.650**	**0.8857**
Dist	0.035	-0.1429
V Dist	0.350	0.6000
Pisc	-0.063	-0.2571
Dem	-0.462	-0.2571
TL	-0.203	-0.3479
Med	0.336	0.4857
L95	0.119	0.1429
PL	-0.098	0.6000
W	**-0.753**	**-0.8286**
SS	0.294	0.3189
SI	-0.462	-0.6000
Curv	-0.490	-0.2000
Xvert	0.538	0.7143
Yvert	**-0.776**	-0.6571

6. SOUTHLAND AND SUB-ANTARCTIC SURVEYS

Twelve spring/summer (November–December) surveys have been conducted in the Southland and Sub-Antarctic region from 1983 to 2005, to monitor relative abundance of hoki, hake, and ling. Since 1991 these surveys have been conducted by RV *Tangaroa*, but before this, surveys in 1983 (*Shinkai Maru*) and 1989 and 1990 (*Amaltal Explorer*) were conducted by other vessels. These surveys are not included in the fishery-independent abundance indices due to concerns over gear and vessel effects, and have been excluded from this analysis for the same reasons, and concerns over changes in the level of taxonomic identification for some species groups in the early years. The core area of the survey has remained virtually unchanged over the time series, and all stations have been allocated to strata as defined in the most recent surveys (Figure 122). Strata are defined on the basis of location and depth. The data have also been examined over four larger areas (combinations of survey strata) following discussions with NIWA scientists involved in the survey (R. O'Driscoll, pers.comm.; Figure 123). Stratum region, depth ranges, and numbers of stations by strata and year are shown in Tables 27 & 28. Stratum names used in the text, tables, and Figure 122 have been derived from the region and depth information (O'Driscoll & Bagley 2006).

Table 27: Numbers of stations by survey stratum for each year. Numbers may not sum to station total in Error! Reference source not found. **as some stations are outside the standard strata.**

Stratum	Region	Depth (m)	1983	1989	1990	1991	1992	1993	2000	2001	2002	2003	2004	2005	Total
1	Puysegur Bank	300–600	0	3	4	7	3	3	4	4	6	4	9	5	52
2	Puysegur Bank	600–800	0	2	2	3	4	4	4	4	5	4	4	6	42
3a	Stewart/Snares	300–600	8	0	2	5	5	6	4	3	5	3	3	3	47
3b	Stewart/Snares	300–600	2	0	1	3	0	1	5	3	3	3	3	4	28
4	Stewart/Snares	600–800	11	7	10	9	14	11	5	6	5	3	5	5	91
5a	Snares/Auckland	600–800	0	2	1	2	1	1	8	5	5	3	4	7	39
5b	Snares/Auckland	600–800	4	0	2	2	4	5	4	3	3	3	4	4	38
6	Auckland Shelf	300–600	12	6	8	8	8	6	5	5	7	4	4	4	77
7	Auckland Shelf	600–800	4	3	8	4	8	5	3	3	4	3	3	2	50
8	Auckland Shelf	600–800	10	7	13	14	16	12	8	8	5	3	5	6	107
9	N Campbell Is	300–600	16	13	14	15	15	12	9	8	9	9	10	8	138
10	S Campbell Is	600–800	4	5	12	11	8	9	5	4	3	3	3	3	70
11	Pukaki Rise	600–800	8	6	13	9	8	7	5	4	4	4	3	3	74
12	Pukaki Rise	300–600	22	21	20	22	21	14	5	10	8	8	7	6	164
13	Campbell Plat.	300–600	16	10	18	12	11	10	5	6	5	4	4	4	105
14	Campbell Plat.	300–600	14	11	13	14	16	17	5	5	4	3	4	2	108
15	Campbell Plat.	600–800	8	7	8	9	7	7	3	4	4	5	3	4	69
25	Puysegur Bank	800–1000	0	1	5	4	5	4	7	7	9	5	6	6	59
26	SW Campbell Is	800–1000	2	0	3	0	0	0	3	4	3	0	0	3	18
27	Pukaki Rise	800–1000	2	1	3	0	0	0	5	6	5	4	3	4	33
28	Stewart/Snares	800–1000	0	0	6	0	0	0	4	4	3	3	3	5	28
other			42	20	11	1	6	4	1	0	0	1	0	2	88
Total			185	125	177	154	160	138	107	106	105	82	90	96	1525

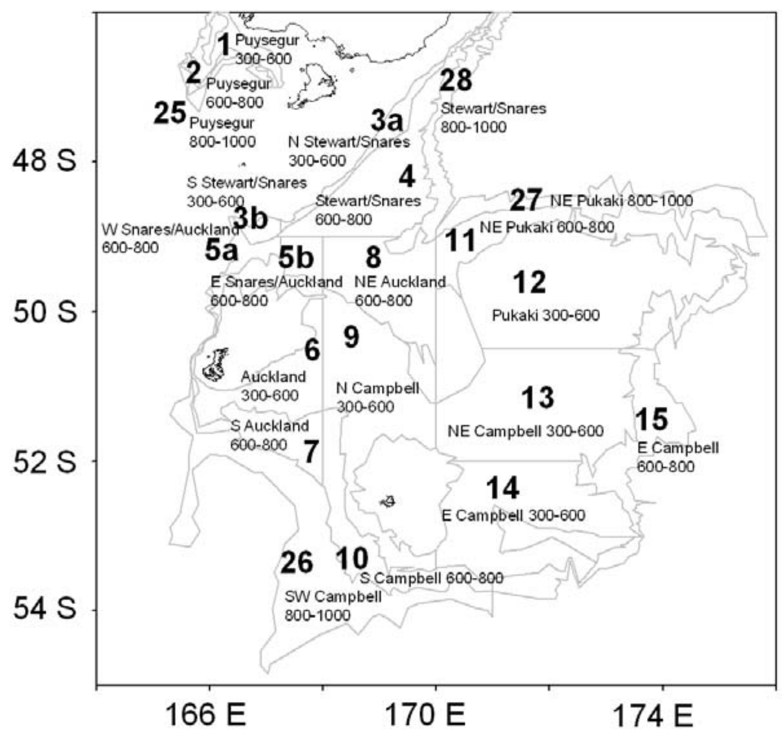


Figure 122: Survey area and stratum boundaries for Sub-Antarctic surveys.

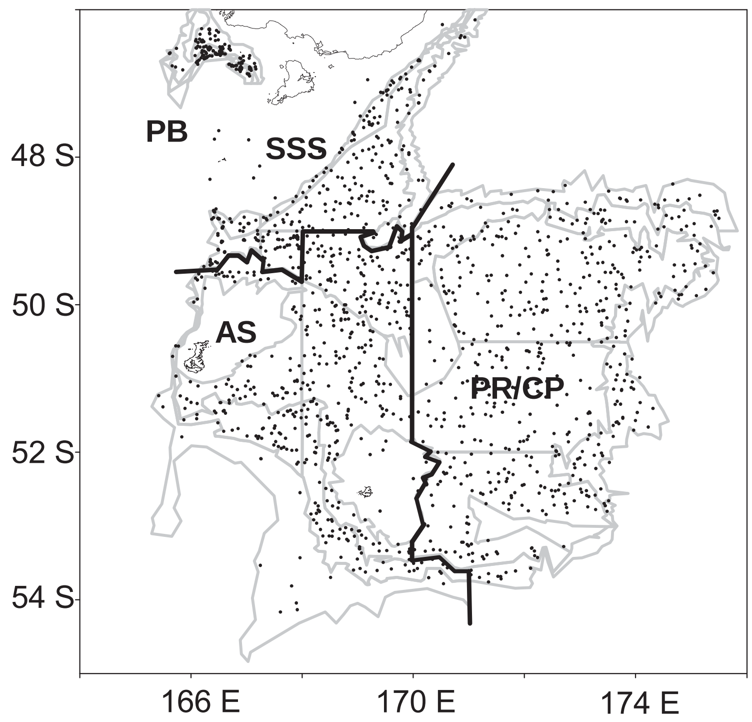


Figure 123: Larger regions defined on basis of fish distribution (R. O'Driscoll, pers comm.). PB – Puysegur Bank; SSS – Stewart Snares Shelf; AS – Auckland Is Shelf; PR/CP – Pukaki Rise & Campbell Plateau.

Table 28: Numbers of stations by larger region strata for each year. PB – Puysegur Bank; SSS – Stewart Snares Shelf; AS – Auckland Is Shelf; PR/CP – Pukaki Rise & Campbell Plateau.

	1983	1989	1990	1991	1992	1993	2000	2001	2002	2003	2004	2005	Total
other	42	20	11	1	6	4	1	0	0	1	0	2	88
AS	48	34	58	52	55	44	33	32	31	22	25	26	460
PB	0	6	11	14	12	11	15	15	20	13	19	17	153
PR/CP	70	56	75	66	63	55	28	35	30	28	24	23	553
SSS	25	9	22	21	24	24	30	24	24	18	22	28	271
Total	185	125	177	154	160	138	107	106	105	82	90	96	1525

The full survey time series of 12 voyages included 1525 stations, listing 408 species. Considering only the nine RV *Tangaroa* voyages, 1037 stations were extracted (where gear performance was considered suitable), listing 172 species of fish or squid (excluding mesopelagics). For each station, numbers measured, and weight caught by species were examined. Not all species were measured on all occasions, but when a species was measured a weight was also recorded. Catch weights and numbers were standardised to a swept area of 1 km^2, using door spread data collected for each tow.

For the catch weight by station data set, all 172 fish and squid species were included. Diet, mean trophic level, and environment (i.e., demersal, pelagic, etc) for each species (or closely related species) were also recorded from the FishBase web site. IUCN Red List status and the FishBase web site Resilience measure were taken as levels of concern in terms of endangered species. Resilience is based on the minimum population doubling time (on the basis of estimates of growth rate, age at maturity and fecundity), and is split into four categories (High – less than 1.4 years minimum population doubling time; Medium - 1.4–4.4 years; Low – 4.5–14 years; Very low - over 14 years). Life history characteristics, including length weight parameters, habitat, feeding type, Red List and resilience status, trophic level and taxonomy are provided by species in Appendix 1.

For the species numbers at length data set, 10 key species of fish were selected, being considered to be appropriately sampled by the gear and consistently measured. For these key species, if a station had a weight recorded but no numbers at length, then the station was excluded from the size-based analysis. Excluding stations where these key species were caught but not measured left 853 stations for analysis. Weight at length for these species (for biomass size spectra) was estimated from length weight relationships either taken from the MFish *rdb* database, or the FishBase web site (http://filaman.ifm-geomar.de/home.htm) (Froese & Pauly 2000).

The various indicators were calculated and analysed at the stratum level, each tow within a stratum being weighted according to its catch. Data examined at the individual tow level tended to be very variable, and giving each tow equal weighting was not considered appropriate given the variability in catches (even within strata). Levels of sampling vary between strata, and stratum 26 was excluded from the analysis at the stratum level.

6.1. Analysis of catch weight by station

6.1.1. Species based indicators

6.1.1.1. Indicator / endangered species

Using the IUCN Red List, Indicator species were taken as those listed within the threatened categories of vulnerable, near threatened, or of less concern. Species included a range of sharks and rays and some chimaeras. The combined weight of these species was calculated for each tow, and examined as a proportion of total catch at the stratum level.

At the scale of the survey strata, significant positive trends in the proportion of threatened species were identified for the Pukaki 300–600 (12), E Campbell 300–600 (14), and S Campbell 600–800 (10) strata (see Figures 125 & 126 and Table 29). Over the larger areas, positive trends were identified for the SSS and AS areas.

Table 29: Slope and P value for linear regressions for each survey strata of ratios of proportion threatened (left) and proportion with low or very low resilience (right) on year. Proportions were arcsin square root transformed. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		Proportion threatened		Prop. L/VL resilience	
Stratum	Name	slope	P	slope	P
1	Puysegur 300–600	-0.0038	0.591	0.0049	0.642
2	Puysegur 600–800	0.0144	0.227	0.0017	0.779
3a	N Stewart/Snares 300–600	0.0043	0.233	**0.0337**	**0.001**
3b	S Stewart/Snares 300–600	-0.0015	0.833	-0.0192	0.193
4	Stewart/Snares 600–800	0.0060	0.337	**0.0197**	**0.048**
5a	W Snares/Auckland 600–800	-0.0121	0.268	0.0093	0.361
5b	E Snares/Auckland 600–800	0.0111	0.199	0.0212	0.088
6	Auckland 300–600	-0.0002	0.958	0.0009	0.943
7	S Auckland 600–800	0.0003	0.940	**0.0190**	**0.021**
8	NE Auckland 600–800	0.0099	0.122	0.0134	0.084
9	N Campbell 300–600	0.0093	0.058	**0.0258**	**0.010**
10	S Campbell 600–800	**0.0079**	**0.039**	**0.0245**	**0.015**
11	NE Pukaki 600–800	0.0031	0.590	0.0275	0.117
12	Pukaki 300–600	**0.0115**	**0.036**	**0.0208**	**0.008**
13	NE Campbell 300–600	0.0111	0.101	**0.0268**	**0.017**
14	E Campbell 300–600	**0.0125**	**0.034**	**0.0317**	**0.002**
15	E Campbell 600–800	0.0097	0.204	0.0211	0.050
25	Puysegur 800–1000	0.0017	0.696	**0.0132**	**0.042**
27	NE Pukaki 800–1000	0.0462	0.446	-0.0029	0.935
28	Stewart/Snares 800–1000	0.0018	0.967	0.0085	0.654
PB		0.0017	0.736	0.0049	0.343
SSS		**0.0082**	**0.022**	**0.0213**	**0.001**
AS		**0.0070**	**0.032**	**0.0194**	**0.003**
PR/CP		0.0067	0.164	**0.0399**	**0.001**

Using low or very low resilience as a measure, the data series also showed positive trends in the proportion of catch over time (Figures 127 & 128 and Table 29). At the survey strata level, positive trends were identified for N Stewart/Snares 300–600 (3a), Stewart/Snares 600–800 (4), S Auckland 600–800 (7), N Campbell 300–600 (9), E Campbell 300–600 and 600–800 (14 and 15), S Campbell 600–800 (10), Pukaki 300–600 (12), NE Campbell 300–600 (13), and Puysegur 800–1000 (25), and over the larger areas, for the SSS, AS, and PR/CP areas.

6.1.1.2. Species distribution index

The overall (across all surveys) ranked percentage of stations occupied by each species (Figure 124) declined exponentially from a maximum of 93 % (HOK), with 87 species recorded at less than 1 % of the stations. In examining the distribution of species, analysis was limited to species recorded at more than 10 % of stations (32 species). Below this cut off point, annual as well as average estimates of distribution over the entire survey history are probably underestimated (Fisher & Frank 2004).

For the examination of species distribution, the whole data set (all years) and the *Tangaroa* series (1991–2005) were examined separately.

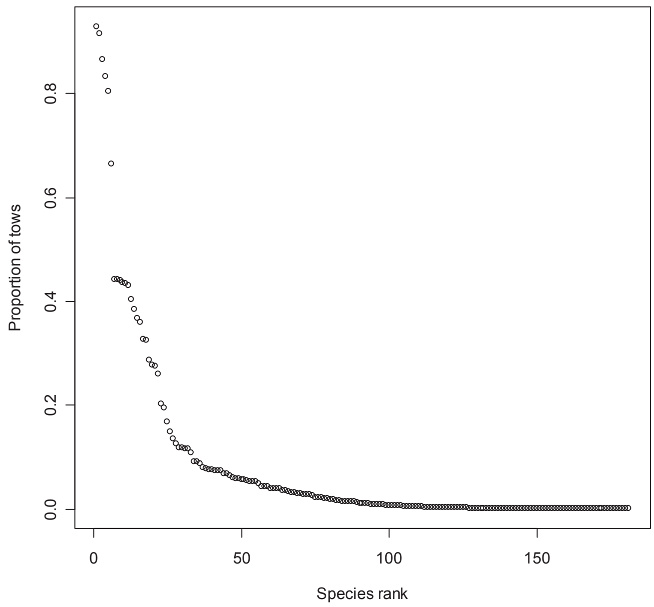


Figure 124: Ranked percentage of surveys occupied by each species.

Plots of the percentage of the survey area over which 90% of the abundance was distributed over time for the main species are shown in Figure 129 and Figure 130. Of this reduced species data set, for the most frequently occurring species, hoki showed a declining trend in the area over which 90% of abundance was distributed (only for years since 1991), while warty squid, southern blue whiting and Baxter's lantern dogfish showed increasing trends. For the slightly less common species, stargazer and shovelnose spiny dogfish showed declining trends, while blackspot rattail showed an increase over time.

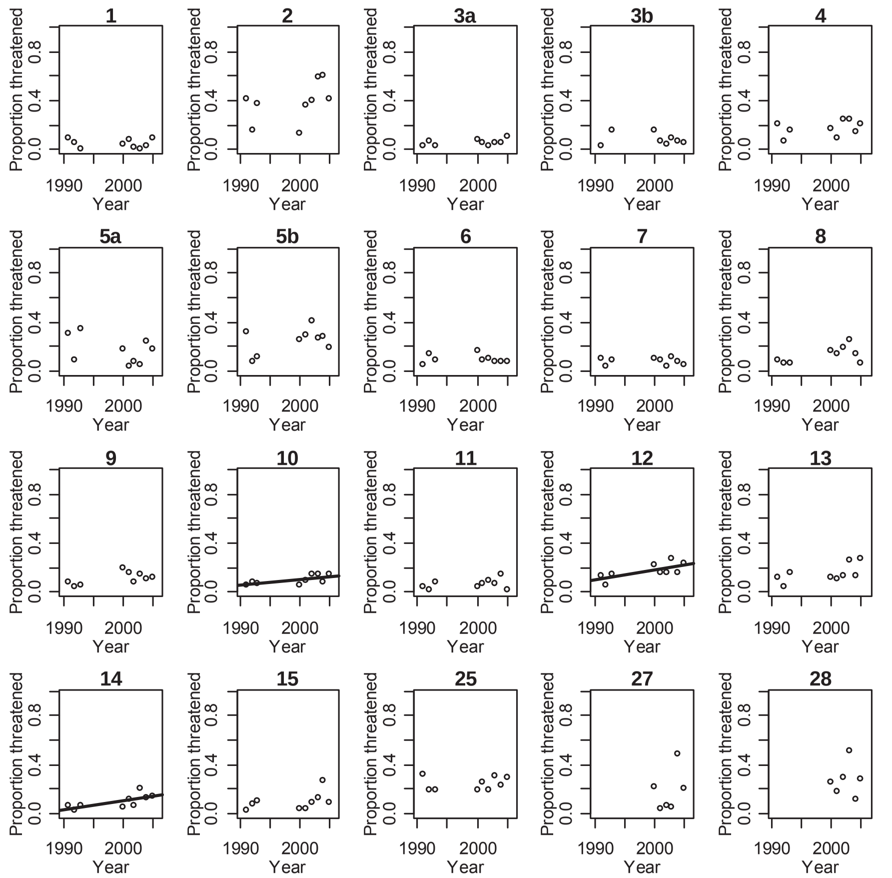


Figure 125: Plots of the proportion threatened (by weight) for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

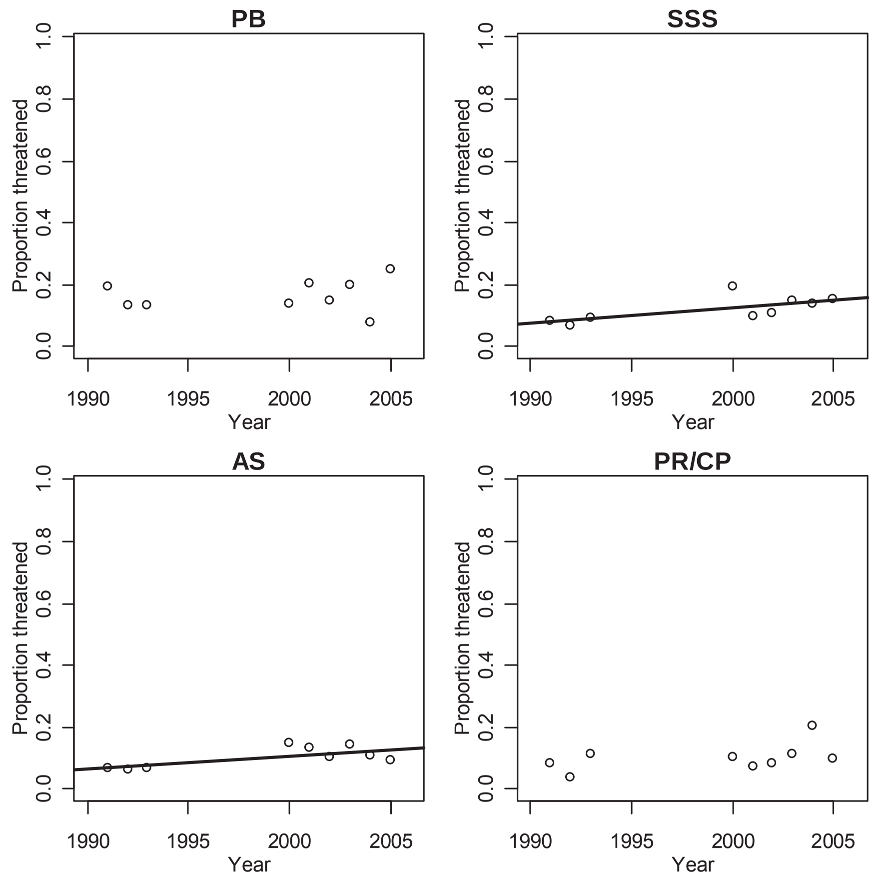


Figure 126: Plots of the proportion threatened (by weight) for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

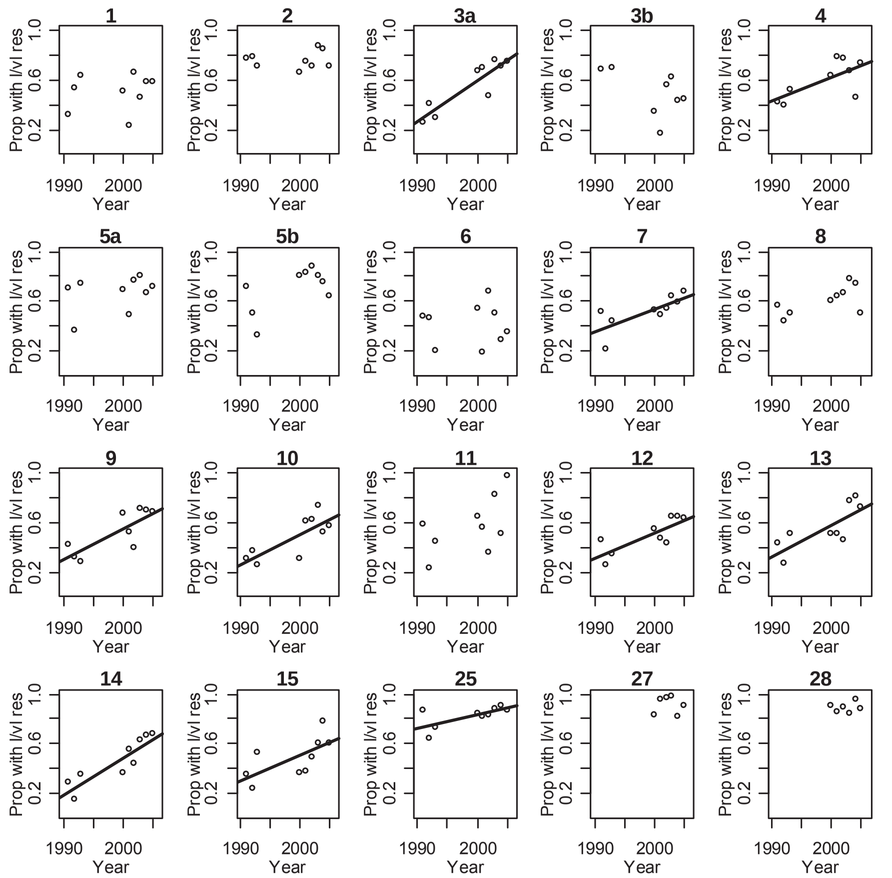


Figure 127: Plots of the proportion with low or very low resilience (by weight) for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

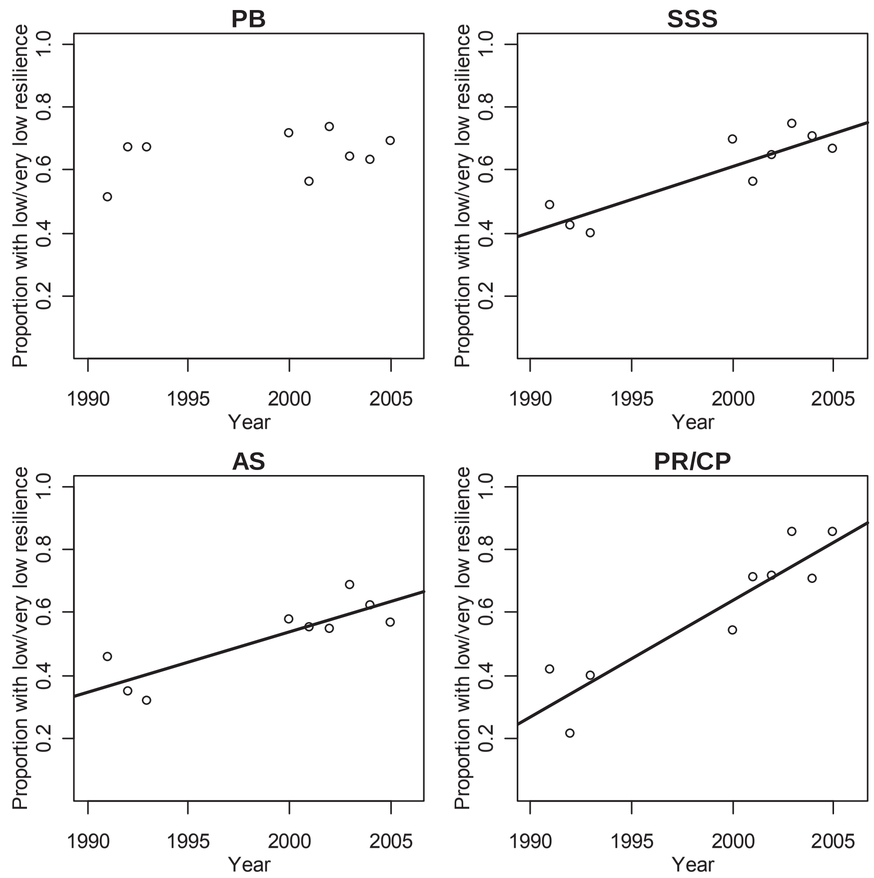


Figure 128: Plots of the roportion with low or very low resilience (by weight) for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

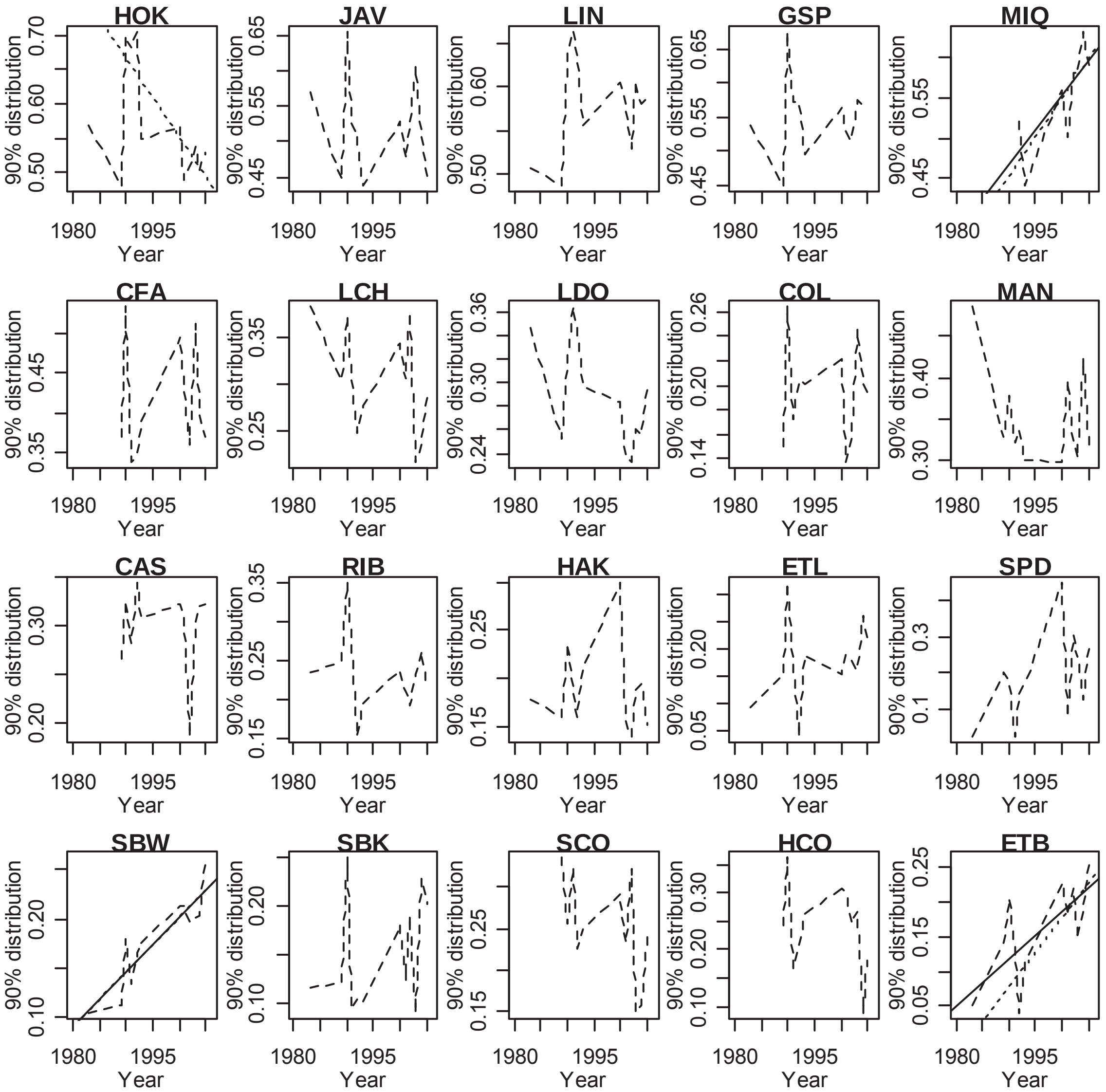


Figure 129: Plots of the percentage of the survey area over which 90% of the abundance (by weight) was distributed for the twenty most frequently caught species. Weighted averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series, and dotted line (where shown) representing a significant linear fit through the data since 1991 (RV *Tangaroa*).

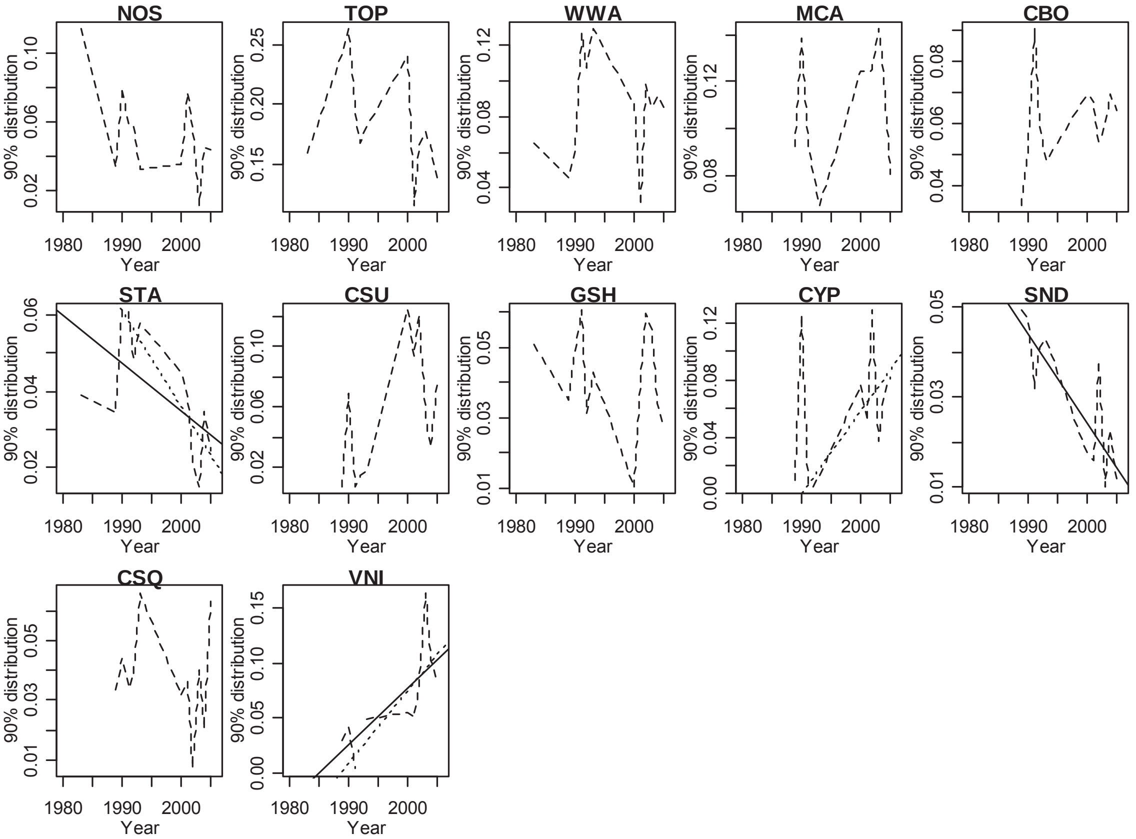


Figure 130: Plots of the percentage of the survey area over which 90% of the abundance (by weight) was distributed for the 21st to 32nd most frequently caught species. Weighted averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series, and dotted line (where shown) representing a significant linear fit through the data since 1991 (RV *Tangaroa*).

6.1.1.3. Diversity indices

As with the analysis of the Hauraki Gulf trawl series, a variety of measures of diversity were calculated on different data sets derived from the species catch weight data. These data sets included a full data set, a data set excluding pelagic species, and a data set including only the key species as used for the numbers at length data set. In addition, the full data set was also aggregated to the family level to see how this affected the results. The indicators are plotted only for the full data set, but trends are examined for each of the sets.

Hill's N1 and N2 diversity indices showed similar patterns (Figures 131–134 and Table 30) with positive trends identified for strata Stewart/Snares 600–800 (4), E Snares/Auckland 600–800 (5b), Auckland 300–600 (6) (almost significant for N1), E Campbell 300–600 and 600–800 (14 and 15), Pukaki 300–600 (12), and S Campbell 600–800 (10), and larger areas SSS and AS.

Species richness and Margarlef's d diversity parameter showed similar patterns, with both positive and negative trends over time (Figures 135–138 and Table 30). At the survey strata level, positive trends were shown by strata S Stewart/Snares 300–600 (3b), W Snares/Auckland 600–800 (5a), and Puyseger 800–1000 (25), while negative trends were shown by E Campbell 300–600 (14) S Campbell 600–800 (10), and S Auckland 600–800 (7) (the trends in Margarlef's d diversity parameter not being significant for 7 or 14). Over the larger areas, both measures showed positive trends for the PB and SSS areas.

Table 30: Slope and P value for linear regressions for each survey strata of N1 (set 1), N2 (set 2), Species Richness (set 3) and Margarlef's d (set 4) on year. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		N1		N2		Species Richness		Margarlef's d	
Stratum	Name	slope	P	slope	P	slope	P	slope	P
1	Puysegur 300–600	0.1397	0.301	0.1017	0.189	0.5583	0.212	0.0580	0.227
2	Puysegur 600–800	0.0236	0.779	-0.0437	0.636	0.4792	0.122	0.0792	0.065
3a	N Stewart/Snares 300–600	0.2107	0.058	0.1541	0.063	-0.0417	0.878	0.0257	0.402
3b	S Stewart/Snares 300–600	0.1767	0.092	0.1032	0.188	**0.7559**	**0.048**	**0.1415**	**0.006**
4	Stewart/Snares 600–800	**0.3191**	**0.003**	**0.2476**	**0.013**	-0.3750	0.282	-0.0414	0.475
5a	W Snares/Auckland 600–800	0.1628	0.348	0.0893	0.555	**1.1792**	**0.001**	**0.1975**	**0.000**
5b	E Snares/Auckland 600–800	**0.2252**	**0.045**	**0.2082**	**0.047**	0.2625	0.206	0.0612	0.063
6	Auckland 300–600	0.1944	0.050	**0.1555**	**0.047**	-0.4792	0.176	-0.0147	0.823
7	S Auckland 600–800	0.2649	0.112	0.2302	0.055	**-0.5958**	**0.024**	-0.0645	0.116
8	NE Auckland 600–800	0.1311	0.121	0.1159	0.076	-0.3583	0.151	-0.0478	0.203
9	N Campbell 300–600	0.2022	0.052	0.1571	0.050	0.0583	0.798	0.0602	0.122
10	S Campbell 600–800	**0.4188**	**0.011**	**0.3356**	**0.007**	**-0.7958**	**0.027**	**-0.0978**	**0.019**
11	NE Pukaki 600–800	-0.0160	0.908	-0.0046	0.960	-0.5292	0.115	-0.0904	0.101
12	Pukaki 300–600	**0.1653**	**0.031**	**0.1725**	**0.015**	**-0.7125**	**0.015**	**-0.0925**	**0.042**
13	NE Campbell 300–600	0.1070	0.248	0.1113	0.091	-0.3083	0.220	-0.0320	0.350
14	E Campbell 300–600	**0.2490**	**0.002**	**0.1967**	**0.001**	**-0.6458**	**0.003**	-0.0595	0.106
15	E Campbell 600–800	**0.3656**	**0.027**	**0.2738**	**0.028**	-0.2250	0.456	0.0041	0.948
25	Puysegur 800–1000	0.3214	0.110	0.1977	0.153	**0.6917**	**0.047**	**0.0984**	**0.027**
27	NE Pukaki 800–1000	0.6769	0.634	0.4664	0.571	-1.5143	0.196	-0.0960	0.756
28	Stewart/Snares 800–1000	-0.1915	0.879	0.0156	0.988	0.0571	0.947	0.0848	0.671
PB		0.2950	0.311	0.1932	0.313	**1.4583**	**0.001**	**0.1817**	**0.001**
SSS		**0.8050**	**0.001**	**0.5003**	**0.005**	**2.2083**	**0.001**	**0.3822**	**0.000**
AS		**0.4443**	**0.004**	**0.2987**	**0.003**	-0.0583	0.914	0.0608	0.424
PR/CP		0.3037	0.051	0.1730	0.150	0.4042	0.358	0.0757	0.181

Pielou's evenness and the Shannon-Weiner diversity parameter showed generally similar patterns, with the only significant trends over time being positive. For Pielou's evenness (Figures 139 & 140 and Table 31), positive trends were identified for Stewart/Snares 600–800 (4), Auckland 300–600 (6), S Auckland 600–800 (7), N Campbell 300–600 (9), E Campbell 300–600 and 600–800 (14 and 15), Pukaki 300–600 (12), NE Campbell 300–600 (13), and S Campbell 600–800 (10), and for the SSS, AS, and PR/CP larger areas. For the Shannon-Weiner diversity parameter (Figures 141 & 142 and Table 31), positive trends were identified for N Stewart/Snares 300–600 (3a), Stewart/Snares 600–800 (4), E Snares/Auckland 600–800 (5b), Auckland 300–600 (6), E Campbell 300–600 and 600–800 (14 and 15), Pukaki 300–600 (12), and S Campbell 600–800 (10), and for the SSS, AS, and PR/CP larger areas.

Average Taxonomic Distinctiveness (Figures 143 & 144 and Table 31) increased over time for Puyseger 800–1000 (25), but declined over time for the larger PR/CP area. Variation in Taxonomic Distinctiveness (Figures 145 & 146 and Table 31) increased over time for Auckland 300–600 (6), NE Auckland 600–800 (8), NE Pukaki 600–800 (11), and NE Campbell 300–600 (13), and for the larger PR/CP area.

6.1.1.4. Comparison across data sets

Comparisons across data sets (full data set, full set at family level, pelagics excluded, key measured species only) have been made on the basis of the direction of any trend over time identified, and whether the trend was significant.

The direction of trends was very consistent between data sets, with the full and pelagics excluded data sets being identical for N1, N2, Margarlef's d, and the Shannon-Weiner index. The family level aggregated set was also identical for the N1 indicator, but showed small differences for the other indicators. The measured species data set was the least consistent. As with the other trawl survey series, the indicators based on taxonomic distinctiveness were the least consistent across data sets.

Significant trends over time were identified for a number of the strata and indicators. For N2 and Pielou's evenness identical patterns of significant positive trends were identified for the full and pelagics excluded data sets. Some of the same significant trends were also identified with the other two data sets, although additional significant trends were also identified with these data. For N1 and the Shannon-Weiner index only significant positive trends were identified, with all four data sets identifying significant trends for NE Auckland 600–800 (8) and E Campbell 300–600 and 600–800 (14 and 15), and the larger AS area, and each data set also showing other significant trends. The pelagics excluded data set was most consistent with the full data set, with the measured species data set being the least consistent. The Species richness and Margarlef's d indicators showed a mixture of positive and negative significant trends, with the pelagics excluded data set being the most consistent with the full data set. Variation in taxonomic distinctiveness showed more consistency between the full and pelagics excluded data set than the others, but less than the other indicators, and the average taxonomic distinctiveness showed least consistency of all the indicators.

Table 31: Slope and P value for linear regressions for each survey stratum of Pielou's evenness (set 1), Shannon-Weiner (set 2), Av Taxonomic distinctiveness (set 3), and Var. Taxonomic distinctiveness (set 4) on year. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		Pielou's evenness		Shannon-Weiner		Av Tax dist		Var. Tax dist	
Strata	Name	slope	P	slope	P	slope	P	slope	P
1	Puysegur 300–600	0.0048	0.506	0.0243	0.334	-0.1332	0.150	-0.4077	0.901
2	Puysegur 600–800	-0.0019	0.541	0.0021	0.818	0.0478	0.726	1.3406	0.593
3a	N Stewart/Snares 300–600	0.0116	0.090	**0.0400**	**0.037**	-0.0536	0.244	-1.1572	0.360
3b	S Stewart/Snares 300–600	0.0014	0.683	0.0311	0.097	-0.3353	0.059	3.8478	0.339
4	Stewart/Snares 600–800	**0.0139**	**0.002**	**0.0419**	**0.003**	0.1070	0.489	1.5194	0.622
5a	W Snares/Auckland 600–800	-0.0029	0.644	0.0215	0.340	-0.0232	0.920	4.8048	0.157
5b	E Snares/Auckland 600–800	0.0081	0.159	**0.0327**	**0.049**	-0.2428	0.084	0.8240	0.633
6	Auckland 300–600	**0.0118**	**0.008**	**0.0306**	**0.040**	-0.1531	0.257	**3.9806**	**0.041**
7	S Auckland 600–800	**0.0169**	**0.035**	0.0417	0.114	-0.2206	0.172	5.7938	0.076
8	NE Auckland 600–800	0.0076	0.071	0.0182	0.122	-0.1531	0.107	**7.2369**	**0.006**
9	N Campbell 300–600	**0.0107**	**0.043**	0.0371	0.056	-0.0998	0.434	2.8550	0.315
10	S Campbell 600–800	**0.0227**	**0.005**	**0.0623**	**0.008**	0.1008	0.533	-4.1018	0.258
11	NE Pukaki 600–800	-0.0001	0.996	-0.0118	0.717	-0.0264	0.882	**6.1259**	**0.036**
12	Pukaki 300–600	**0.0132**	**0.001**	**0.0278**	**0.036**	0.0939	0.328	3.0096	0.289
13	NE Campbell 300–600	**0.0100**	**0.033**	0.0214	0.206	0.1792	0.173	2.4169	0.188
14	E Campbell 300–600	**0.0193**	**0.000**	**0.0438**	**0.001**	0.1039	0.165	**12.8607**	**0.009**
15	E Campbell 600–800	**0.0201**	**0.006**	**0.0584**	**0.021**	-0.0845	0.667	3.6336	0.327
25	Puysegur 800–1000	0.0051	0.140	0.0290	0.071	**0.2198**	**0.016**	-1.6283	0.485
27	NE Pukaki 800–1000	0.0354	0.549	0.1014	0.641	-0.7963	0.118	6.9656	0.528
28	Stewart/Snares 800–1000	-0.0163	0.700	-0.0568	0.711	0.5242	0.290	5.4398	0.733
PB		0.0028	0.660	0.0239	0.372	0.1242	0.092	-1.2690	0.528
SSS		**0.0130**	**0.003**	**0.0743**	**0.001**	0.0166	0.842	0.6046	0.727
AS		**0.0144**	**0.003**	**0.0565**	**0.002**	-0.0483	0.494	1.7655	0.305
PR/CP		**0.0097**	**0.039**	**0.0418**	**0.038**	**-0.1838**	**0.035**	**5.6906**	**0.002**

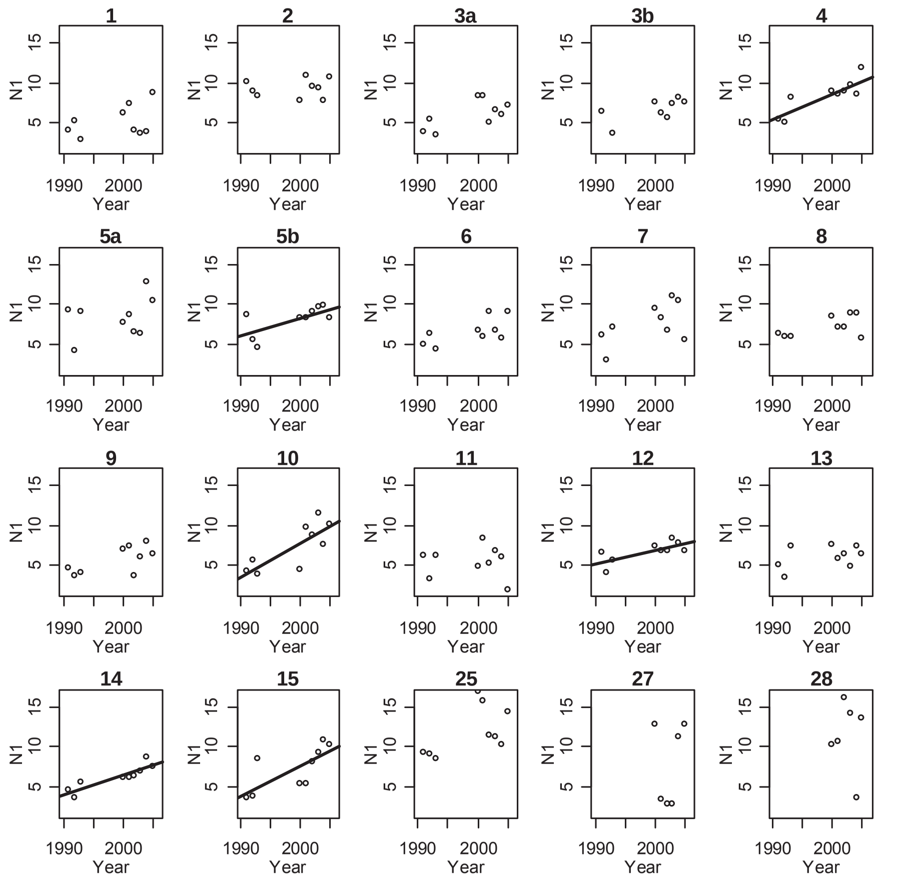


Figure 131: Plots of Hill's N1 diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

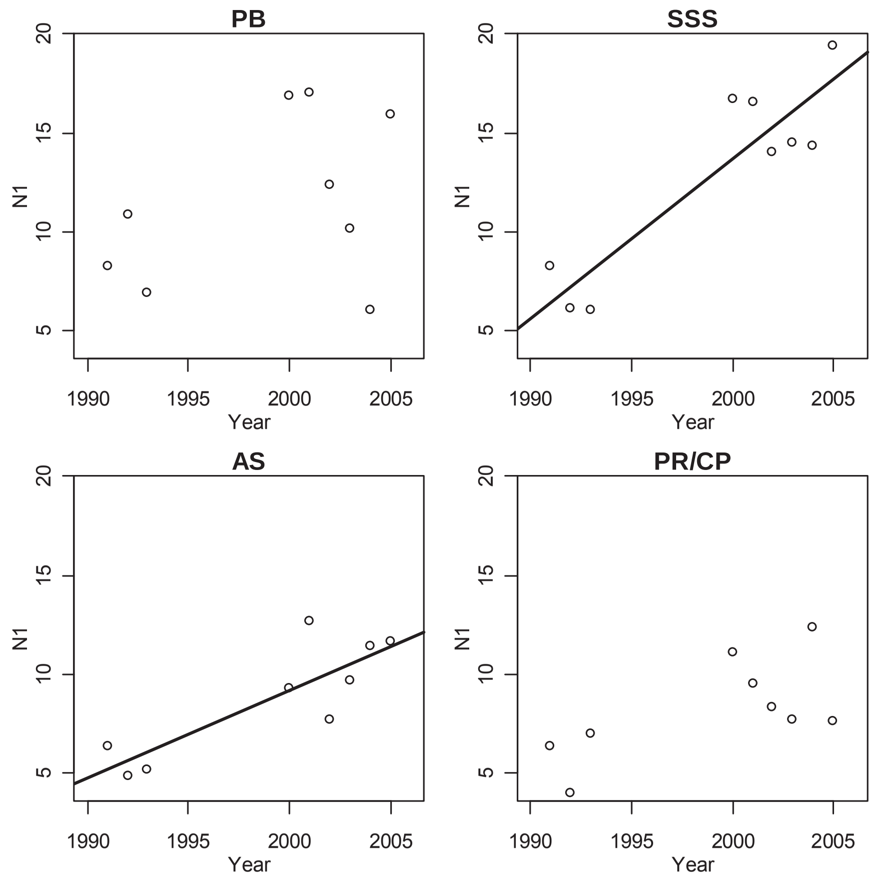


Figure 132: Plots of Hill's N1 diversity parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

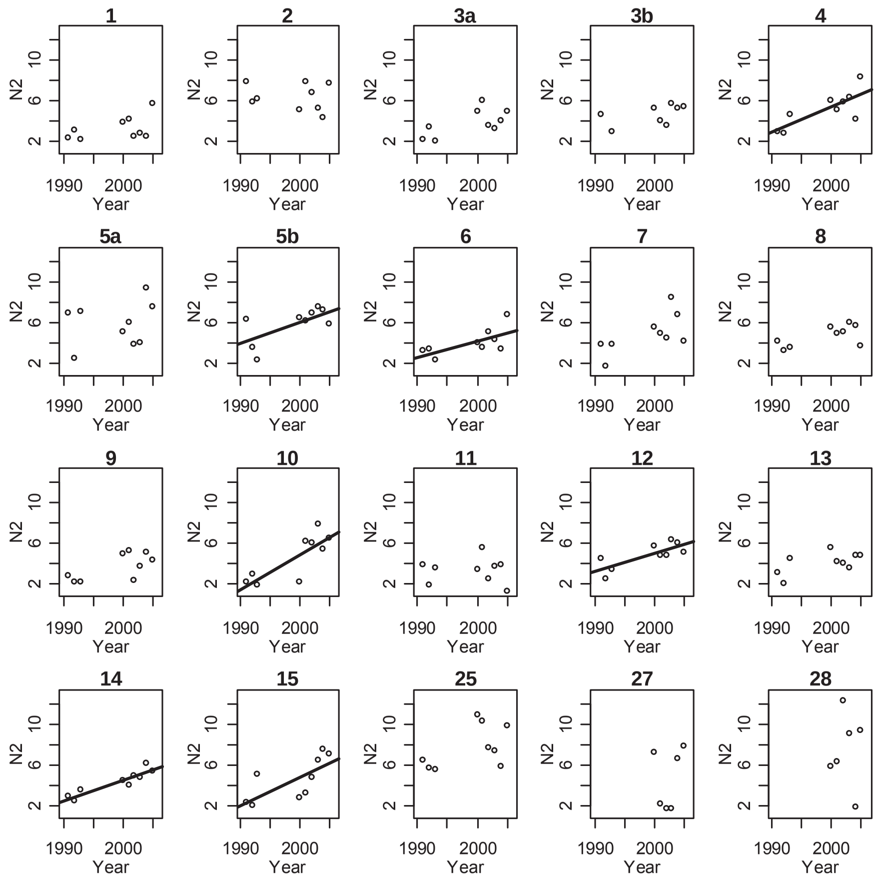


Figure 133: Plots of Hill's N2 diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

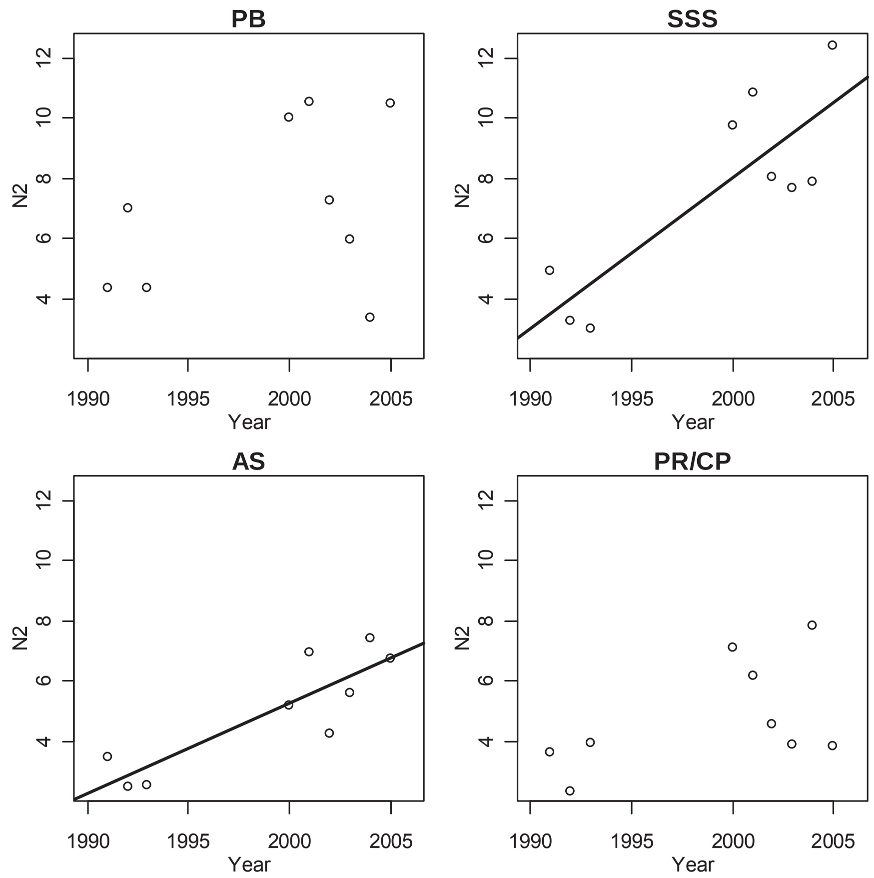


Figure 134: Plots of Hill's N2 diversity parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

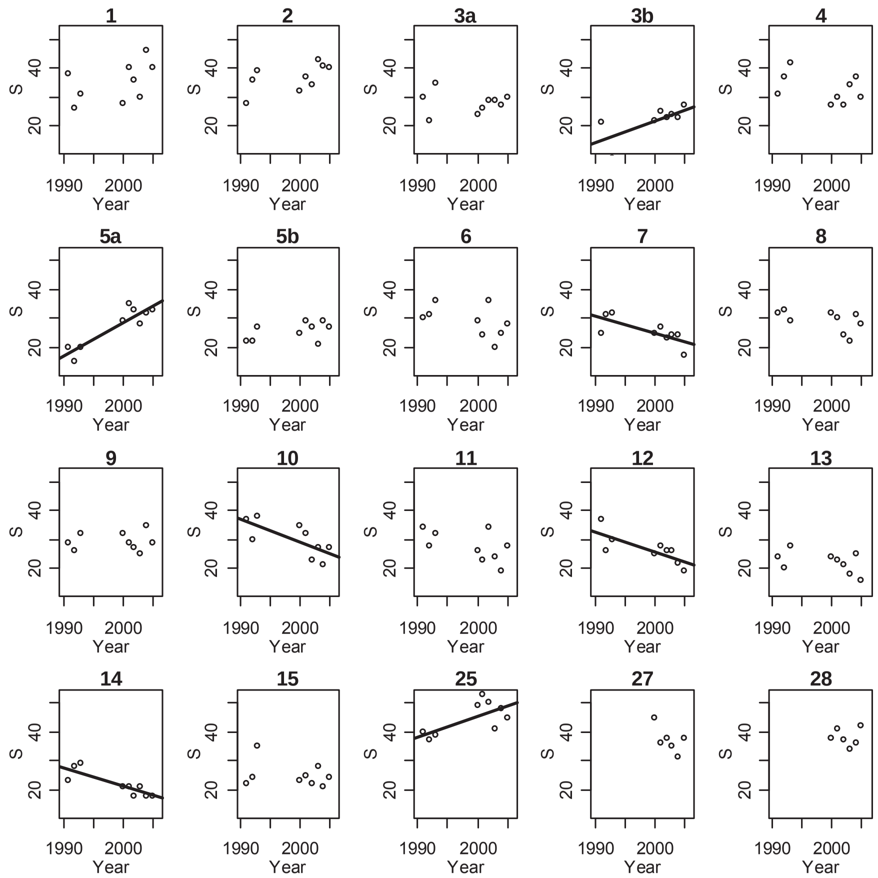


Figure 135: Plots of species richness for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

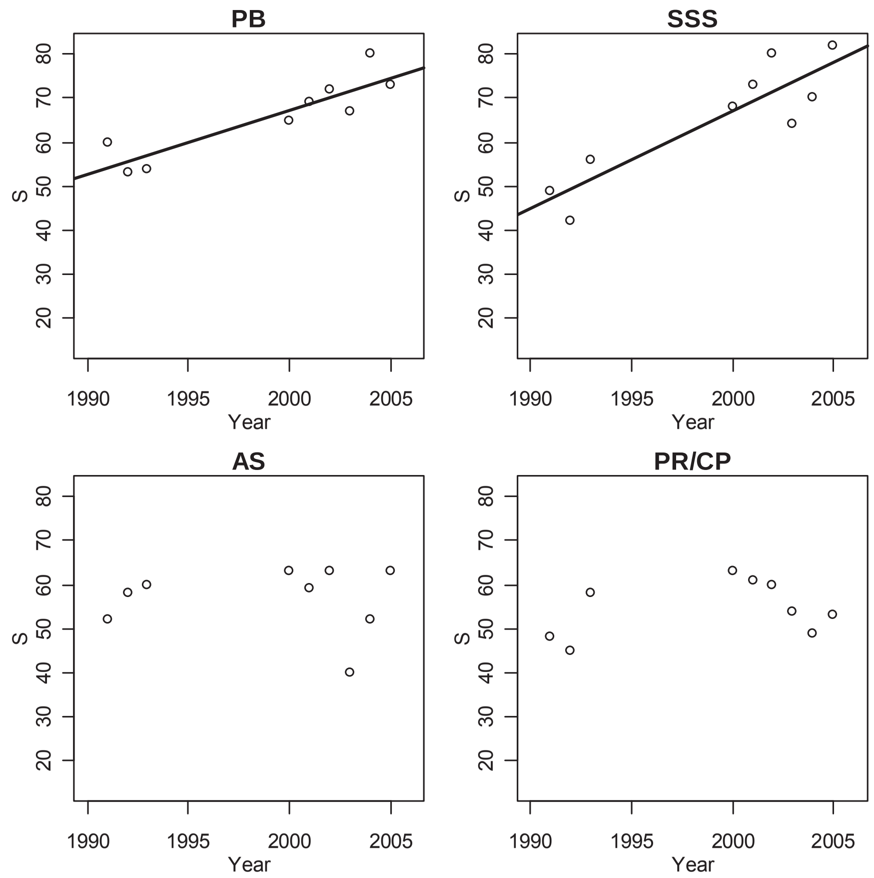


Figure 136: Plots of species richness for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

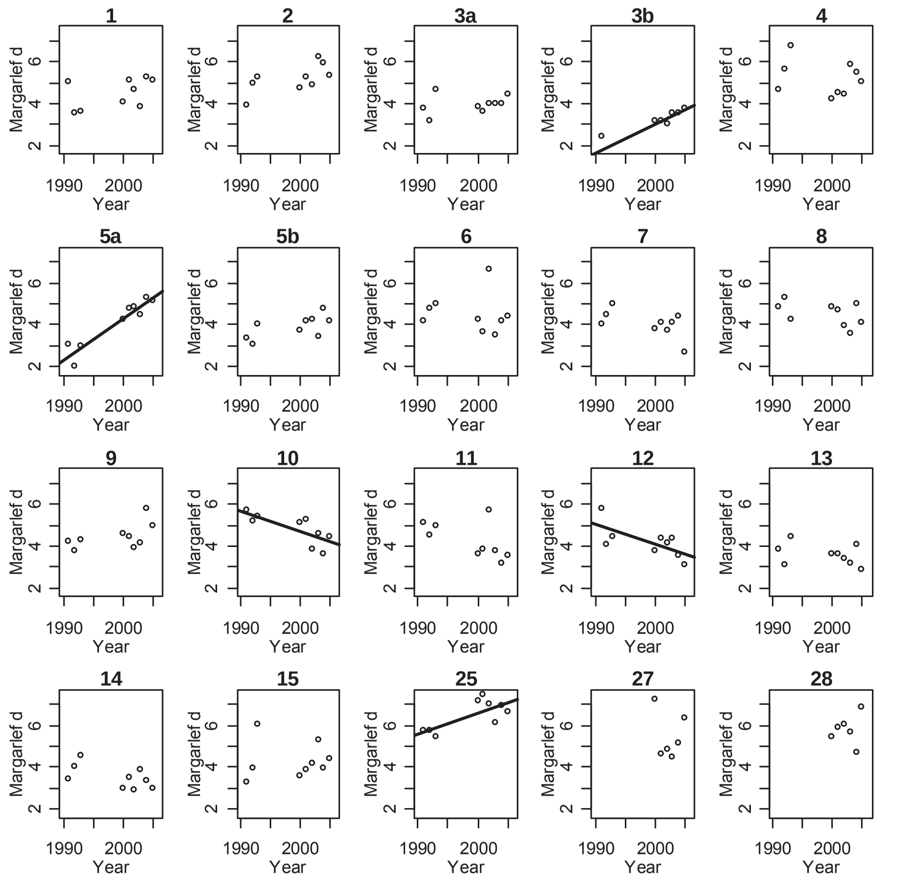


Figure 137: Plots of Margarlef's d diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

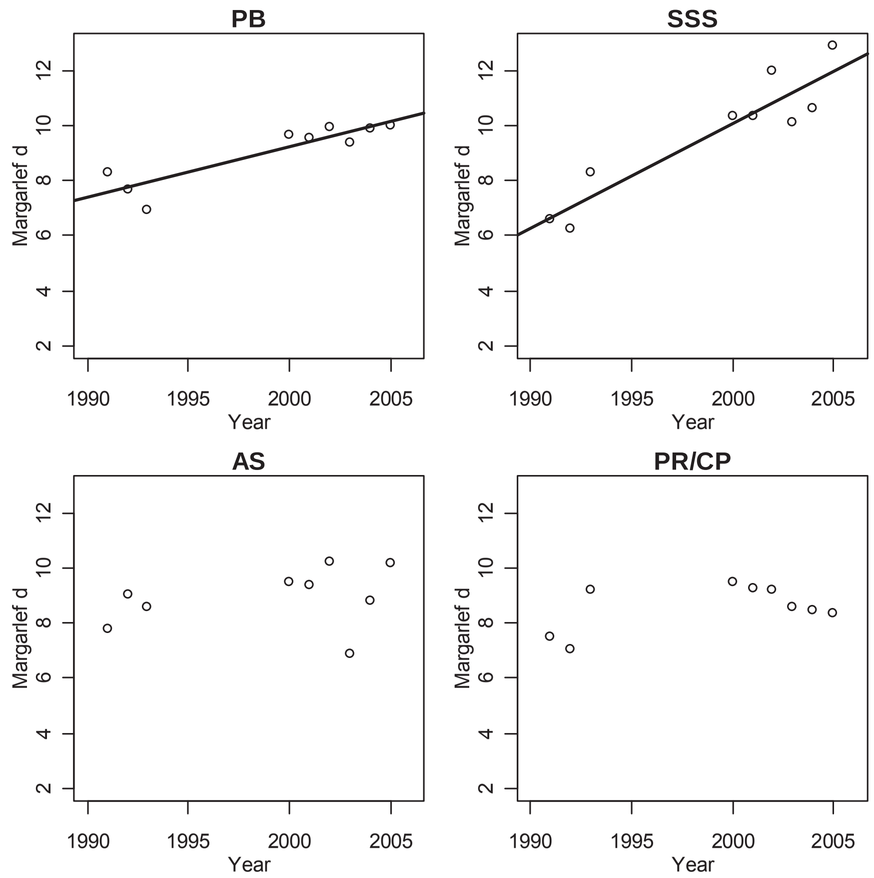


Figure 138: Plots of Margarlef's d diversity parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

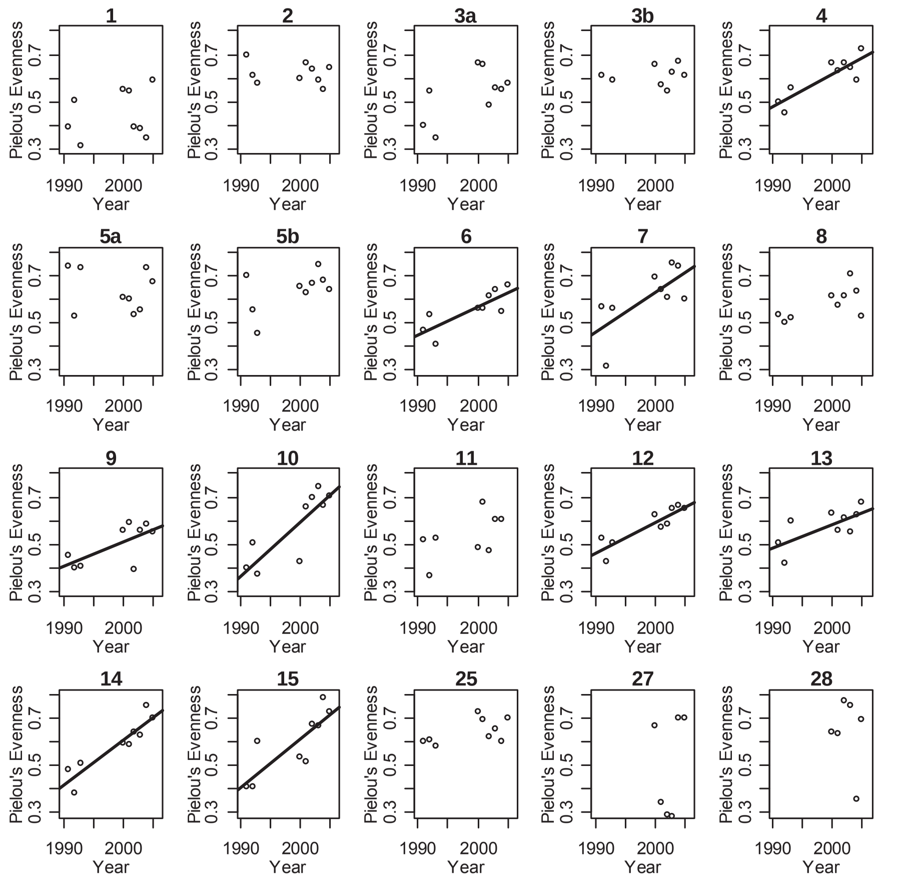


Figure 139: Plots of Pielou's evenness parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

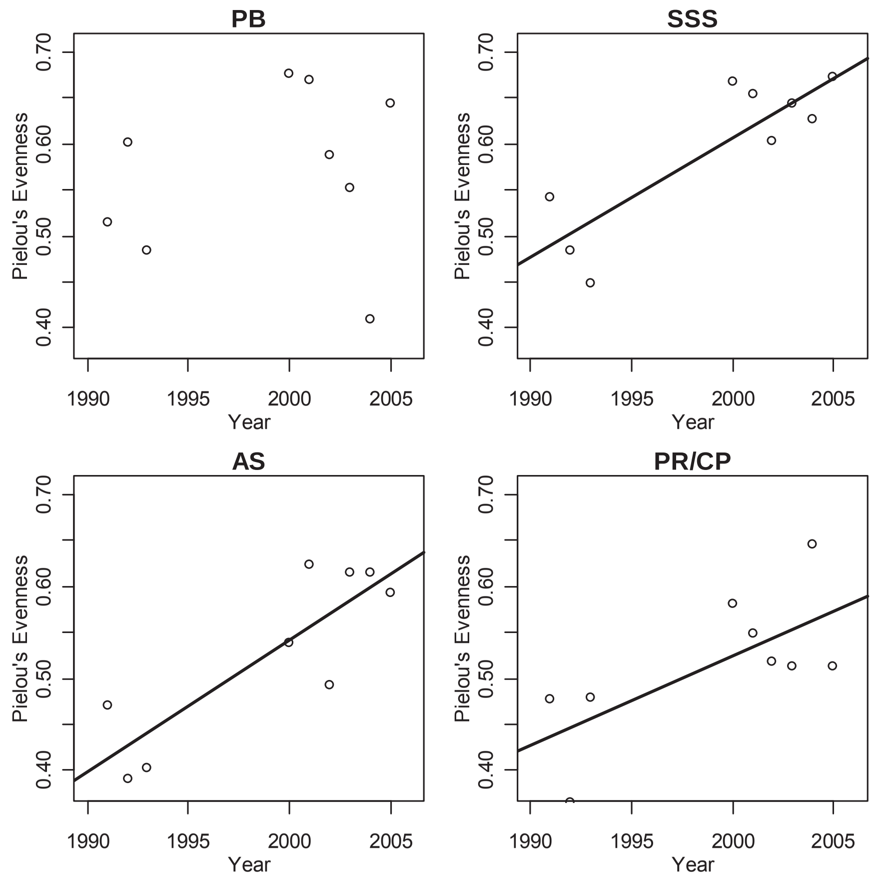


Figure 140: Plots of Pielou's evenness parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

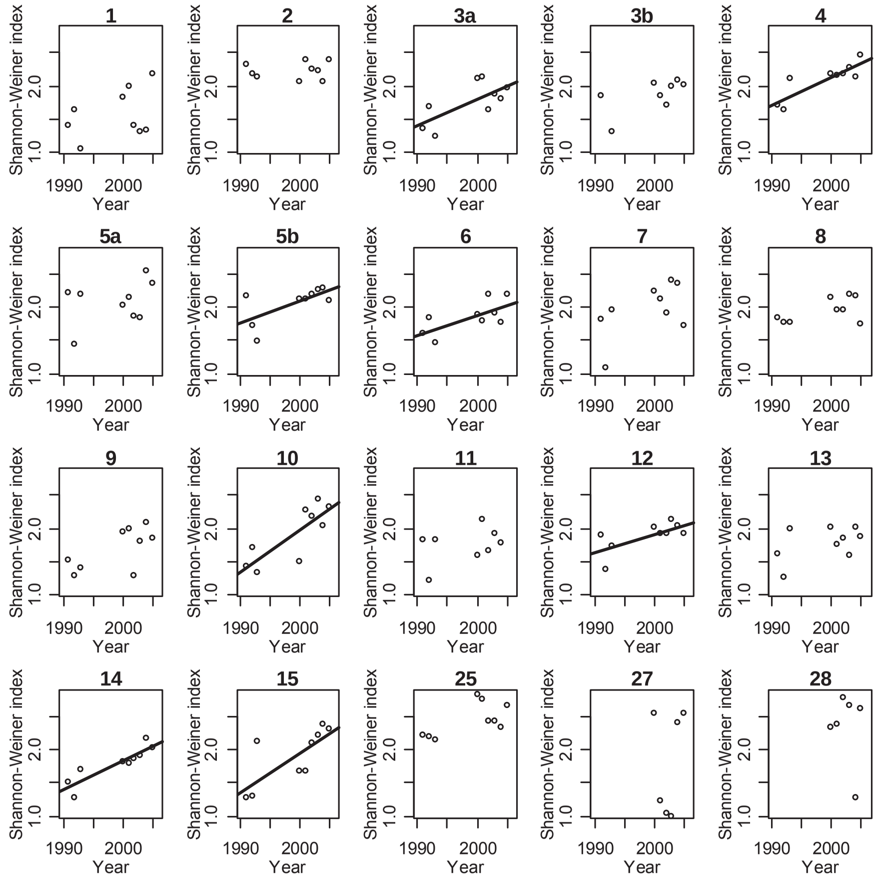


Figure 141: Plots of Shannon-Weiner diversity parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

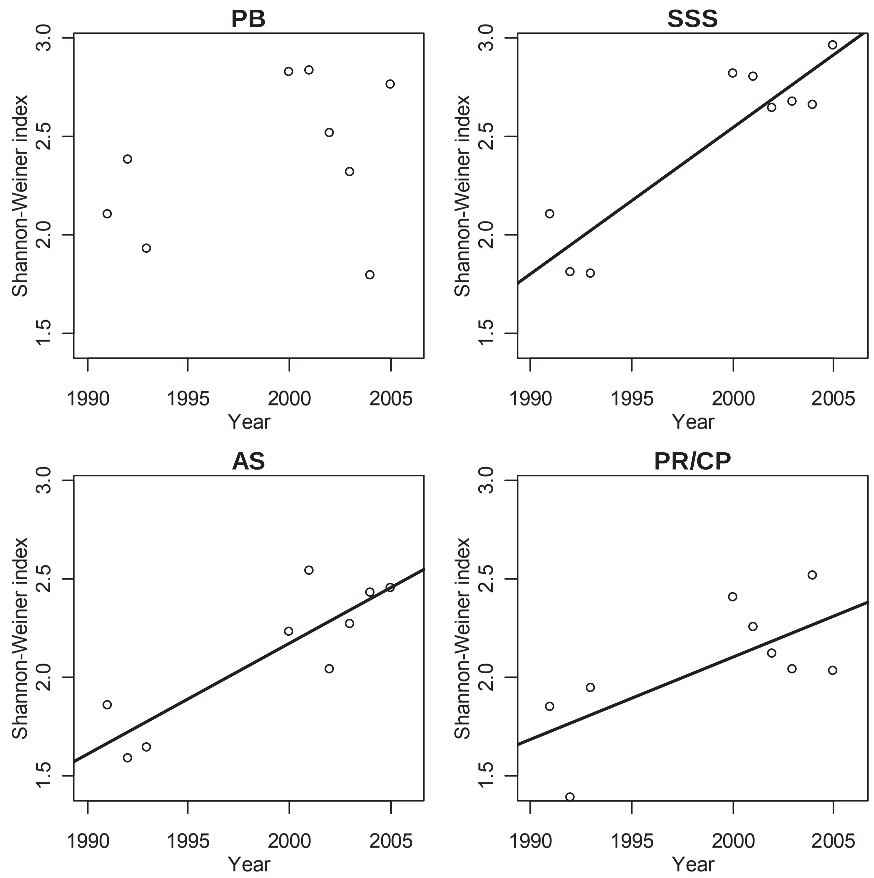


Figure 142: Plots of Shannon-Weiner diversity parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

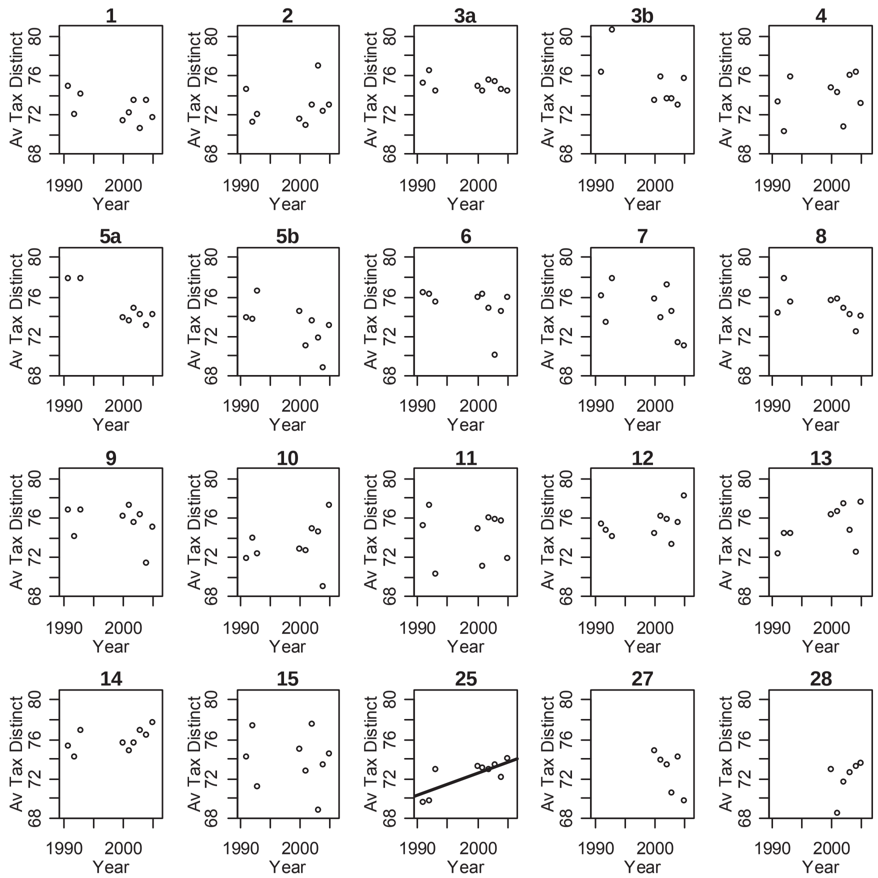


Figure 143: Plots of Average Taxonomic Distinctiveness parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

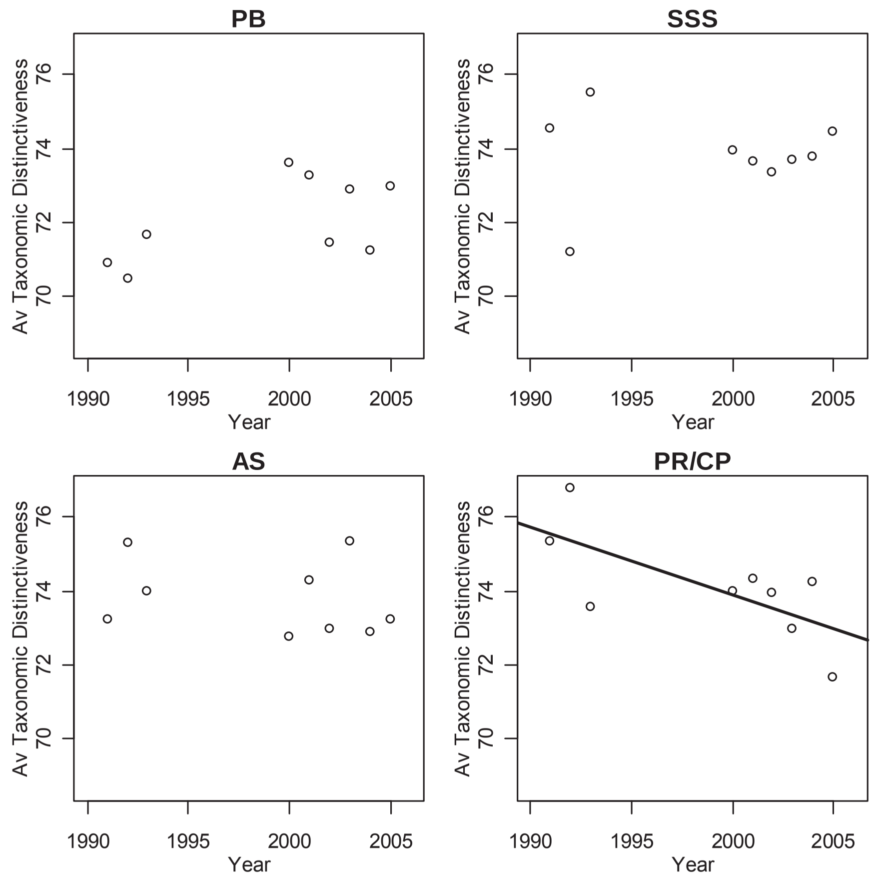


Figure 144: Plots of Average Taxonomic Distinctiveness parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

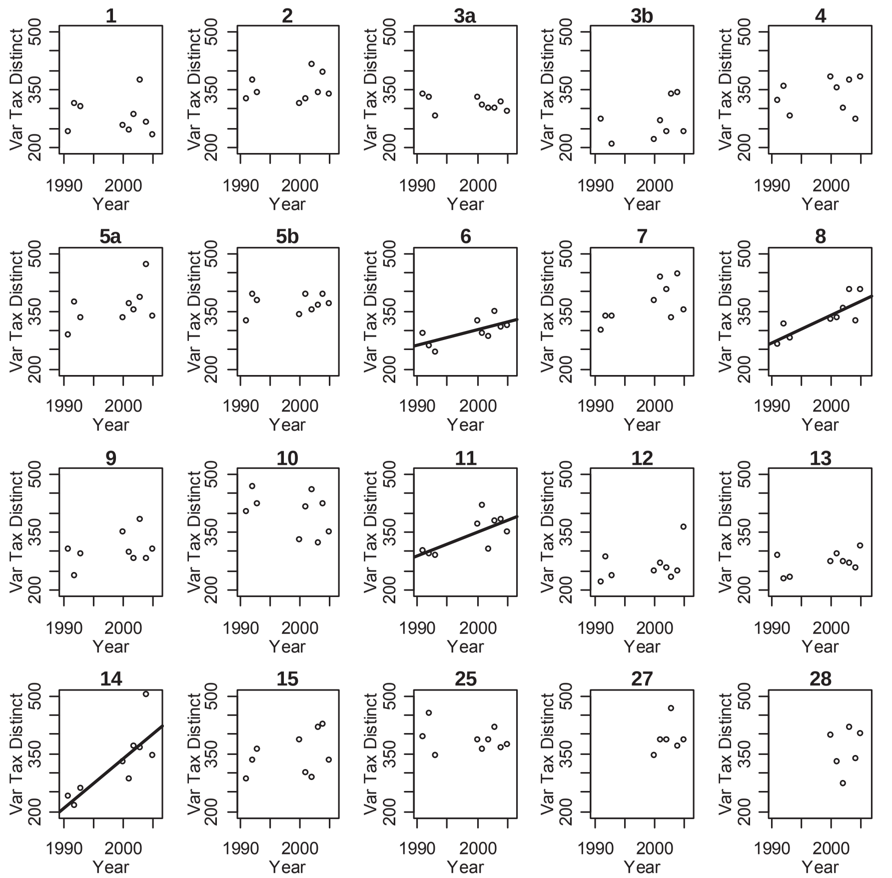


Figure 145: Plots of Variation in taxonomic distinctiveness parameter for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

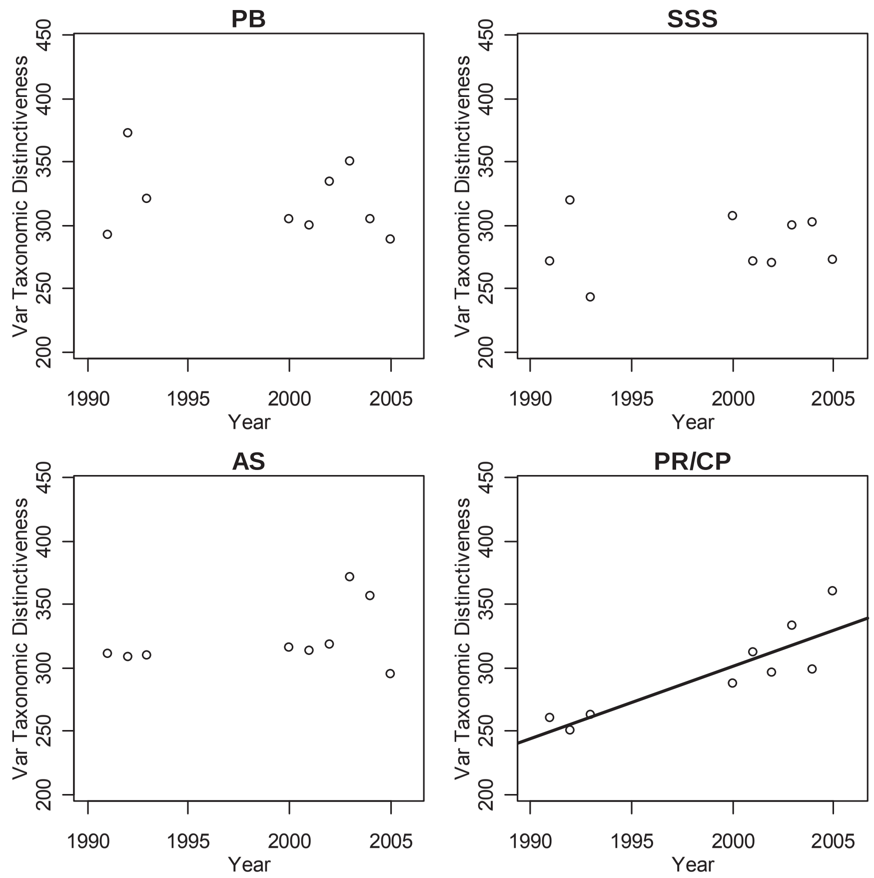


Figure 146: Plots of Variation in taxonomic distinctiveness parameter for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

6.1.2. Trophodynamic indicators

6.1.2.1. Biomass ratio

On the basis of life history knowledge for each species, the catch for each station was summed by main feeding group and habitat. The ratio of Pisciverous:Total (Figures 147 & 148) and Demersal:Total (Figures 149 & 150) catch weight were examined over time for each stratum. The demersal species group was defined as those species within the working data set that were not pelagic or bathypelagic.

For the ratio of Pisciverous:Total catch weight, significant positive trends were identified for S Campbell 600–800 (10), Pukaki 300–600 (12), NE Campbell 300–600 (13), and E Campbell 600–800 (13 and 15), but over the larger areas the significant trends identified for AS and PR/CP were negative (Table 32). For the ratio of Demersal:Total catch weight, significant negative trends were identified for E Snares/Auckland 600–800 (5b), Pukaki 300–600 (12), and NE Campbell 300–600 (13) and for the larger AS and PR/CP areas (Table 32).

Table 32: Slope and P value for linear regressions for each survey strata of Pisciverous:Total (left), Demersal:Total (centre) and Mean TL (right) on year. Proportions were arcsin square root transformed. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		Pisciverous:Total		Demersal:Total		Mean TL	
Stratum	Name	slope	P	slope	P	slope	P
1	Puysegur 300–600	0.0062	0.678	-0.0040	0.208	-0.0071	0.572
2	Puysegur 600–800	-0.0001	0.966	-0.0014	0.532	-0.0045	0.205
3a	N Stewart/Snares 300–600	0.0046	0.381	-0.0045	0.125	**-0.0104**	**0.047**
3b	S Stewart/Snares 300–600	-0.0022	0.808	-0.0092	0.211	-0.0067	0.470
4	Stewart/Snares 600–800	0.0012	0.746	0.0051	0.327	**-0.0067**	**0.039**
5a	W Snares/Auckland 600–800	-0.0014	0.888	-0.0173	0.155	-0.0031	0.698
5b	E Snares/Auckland 600–800	0.0075	0.320	**-0.0041**	**0.018**	-0.0104	0.145
6	Auckland 300–600	0.0227	0.057	-0.0100	0.146	**-0.0220**	**0.024**
7	S Auckland 600–800	0.0056	0.254	-0.0068	0.062	-0.0114	0.079
8	NE Auckland 600–800	0.0096	0.158	-0.0004	0.903	**-0.0086**	**0.038**
9	N Campbell 300–600	0.0088	0.227	-0.0015	0.280	-0.0105	0.059
10	S Campbell 600–800	**0.0127**	**0.006**	-0.0073	0.154	**-0.0177**	**0.006**
11	NE Pukaki 600–800	0.0273	0.239	-0.0238	0.354	-0.0255	0.191
12	Pukaki 300–600	**0.0128**	**0.046**	**-0.0086**	**0.018**	**-0.0150**	**0.014**
13	NE Campbell 300–600	**0.0128**	**0.048**	**-0.0029**	**0.047**	**-0.0131**	**0.015**
14	E Campbell 300–600	0.0103	0.213	-0.0032	0.347	**-0.0158**	**0.004**
15	E Campbell 600–800	**0.0182**	**0.001**	-0.0047	0.386	**-0.0153**	**0.012**
25	Puysegur 800–1000	0.0047	0.163	-0.0040	0.152	-0.0050	0.122
27	NE Pukaki 800–1000	-0.1099	0.270	0.0604	0.546	0.0664	0.344
28	Stewart/Snares 800–1000	-0.0059	0.925	0.0487	0.264	0.0124	0.723
PB		-0.0049	0.516	-0.0028	0.287	-0.0059	0.347
SSS		-0.0126	0.129	-0.0092	0.072	**-0.0175**	**0.003**
AS		**-0.0113**	**0.013**	**-0.0044**	**0.048**	**-0.0130**	**0.003**
PR/CP		**-0.0304**	**0.017**	**-0.0378**	**0.018**	**-0.0342**	**0.004**

6.1.2.2. Trophic level of catch

The mean TL of the survey catch was examined over time for each stratum (Figures 151 & 152 and Table 32). The mean TL data appeared more sensitive to trends in the fish communities over time, and showed negative trends for N Stewart/Snares 300–600 (3a), Stewart/Snares 600–800 (4), Auckland 300–600 (6), NE Auckland 600–800 (8), E Campbell 300–600 and 600–800 (14 and 15), Pukaki 300–600 (12), NE Campbell 300–600 (13), and S Campbell 600–800 (10), and the SSS, AS and PR/CP larger areas.

6.1.2.3. Trophic spectra

Cumulative relative biomass trophic spectra are plotted for each year in each survey stratum in Figures 153 & 154.

Between year pairs of cumulative relative biomass spectra were compared using a Kolmogorov-Smirnov test as described for the Hauraki Gulf dataset, with the P values from the pairwise tests used as measures of similarity in MDS plots (Figures 155 & 156). As with the other trawl series, the plots were quite scattered, but some strata (e.g., N Stewart/Snares 300–600 (3a), E Campbell 300–600 and 600–800 (14 and 15), and S Campbell 600–800 (10)), and larger areas (SSS, AS and PR/CP) showed evidence that samples from the early 1990s were distinct from those collected after 2000, suggesting that the trophic spectra may have changed between these periods.

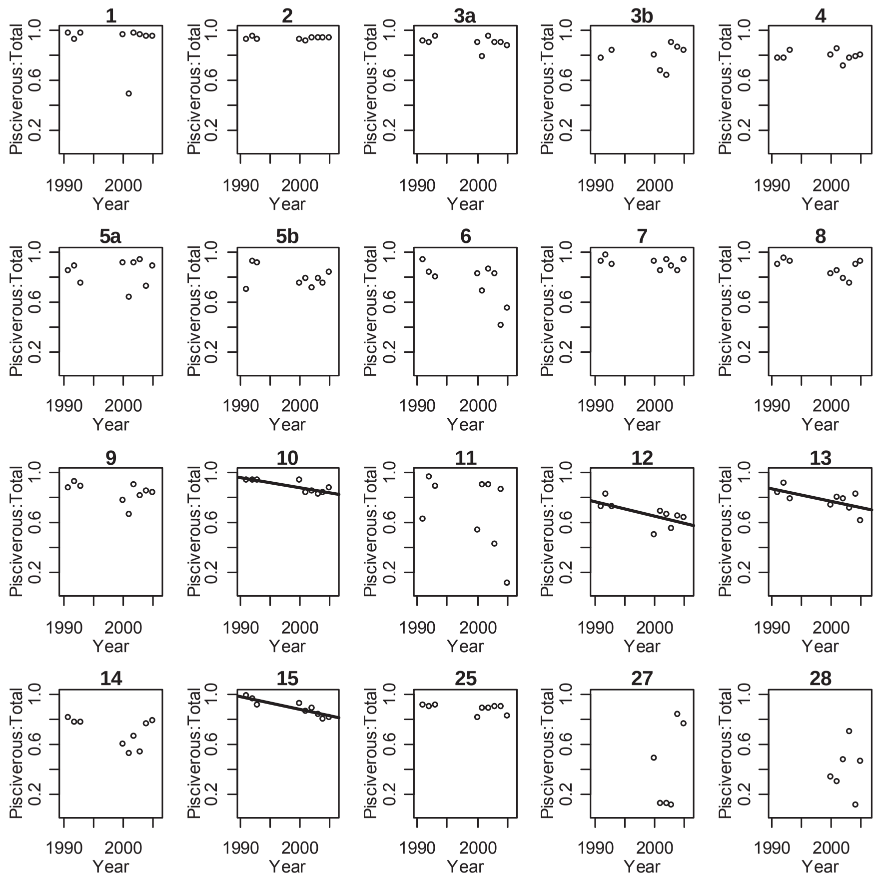


Figure 147: Plots of the Pisciverous:Total catch weight ratio for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

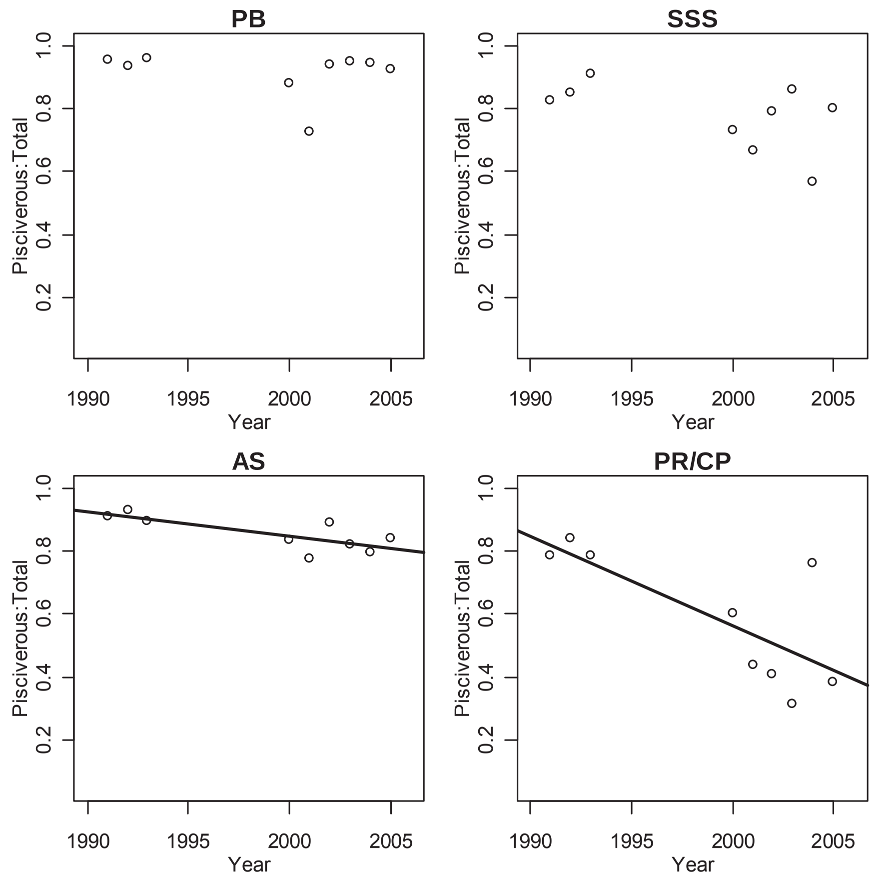


Figure 148: Plots of the Pisciverous:Total catch weight ratio for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

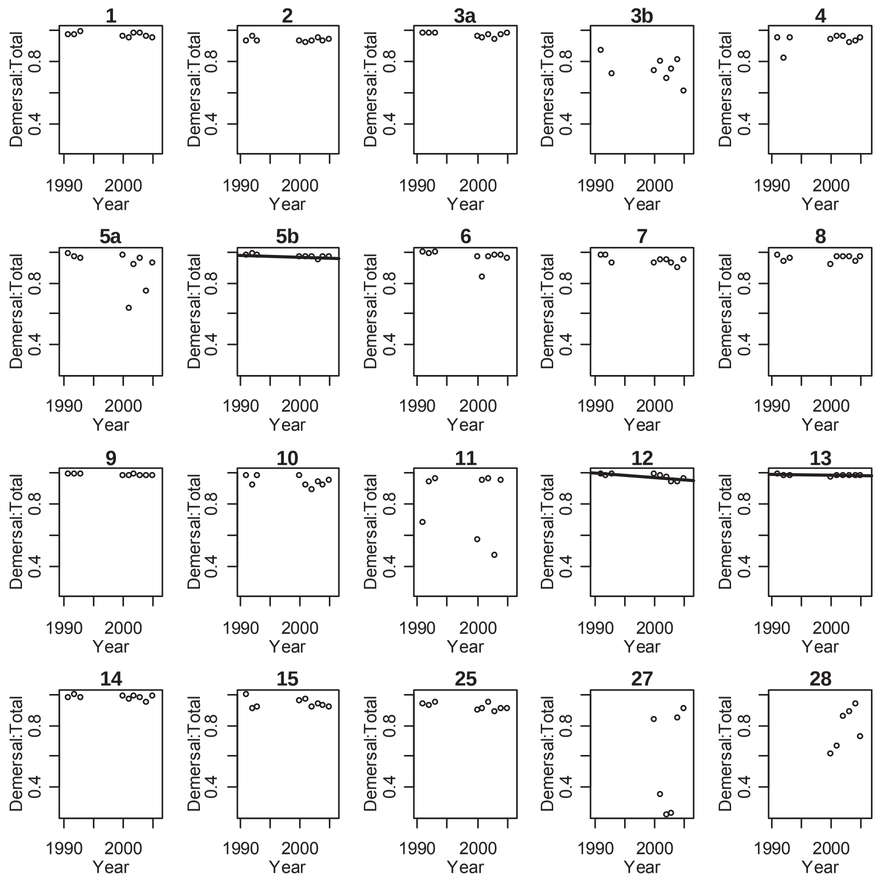


Figure 149: Plots of the Demersal:Total catch weight ratio for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

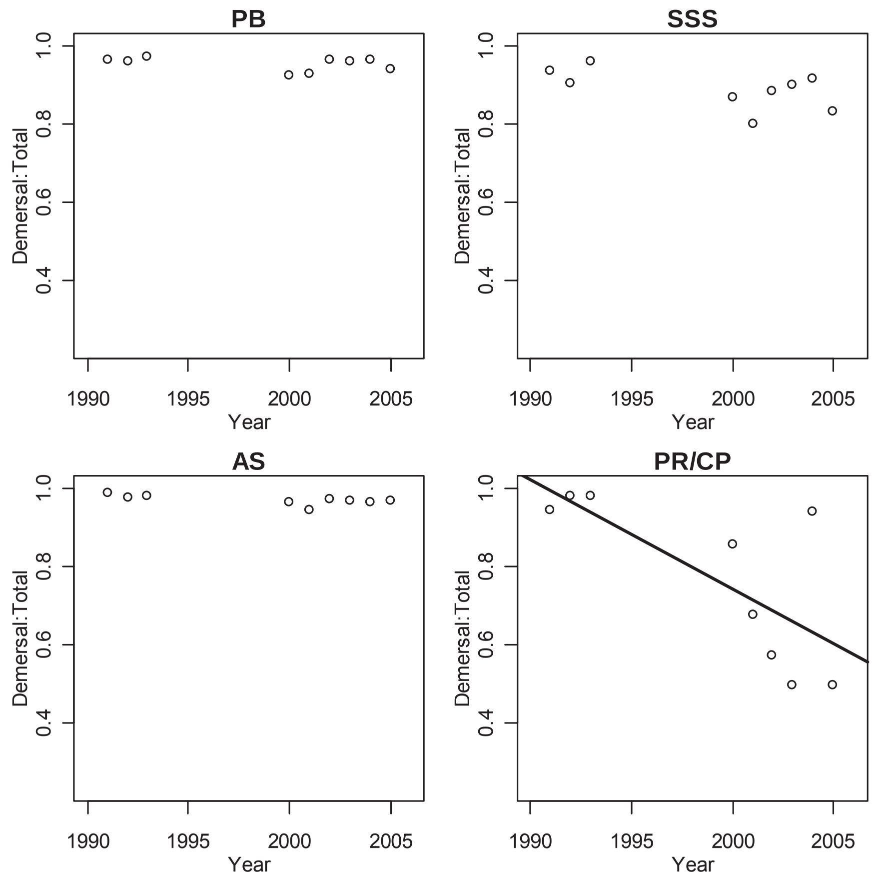


Figure 150: Plots of the Demersal:Total catch weight ratio for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

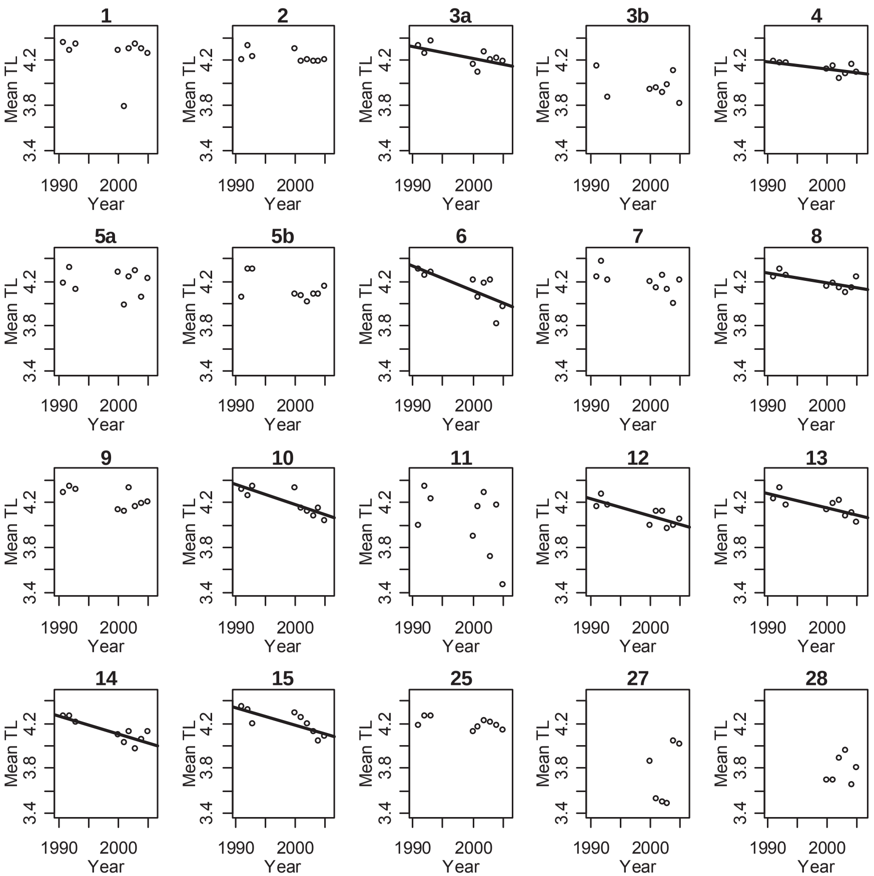


Figure 151: Plots of Mean TL for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

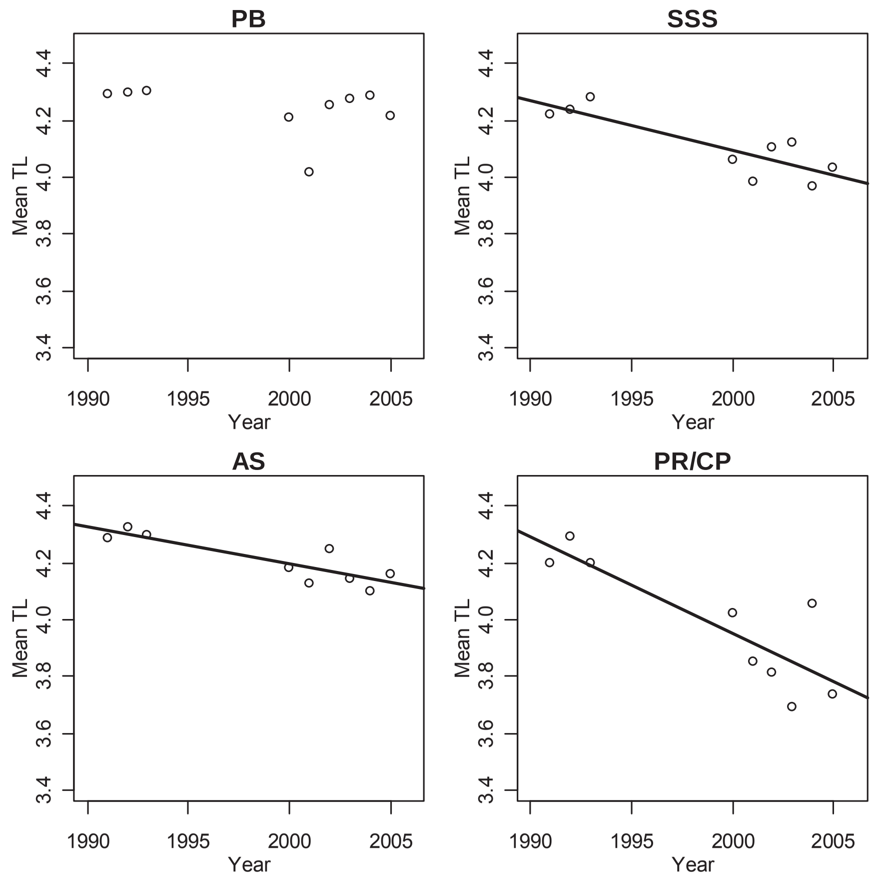


Figure 152: Plots of Mean TL for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

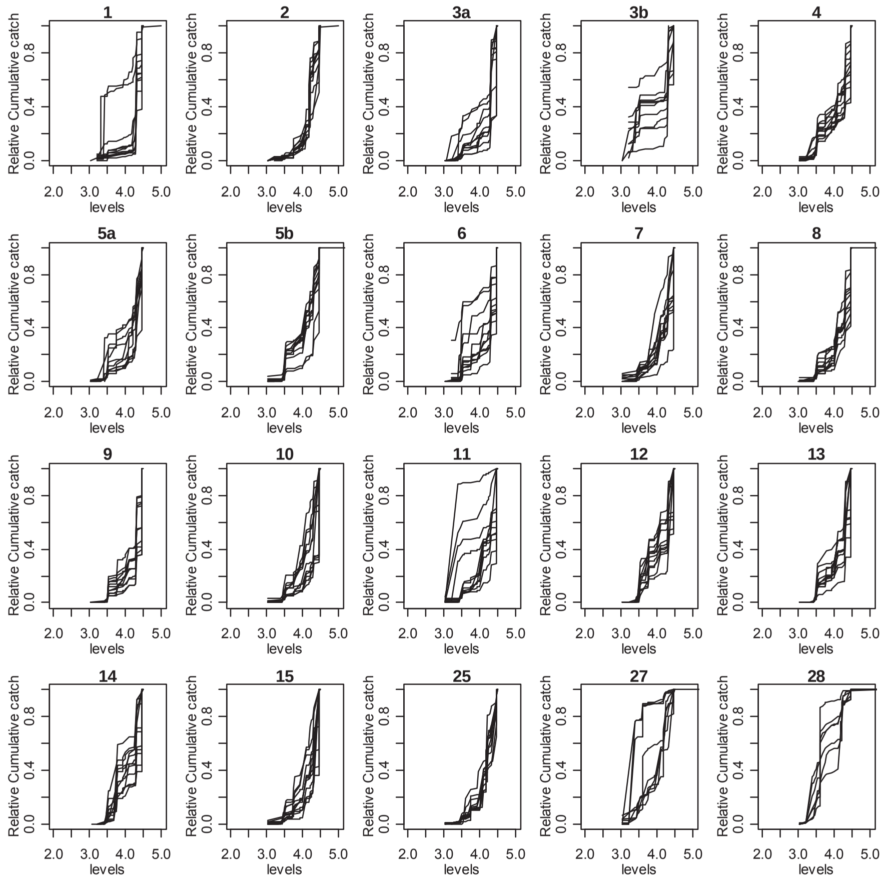


Figure 153: Plots of cumulative relative biomass trophic level spectra for each survey stratum.

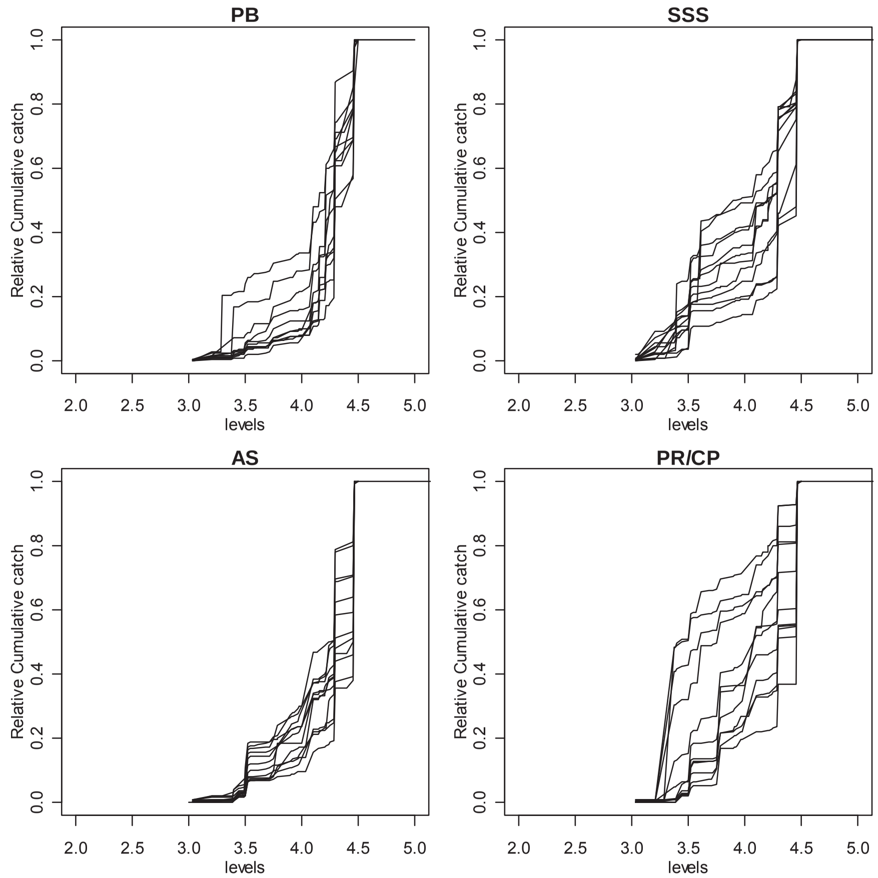


Figure 154: Plots of cumulative relative biomass trophic level spectra for each larger region stratum.

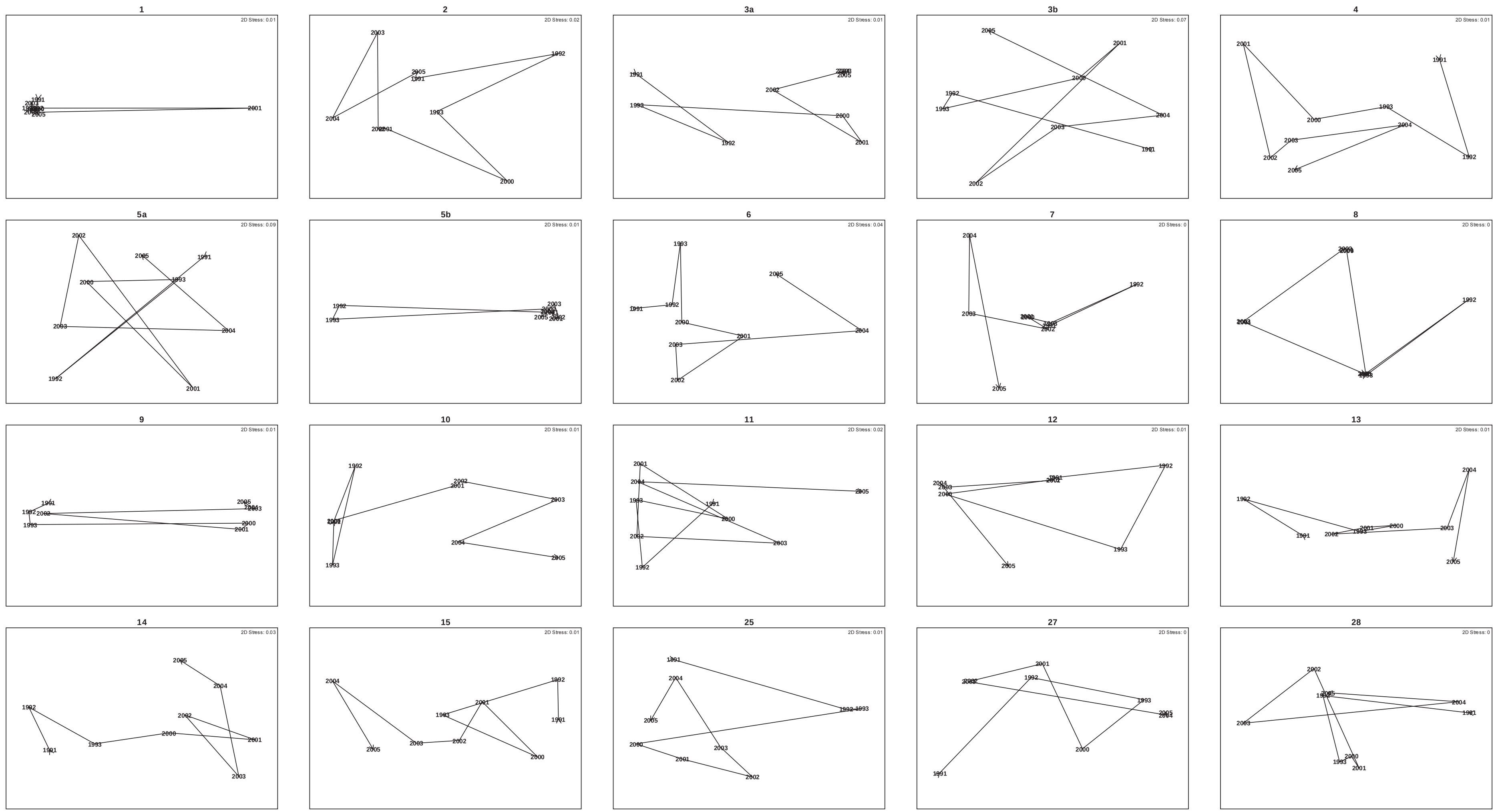


Figure 155: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of relative biomass trophic spectra over time for each survey stratum.

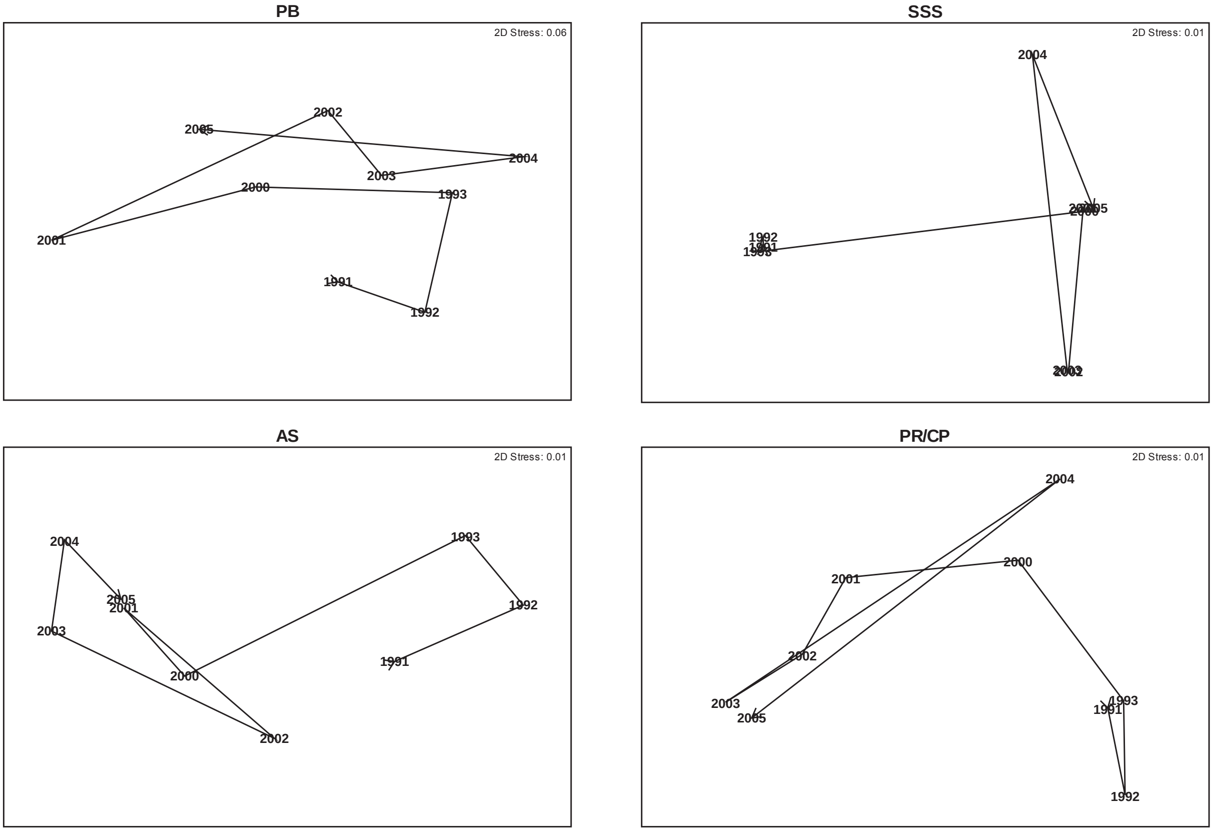


Figure 156: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of relative biomass trophic spectra over time for each of the larger area strata.

6.2. Analysis of catch numbers at length by station

Not all species caught during a tow are measured, and so for examination of size-based indicators, a set of species was selected, being considered to be appropriately sampled by the gear and consistently measured. Only tows in which all the species were measured (assuming they were caught) were included in the analysis. Indicators were calculated for the full combined length frequency distribution of the species. The species were ghost shark, pale ghost shark, hake, hoki, lookdown dory, ling, spiny dogfish, southern blue whiting, stargazer, and ribaldo.

6.2.1. Median and L95 size

Median length showed negative trends over time for Puysegur 300–600 (1), E Snares/Auckland 600–800 (5b), Pukaki 300–600 (12), and E Campbell 300–600 (14), and for the PB, SSS and PR/CP larger areas (Figures 157 & 158 and Table 33). L95 length did not show any significant trends over the larger areas, but showed positive trends over time for E Snares/Auckland 600–800 (5b) and N Campbell 300–600 (9), S Campbell 600–800 (10) and NE Pukaki 600–800 (11) (Figures 159 & 160 and Table 33).

Table 33: Slope and P value for linear regressions for each survey strata of median length (set 1), L95 (set 2), Proportion > 50 cm (set 3) and W statistic (set 4) on year. Proportions were arcsin square root transformed. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		Median length		L95		Proportion > 50cm		W statistic	
Stratum	Name	slope	P	slope	P	slope	P	slope	P
1	Puysegur 300–600	**-1.7682**	**0.023**	-0.9825	0.076	-0.0501	0.062	-0.0098	0.121
2	Puysegur 600–800	-0.1027	0.818	0.3344	0.107	-0.0192	0.085	-0.0009	0.882
3a	N Stewart/Snares 300–600	-0.8988	0.148	-0.5393	0.123	-0.0239	0.071	0.0044	0.424
3b	S Stewart/Snares 300–600	-0.3675	0.534	-0.0612	0.925	-0.0022	0.855	-0.0073	0.528
4	Stewart/Snares 600–800	-0.4167	0.066	0.2116	0.462	-0.0066	0.208	-0.0001	0.978
5a	W Snares/Auckland 600–800	-3.3143	0.117	0.0571	0.948	-0.0217	0.297	-0.0050	0.881
5b	E Snares/Auckland 600–800	**-0.8863**	**0.028**	**0.5584**	**0.044**	-0.0040	0.621	-0.0035	0.590
6	Auckland 300–600	-1.4048	0.078	0.0452	0.832	-0.0201	0.255	0.0000	0.999
7	S Auckland 600–800	-0.2381	0.375	0.3333	0.071	-0.0155	0.066	0.0058	0.134
8	NE Auckland 600–800	-0.0298	0.924	0.3048	0.132	-0.0010	0.789	0.0011	0.582
9	N Campbell 300–600	-0.4226	0.531	**0.3869**	**0.041**	-0.0005	0.974	0.0037	0.264
10	S Campbell 600–800	0.0417	0.914	**0.2850**	**0.016**	**-0.0186**	**0.002**	**0.0054**	**0.011**
11	NE Pukaki 600–800	0.2667	0.518	**0.2854**	**0.041**	**-0.0134**	**0.032**	**0.0084**	**0.036**
12	Pukaki 300–600	**-2.1542**	**0.022**	-0.0219	0.917	-0.0202	0.075	-0.0071	0.283
13	NE Campbell 300–600	-0.8000	0.115	0.2277	0.276	-0.0165	0.113	0.0041	0.347
14	E Campbell 300–600	**-1.7292**	**0.036**	0.0096	0.976	-0.0191	0.143	-0.0037	0.593
15	E Campbell 600–800	-0.2417	0.769	0.2254	0.110	**-0.0261**	**0.014**	0.0033	0.191
25	Puysegur 800–1000	-0.5625	0.063	0.0388	0.794	**-0.0144**	**0.010**	-0.0033	0.498
27	NE Pukaki 800–1000	-3.2571	0.108	0.5671	0.179	-0.0356	0.334	0.0106	0.665
28	Stewart/Snares 800–1000	-0.9857	0.403	0.5086	0.480	-0.0381	0.198	0.0005	0.987
PB		**-2.0500**	**0.009**	-0.6292	0.061	**-0.0495**	**0.029**	-0.0088	0.185
SSS		**-0.9226**	**0.037**	-0.1012	0.538	**-0.0143**	**0.033**	-0.0041	0.211
AS		-0.3583	0.178	0.2425	0.067	-0.0156	0.082	**0.0056**	**0.005**
PR/CP		**-1.6083**	**0.023**	0.2375	0.131	**-0.0192**	**0.040**	-0.0011	0.659

6.2.2. Proportion of large individuals

Previous studies have used the proportion of fish over 30 cm as an indicator of the proportion of large individuals (Greenstreet & Rogers 2006). Preliminary analysis of the Southland and Sub-Antarctic series suggested that there were very few individuals under 30 cm caught, and so a larger size of 50 cm was taken as a cut off value.

The proportion (by number) of the catch under 50 cm shows negative trends over time for S Campbell 600–800 (10), E Campbell 600–800 (15), and Puyseger 800–1000 (25), and for the PB, SSS, and PR/CP larger areas (Figures 161 & 162 and Table 33).

6.2.3. W statistic

Overall the W statistic values were generally scattered around zero, suggesting the group of measured species made up a moderately disturbed community. At the survey strata level, only S Campbell 600–800 (10) and NE Pukaki 600–800 (11) showed significant trends (+ve), and over the larger areas, the AS area also showed a positive trend (Figures 163 & 164 and Table 33).

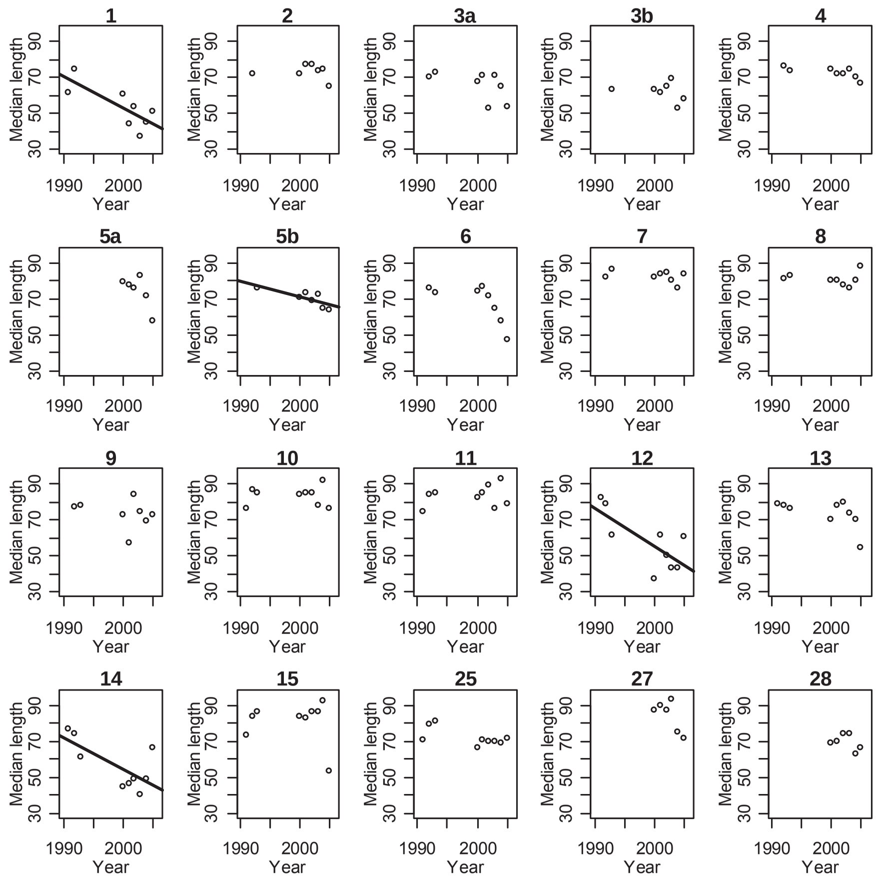


Figure 157: Plots of the Median length for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

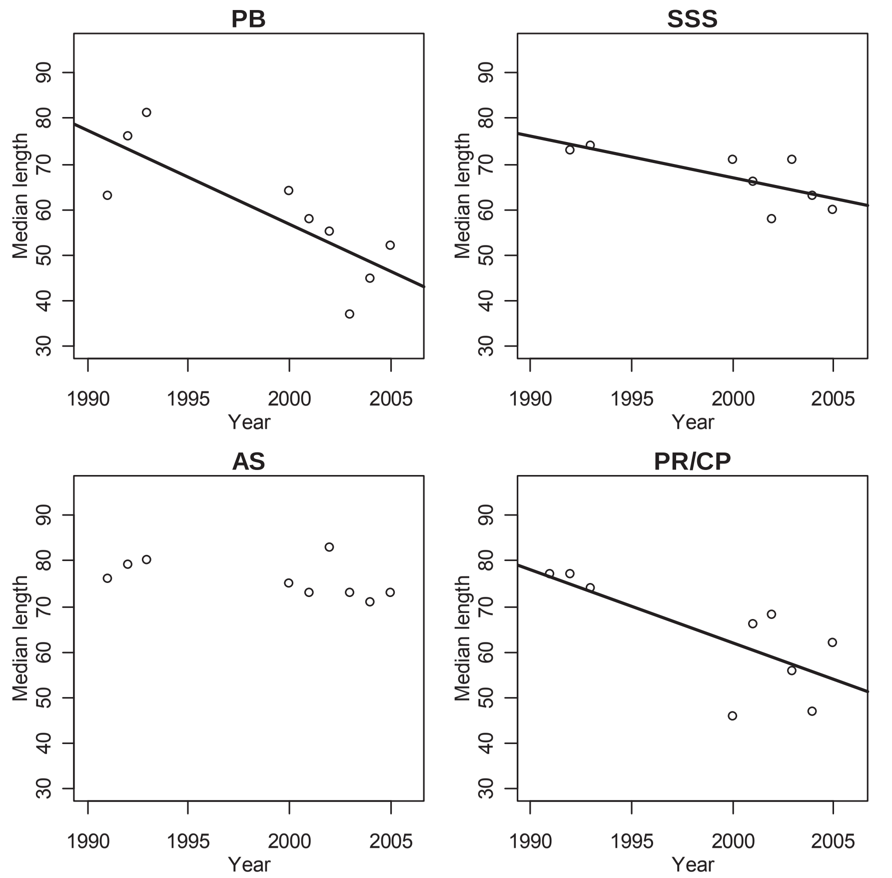


Figure 158: Plots of the Median length for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

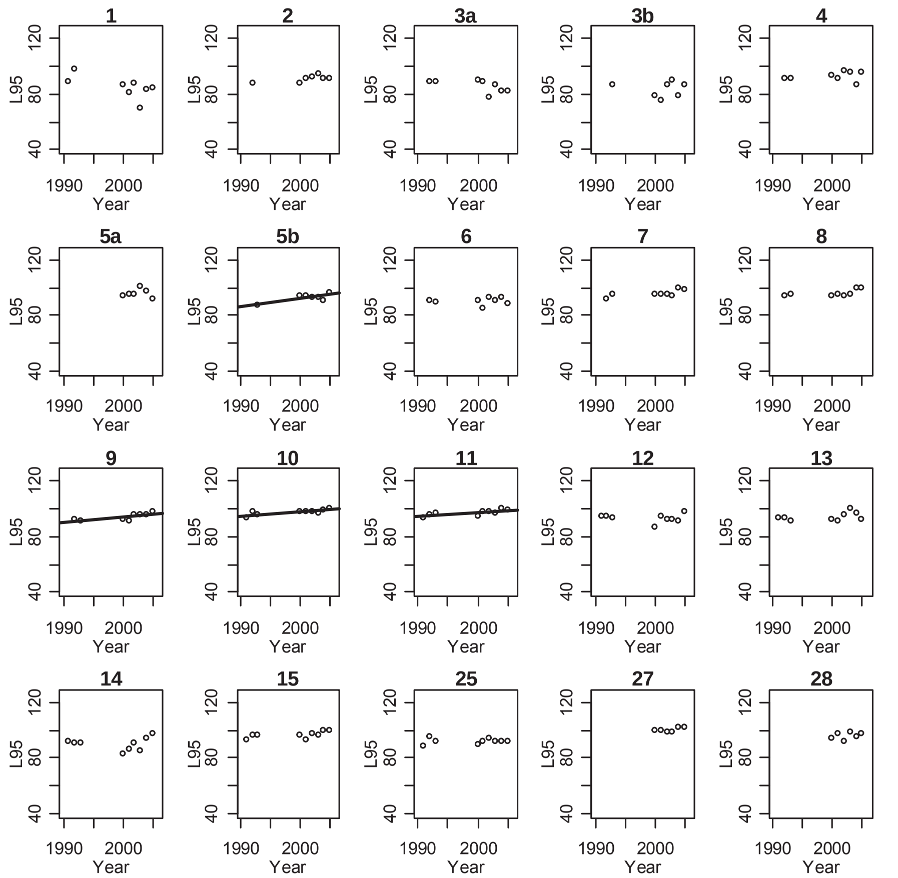


Figure 159: Plots of L95 for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

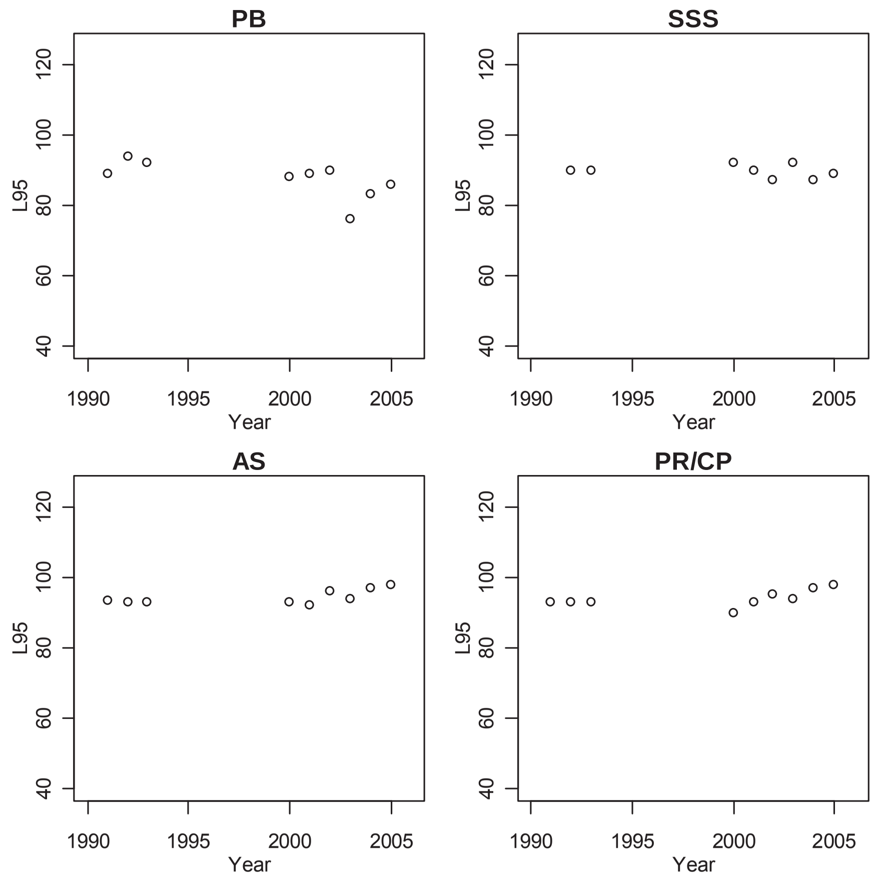


Figure 160: Plots of L95 for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

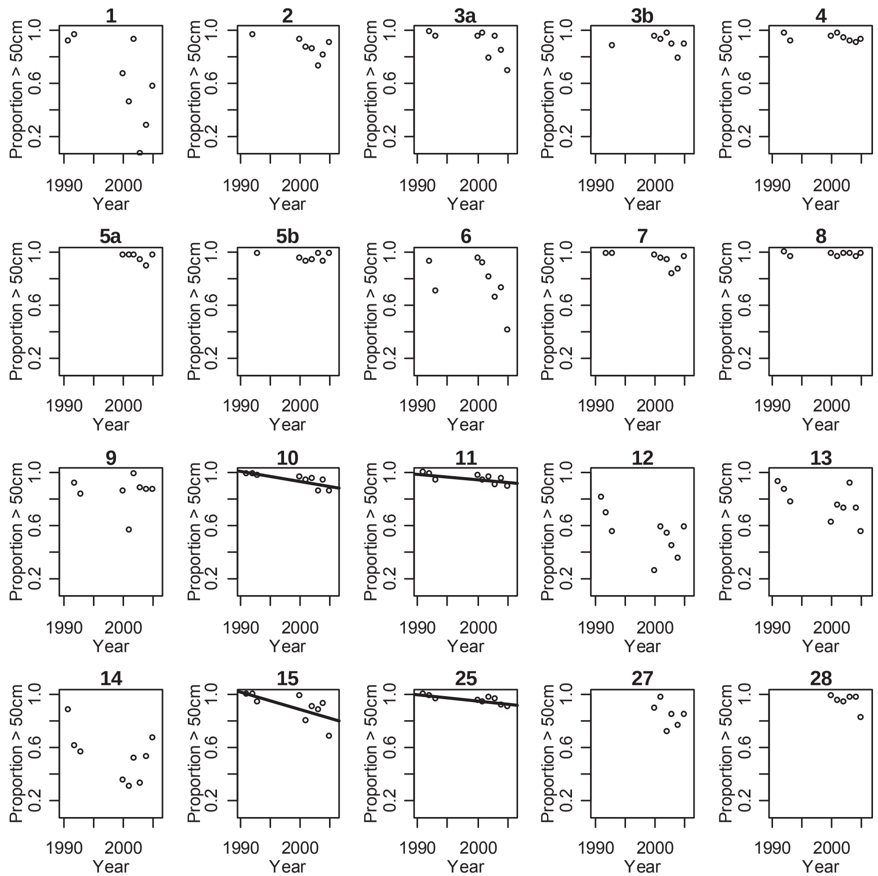


Figure 161: Plots of the Proportion >50 cm length for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

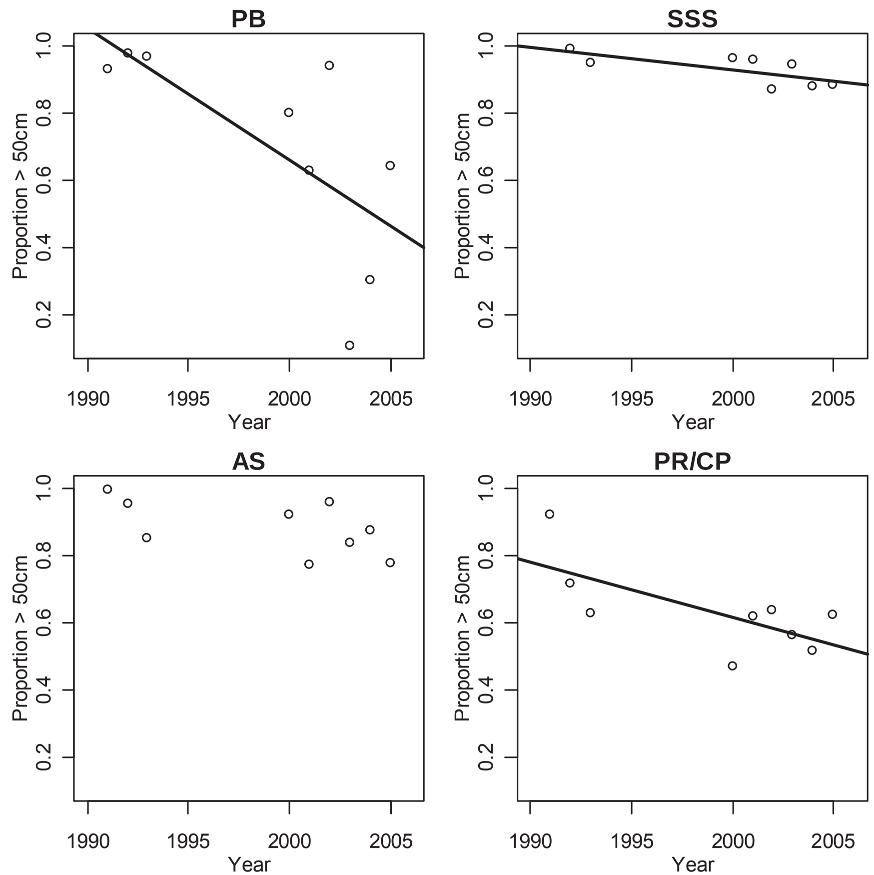


Figure 162: Plots of the Proportion >50 cm length for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

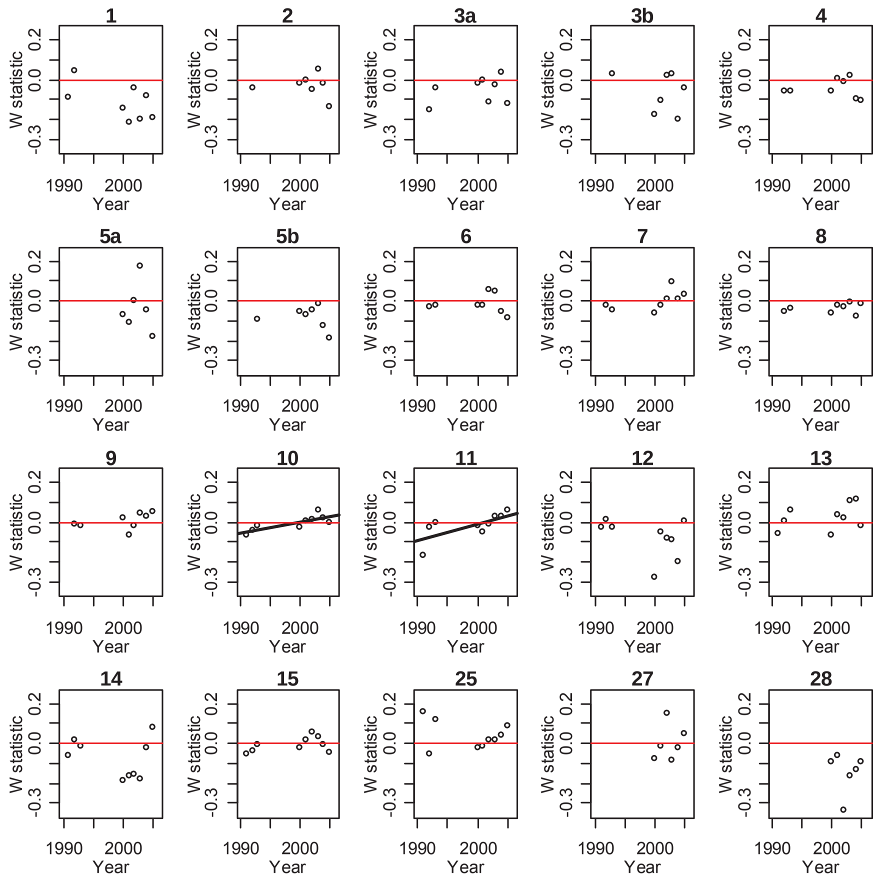


Figure 163: Plots of the W statistic for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

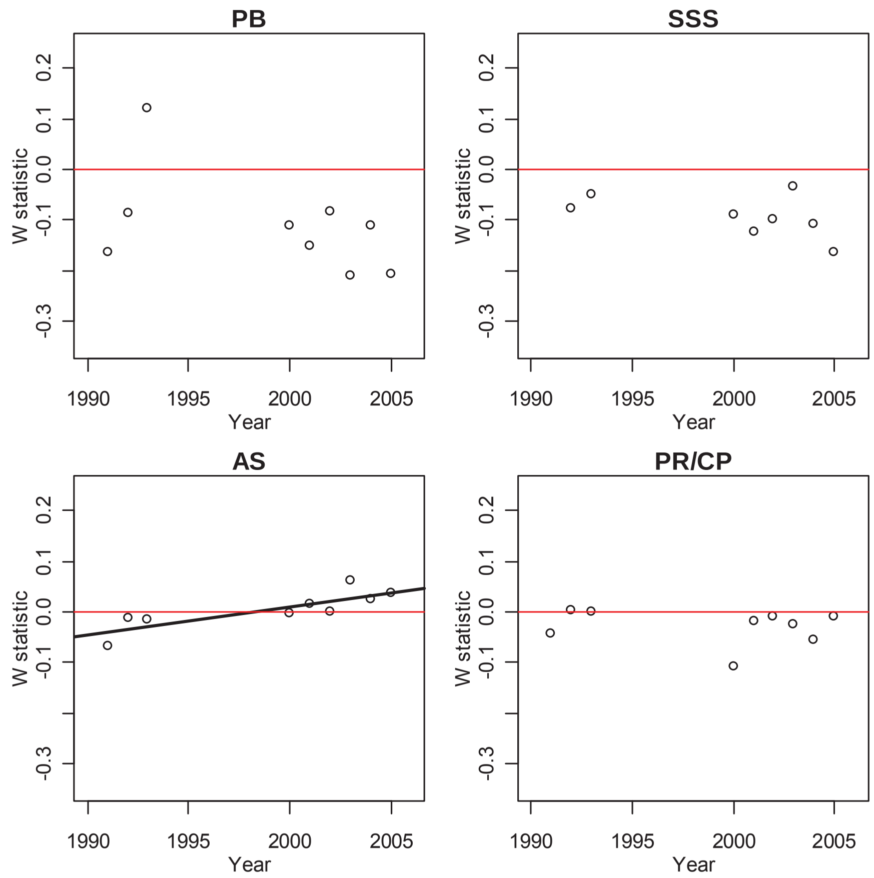


Figure 164: Plots of the W statistic for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

6.2.4. Abundance and biomass size spectra

Abundance and biomass size spectra were calculated for the combined set of the same species, and changes in the spectra were examined over time for each stratum.

The slope of the size spectra showed a negative trend for Puysegur 300–600 (1), and a positive trend for NE Pukaki 600–800 (11). Over the larger areas, the slope showed a negative trend for the PB area (Figures 165 & 166 and Table 34).

The intercept of the size spectra appeared more sensitive to any trends in the length composition, and showed negative trends for N Stewart/Snares 300–600 (3a), Auckland 300–600 (6), Pukaki 300–600 (12), E Campbell 300–600 and 600–800 (14 and 15), and a positive trend for Puyseger 800–1000 (25). Over the larger areas, a positive trend was identified for the PB area, and a negative trend for the PR/CP area (Figures 167 & 168 and Table 34).

Table 34: Slope and P value for linear regressions for each survey stratum Size spectra slope (left) and intercept (right) on year. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		Size spectra slope		Size spectra intercept	
Stratum	Name	slope	P	slope	P
1	Puysegur 300–600	**-0.0037**	**0.006**	0.1067	0.070
2	Puysegur 600–800	-0.0019	0.209	-0.0230	0.593
3a	N Stewart/Snares 300–600	-0.0025	0.180	**-0.0737**	**0.003**
3b	S Stewart/Snares 300–600	-0.0013	0.542	0.0378	0.510
4	Stewart/Snares 600–800	0.0011	0.528	-0.0430	0.353
5a	W Snares/Auckland 600–800	-0.0024	0.653	-0.1352	0.218
5b	E Snares/Auckland 600–800	0.0003	0.837	0.0198	0.852
6	Auckland 300–600	-0.0006	0.677	**-0.0913**	**0.007**
7	S Auckland 600–800	0.0022	0.276	-0.0145	0.849
8	NE Auckland 600–800	0.0024	0.197	0.0433	0.111
9	N Campbell 300–600	0.0016	0.424	-0.0330	0.375
10	S Campbell 600–800	-0.0004	0.673	-0.0713	0.147
11	NE Pukaki 600–800	**0.0047**	**0.016**	0.0257	0.437
12	Pukaki 300–600	-0.0010	0.271	**-0.0840**	**0.047**
13	NE Campbell 300–600	0.0008	0.303	-0.0522	0.217
14	E Campbell 300–600	0.0011	0.315	**-0.1401**	**0.000**
15	E Campbell 600–800	-0.0018	0.159	**-0.1119**	**0.028**
25	Puysegur 800–1000	-0.0002	0.912	**0.1280**	**0.039**
27	NE Pukaki 800–1000	-0.0045	0.288	-0.2377	0.101
28	Stewart/Snares 800–1000	0.0023	0.546	-0.1678	0.272
PB		**-0.0046**	**0.028**	**0.1163**	**0.011**
SSS		-0.0016	0.095	0.0051	0.851
AS		-0.0012	0.288	-0.0408	0.171
PR/CP		0.0001	0.876	**-0.0913**	**0.005**

From the analysis of the biomass spectra, Puysegur 600–800 and 800–1000 (2 and 25) showed positive trends in the biomass spectra curvature over time, while the PR/CP larger area showed a negative trend (Figures 169 & 170 and Table 35).

The x vertex of the biomass spectra did not show any significant trends over time at the survey strata level, but the PB larger area showed a negative trend (Figures 171 & 172 and Table 35).

The y vertex of the biomass spectra appeared somewhat more sensitive to any trends in the biomass composition, with a positive trend identified for Puysegur 300–600 and 800–1000 (1 and 25), and negative trends identified for S Auckland 600–800 (7), E Campbell 300–600 and 600–800 (14 and 15), S Campbell 600–800 (10), and Stewart/Snares 800–1000 (28). Over the larger areas, PB showed a positive trend (Figures 173 & 174 and Table 35).

Table 35: Slope and P value for linear regressions for each survey strata of biomass spectra curvature (left), x vertex (middle) and y vertex (right) on year. Regression parameters are presented for the whole series (solid lines in figures) for data averaged across a survey strata for each year (upper table) and larger region strata (lower table). Slopes significantly different from zero are in bold.

		Biomass spectra curvature		Biomass spectra x vertex		Biomass spectra y vertex	
Stratum	Name	slope	P	slope	P	slope	P
1	Puysegur 300–600	0.0213	0.347	-0.0671	0.077	**0.2003**	**0.029**
2	Puysegur 600–800	**0.0517**	**0.047**	-0.0056	0.618	-0.0215	0.669
3a	N Stewart/Snares 300–600	0.0298	0.175	-0.0420	0.114	-0.0670	0.084
3b	S Stewart/Snares 300–600	0.0130	0.485	-0.0032	0.900	0.0676	0.219
4	Stewart/Snares 600–800	0.0158	0.448	-0.0063	0.613	-0.0964	0.117
5a	W Snares/Auckland 600–800	0.0778	0.216	-0.0349	0.651	-0.2737	0.217
5b	E Snares/Auckland 600–800	0.0039	0.841	0.0042	0.791	-0.0263	0.675
6	Auckland 300–600	-0.0452	0.182	-0.0642	0.090	-0.0605	0.213
7	S Auckland 600–800	0.0426	0.172	0.0259	0.528	**-0.1419**	**0.013**
8	NE Auckland 600–800	-0.0264	0.258	-0.0163	0.090	-0.0467	0.366
9	N Campbell 300–600	-0.0214	0.325	0.0212	0.188	-0.0490	0.323
10	S Campbell 600–800	0.0416	0.166	0.1053	0.055	**-0.1115**	**0.020**
11	NE Pukaki 600–800	-0.0567	0.349	0.0032	0.721	-0.0635	0.192
12	Pukaki 300–600	-0.0063	0.636	-0.0035	0.826	-0.0321	0.521
13	NE Campbell 300–600	-0.0205	0.342	0.0170	0.219	-0.0162	0.660
14	E Campbell 300–600	0.0073	0.696	0.0269	0.180	**-0.1617**	**0.010**
15	E Campbell 600–800	0.0584	0.310	0.0208	0.160	**-0.1341**	**0.028**
25	Puysegur 800–1000	**0.0760**	**0.024**	0.0107	0.712	**0.0913**	**0.030**
27	NE Pukaki 800–1000	0.0503	0.399	0.0745	0.565	-0.1687	0.288
28	Stewart/Snares 800–1000	0.0998	0.572	-0.0429	0.467	**-0.2735**	**0.010**
PB		0.0685	0.075	**-0.0703**	**0.016**	**0.2015**	**0.023**
SSS		0.0318	0.051	-0.0144	0.294	-0.0098	0.823
AS		0.0031	0.889	-0.0046	0.438	-0.0193	0.590
PR/CP		**-0.0260**	**0.040**	-0.0040	0.664	-0.0476	0.241

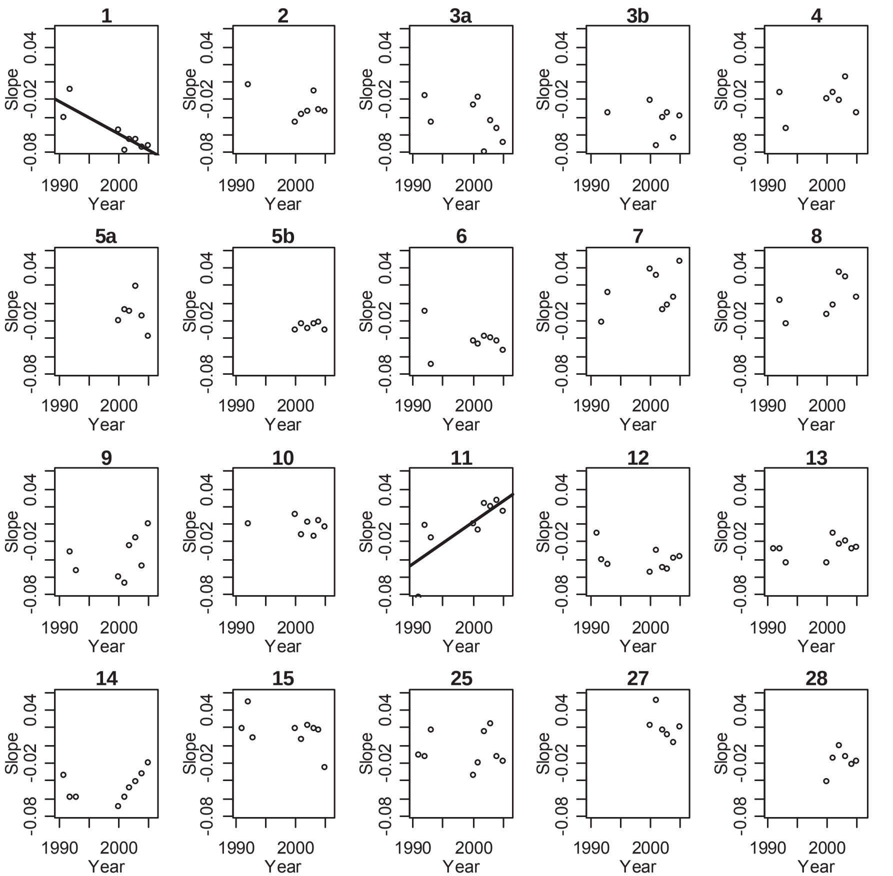


Figure 165: Plots of the size spectra slope for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

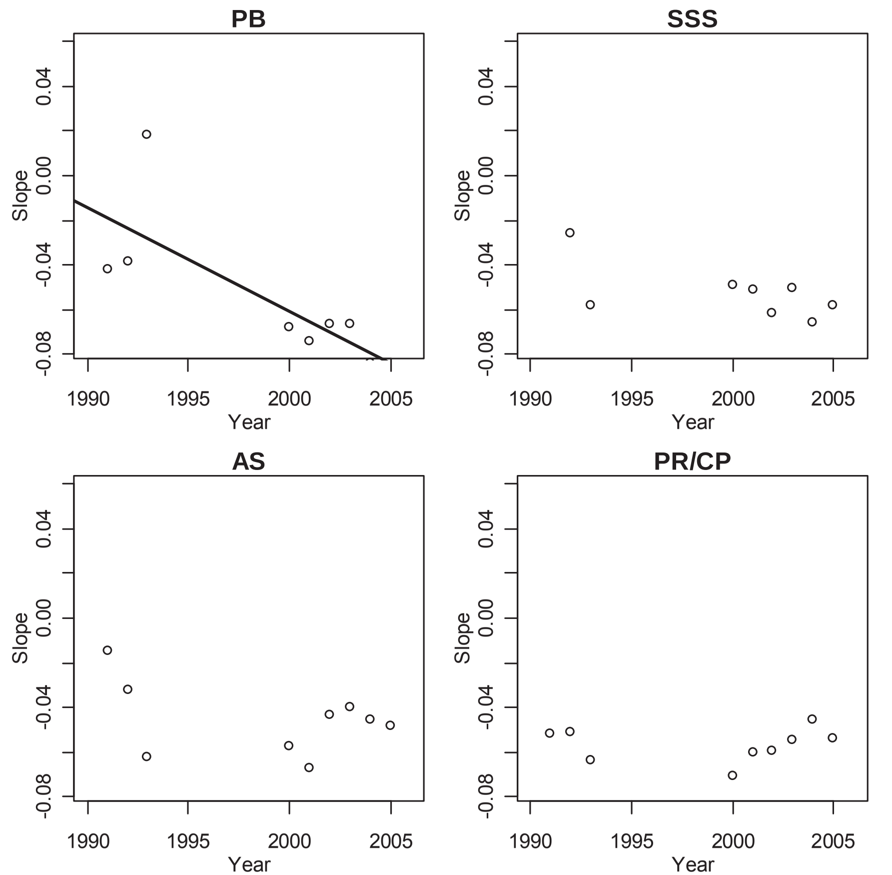


Figure 166: Plots of the size spectra slope for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

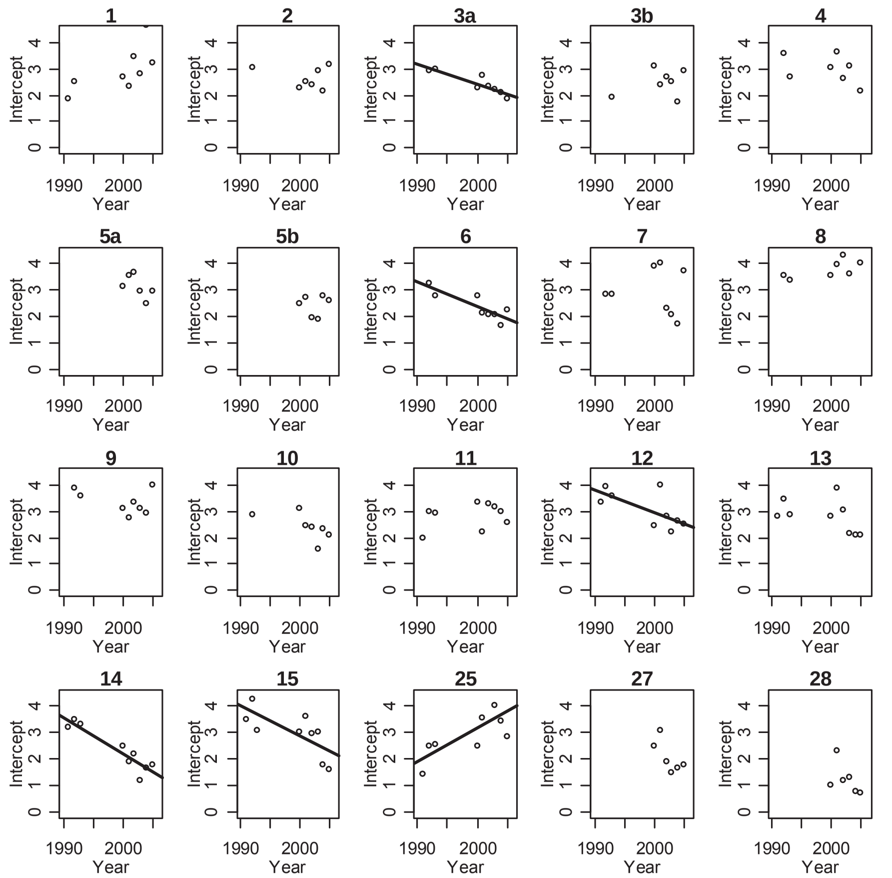


Figure 167: Plots of the size spectra intercept for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

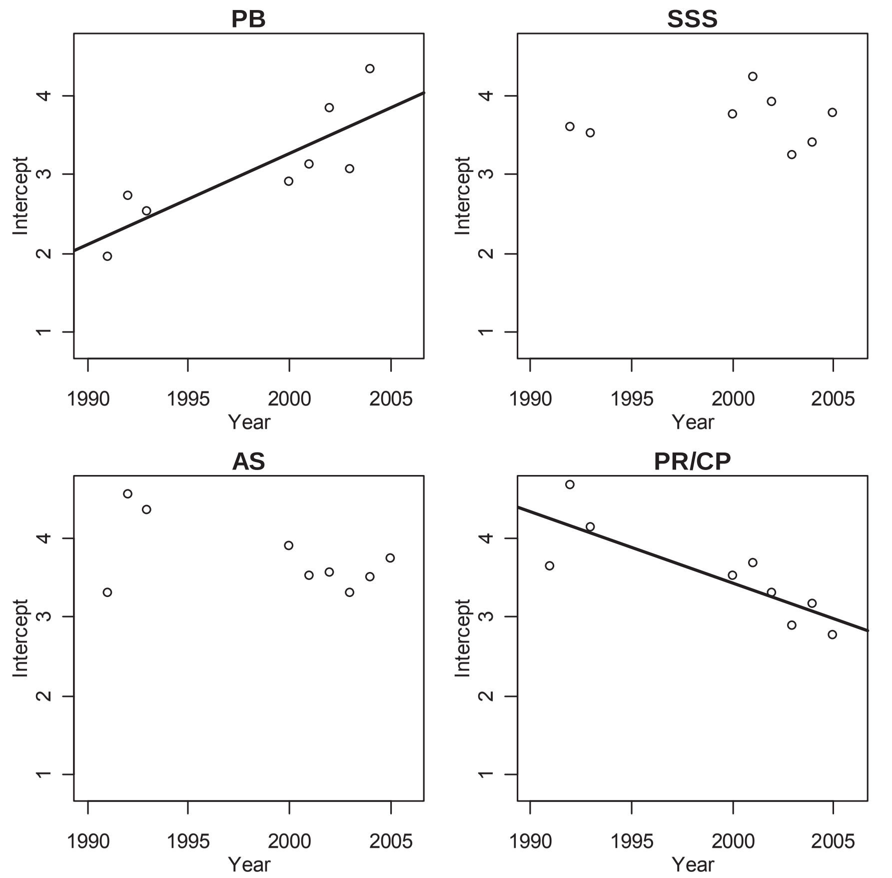


Figure 168: Plots of the size spectra intercept for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

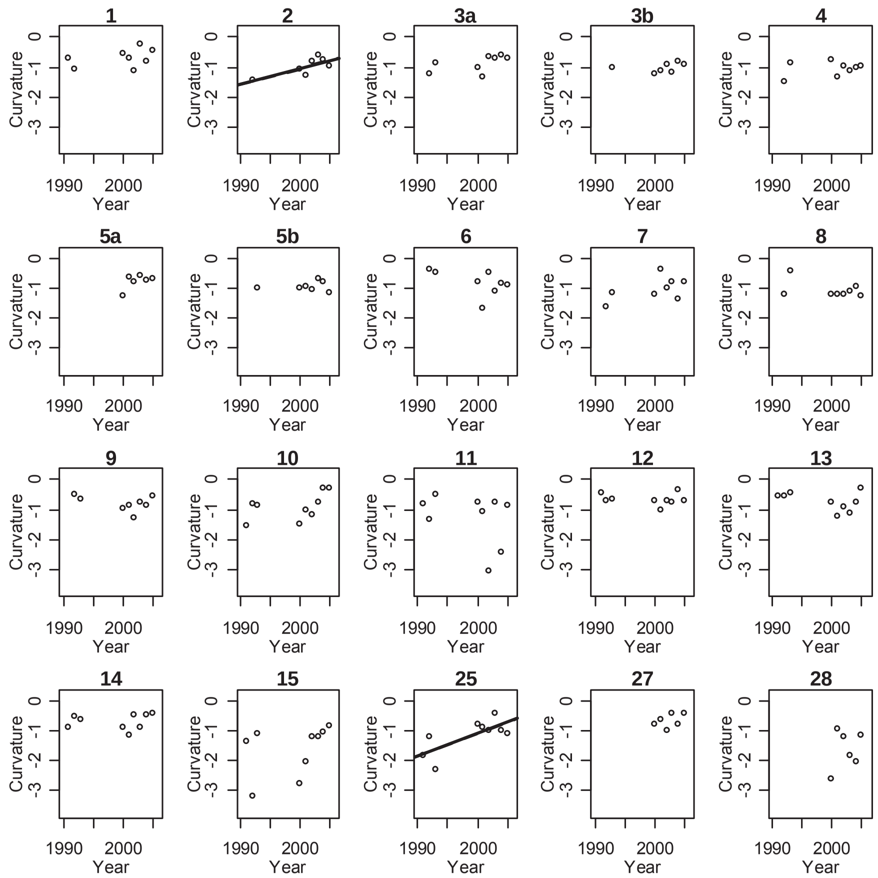


Figure 169: Plots of the biomass spectra curvature for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

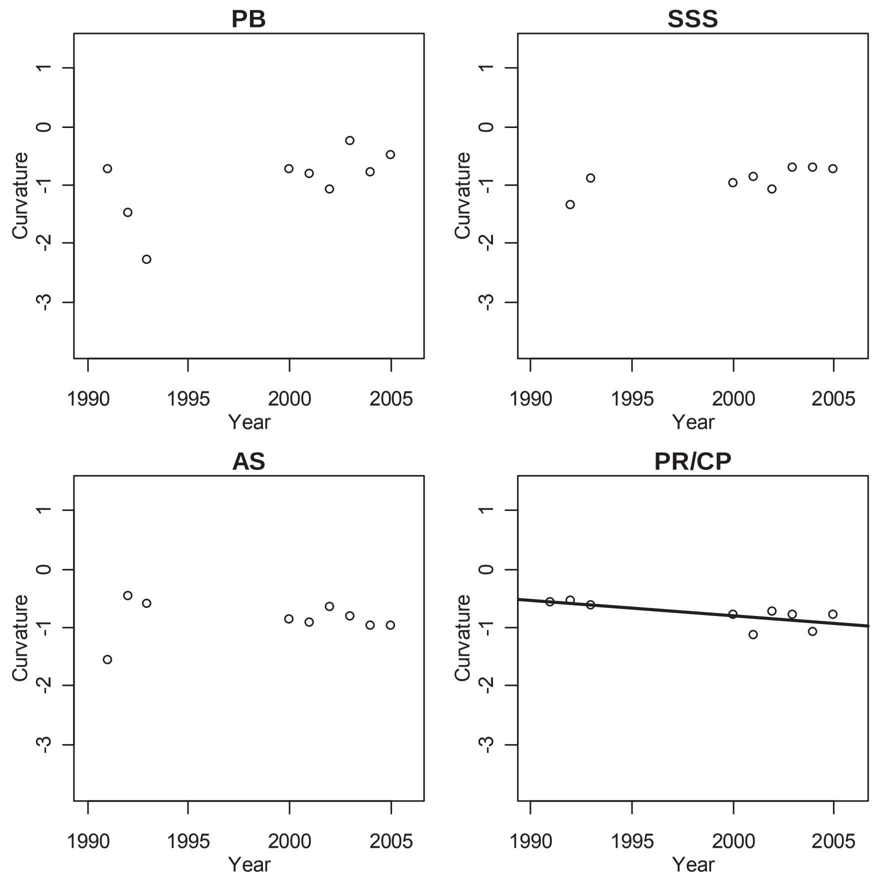


Figure 170: Plots of the biomass spectra curvature for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

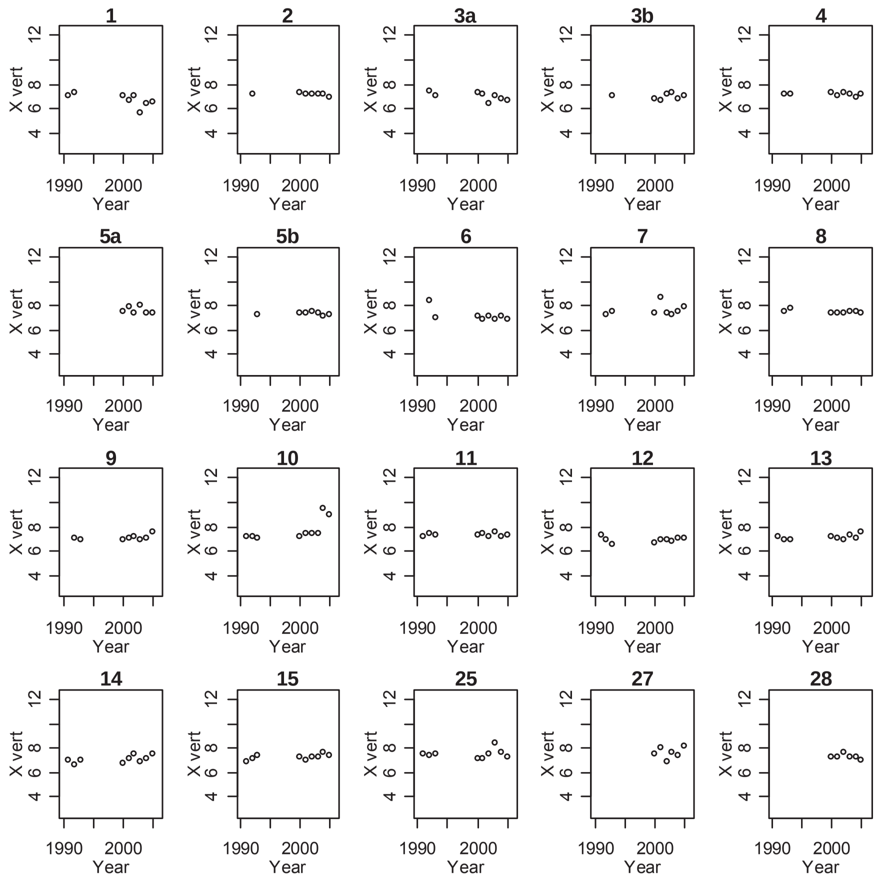


Figure 171: Plots of the biomass spectra x vertex for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

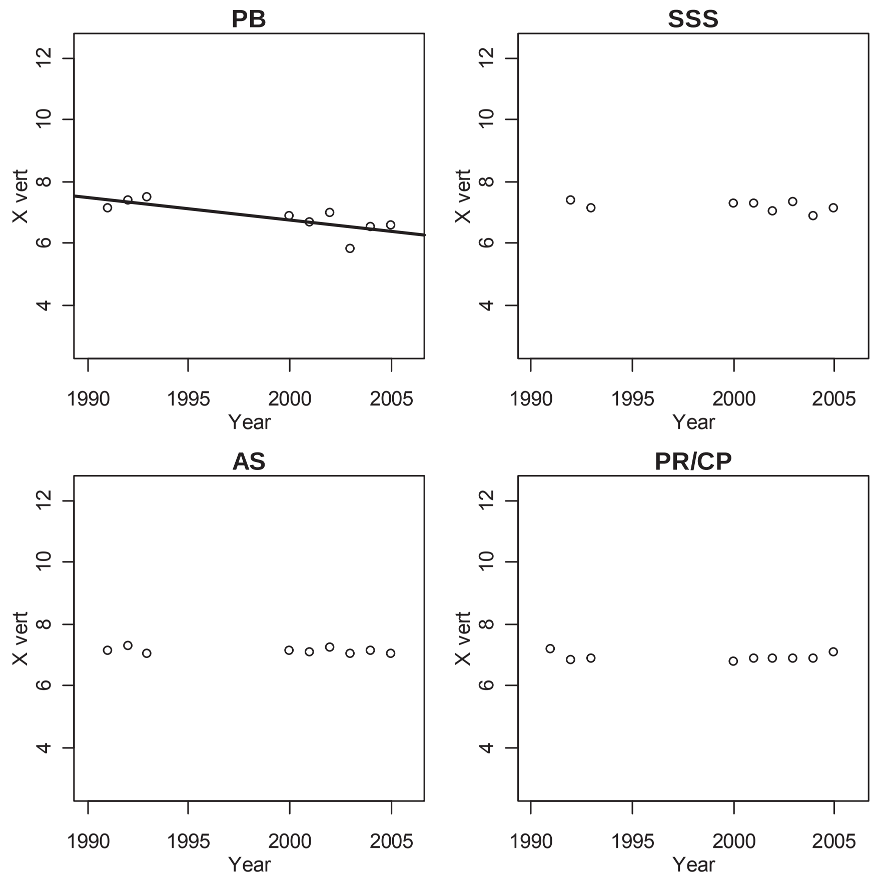


Figure 172: Plots of the biomass spectra x vertex for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

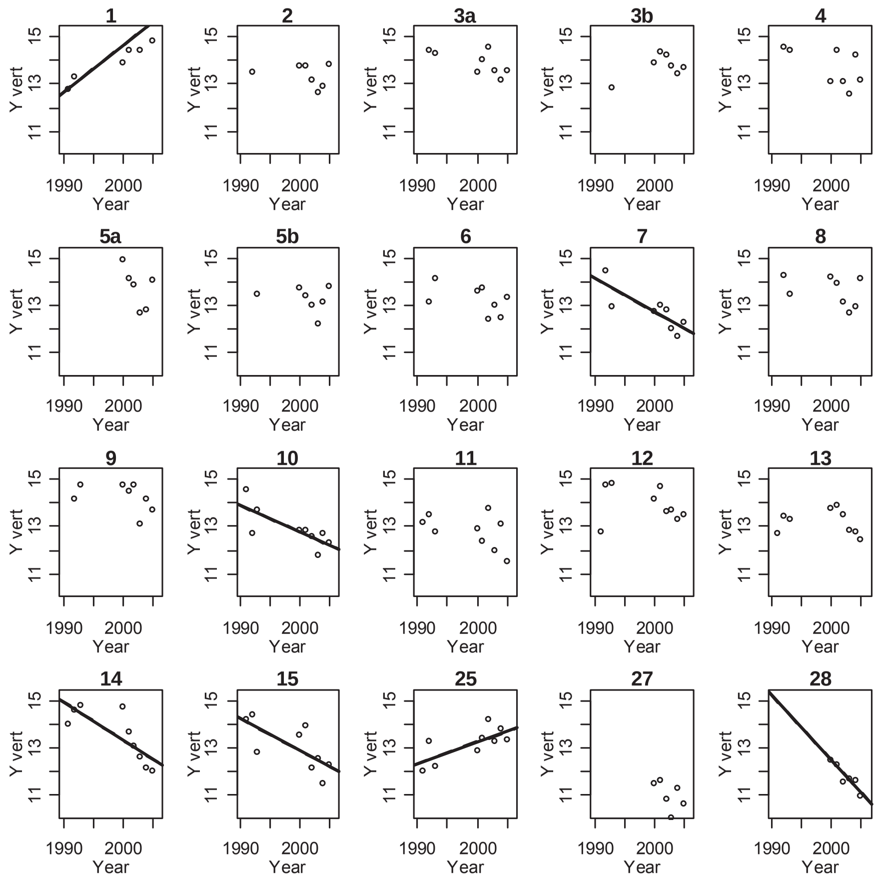


Figure 173: Plots of the biomass spectra y vertex for each survey stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

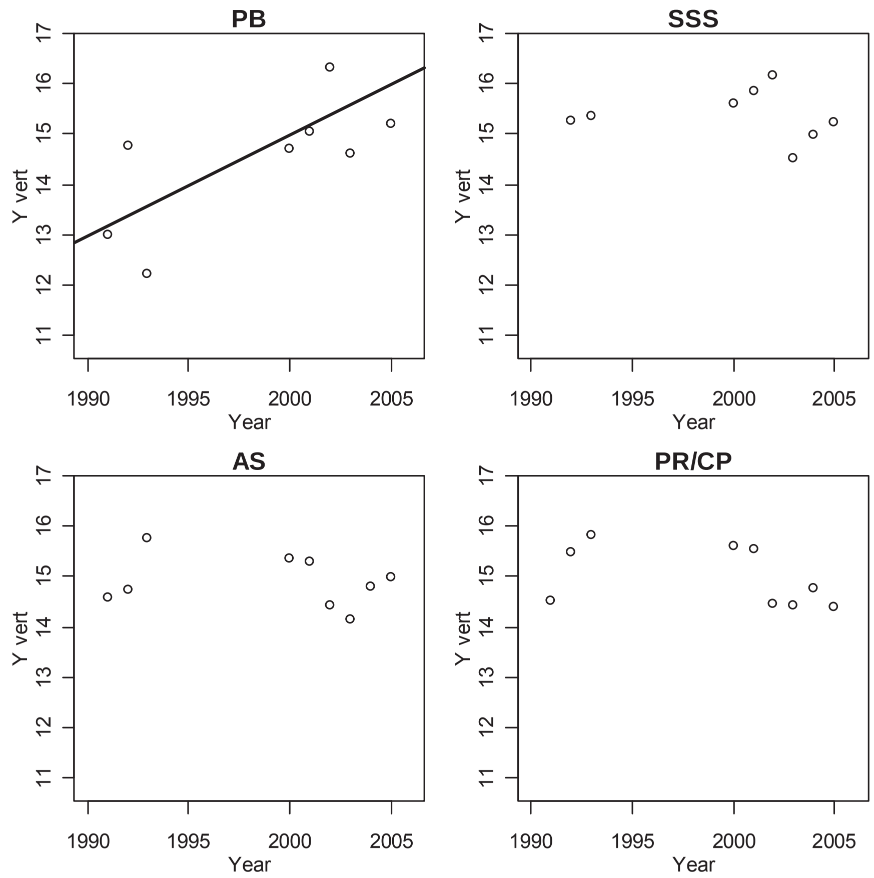


Figure 174: Plots of the biomass spectra y vertex for each larger region stratum and year. Weighted stratum averages are plotted for each year, with the solid line (where shown) representing a significant linear fit through whole series.

6.2.5. Diversity spectra

As with the Hauraki Gulf and Chatham Rise data sets, preliminary examination of the diversity size spectra for the measured species within the Southland and Sub-Antractic data set (Figures 175 & 176) suggests that fitting a linear relationship to the data above a standard length may not be the most appropriate approach (the diversity spectra were sometimes bimodal, and for others did not decline over the larger sizes, or the size at which decline starts varies between strata).

As described for the Hauraki Gulf dataset, an alternative approach comparing the cumulative relative diversity has been considered. Plots of the cumulative relative diversity for each strata and larger area are shown in Figures 177 & 178. The diversity spectra have been compared using the same Kolmogerov-Smirnov approach as the trophic spectra.

MDS plots of the pairwise P values are shown for the survey strata in Figure 179, and for the larger areas in Figure 180. The plots are very scattered, and most strata or areas show no evidence of any trend over time. Only the larger PR/CP area shows some suggestion of a gradual shift over time, with the points moving across the plot as the years progress, implying that the diversity spectra may have changed over time.

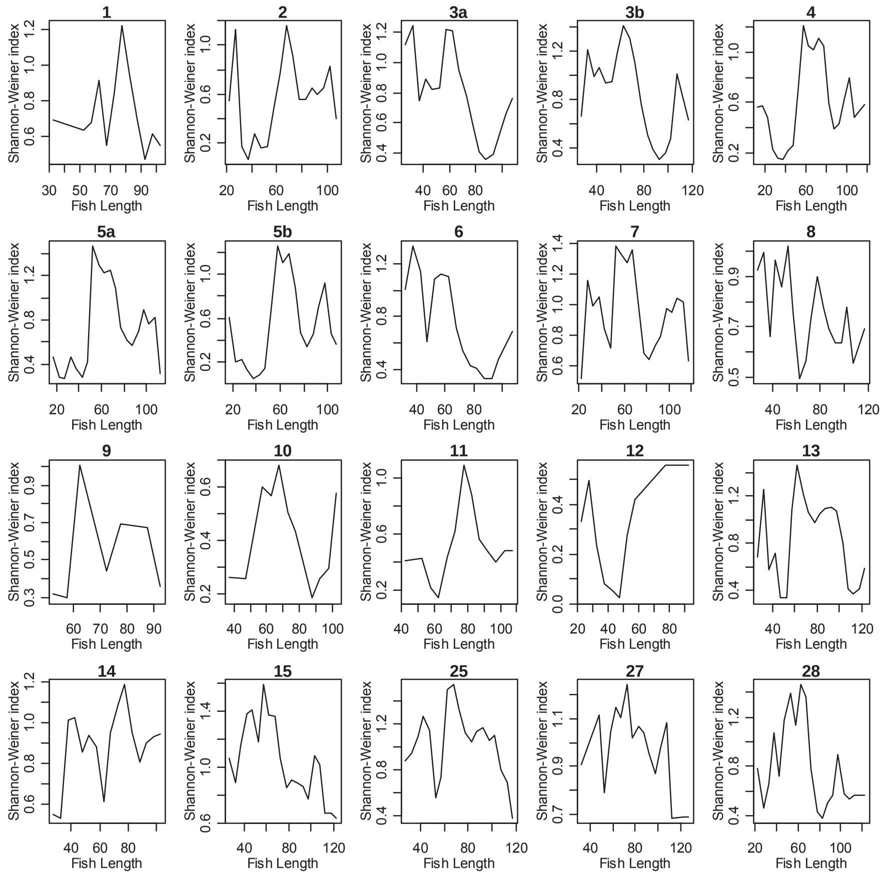


Figure 175: Plot of diversity (Shannon-Weiner index) size spectra for each survey stratum (all years).

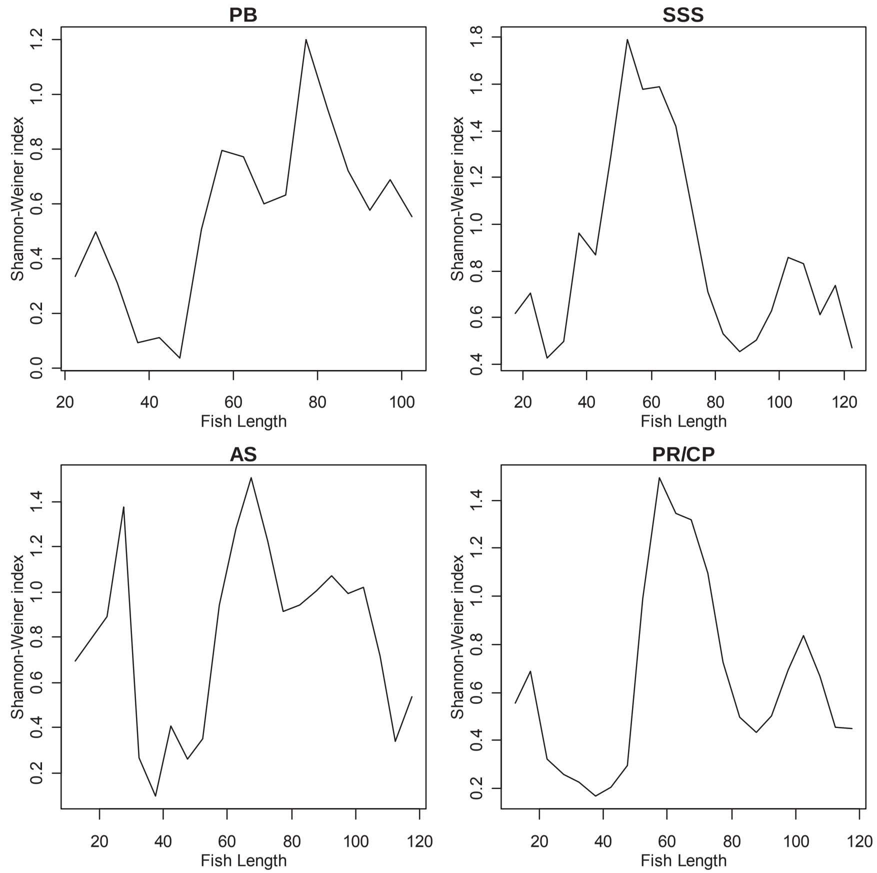


Figure 176: Plot of diversity (Shannon-Weiner index) size spectra for each larger region stratum (all years).

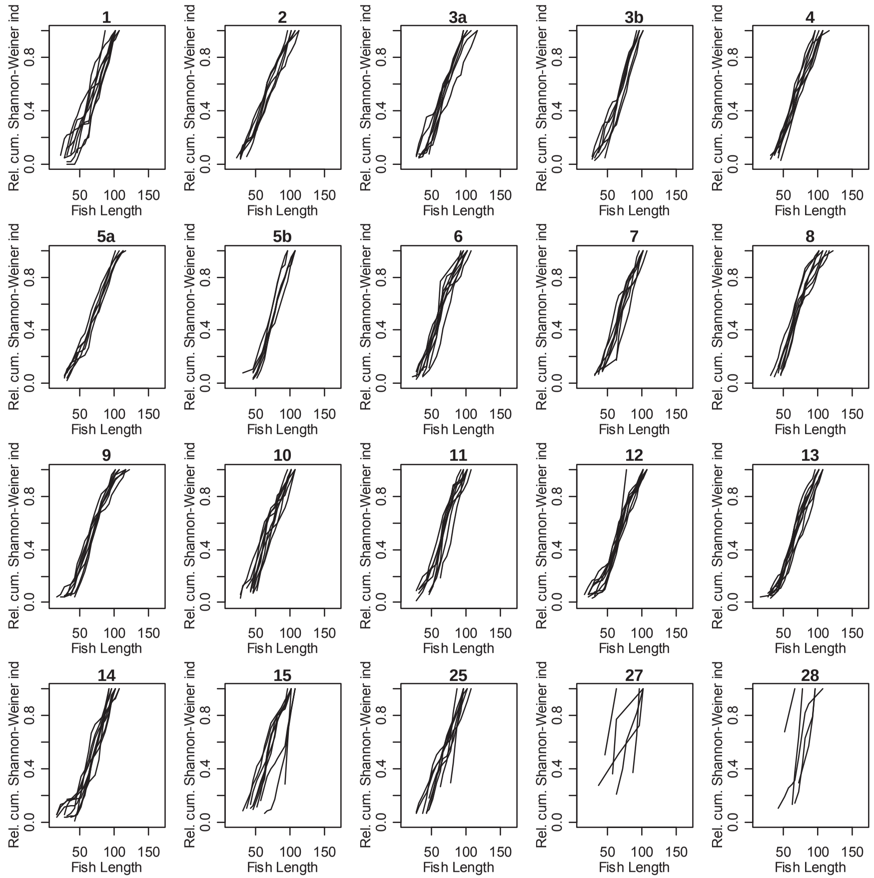


Figure 177: Plots of cumulative diversity spectra for each survey stratum.

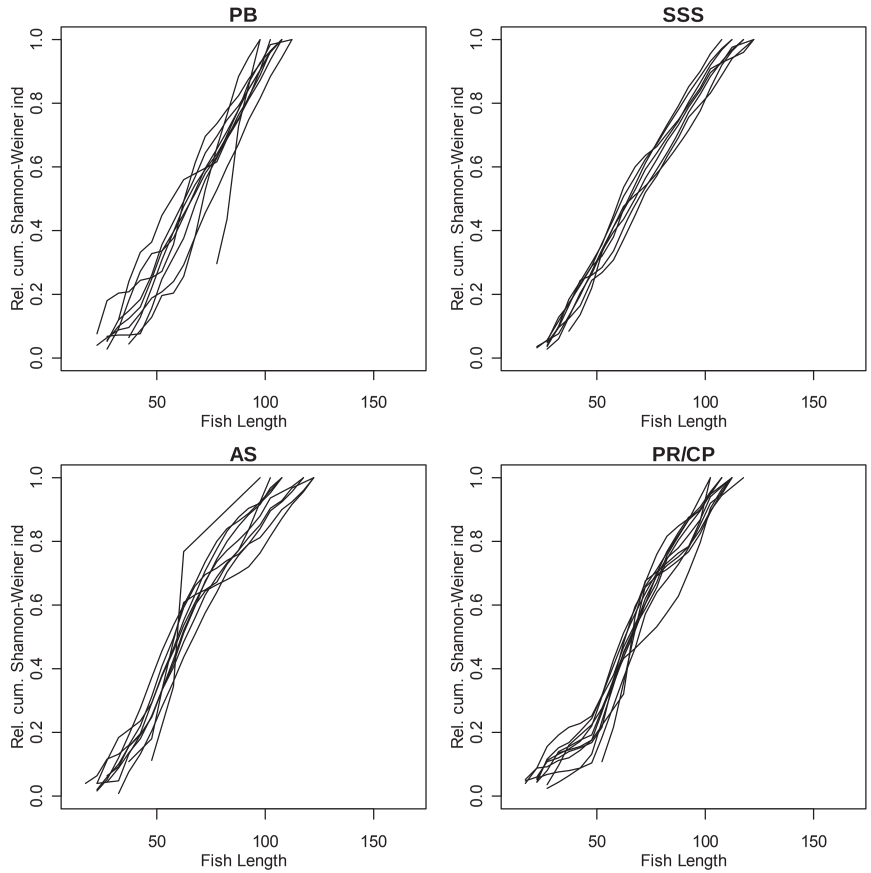


Figure 178: Plots of cumulative diversity spectra for each larger region stratum.

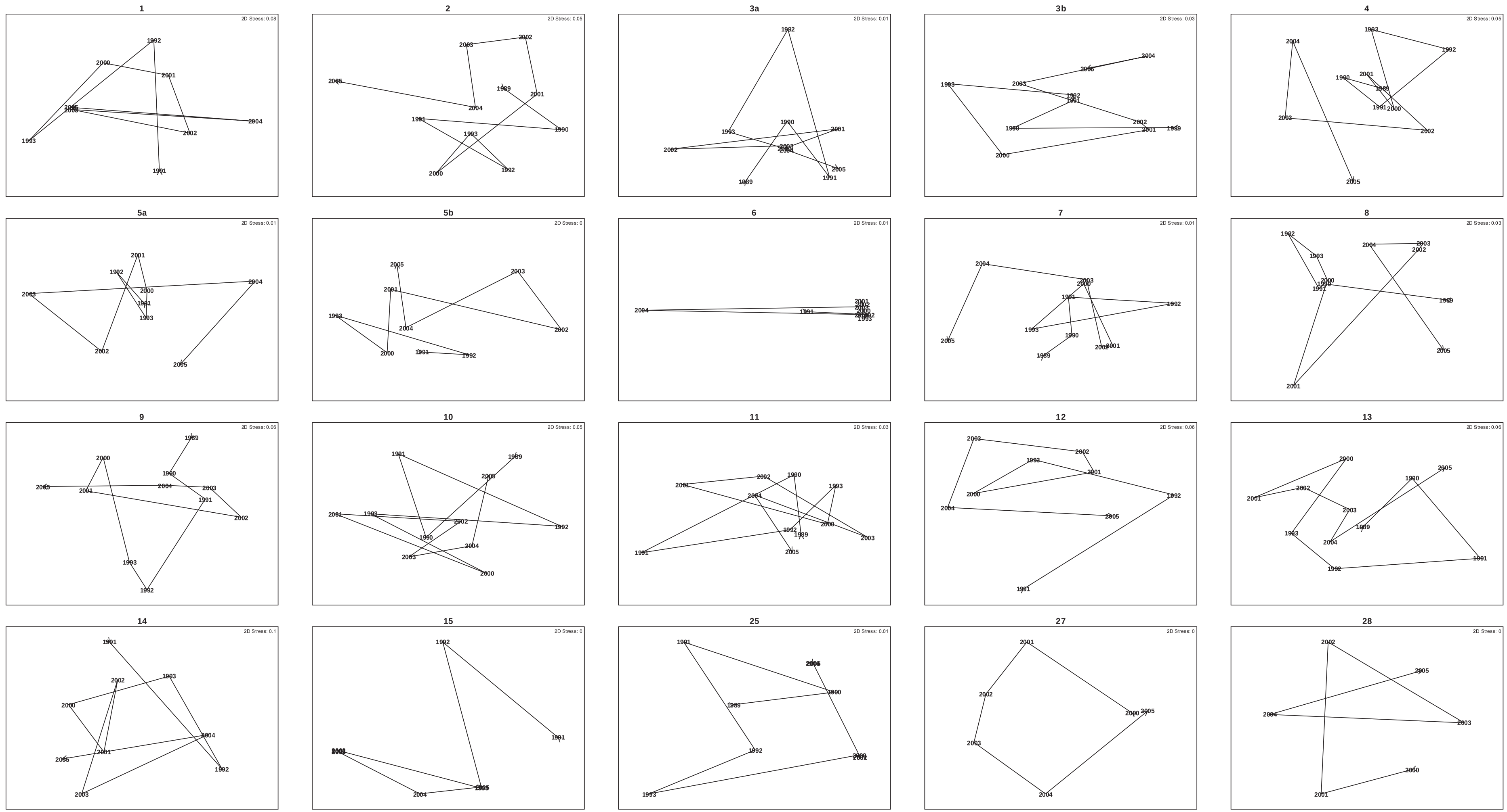


Figure 179: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of diversity spectra over time for each of the survey stratum.

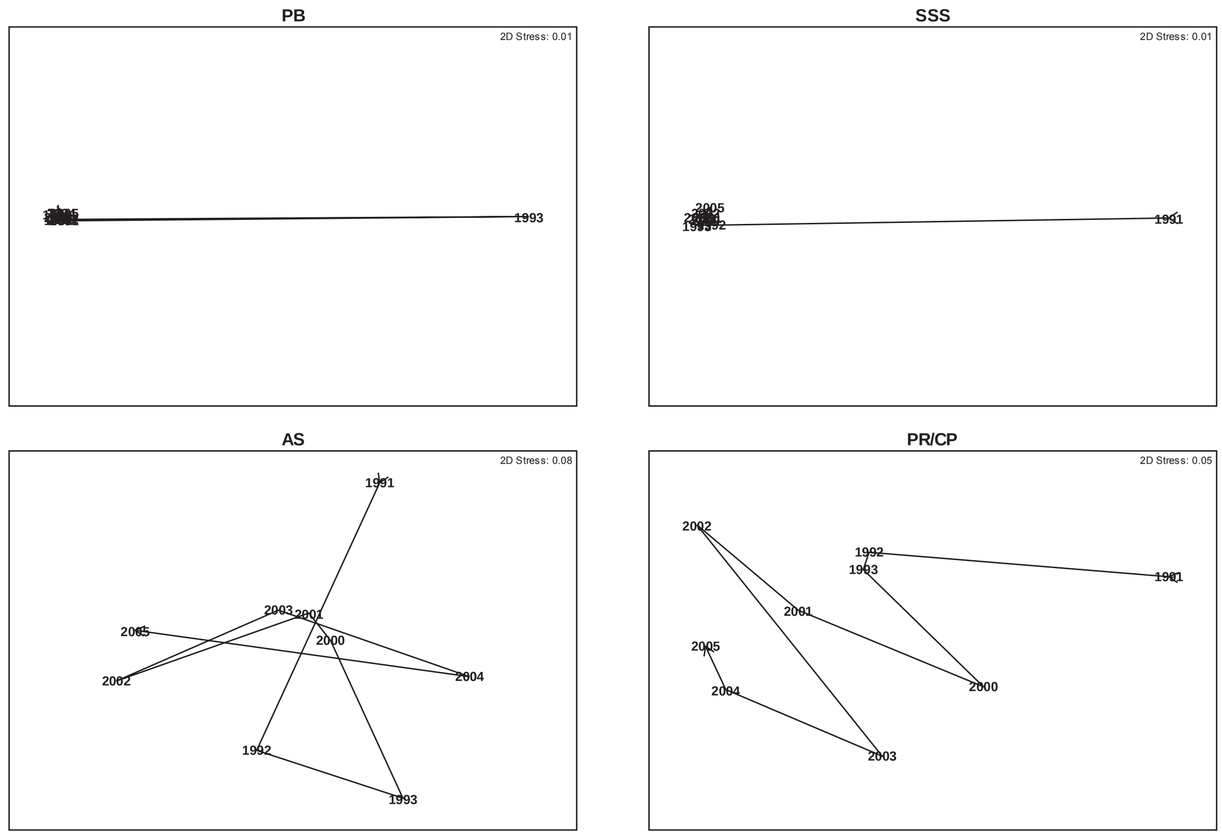


Figure 180: MDS plots of pairwise P values (taken as measures of similarity) generated from KS tests of diversity spectra over time for each of the larger areas.

6.3. Effort patterns

Trends in the cumulative area fished (as extracted from the BEN200601 database, based on TCEPR data) as a proportion of the strata area for survey strata and the larger sediment/depth areas, are shown in Figure 181. As with the Chatham Rise fishery, vessels have been required to use the TCEPR system from its onset, and data go back to the 1989–1990 fishing year. As might be expected over such a large area, the level of fishing has varied markedly, with certain northern strata (which are closest to the South Island) being fished most often. By far the most intensively fished strata appear to be S and N Stewart/Snares 300–600 (3b and 3a), with ratios of cumulative area fished:strata area of 2.23 and 1.64, respectively. Some of the other strata had more intermediate ratio values (Puysegur 600–800 (2), W Snares/Auckland 600–800 (5a), Puysegur 300–600 (1), E Snares/Auckland 600–800 (5b), NE Auckland 600–800 (8), Auckland 300–600 (6), and Stewart/Snares 600–800 (4), with ratio values of 0.55, 0.47, 0.41, 0.39, 0.20, 0.18 and 0.17, respectively), while the remainder of strata had values averaged over the 1990 to 2005 period of less than 0.1).

For the larger areas, the most intensively fished area appeared to be SSS (average ratio 1990 to 2005 of 0.40), followed by the PB (0.35), with AS (0.07) and PR/CP very lightly fished (0.01).

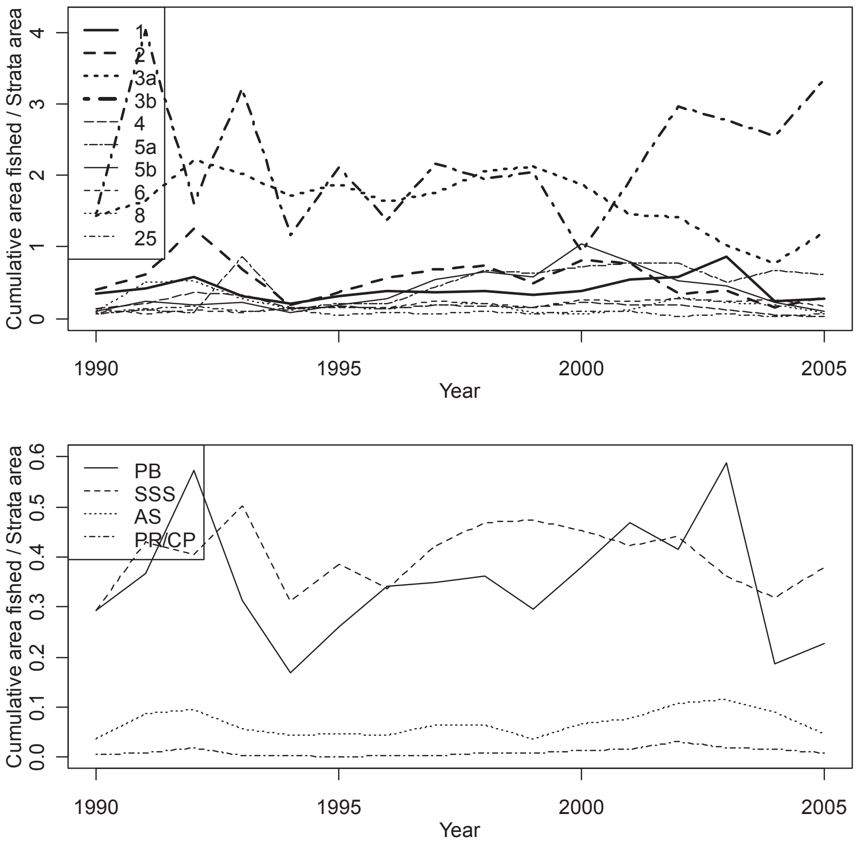


Figure 181: Plots of cumulative area fished:total strata area as estimated from data extracted from BEN200601 database for Southland & Sub-Antarctic survey strata (upper plot) and larger areas (lower plot). Survey strata not shown in the upper plot had low average effort recorded (average <5% of strata area).

6.4. Comparison across indicators and relationship with fishing effort

The slopes of the linear fits for each parameter for each stratum are provided in Table 36. As with the Chatham Rise data set, markedly more significant trends were identified than for the Hauraki Gulf. In Table 36 the indicators have been split into life history based (including species-based and trophodynamic indicators), diversity-based (all species based) and size-based indicators. The life history based indicators showed both positive and negative significant trends, but were consistent within indicator. The significant trends for the diversity-based indicators were generally positive (although both species richness and Margarlef's d showed a mixture of trends), and the significant trends for the size-based indicators were mostly negative (although L95 and the W statistic showed only significant positive trends). The proportion threatened and proportion with low or very low resilience both showed significant positive trends for E Campbell 300–600 (14) and S Campbell 600–800 (10) and Pukaki 300–600 (12), and for the larger SSS and AS areas. Other strata showed positive trends in both indicators, but not always significantly. The proportion pisciverous and mean trophic level showed little consistency at the survey strata level, but showed negative trends for the larger AS and PR/CP areas. The trophic spectra showed evidence of change over time for some of the survey strata (N Stewart/Snares 300–600 (3a), E Campbell 300–600 (14), and S Campbell 600–800 (10)), and the larger areas (SSS, AS and PR/CP) that showed significant negative trends in mean TL. However, other strata also showed negative trends in mean TL without obvious changes over time in the trophic spectra.

Of the diversity indicators, Hill's N1 and N2, Pielou's evenness, and the Shannon-Weiner index generally showed similar patterns, and had significant positive trends for Stewart/Snares 600–800 (4), E Snares/Auckland 600–800 (5b) (not evenness), Auckland 300–600 (6) (not N1), S Campbell 600–800 (10), Pukaki 300–600 (12), and E Campbell 600–800 (15), and the SSS and AS larger areas. Species richness and Margarlef's d showed similar patterns, with significant positive trends for S Stewart/Snares (3b), W Snares/Auckland 600–800 (5a), and Puyseger 800–1000 (25), and the larger PB and SSS areas, and significant negative trends for strata S Campbell 600–800 (10) and Pukaki 300–600 (12). Although a number of significant (mostly negative) relationships were identified for the size-based indicators, there were few consistent patterns with the same groups of indicators showing significant trends for different strata or areas.

To examine the trends in indicators in relation to fishing effort, the correlation (Spearman rank) between the strata slopes for each parameter (Table 36) and the average ratio of area fished:total strata area (taken as a measure of overall fishing intensity) was examined for both survey strata and the larger sediment/depth areas (Table 37). Statistical significance was examined through comparing observed correlation with distribution of correlations calculated for each parameter with 1000 resampled effort data sets. Correlations were considered significant if the correlation coefficient was outside the 2.5 to 97.5 % quantiles of the correlations on the resampled effort data. At the survey strata level there were significant positive correlations between fishing intensity and species richness and Margarlef's d, and significant negative correlations with Pielou's evenness, the W statistic, and the X vertex of the biomass spectra. Over the larger areas, none of the correlations were found to be significant.

As with the Chatham Rise series, the distinction between time periods in the trophic and diversity spectra has been judged "by eye", but for this series, the most intensively fished strata show a less consistent pattern of change in the spectra.

Table 36: Slope of linear relationships of parameters against year for each survey stratum and larger areas. To aid visualisation, significant relationships are in colour, with positive trends over time in green and negative trends over time in red. PT – proportion threatened; PLR – proportion with low or very low resilience; N1 – Hill's N1; N2 – Hill's N2; S – Species richness; d – Margarlef's d; J – Pielou's evenness; H – Shannon-Weiner diversity; Dist – average taxonomic distinctiveness; v Dist – variation in taxonomic distinctiveness; Pisc – Pisciverous:Total catch ratio; Dem – Demersal:Total catch ratio; TL – average trophic level; Med – median length; L95 – L95 length; PL – proportion of large fish; W – W statistic; SS – size spectra slope; SI – size spectra intercept; Curv – biomass spectra curvature; Xvert – biomass spectra x vertex; Yvert – biomass spectra y vertex.

		Life history based					Diversity based								Size based								
Strata	Name	PT	PLR	Pisc	Dem	TL	N1	N2	S	d	J	H	Dist	v Dist	Med	L95	PL	W	SS	SI	Curv	Xvert	Yvert
1	Puysegur 300–600	-0.0038	0.0049	0.0062	-0.0040	-0.0071	0.1397	0.1017	0.5583	0.0580	0.0048	0.0243	-0.1332	-0.4077	**-1.7682**	-0.9825	-0.0501	-0.0098	**-0.0037**	0.1067	0.0213	-0.0671	**0.2003**
2	Puysegur 600–800	0.0144	0.0017	-0.0001	-0.0014	-0.0045	0.0236	-0.0437	0.4792	0.0792	-0.0019	0.0021	0.0478	1.3406	-0.1027	0.3344	-0.0192	-0.0009	-0.0019	-0.0230	**0.0517**	-0.0056	-0.0215
3a	N Stewart/Snares 300–600	0.0043	**0.0337**	0.0046	-0.0045	**-0.0104**	0.2107	0.1541	-0.0417	0.0257	0.0116	**0.0400**	-0.0536	-1.1572	-0.8988	-0.5393	-0.0239	0.0044	-0.0025	**-0.0737**	0.0298	-0.0420	-0.0670
3b	S Stewart/Snares 300–600	-0.0015	-0.0192	-0.0022	-0.0092	-0.0067	0.1767	0.1032	**0.7559**	**0.1415**	0.0014	0.0311	-0.3353	3.8478	-0.3675	-0.0612	-0.0022	-0.0073	-0.0013	0.0378	0.0130	-0.0032	0.0676
4	Stewart/Snares 600–800	0.0060	**0.0197**	0.0012	0.0051	**-0.0067**	**0.3191**	**0.2476**	-0.3750	-0.0414	**0.0139**	**0.0419**	0.1070	1.5194	-0.4167	0.2116	-0.0066	-0.0001	0.0011	-0.0430	0.0158	-0.0063	-0.0964
5a	W Snares/Auckland 600–800	-0.0121	0.0093	-0.0014	-0.0173	-0.0031	0.1628	0.0893	**1.1792**	**0.1975**	-0.0029	0.0215	-0.0232	4.8048	-3.3143	0.0571	-0.0217	-0.0050	-0.0024	-0.1352	0.0778	-0.0349	-0.2737
5b	E Snares/Auckland 600–800	0.0111	0.0212	0.0075	**-0.0041**	-0.0104	**0.2252**	**0.2082**	0.2625	0.0612	0.0081	**0.0327**	-0.2428	0.8240	**-0.8863**	**0.5584**	-0.0040	-0.0035	0.0003	0.0198	0.0039	0.0042	-0.0263
6	Auckland 300–600	-0.0002	0.0009	0.0227	-0.0100	**-0.0220**	0.1944	**0.1555**	-0.4792	-0.0147	**0.0118**	**0.0306**	-0.1531	**3.9806**	-1.4048	0.0452	-0.0201	0.0000	-0.0006	**-0.0913**	-0.0452	-0.0642	-0.0605
7	S Auckland 600–800	0.0003	**0.0190**	0.0056	-0.0068	-0.0114	0.2649	0.2302	**-0.5958**	-0.0645	**0.0169**	0.0417	-0.2206	5.7938	-0.2381	0.3333	-0.0155	0.0058	0.0022	-0.0145	0.0426	0.0259	**-0.1419**
8	NE Auckland 600–800	0.0099	0.0134	0.0096	-0.0004	**-0.0086**	0.1311	0.1159	-0.3583	-0.0478	0.0076	0.0182	-0.1531	**7.2369**	-0.0298	0.3048	-0.0010	0.0011	0.0024	0.0433	-0.0264	-0.0163	-0.0467
9	N Campbell 300–600	0.0093	**0.0258**	0.0088	-0.0015	-0.0105	0.2022	0.1571	0.0583	0.0602	**0.0107**	0.0371	-0.0998	2.8550	-0.4226	**0.3869**	-0.0005	0.0037	0.0016	-0.0330	-0.0214	0.0212	-0.0490
10	S Campbell 600–800	**0.0079**	**0.0245**	**0.0127**	-0.0073	**-0.0177**	**0.4188**	**0.3356**	**-0.7958**	**-0.0978**	**0.0227**	**0.0623**	0.1008	-4.1018	0.0417	**0.2850**	**-0.0186**	**0.0054**	-0.0004	-0.0713	0.0416	0.1053	**-0.1115**
11	NE Pukaki 600–800	0.0031	0.0275	0.0273	-0.0238	-0.0255	-0.0160	-0.0046	-0.5292	-0.0904	-0.0001	-0.0118	-0.0264	**6.1259**	0.2667	**0.2854**	**-0.0134**	**0.0084**	**0.0047**	0.0257	-0.0567	0.0032	-0.0635
12	Pukaki 300–600	**0.0115**	**0.0208**	**0.0128**	**-0.0086**	**-0.0150**	**0.1653**	**0.1725**	**-0.7125**	**-0.0925**	**0.0132**	**0.0278**	0.0939	3.0096	**-2.1542**	-0.0219	-0.0202	-0.0071	-0.0010	**-0.0840**	-0.0063	-0.0035	-0.0321
13	NE Campbell 300–600	0.0111	**0.0268**	**0.0128**	**-0.0029**	**-0.0131**	0.1070	0.1113	-0.3083	-0.0320	**0.0100**	0.0214	0.1792	2.4169	-0.8000	0.2277	-0.0165	0.0041	0.0008	-0.0522	-0.0205	0.0170	-0.0162
14	E Campbell 300–600	**0.0125**	**0.0317**	0.0103	-0.0032	**-0.0158**	**0.2490**	**0.1967**	**-0.6458**	-0.0595	**0.0193**	**0.0438**	0.1039	**12.8610**	**-1.7292**	0.0096	-0.0191	-0.0037	0.0011	**-0.1401**	0.0073	0.0269	**-0.1617**
15	E Campbell 600–800	0.0097	**0.0211**	**0.0182**	-0.0047	**-0.0153**	**0.3656**	**0.2738**	-0.2250	0.0041	**0.0201**	**0.0584**	-0.0845	3.6336	-0.2417	0.2254	**-0.0261**	0.0033	-0.0018	**-0.1119**	0.0584	0.0208	**-0.1341**
25	Puysegur 800–1000	0.0017	**0.0132**	0.0047	-0.0040	-0.0050	0.3214	0.1977	**0.6917**	**0.0984**	0.0051	0.0290	**0.2198**	-1.6283	-0.5625	0.0388	**-0.0144**	-0.0033	-0.0002	**0.1280**	**0.0760**	0.0107	**0.0913**
27	NE Pukaki 800–1000	0.0462	-0.0029	-0.1099	0.0604	0.0664	0.6769	0.4664	-1.5143	-0.0960	0.0354	0.1014	-0.7963	6.9656	-3.2571	0.5671	-0.0356	0.0106	-0.0045	-0.2377	0.0503	0.0745	-0.1687
28	Stewart/Snares 800–1000	0.0018	0.0085	-0.0059	0.0487	0.0124	-0.1915	0.0156	0.0571	0.0848	-0.0163	-0.0568	0.5242	5.4398	-0.9857	0.5086	-0.0381	0.0005	0.0023	-0.1678	0.0998	-0.0429	**-0.2735**
PB		0.0017	0.0049	-0.0049	-0.0028	-0.0059	0.2950	0.1932	**1.4583**	**0.1817**	0.0028	0.0239	0.1242	-1.2690	**-2.0500**	-0.6292	**-0.0495**	-0.0088	**-0.0046**	**0.1163**	0.0685	**-0.0703**	**0.2015**
SSS		**0.0082**	**0.0213**	-0.0126	-0.0092	**-0.0175**	**0.8050**	**0.5003**	**2.2083**	**0.3822**	**0.0130**	**0.0743**	0.0166	0.6046	**-0.9226**	-0.1012	**-0.0143**	-0.0041	-0.0016	0.0051	0.0318	-0.0144	-0.0098
AS		**0.0070**	**0.0194**	**-0.0113**	**-0.0044**	**-0.013**	**0.4443**	**0.2987**	-0.0583	0.0608	**0.0144**	**0.0565**	-0.0483	1.7655	-0.3583	0.2425	-0.0156	**0.0056**	-0.0012	-0.0408	0.0031	-0.0046	-0.0193
PR/CP		0.0067	**0.0399**	**-0.0304**	**-0.0378**	**-0.0342**	0.3037	0.1730	0.4042	0.0757	**0.0097**	**0.0418**	**-0.1838**	**5.6906**	**-1.6083**	0.2375	**-0.0192**	-0.0011	0.0001	**-0.0913**	**-0.0260**	-0.0040	-0.0476

Table 37: Summary of Spearman rank correlation tests between slopes of trends in indicator parameters over time and average ratio of area fished:strata area. Correlation coefficient provided for rank correlations over survey strata and larger areas. Significant correlations (on basis of effort bootstraps) are in bold red (negative) and green (positive) font.

	Survey strata	Larger areas
PT	-0.421	0.4000
PLR	-0.362	-0.4000
N1	-0.208	0.4000
N2	-0.391	0.8000
S	**0.690**	0.8000
d	**0.660**	0.8000
J	**-0.502**	0.0000
H	-0.214	0.4000
Dist	-0.237	0.8000
V Dist	-0.358	-0.8000
Pisc	-0.447	0.4000
Dem	-0.119	0.4000
TL	0.411	0.4000
Med	-0.030	0.0000
L95	-0.314	-0.6000
PL	0.104	0.4000
W	**-0.529**	-0.6000
SS	-0.330	-0.8000
SI	0.368	0.8000
Curv	0.128	0.8000
Xvert	**-0.620**	-0.8000
Yvert	0.325	0.8000

7. CONSISTENCY IN RELATIONSHIPS WITH FISHING INTENSITY BETWEEN TRAWL SURVEY SERIES

It has clearly been possible to examine changes in fish communities in relation to fishing intensity only over the time period for which trawl survey and fishing effort data are available. If significant changes to fish communities or their length or trophic structure occurred before this, then this may have influenced the potential for the indicators to detect changes over the more recent period.

While a number of significant correlations were identified between indicator slopes over time and strata fishing intensity, only Pielou's evenness was significant for all three series (and only at the survey strata level, not over larger areas), and the diversity-based indicators generally appeared most useful in identifying changes in the community that were correlated with fishing intensity. Because of the way in which some of the diversity indicators (e.g., N1, N2, Shannon-Weiner) are calculated (combining two distinct facets of diversity – species richness and the way individuals are distributed among species (evenness)), fishing may result in either an increase or a decrease in an indicator. The two facets may work in opposite directions and their effects are confounding, so major changes in diversity may result in similar diversity indices.

The nature of the correlation between fishing intensity and Pielou's evenness varied between areas (negative for the Hauraki Gulf and Sub-Antarctic, but positive for the Chatham Rise), but these correlations were consistent with other (not necessarily significant) correlations and trends for the respective trawl series. The negative correlations for the Hauraki Gulf and Sub-Antractic were associated with negative correlations for N1 and N2, but positive correlations with species richness and Margarlef's d. The significant negative correlation for Pielou's evenness for the Chatham Rise series is associated with positive correlations for N1 and N2, but negative correlations with species richness and Margarlef's d. The fact that both N1 and N2 have the same correlation with fishing intensity (within trawl series) implies the changes for all the series are related to changes in the relative abundance of the dominant species. For the Chatham Rise, a number of the most dominant species declined in their distribution (see Figure 69), which will have had a negative effect on dominance, and hence a positive effect on evenness.

The only other indicators giving a consistent correlation with fishing intensity were the W statistic, proportion threatened, and proportion demersal. The W statistic was consistently negatively correlated with fishing intensity (areas with higher fishing intensity show steeper slope for W statistic, becoming more disturbed over time) but was not significant for the Hauraki Gulf. Both the proportion threatened and proportion demersal also showed consistent negative correlations with fishing intensity, but correlations were not significant in any of the series. Interestingly, proportion threatened and proportion with low/very low resilience both showed a number of significant positive trends over time at both the strata and larger area level for the Chatham Rise and Southland and Sub-Antarctic data sets. The indicators based on a proportion of the total catch are likely to be sensitive to changes in overall catch level however, and are likely to be less useful for data sets where significant changes in overall catch or the most dominant species have taken place.

Indicators based on feeding groups (proportion pisciverous and mean TL) did not appear correlated with fishing intensity, but no account was taken of changes in feeding with size, and this may have limited the potential of these indicators.

Although the W statistic (calculated using the measured species data, as the number of individuals by species was required), provided a consistent pattern in relation to fishing intensity, the other indicators calculated from the measured species data did not provide significant correlations with fishing intensity. There were a number of significant trends (generally negative) over time for individual strata however. This failure to detect changes related to fishing intensity across strata may be associated with the fact that the indicator is based on only a relatively small subset of species, which may not be evenly distributed across all strata, and responses to fishing pressure may therefore be different in individual strata, depending on the make up of the measured fish community.

8. CONCLUSIONS

Species-based diversity type, and size-based mean size and size spectra type indicators have been the most commonly investigated approaches for developing ecosystem indicators from trawl survey data (Rochet & Trenkel 2003, Trenkel & Rochet 2003, Fulton et al. 2005, Jennings & Dulvy 2005, Mueter & Megrey 2005), although trophodynamic indicators have also been use to a lesser extent (Jennings et al. 2002, Cury et al. 2005, Sosa-Lopez et al. 2005), and all have been used successfully to identify the effects of fishing on fish communities.

Length distributions and catch weight by species are routinely recorded from New Zealand trawl surveys, which means that data are available to calculate the "standard" species-based and size-based indicators. Other species- and size-based indicators also require additional life history characteristic information, some of which may be readily available (e.g., indicator or endangered species), and some of which may not (e.g., length at age and maturity). The trophodynamic indicators require data on feeding patterns and trophic level, which are not routinely collected on surveys, but can be found through literature searches.

A range of trawl surveys is available, with the longer, more consistent (in terms of vessel and spatial coverage) series appearing to be in the inshore and middle depths. Some issues in relation to species identification and measurement practices have previously been identified, and given their potentially confounding nature, these need to be clarified before analysis takes place.

A review of available indicators, trawl survey data, and recommendations for analysis within this project was presented to an AEWG/stakeholder workshop in 2007. On the basis of discussions at this workshop, the Hauraki Gulf, Chatham Rise, and Southland and Sub-Antarctic trawl survey series documented in this report were analysed.

A range of ecosystem indicators identified from the literature was examined and applied to the three trawl survey series. These indicators included species-based indicators (various measures of diversity and key indicator species), size-based indicators and trophodynamic indicators. Previous studies elsewhere have found each of these groups useful in identifying changes in trawl survey communities in relation to fishing pressure.

Within the current study, indicators were examined at the scale of survey strata and larger areas. There are advantages to both approaches, and, ultimately, some combined approach related to the distribution of fishing pressure and environmental drivers influencing habitats may offer the best solution. While the analysis at the individual survey stratum level may have been limited by low sampling levels for some areas, the combination of strata to larger areas may have resulted in the combination of data from areas of quite different fishing histories, which would limit the potential to detect changes in relation to fishing intensity.

The data sets used for the analysis were partly related to the data requirements of the indicators in question (i.e., measured species required for size based indicators), but for the species-based approaches, various subsets of the data were examined (either excluding certain species groups, or aggregating the data to family level rather than conducting the analysis at the species level). Analyses of indicators from trawl survey time series elsewhere have often excluded pelagic species (since these may not be sampled consistently by demersal trawl survey gear), and the exclusion of pelagic species from the analyses documented here appeared to have minimal effect on the trends observed. The application of species-based indicators to the measured species data set generally resulted in different trends (to the full or pelagics excluded data) being identified, and would therefore not be recommended. Given that the measured species represented quite a small subset of the full species range, they are unlikely to represent the full community particularly well. For one data series, aggregation of the full data set to family level was also considered. The results were less consistent (with the full data set) than excluding pelagic species, but more consistent than the measured species, and may provide a useful approach where the level of taxonomic identification has varied on surveys.

From this examination of three New Zealand trawl survey series, species-based measures of diversity appear to be the most useful in identifying changes correlated with fishing intensity. Of the diversity measures, Pielou's evenness appears to most consistently show a significant correlation with fishing intensity, but the Shannon-Weiner index, species richness, and Hill's N1 and N2 also showed patterns in relation to fishing pressure. The direction of the change in diversity in relation to fishing is not necessarily down, and depends on the nature of the community in question. Size-based indicators did not appear as useful for New Zealand trawl survey series as they have been elsewhere, and this may be related to the requirement to reduce the data set to key measured species. The size-based indicators did show significant trends over time (generally negative) for some strata, but these did not produce significant correlations with fishing intensity when all strata were considered. Where size-based approaches have been used successfully elsewhere, long time series of trawl surveys where all fish species are measured are available (e.g., North Sea). While not strictly a size-based indicator, the W statistic was calculated from the measured species data set (owing to the need for numbers and weight caught). The W statistic was consistently negatively correlated with fishing intensity (not always significantly), but its usefulness here may have been limited by its reliance on a small pool of measured species.

9. RECOMMENDATIONS

Future analyses

While this report provides a useful examination of the suite of indicators selected, the scope of the study has meant that some indicators that have proved useful elsewhere (particularly those requiring data on individual fish age, weight, or maturity details) were not considered. In addition, other indicators have come to light more recently (Hsieh et al. 2006, Anderson et al. 2008) which warrant examination. **We would therefore recommend that any future analysis of this sort does not limit itself to the indicators identified as being useful in this study, but also considers some of the other indicators, where data are available.**

The trends over time observed in the indicators are likely to vary with the spatial scale over which the indicators are examined. This study has examined the indicators over survey strata, or combinations of strata based on environmental or fish community patterns, and no account was taken of the patterns in fishing effort in determining the areas to consider. Some of the large strata may have a spatial mismatch in the distribution of survey stations (from which the data are collected) and concentrations of fishing effort. **We would therefore also recommend fishing effort patterns be included in the data considered in determination of the spatial extent of strata over which to examine trends in various indicators.**

Survey data collection

Although trawl surveys have been widely used in fisheries research in New Zealand, some trawl survey series (particularly for deepwater areas) were not considered consistent enough for meaningful analysis in this study. For others that were examined, considerable data grooming was required and only a small component of the catch was measured consistently over time, and therefore available for analysis with size-based indicators. Where size-based indicators have proved useful elsewhere, it has generally been where most or all the fish catch is measured. While measuring all fish catch on all surveys would clearly be a large and expensive commitment, **we recommend that survey protocols are reviewed to determine the most appropriate balance between cost and utility, to improve sampling and routine data collection on trawl surveys, and provide consistent data sets for future analyses.** One limitation of the study is that it has not examined a deepwater survey (as none were considered consistent enough), and **we recommend a consistent deepwater survey series is developed.**

Although indicators based on trophic level were examined within the current study, single values were applied to each species, which may not have been appropriate given many species change their diet as they grow. The use of a single value per species largely owed to lack of available information on size specific trophic level. Trophic level studies are currently underway for some fish communities in New Zealand, and **we recommend that existing data on fish diet composition and trophic level in New Zealand be compiled to identify knowledge gaps and research needs.**

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Appendix 1: Species life history characteristics used in analysis .(a & b – length weight parameters; RL – Reed List; R – Resiliance; FEED – feeding group; TL – Tropic level; H, C & S – recorded in Hauraki Gulf, Chatham Rise or Southland/Sun Antarctic data set)

spec	a	b	HAB	RL	R	FEED	TL	Species	Genus	Family	Order	Class	Phylum	H	C	S
ABR			PEL	NL	M	INV	3.81	Alepisaurus brevirostris	Alepisaurus	Alepisauridae	Aulopiformes	Actinopterygii	Chordata			1
ACT			DEM	NL	M	BEN INV	3.37	Achiropsetta tricholepis	Achiropsetta	Bothidae	Pleuronecteformes	Actinopterygii	Chordata			1
AGR			PEL	NL	VL	BEN INV	3.2	Agrostichthys parkeri	Agrostichthys	Regalecidae	Lampriformes	Actinopterygii	Chordata		1	1
AME			BATDEM	NL	H			Antipodocottus megalops	Antipodocottus	Cottidae	Scorpaeniformes	Actinopterygii	Chordata			1
ANC	0.00799	3.0650	PEL	NL	H	PLANK	3	Engraulis australis	Engraulis	Engraulididae	Clupeiforms	Actinopterygii	Chordata	1		
ANO	0.01790	3.0000	BATPEL	NL	M	PISC	4.01	Anoplogaster cornuta	Anoplogaster	Anoplogaster	Beryciformes	Actinopterygii	Chordata		1	1
API	0.02000	3.0000	BATDEM	NL		BEN INV	3.29	Alertichthys blacki	Alertichthys	Congiopodidae	Scorpaeniformes	Actinopterygii	Chordata		1	1
APR	0.00270	3.0477	BATDEM	LC	L	PISC	3.2	Apristurus spp.	Apristurus	Scyliorhinidae	Carchariniformes	Elasmobranchii	Chordata		1	1
AST	0.00130	3.1060	BATPEL	NL	M	PISC	4.03	Astronesthidae	Astronesthes	Stomiidea	Stomiiformes	Actinopterygii	Chordata		1	1
BAC			BATDEM	NL	M	PISC	3.9	Bathygadus cottoides	Bathygadus	Macrouridae	Gadiformes	Actinopterygii	Chordata			1
BAN			BATDEM	NL	M	PISC	3.6	Borostomias antarcticus	Borostomias	Stomiidea	Stomiiformes	Actinopterygii	Chordata		1	
BAR	0.00910	2.8800	BENPEL	NL	M	PISC	4.19	Thyrsites atun	Thyrsites	Gempylidae	Perciformes	Actinopterygii	Chordata	1	1	1
BAS	0.02340	2.9220	BATDEM	DD	L	PISC	4.14	Polyprion americanus	Polyprion	Percichthyidae	Perciformes	Actinopterygii	Chordata		1	
BBE	0.00580	2.9997	BATDEM	NL	M	INV	3.57	Centriscops humerosus	Centriscops	Macrorhamphosidae	Syngathiformes	Actinopterygii	Chordata		1	1
BBR	0.00520	3.2916	DEM	NL	L	PISC	4.4	Xenobrama microlepis	Xenobrama	Bramidae	Perciformes	Actinopterygii	Chordata		1	1
BCA	0.00190	2.9460	BATPEL	NL	M	PISC	4.5	Magnisudis prionosa	Magnisudis	Paralepididae	Aulopiformes	Actinopterygii	Chordata		1	1
BCO	0.01224	3.0746	DEM	NL	M	PISC	3.87	Parapercis colias	Parapercis	Pinguipedidae	Perciformes	Actinopterygii	Chordata	1		1
BCR			BATPEL	NL	L	PISC	4.3	Brotulotaenia crassa	Brotulotaenia	Ophidiidae	Ophidiiformes	Actinopterygii	Chordata		1	
BEE			BATDEM	NL	L	INV	3.68	Diastobranchus capensis	Diastobranchus	Synaphobranchidae	Anguilliformes	Actinopterygii	Chordata	1	1	1
BER			DEM	DD	L	BEN INV	4.5	Typhlonarke spp.	Typhlonarke	Narkidae	Torpediniformes	Elasmobranchii	Chordata		1	1
BGZ	0.01548	3.0279	DEM	NL	M	PISC	3.29	Kathetostoma spp.	Kathetostoma	Uranoscopidae	Perciformes	Actinopterygii	Chordata		1	1
BJA			BENPEL	NL	L	BEN INV	3.79	Mesobius antipodum	Mesobius	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
BMO			BATPEL	NL	M	PISC	3.98	Borostomias mononema	Borostomias	Stomiidea	Stomiiformes	Actinopterygii	Chordata			1
BNS	0.00960	3.1730	BENPEL	NL	L	PISC	3.95	Hyperoglyphe antarctica	Hyperoglyphe	Centrolophidae	Perciformes	Actinopterygii	Chordata		1	1
BOA	0.01650	3.0000	DEM	NL	L	BEN INV	3.3	Paristiopterus labiosus	Paristiopterus	Pentacerotidae	Perciformes	Actinopterygii	Chordata	1	1	1
BRA	0.02960	3.0000	DEM	LC	VL	BEN INV	3.87	Dasyatis brevicaudata	Dasyatis	Dasyatidae	Rajiformes	Elasmobranchii	Chordata	1		
BRC	0.00080	3.0080	REEF	NL	H	OMNIV	3.42	Pseudophycis breviuscula	Pseudophycis	Moridae	Gadiformes	Actinopterygii	Chordata	1		1
BRI	0.00850	3.0854	DEM	NL	VL	BEN INV	3.06	Colistium guntheri	Colistium	Pleuronectidae	Pleuronecteformes	Actinopterygii	Chordata	1		
BRZ	0.01360	3.0321	DEM	NL	M	PISC	4.29	Xenocephalus armatus	Xenocephalus	Uranoscopidae	Perciformes	Actinopterygii	Chordata	1	1	
BSH	0.00180	3.2400	BATDEM	DD	L	PISC	4.15	Dalatias licha	Dalatias	Datatiidae	Squaliformes	Elasmobranchii	Chordata		1	1

Appendix 1 continued

spec	a	b	HAB	RL	R	FEED	TL	Species	Genus	Family	Order	Class	Phylum	H	C	S
BSK			PEL	VU	VL	PLANK	3.2	Cetorhinus maximus	Cetorhinus	Cetorhinidae	Lamniformes	Elasmobranchii	Chordata	1		1
BSP	0.04790	3.0000	PEL	NL	VL	PISC	4.5	Taratichthys longipinnis	Taratichthys	Bramidae	Perciformes	Actinopterygii	Chordata		1	1
BSQ	0.27770	1.4130	PEL	NL	H	PISC	3.44	Sepioteuthis australis	Sepioteuthis	Loliginidae	Teuthoidea	Cephalopoda	Mollusca	1		
BTA	0.00440	3.1574	BATDEM	NL	L	OMNIV	3.98	Notoraja asperula	Notoraja	Rajidae	Rajiformes	Elasmobranchii	Chordata		1	1
BTH	0.00440	3.1574	BATDEM	NL	L	OMNIV	3.98	Notoraja spp.	Notoraja	Rajidae	Rajiformes	Elasmobranchii	Chordata		1	1
BTS	0.00440	3.1574	BATDEM	NL	L	OMNIV	3.98	Notoraja spinifera	Notoraja	Rajidae	Rajiformes	Elasmobranchii	Chordata		1	1
BYD	0.01390	3.0000	BATDEM	NL	L	PISC	4.13	Beryx decadactylus	Beryx	Berycidae	Beryciformes	Actinopterygii	Chordata		1	
BYS	0.01864	3.0693	BENPEL	NL	L	PISC	4.38	Beryx splendens	Beryx	Berycidae	Beryciformes	Actinopterygii	Chordata		1	1
CAR	0.00270	3.0477	REEF	LC	L	PISC	4.2	Cephaloscyllium isabellum	Cephaloscyllium	Scyliorhinidae	Carchariniformes	Elasmobranchii	Chordata	1	1	1
CAS	0.02430	2.7355	BENPEL	NL	M	PISC	3.97	Caelorinchus aspercephalus	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CBA			BATDEM	NL	L	BEN INV	3.72	Coryphaenoides dossenus	Coryphaenoides	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CBE			DEM	NL	M	INV	3.47	Notopogon lilliei	Notopogon	Macrorhamphosidae	Syngathiformes	Actinopterygii	Chordata		1	
CBI	0.02430	2.7355	BENPEL	NL	L	PISC	3.9	Caelorinchus biclinozonalis	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CBO	0.02430	2.7355	BENPEL	NL	M	PISC	3.9	Caelorinchus bollonsi	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CBX			PEL	NL	M	INV	3.4	Cubiceps baxteri	Cubiceps	Nomeidae	Perciformes	Actinopterygii	Chordata		1	
CCA			PEL	NL	M	INV	3.51	Cubiceps caeruleus	Cubiceps	Nomeidae	Perciformes	Actinopterygii	Chordata		1	
CCX	0.02430	2.7355	BATDEM	NL	M	PISC	3.9	Caelorinchus parvifasciatus	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CDO	0.04800	2.7000	DEM	NL	VL	PISC	4	Capromimus abbreviatus	Capromimus	Zeidae	Zeiformes	Actinopterygii	Chordata	1	1	1
CDX			BATDEM	NL	M	PISC	3.9	Caelorinchus maurofasciatus	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CEP	0.02010	1.9637	DEM	NL	M	BEN INV	3.13	Cepola aotea	Cepola	Cepolidae	Perciformes	Actinopterygii	Chordata	1		
CEX			BATDEM	NL	VL	PISC	3.9	Caelorinchus celaenostomus	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata			1
CFA	0.02430	2.7355	BATDEM	NL	M	PISC	3.9	Caelorinchus fasciatus	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CFL	0.03846	2.6584	DEM	NL	H	BEN INV	3.5	Lophonectes gallus	Lophonectes	Bothidae	Pleuronecteformes	Actinopterygii	Chordata	1		1
CGX			BATDEM	NL	M	PISC	3.9	Caelorinchus infuscus	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	
CHG			BATDEM	LC	L	BEN INV	3.52	Chimaera lignaria	Chimaera	Chimaeridae	Chimaeriformes	Holocephali	Chordata		1	
CHI			BATDEM	LC	L	BEN INV	3.52	Chimaera spp.	Chimaera	Chimaeridae	Chimaeriformes	Holocephali	Chordata		1	
CHP			BATDEM	LC	L	BEN INV	3.52	Chimaera sp.	Chimaera	Chimaeridae	Chimaeriformes	Holocephali	Chordata		1	1
CHX			BATDEM	NL	M	PISC	4	Chaunax pictus	Chaunax	Chaunacidae	Lophiiformes	Actinopterygii	Chordata		1	
CIN	0.02430	2.7355	BATDEM	NL	M	PISC	3.9	Caelorinchus innotabilis	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CJX			BATDEM	NL	M	PISC	3.9	Caelorinchus mycterismus	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata			1
CKA			BATDEM	NL	M	PISC	3.9	Caelorinchus kaiyomaru	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1

Appendix 1 continued

spec	a	b	HAB	RL	R	FEED	TL	Species	Genus	Family	Order	Class	Phylum	H	C	S
CKX			BATDEM	NL	M	PISC	3.9	Caelorinchus trachycarus & C acanthiger	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CMA	0.02430	2.7355	BATDEM	NL	L	PISC	3.9	Caelorinchus matamua	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CMU			BATDEM	NL	M	BEN INV	3.72	Coryphaenoides murrayi	Coryphaenoides	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CNI			BATPEL	NL	M	PISC	4.2	Chiasmodon niger	Chiasmodon	Chiasmodontidae	Perciformes	Actinopterygii	Chordata			1
COL	0.02430	2.7355	BATDEM	NL	M	PISC	3.9	Caelorinchus oliverianus	Caelorinchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CON	0.00060	3.2677	REEF	NL	VL	PISC	4.29	Conger spp.	Conger	Congridae	Anguilliformes	Actinopterygii	Chordata	1	1	1
COT			DEM	NL	L	BEN INV	3.4	Cottunculus nudus	Cottunculus	Psychrolutidae	Scorpaeniformes	Actinopterygii	Chordata		1	1
CRD			BATPEL	NL	VL	PISC	4.5	Coryphaenoides rudis	Coryphaenoides	Macrouridae	Gadiformes	Actinopterygii	Chordata			1
CSE			BATDEM	NL	L	BEN INV	3.72	Coryphaenoides serrulatus	Coryphaenoides	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CSQ	0.00910	3.0000	BENPEL	VU	VL	PISC	4.22	Centrophorus squamosus	Centrophorus	Squalidae	Squaliformes	Elasmobranchii	Chordata		1	1
CSU			BATDEM	NL	M	BEN INV	3.72	Coryphaenoides subserrulatus	Coryphaenoides	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
CTR			BATPEL	NL	L	PISC	4	Coryphaenoides striaturus	Coryphaenoides	Macrouridae	Gadiformes	Actinopterygii	Chordata			1
CUB			PEL	NL	M	INV	3.51	Cubiceps spp.	Cubiceps	Nomeidae	Perciformes	Actinopterygii	Chordata		1	
CUC	0.00910	3.0000	DEM	NL	M	PISC	4.03	Chlorophthalmus nigripinnis	Chlorophthalmus	Chlorophthalmidae	Aulopiformes	Actinopterygii	Chordata	1	1	
CYL			BATDEM	NT	L	PISC	4.35	Centroscymnus coelolepis	Centroscymnus	Squalidae	Squaliformes	Elasmobranchii	Chordata		1	1
CYO	0.00100	3.6100	BATDEM	LC	L	PISC	4.5	Centroscymnus owstoni	Centroscymnus	Squalidae	Squaliformes	Elasmobranchii	Chordata		1	1
CYP	0.00240	3.2500	BATDEM	LC	VL	PISC	4.16	Centroscymnus crepidater	Centroscymnus	Squalidae	Squaliformes	Elasmobranchii	Chordata		1	1
DCO			BENPEL	NL	H	OMNIV	3.5	Notophycis marginata	Notophycis	Moridae	Gadiformes	Actinopterygii	Chordata		1	1
DCS	0.00250	3.0500	BATDEM	DD	L	BEN INV	3.39	Halaelurus dawsoni	Halaelurus	Scyliorhinidae	Carchariniformes	Elasmobranchii	Chordata		1	1
DEA			BATPEL	NL	L	PISC	4.5	Trachipterus trachypterus	Trachipterus	Trachipteridae	Lampriformes	Actinopterygii	Chordata		1	1
DEQ			BATDEM	NL	L	PISC	4.5	Deania quadrispinosum	Deania	Squalidae	Squaliformes	Elasmobranchii	Chordata			1
DGT			DEM	NL	M	BEN INV	3.27	Callionymidae	Callionymidae	Callionymidae	Perciformes	Actinopterygii	Chordata		1	
DIS			BATPEL	NL	L	INV	3.45	Diretmus argenteus	Diretmus	Diretmidae	Beryciformes	Actinopterygii	Chordata		1	1
DSK			BATDEM	NL	L	OMNIV	3.84	Amblyraja hyperborea	Amblyraja	Rajidae	Rajiformes	Elasmobranchii	Chordata		1	1
DSP			BATDEM	NL		BEN INV	3.29	Congiopodus coriaceus	Congiopodus	Congiopodidae	Scorpaeniformes	Actinopterygii	Chordata		1	1
DWD			BENPEL	NL	VL	PISC	4.3	Squalus spp.	Squalus	Squalidae	Squaliformes	Elasmobranchii	Chordata		1	1
ECR			BATDEM	NL	L	PISC	4.3	Echiodon cryomargarites	Echiodon	Carapidae	Ophidiiformes	Actinopterygii	Chordata			1
EGR	0.02960	3.0000	BENPEL	LC	L	BEN INV	3.46	Myliobatis tenuicaudatus	Myliobatis	Myliobatidae	Rajiformes	Elasmobranchii	Chordata	1	1	
ELE			DEM	LC	L	BEN INV	3.6	Callorhinchus milii	Callorhinchus	Callorhynchidae	Chimaeriformes	Holocephali	Chordata			1
EMA	0.00631	3.2334	PEL	NL	M	PISC	4.2	Scomber australasicus	Scomber	Scombridae	Perciformes	Actinopterygii	Chordata	1		
ERA	0.02960	3.0000	DEM	DD	VL	BEN INV	4.5	Torpedo fairchildi	Torpedo	Torpedinidae	Torpediniformes	Elasmobranchii	Chordata	1	1	1
ESO	0.00485	3.2133	DEM	NL	M	BEN INV	3.06	Peltorhamphus novaezeelandiae	Peltorhamphus	Pleuronectidae	Pleuronecteformes	Actinopterygii	Chordata	1		

Appendix 1 continued

spec	a	b	HAB	RL	R	FEED	TL	Species	Genus	Family	Order	Class	Phylum	H	C	S
ETB	0.00300	3.1300	BATDEM	LC	L	PISC	4.21	Etmopterus baxteri	Etmopterus	Etmopteridae	Squaliformes	Elasmobranchii	Chordata		1	1
ETL	0.00300	3.1300	BATDEM	NL	VL	PISC	4.15	Etmopterus lucifer	Etmopterus	Etmopteridae	Squaliformes	Elasmobranchii	Chordata		1	1
ETP			BATDEM	NL	L	PISC	4.22	Etmopterus pusillus	Etmopterus	Etmopteridae	Squaliformes	Elasmobranchii	Chordata		1	1
EUC			BATDEM	NL	M	INV	3.79	Euclichthys polynemus	Euclichthys	Euclichthyidae	Gadiformes	Actinopterygii	Chordata		1	1
FAN			PEL	NL	M	PISC	4.14	Pterycombus petersii	Pterycombus	Bramidae	Perciformes	Actinopterygii	Chordata		1	
FHD	0.00510	3.0000	BATDEM	NL		PISC	4.1	Hoplichthys haswelli	Hoplichthys	Hoplichthyidae	Scorpaeniformes	Actinopterygii	Chordata		1	1
FRO	0.00040	3.1629	BATDEM	NL	M	PISC	3.85	Lepidopus caudatus	Lepidopus	Trichiuridae	Perciformes	Actinopterygii	Chordata	1		
FRS	0.00910	3.0000	BATDEM	NT	VL	PISC	4.21	Chlamydoselachus anguineus	Chlamydoselachus	Chlamydodelachidae	Hexanchiformes	Elasmobranchii	Chordata		1	
GAR	0.00070	3.4927	PEL	NL	H	PLANK & ALGAE	3.2	Hyporhamphus ihi	Hyporhamphus	Hemirhamphidae	Beloniformes	Actinopterygii	Chordata	1		
GFL			DEM	NL	M	BEN INV	3.06	Rhombosolea tapirina	Rhombosolea	Pleuronectidae	Pleuronecteformes	Actinopterygii	Chordata			1
GMU	0.03600	2.7537	BENPEL	NL	M	DET	2.2	Mugil cephalus	Mugil	Mugilidae	Perciformes	Actinopterygii	Chordata	1		
GNO			BENPEL	NL	H	BEN INV	3.5	Gadella norops	Gadella	Moridae	Gadiformes	Actinopterygii	Chordata		1	1
GON	0.00160	3.0000	DEM	NL		BEN INV	3.3	Gonorynchus forsteri & G. greyi	Gonorynchus	Gonorynchidae	Gonorhynchiformes	Actinopterygii	Chordata	1	1	1
GRC			BATDEM	NL	L	BEN INV	3.03	Tripterophycis gilchristi	Tripterophycis	Moridae	Gadiformes	Actinopterygii	Chordata		1	1
GSH	0.00277	3.2458	BATDEM	LC	L	BEN INV	3.52	Hydrolagus novaezealandiae	Hydrolagus	Chimaeridae	Chimaeriformes	Holocephali	Chordata		1	1
GSP	0.01021	2.9174	BATDEM	LC	L	BEN INV	3.52	Hydrolagus bemisi	Hydrolagus	Chimaeridae	Chimaeriformes	Holocephali	Chordata		1	1
GSQ			PEL	NL	H	PISC	3.44	Architeuthis spp.	Architeuthis	Architeuthidae	Teuthida	Cephalopoda	Mollusca		1	
GUR	0.00998	2.9900	DEM	NL	M	BEN INV	3.68	Chelidonichthys kumu	Chelidonichthys	Triglidae	Scorpaeniformes	Actinopterygii	Chordata	1	1	1
HAG			BATDEM	NL	L	PISC	5	Eptatretus cirrhatus	Eptatretus	Myxinidae	Myxiniformes	Pteraspidomorpha	Chordata		1	1
HAK	0.00200	3.2920	BENPEL	NL	L	PISC	4.45	Merluccius australis	Merluccius	Merlucciidae	Gadiformes	Actinopterygii	Chordata		1	1
HAL			BATDEM	NL	L	BEN INV	3.27	Halosauropsis macrochir	Halosauropsis	Halosauridae	Notacanthiformes	Actinopterygii	Chordata		1	
HAP	0.01423	2.9980	DEM	NL	VL	PISC	4.45	Polyprion oxygeneios	Polyprion	Percichthyidae	Perciformes	Actinopterygii	Chordata	1	1	1
HCO	0.00006	3.2486	DEM	NL	L	PISC	4.29	Bassanago hirsutus	Bassanago	Congridae	Anguilliformes	Actinopterygii	Chordata		1	
HEP	0.00120	3.4740	BATDEM	NL	VL	PISC	4.24	Heptranchias perlo	Heptranchias	Hexanchidae	Hexanchiformes	Elasmobranchii	Chordata		1	1
HEX			REEF	NT	L	PISC	4.28	Hexanchus griseus	Hexanchus	Hexanchidae	Hexanchiformes	Elasmobranchii	Chordata		1	
HHS	0.00140	3.3000	REEF	NL	L	PISC	4.5	Sphyrna zygaena	Sphyrna	Sphyrnidae	Carchariniformes	Elasmobranchii	Chordata	1		
HIA			BENPEL	NL	M	PISC	4.04	Himantolophus appelii	Himantolophus	Himantolophidae	Lophiiformes	Actinopterygii	Chordata		1	
HJO	0.00450	3.1452	BATPEL	NL	M	BEN INV	3.38	Halargyreus johnsonii	Halargyreus	Moridae	Gadiformes	Actinopterygii	Chordata		1	1
HOK	0.00358	2.9567	BENPEL	NL	H	PISC	4.47	Macruronus novaezelandiae	Macruronus	Merlucciidae	Gadiformes	Actinopterygii	Chordata		1	1
HPE			BATDEM	NL	L	BEN INV	3.27	Halosaurus pectoralis	Halosaurus	Halosauridae	Notacanthiformes	Actinopterygii	Chordata		1	
HYP			BATDEM	DD	L	BEN INV	3.52	Hydrolagus trolli	Hydrolagus	Chimaeridae	Chimaeriformes	Holocephali	Chordata			1

Appendix 1 continued

spec	a	b	HAB	RL	R	FEED	TL	Species	Genus	Family	Order	Class	Phylum	H	C	S
JAV	0.00080	3.2609	BENPEL	NL	L	PISC	4.1	Lepidorhynchus denticulatus	Lepidorhynchus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
JDO	0.04800	2.7000	DEM	NL	L	PISC	4.5	Zeus faber	Zeus	Zeidae	Zeriformes	Actinopterygii	Chordata	1		
JGU	0.02463	2.8640	DEM	NL	M	BEN INV	3.5	Pterygotrigla picta	Pterygotrigla	Triglidae	Scorpaeniformes	Actinopterygii	Chordata	1	1	
JMA	0.02300	2.8400	BENPEL	NL	M	PISC	3.93	Trachurus declivis, T.m., T.nz.	Trachurus	Carangidae	Perciformes	Actinopterygii	Chordata	1	1	
JMD	0.02300	2.8400	BENPEL	NL	M	PISC	3.93	Trachurus declivis	Trachurus	Carangidae	Perciformes	Actinopterygii	Chordata	1	1	
JMM	0.02300	2.8400	BENPEL	NL	M	PISC	3.93	Trachurus symmrtricus murphyi	Trachurus	Carangidae	Perciformes	Actinopterygii	Chordata	1	1	1
JMN	0.02800	2.8400	BENPEL	NL	M	PISC	3.93	Trachurus novaezelandiae	Trachurus	Carangidae	Perciformes	Actinopterygii	Chordata	1		
KAH	0.02360	2.8900	PEL	NL	M	PISC	3.8	Arripis trutta	Arripis	Arripidae	Perciformes	Actinopterygii	Chordata	1		
KAI			BATPEL	NL	M	PISC	4.2	Kali indica	Kali	Chiasmodontidae	Perciformes	Actinopterygii	Chordata			1
KIN	0.02463	2.8449	BENPEL	NL	M	PISC	4.2	Kali indica	Kali	Chiasmodontidae	Perciformes	Actinopterygii	Chordata	1		
KOH	0.01060	3.0124	PEL	NL	H	PLANK & PISC	3.13	Decapterus koheru	Decapterus	Carangidae	Perciformes	Actinopterygii	Chordata	1		
LAE			BATDEM	NL	L	INV	3.5	Laemonema spp.	Laemonema	Moridae	Gadiformes	Actinopterygii	Chordata		1	1
LCH	0.00649	3.0816	BATDEM	LC	L	BEN INV	3.55	Harriotta raleighana	Harriotta	Rhinochimaeridae	Chimaeriformes	Holocephali	Chordata		1	1
LDO	0.02423	2.9722	BATDEM	NL	VL	PISC	4.25	Cyttus traversi	Cyttus	Zeidae	Zeiformes	Actinopterygii	Chordata		1	1
LEA	0.00876	3.2110	DEM	NL	M	ENCRUST INV	2.95	Parika scaber	Parika	Monacanthidae	Tetraodontiformes	Actinopterygii	Chordata	1		
LEG			BATDEM	NL	L	INV	3.5	Lepidion schmidti & Lepidion inosimae	Lepidion	Moridae	Gadiformes	Actinopterygii	Chordata			1
LFB	0.01650	3.0000	DEM	NL		BEN INV	3.3	Zanclistius elevatus	Zanclistius	Pentacerotidae	Perciformes	Actinopterygii	Chordata	1		
LIN	0.00125	3.3078	DEM	NL	L	PISC	4.3	Genypterus blacodes	Genypterus	Ophidiidae	Ophidiiformes	Actinopterygii	Chordata	1	1	1
LSO	0.00761	3.0728	DEM	NL	M	BEN INV	3.06	Pelotretis flavilatus	Pelotretis	Pleuronectidae	Pleuronecteformes	Actinopterygii	Chordata	1	1	1
LYC			BATDEM	NL	M	PISC	5.47	Lyconus sp.	Lyconus	Merlucciidae	Gadiformes	Actinopterygii	Chordata			1
MAK			REEF	NT	VL	PISC	4.5	Isurus oxyrinchus	Isurus	Lamnidae	Lamniformes	Elasmobranchii	Chordata		1	1
MAN			BATDEM	NL	M	BEN INV	3.91	Neoachiropsetta milfordi	Neoachiropsetta	Bothidae	Pleuronecteformes	Actinopterygii	Chordata		1	1
MCA	0.01200	2.9385	BATDEM	NL	L	PISC	4.24	Macrourus carinatus	Macrourus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
MDA			BENPEL	NL	M	PISC	4.5	Macroparalepis danae	Macroparalepis	Paralepididae	Aulopiformes	Actinopterygii	Chordata		1	
MDO	0.00957	3.0920	BATDEM	NL	M	PISC	3.98	Zenopsis nebulosus	Zenopsis	Zeidae	Zeiformes	Actinopterygii	Chordata	1	1	
MEL			BENPEL	NL	M	BEN INV	3.79	Melanonus gracilis	Melanonus	Melanonidae	Gadiformes	Actinopterygii	Chordata		1	
MEZ			BENPEL	NL	M	BEN INV	3.79	Melanonus zugmayeri	Melanonus	Melanonidae	Gadiformes	Actinopterygii	Chordata		1	
MIQ	0.27770	1.4130	PEL	NL	H	PISC	3.44	Moroteuthis ingens	Moroteuthis	Onychoteuthidae	Teuthida	Cephalopoda	Mollusca		1	1
MMA			BATPEL	NL	M	PISC	4.5	Macroparalepis macrugeneion	Macroparalepis	Paralepididae	Aulopiformes	Actinopterygii	Chordata		1	
MOD			BATPEL	NL	L	OMNIV	3.5	Moridae	Moridae	Moridae	Gadiformes	Actinopterygii	Chordata		1	
MOO			BATPEL	NL	L	PISC	4.22	Lampris guttatus	Lampris	Lampridae	Lampriformes	Actinopterygii	Chordata			1

Appendix 1 continued

spec	a	b	HAB	RL	R	FEED	TL	Species	Genus	Family	Order	Class	Phylum	H	C	S
MRQ	0.27770	1.4130	PEL	NL	H	PISC	3.44	Moroteuthis robsoni	Moroteuthis	Onychoteuthidae	Teuthida	Cephalopoda	Mollusca		1	1
MSQ			PEL	NL	H	PISC	3.44	Mastigoteuthis sp.	Mastigoteuthis	Mastigoteuthidae	Teuthida	Cephalopoda	Mollusca		1	
NBI			DEM	NL	L	PISC	5	Neomyxine biniplicata	Neomyxine	Myxinidae	Myxiniformes	Pteraspidomorpha	Chordata		1	
NBU			BATDEM	NL	L	BEN INV	3.72	Kuronezumia bubonis	Kuronezumia	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	
NCU			BATPEL	NL	L	INV	3.3	Nemichthys curvirostris	Nemichthys	Nemichthyidae	Anguilliformes	Actinopterygii	Chordata		1	
NEM			BATPEL	NL	L	INV	3.5	Nemichthys scolopaceus	Nemichthys	Nemichthyidae	Anguilliformes	Actinopterygii	Chordata		1	1
NEN			BATPEL	NL	M	PISC	4	Neonesthes capensis	Neonesthes	Stomiidea	Stomiiformes	Actinopterygii	Chordata		1	
NNA			BATDEM	NL	M	BEN INV	3.79	Nezumia namatahi	Nezumia	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
NOC			BENPEL	NL	L	BEN INV	3.5	Notocanthus chemnitzi	Notacanthus	Notacanthidae	Notocanthiformes	Actinopterygii	Chordata			1
NOF			BATDEM	NL	M	INV	3.47	Notopogon fernandezianus	Notopogon	Macrorhamphosidae	Syngathiformes	Actinopterygii	Chordata		1	1
NOG	0.27770	1.4130	PEL	NL	H	PISC	3.2	Nototodarus gouldi	Nototodarus	Ommastephidea	Teuthoidea	Cephalopoda	Mollusca	1		
NOS	0.27770	1.4130	PEL	NL	H	PISC	3.2	Nototodarus sloanii	Nototodarus	Ommastrephidae	Teuthida	Cephalopoda	Mollusca		1	1
NSD	0.00335	3.0781	BATDEM	DD	VL	PISC	4.45	Squalus mitsukurii	Squalus	Squalidae	Squaliformes	Elasmobranchii	Chordata	1	1	
OAR			PEL	NL	VL	BEN INV	3.2	Regalecus glesne	Regalecus	Regalecidae	Lampriformes	Actinopterygii	Chordata		1	1
ODN			BATPEL	NL	M	PISC	4.32	Odontostomops normalops	Odontostomops	Evermannellidae	Aulopiformes	Actinopterygii	Chordata			1
OEO			BATPEL	NL	VL	INV	3.38	P. maculatus, A. niger, & N. rhomboidalis	Allocyttus	Oreosomatidae	Zeiformes	Actinopterygii	Chordata		1	
OFH	0.00960	3.0000	BENPEL	NL	L	PISC	4.18	Ruvettus pretiosus	Ruvettus	Gempylidae	Perciformes	Actinopterygii	Chordata		1	
OMO			BATPEL	NL	M	PISC	4.29	Omosudis lowei	Omosudis	Omosudidae	Aulopiformes	Actinopterygii	Chordata			1
OPA	0.00620	2.9400	DEM	NL	M	GEN CAR	4	Hemerocoetes spp.	Hemerocoetes	Percophidae	Perciformes	Actinopterygii	Chordata	1	1	1
OPE	0.01520	3.0063	BATDEM	NL	M	INV	3.47	Lepidoperca aurantia	Lepidoperca	Serranidae	Perciformes	Actinopterygii	Chordata		1	1
ORH	0.06870	2.7920	BATPEL	NL	VL	PISC	4.3	Hoplostethus atlanticus	Hoplostethus	Trachichthyidae	Beryciformes	Actinopterygii	Chordata		1	1
OSQ			PEL	NL	H	PISC	3.44	Octopoteuthiidae	Octopoteuthiidae	Octopoteuthiidae	Teuthida	Cephalopoda	Mollusca		1	1
PAR	0.01630	3.0220	BENPEL	NL	M	HERB	2	Girella tricuspidata	Girella	Kyphosidae	Perciformes	Actinopterygii	Chordata	1		
PCO			PEL	NL	H	BEN INV	3.5	Auchenoceros punctatus	Auchenoceros	Moridae	Gadiformes	Actinopterygii	Chordata	1		1
PDG	0.00300	3.1300	BATDEM	DD	VL	PISC	4.03	Oxynotus bruniensis	Oxynotus	Oxynotidae	Squaliformes	Elasmobranchii	Chordata		1	1
PDS			BATDEM	NL	M	PISC	4.5	Paradiplospinus gracilis	Paradiplospinus	Gempylidae	Perciformes	Actinopterygii	Chordata			1
PIG			BATDEM	NL		BEN INV	3.29	Congiopodus leucopaecilus	Congiopodus	Congiopodidae	Scorpaeniformes	Actinopterygii	Chordata		1	1
PIL	0.00000	3.3000	PEL	NL	M	PLANK	2.5	Sardinops neopilchardus	Sardinops	Clupeidae	Clupeiforms	Actinopterygii	Chordata	1		
PLA			PEL	NL		INV	3.1	Platyberyx sp.	Platyberyx	Caristiidae	Perciformes	Actinopterygii	Chordata		1	
PLC			DEM	NL	H	INV	3.3	Plectranthias maculicauda	Plectranthias	Serranidae	Perciformes	Actinopterygii	Chordata		1	
PLS	0.00490	3.1625	BATDEM	NT	L	PISC	4.5	Centroscymnus plunketi	Centroscymnus	Somniosidae	Squaliformes	Elasmobranchii	Chordata		1	1
PLU			BATDEM	NL	M	OMNIV	3.5	Physiculus luminosa	Physiculus	Moridae	Gadiformes	Actinopterygii	Chordata		1	

Appendix 1 continued

spec	a	b	HAB	RL	R	FEED	TL	Species	Genus	Family	Order	Class	Phylum	H	C	S
PMA	0.01520	3.0063	REEF	NL	M	PLANK	3.92	Caprodon longimanus	Caprodon	Serranidae	Perciformes	Actinopterygii	Chordata	1		1
POP	0.12200	2.6195	DEM	NL		BEN INV	3.5	Allomycterus jaculiferus	Allomycterus	Diodontidae	Tetraodontiformes	Actinopterygii	Chordata	1		1
POR	0.00380	3.1750	DEM	NL	VL	BEN INV	3.4	Nemadactylus douglasi	Nemadactylus	Cheilodactylidae	Perciformes	Actinopterygii	Chordata	1		
POS	0.02860	2.9240	PEL	VU	VL	PISC	4.5	Lamna nasus	Lamna	Lamnidae	Lamniformes	Elasmobranchii	Chordata		1	
PSK	0.00430	3.0742	BATDEM	NL	L	OMNIV	3.98	Bathyraja shuntovi	Bathyraja	Rajidae	Rajiformes	Elasmobranchii	Chordata		1	
PSQ			PEL	NL	H	PISC	3.44	Pholidoteuthis boschmai	Pholidoteuthis	Pholidoteuthidae	Teuthida	Cephalopoda	Mollusca			1
PSY			BATDEM	NL	L	BEN INV	3.4	Psychrolutes microporos	Psychrolutes	Psychrolutidae	Scorpaeniformes	Actinopterygii	Chordata		1	1
PUF	0.06120	2.7130	DEM	NL	M	PISC	4.2	Sphoeroides pachygaster	Sphoeroides	Tetraodontidae	Tetraodontiformes	Actinopterygii	Chordata	1		
PVE			BENPEL	NL	L	PISC	4.3	Pyramodon ventralis	Pyramodon	Carapidae	Ophidiiformes	Actinopterygii	Chordata			1
RAG			PEL	NL	L	PLANK	3.7	Icichthys australis	Icichthys	Centrolophidae	Perciformes	Actinopterygii	Chordata		1	1
RAT			BATDEM	NL	M	BEN INV	3.79	Macrouridae	Macrouridae	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
RBT	0.00495	3.2592	BATDEM	NL	M	PLANK	3.6	Emmelichthys nitidus	Emmelichthys	Emmelichtyidae	Perciformes	Actinopterygii	Chordata	1	1	1
RBY	0.01410	3.1200	BATDEM	NL	M	PLANK	3.4	Plagiogeneion rubiginosum	Plagiogeneion	Emmelichtyidae	Perciformes	Actinopterygii	Chordata		1	
RCH	0.00649	3.0816	BATDEM	LC	L	BEN INV	3.5	Rhinochimaera pacifica	Rhinochimaera	Rhinochimaeridae	Chimaeriformes	Holocephali	Chordata		1	1
RCO	0.00932	3.0008	DEM	NL	M	OMNIV	3.5	Pseudophycis bachus	Pseudophycis	Moridae	Gadiformes	Actinopterygii	Chordata	1	1	1
RHY	0.02030	2.9807	BATPEL	NL	VL	PISC	4.12	Paratrachichthys trailli	Paratrachichthys	Trachichthyidae	Beryciformes	Actinopterygii	Chordata	1	1	1
RIB	0.00321	3.3444	BATPEL	NL	L	INV	3.75	Mora moro	Mora	Moridae	Gadiformes	Actinopterygii	Chordata		1	1
RIS			BATDEM	NL	L	OMNIV	4.02	Bathyraja richardsoni	Bathyraja	Rajidae	Rajiformes	Elasmobranchii	Chordata		1	
RMU	0.00970	3.1440	BENPEL	NL	H	DET	3.4	Upeneichthys lineatus	Upeneichthys	Mullidae	Perciformes	Actinopterygii	Chordata	1	1	
RPI	0.02010	2.9992	REEF	NL	L	INV	3.5	Bodianus vulpinus	Bodianus	Labridae	Perciformes	Actinopterygii	Chordata	1		
RRC	0.01670	3.0180	DEM	NL	M	BEN INV	3.52	Scorpaena cardinalis & S. papillosus	Scorpaena	Scorpaenidae	Scorpaeniformes	Actinopterygii	Chordata	1		
RSK	0.03397	2.8767	DEM	LC	L	BEN INV	3.68	Dipturus nasutus	Dipturus	Rajidae	Rajiformes	Elasmobranchii	Chordata	1	1	1
RSN	0.02320	3.0129	BENPEL	NL	M	PISC	3.81	Centroberyx affinis	Centroberyx	Berycidae	Beryciformes	Actinopterygii	Chordata	1		
RSQ	0.27770	1.4130	PEL	NL	H	PISC	3.44	Ommastrephes bartrami	Ommastrephes	Ommastrephidae	Teuthida	Cephalopoda	Mollusca		1	1
RUD	0.00240	3.3460	BATPEL	NL	VL	PISC	3.92	Centrolophus niger	Centrolophus	Centrolophidae	Perciformes	Actinopterygii	Chordata		1	1
SAB			BENPEL	NL	M	PISC	4.2	Evermanella indica	Evermanella	Evermannellidae	Aulopiformes	Actinopterygii	Chordata		1	1
SAU	0.00150	3.1930	PEL	NL	M	INV	3.64	Scomberesox saurus	Scomberesox	Scomberesocidae	Beloniformes	Actinopterygii	Chordata		1	
SBK	0.00160	3.0581	BATDEM	NL	L	INV	3.03	Notacanthus sexspinis	Notacanthus	Notacanthidae	Notocanthiformes	Actinopterygii	Chordata		1	1
SBO			PEL	NL	M	INV	3.5	Pseudopentaceros richardsoni	Pseudopentaceros	Pentacerotidae	Perciformes	Actinopterygii	Chordata		1	
SBR			DEM	NL	M	OMNIV	3.5	Pseudophycis barbata	Pseudophycis	Moridae	Gadiformes	Actinopterygii	Chordata		1	1
SBW	0.00410	3.1520	BENPEL	NL	M	INV	3.79	Micromesistius australis	Micromesistius	Gadidae	Gadiformes	Actinopterygii	Chordata		1	1
SCD			BENPEL	NL	L	PISC	3.93	Paranotothenia microlepidota	Paranotothenia	Nototheniidae	Notocanthiformes	Actinopterygii	Chordata			1

Appendix 1 continued

spec	a	b	HAB	RL	R	FEED	TL	Species	Genus	Family	Order	Class	Phylum	H	C	S
SCG	0.00960	3.1188	DEM	NL	H	BEN INV	3.5	Lepidotrigla brachyoptera	Lepidotrigla	Triglidae	Scorpaeniformes	Actinopterygii	Chordata	1	1	
SCH	0.00030	3.5800	BENPEL	VU	VL	PISC	4.21	Galeorhinus galeus	Galeorhinus	Triakidae	Carchariniformes	Elasmobranchii	Chordata	1	1	1
SCM			BATDEM	DD	L	PISC	4.35	Centroscymnus macracanthus	Centroscymnus	Squalidae	Squaliformes	Elasmobranchii	Chordata			1
SCO	0.00006	3.2486	BATDEM	NL	L	PISC	4.29	Bassanago bulbiceps	Bassanago	Congridae	Anguilliformes	Actinopterygii	Chordata		1	1
SCP			BATPEL	NL	M	PISC	4.2	Scopelarchus sp.	Scopelarchus	Scopelarchidae	Aulopiformes	Actinopterygii	Chordata		1	
SDE			BATPEL	NL	M	PISC	4.5	Cryptopsaras couesi	Cryptopsaras	Ceratiidae	Lophiiformes	Actinopterygii	Chordata		1	1
SDF			DEM	NL	M	BEN INV	3.06	Azygopus pinnifasciatus	Azygopus	Pleuronectidae	Pleuronecteformes	Actinopterygii	Chordata		1	1
SDO	0.02630	2.9740	DEM	NL	VL	PISC	4.25	Cyttus novaezealandiae	Cyttus	Zeidae	Zeiformes	Actinopterygii	Chordata	1	1	1
SEE	0.00060	3.2486	DEM	NL	M	PISC	4.29	Gnathophis habenatus	Gnathophis	Congridae	Anguilliformes	Actinopterygii	Chordata	1		
SFL	0.03846	2.6584	DEM	NL	M	BEN INV	3.06	Rhombosolea plebeia	Rhombosolea	Pleuronectidae	Pleuronecteformes	Actinopterygii	Chordata	1		
SFN			BATPEL	NL	L	INV	3.45	Diretmoides parini	Diretmoides	Diretmidae	Beryciformes	Actinopterygii	Chordata			1
SHE			DEM	NL	M	BEN INV	3.06	Azygopus pinnifasciatus	Azygopus	Pleuronectidae	Pleuronecteformes	Actinopterygii	Chordata		1	
SKA	0.01460	2.9795	DEM	LC	L	BEN INV	3.68	Rajidae Arhynchobatidae (Families)	Rajidae	Rajidae	Rajiformes	Elasmobranchii	Chordata	1	1	1
SKI	0.00170	3.3419	DEM	NL	L	PISC	4.31	Rexea solandri	Rexea	Gempylidae	Perciformes	Actinopterygii	Chordata	1	1	1
SLR			REEF	NL	VL	BEN INV	3.49	Optivus elongatus	Optivus	Trachichthyidae	Beryciformes	Actinopterygii	Chordata			1
SMC			BATDEM	NL	M	INV	3.5	Lepidion microcephalus	Lepidion	Moridae	Gadiformes	Actinopterygii	Chordata		1	1
SNA	0.04467	2.7930	DEM	NL	M	BEN INV	3.3	Pagrus auratus	Pagrus	Sparidae	Perciformes	Actinopterygii	Chordata	1		
SND	0.00525	3.1763	BATDEM	LC	VL	PISC	4.22	Deania calcea	Deania	Centrophoridae	Squaliformes	Elasmobranchii	Chordata		1	1
SNE			BATDEM	NL	M	INV	3.68	Simenchelys parasiticus	Simenchelys	Synaphobranchidae	Anguilliformes	Actinopterygii	Chordata		1	
SNI	0.00860	2.8490	DEM	NL	M	BEN INV	3.47	Macrorhamphosus scolopax	Macrorhamphosus	Macrorhamphosidae	Syngnathiformes	Actinopterygii	Chordata	1	1	1
SNR			BATDEM	NL	L	PISC	4.22	Deania histricosa	Deania	Centrophoridae	Squaliformes	Elasmobranchii	Chordata		1	1
SOP			BENPEL	DD	L	PISC	4.25	Somniosus pacificus	Somniosus	Somniosidae	Squaliformes	Elasmobranchii	Chordata			1
SPD	0.00155	3.2856	BENPEL	NL	VL	PISC	4.3	Squalus acanthias	Squalus	Squalidae	Squaliformes	Elasmobranchii	Chordata	1	1	1
SPE	0.00936	3.1700	DEM	NL	L	PISC	4.07	Helicolenus spp.	Helicolenus	Scorpaenidae	Scorpaeniformes	Actinopterygii	Chordata	1	1	1
SPF	0.01410	3.0090	REEF	NL	M	INV	3.56	Pseudolabrus miles	Pseudolabrus	Labridae	Perciformes	Actinopterygii	Chordata	1	1	1
SPK			DEM	NL	M	PISC	4.4	Macrorhamphosodes uradoi	Macrorhamphosodes	Triacanthodidae	Tetradontiformes	Actinopterygii	Chordata			1
SPO	0.00332	3.0529	DEM	NL	VL	BEN INV	3.5	Mustelus lenticulatus	Mustelus	Triakidae	Carchariniformes	Elasmobranchii	Chordata	1	1	1
SPP	0.09780	2.6430	REEF	NL	M	PLANK	3.1	Callanthias spp.	Callanthias	Serranidae	Perciformes	Actinopterygii	Chordata	1	1	
SPR	0.00270	3.3221	PEL	NL	H	PLANK	3	Sprattus antipodum, S. muelleri	Sprattus	Clupeidae	Clupeiforms	Actinopterygii	Chordata	1		
SPS	0.00761	3.0728	DEM	NL	M	BEN INV	3.06	Peltorhamphus latus	Peltorhamphus	Pleuronectidae	Pleuronecteformes	Actinopterygii	Chordata	1		
SPZ	0.00715	3.2287	DEM	NL	M	PISC	4.29	Genyagnus monopterygius	Genyagnus	Uranoscopidae	Perciformes	Actinopterygii	Chordata	1		

Appendix 1 continued

spec	a	b	HAB	RL	R	FEED	TL	Species	Genus	Family	Order	Class	Phylum	H	C	S
SQA			BENPEL	NL	VL	PISC	4.3	Squalus spp.	Squalus	Squalidae	Squaliformes	Elasmobranchii	Chordata		1	
SQU			PEL	NL	H	PISC	3.2	Nototodarus sloanii & N gouldi	Nototodarus	Ommastephidea	Teuthoidea	Cephalopoda	Mollusca	1	1	1
SRB	0.00290	3.4030	PEL	NL	L	PISC	4.14	Brama australis	Brama	Bramidae	Perciformes	Actinopterygii	Chordata		1	1
SRH	0.00830	3.1500	BENPEL	NL	L	BEN INV	3.49	Hoplostethus mediterraneus	Hoplostethus	Trachichthyidae	Beryciformes	Actinopterygii	Chordata		1	1
SRR			BATDEM	NL	L	OMNIV	3.9	Amblyraja georginian	Amblyraja	Rajidae	Rajiformes	Elasmobranchii	Chordata		1	
SSH			BATDEM	LC	VL	PISC	4.22	Gollum attenuatus	Gollum	Pseudotriakidae	Carchariniformes	Elasmobranchii	Chordata			1
SSI	0.00188	3.3874	DEM	NL	M	PLANK	3.4	Argentina elongata	Argentina	Argentinidae	Osmeriformes	Actinopterygii	Chordata	1		1
SSK	0.03285	2.8786	DEM	NT	L	OMNIV	3.98	Dipturus innominatus	Dipturus	Rajidae	Rajiformes	Elasmobranchii	Chordata	1	1	
SSO	0.03172	2.8906	BATDEM	NL	VL	INV	3.61	Pseudocyttus maculatus	Pseudocyttus	Oreosomatidae	Zeiformes	Actinopterygii	Chordata		1	1
STA	0.01548	3.0279	DEM	NL	M	PISC	4.29	Kathetostoma giganteum	Kathetostoma	Uranoscopidae	Perciformes	Actinopterygii	Chordata	1	1	1
STY	0.00470	3.2270	REEF	NL	M	BEN INV	3.3	Notolabrus celidotus	Notolabrus	Labridae	Perciformes	Actinopterygii	Chordata	1		
SUH			BATPEL	NL	L	PLANK	3.4	Schedophilus huttoni	Schedophilus	Centrolophidae	Perciformes	Actinopterygii	Chordata		1	1
SUM			PEL	NL	M	PLANK	3.4	Schedophilus maculatus	Schedophilus	Centrolophidae	Perciformes	Actinopterygii	Chordata		1	1
SUS			PEL	NL	M	PLANK	3.4	Schedophilus sp.	Schedophilus	Centrolophidae	Perciformes	Actinopterygii	Chordata		1	1
SWA	0.01105	3.1594	BENPEL	NL	M	JELLY	3.4	Seriolella punctata	Seriolella	Centrolophidae	Perciformes	Actinopterygii	Chordata	1	1	1
SWE	0.01220	3.0300	DEM	NL	M	PLANK	3.4	Scorpis lineolatus	Scorpis	Kyphosidae	Perciformes	Actinopterygii	Chordata	1		
TAR	0.02800	2.8790	DEM	NL	L	BEN INV	3.4	Nemadactylus macropterus	Nemadactylus	Cheilodactylidae	Perciformes	Actinopterygii	Chordata	1	1	1
TAS			PEL	NL	L	PISC	4.14	Taractes asper	Taractes	Bramidae	Perciformes	Actinopterygii	Chordata		1	
TDQ			PEL	NL	H	PISC	3.2	Taningia danae	Taningia	Octopoteuthiidae	Teuthida	Cephalopoda	Mollusca			1
TET			BATPEL	NL	L	INV	3.78	Tetragonurus cuvieri	Tetragonurus	Tetragonuridae	Perciformes	Actinopterygii	Chordata		1	1
THR	0.01880	2.5190	PEL	NL	VL	PISC	4.5	Alopias vulpinus	Alopias	Alopiidae	Lamniformes	Elasmobranchii	Chordata	1		
TOA			BATDEM	NL	L	BEN INV	3.4	Neophrynichthys sp.	Neophrynichthys	Psychrolutidae	Scorpaeniformes	Actinopterygii	Chordata		1	1
TOD			BATDEM	NL	L	BEN INV	3.4	Neophrynichthys latus	Neophrynichthys	Psychrolutidae	Scorpaeniformes	Actinopterygii	Chordata		1	1
TOP	0.02310	3.0000	DEM	NL	L	BEN INV	3.4	Ambophthalmos angustus	Ambophthalmos	Psychrolutidae	Scorpaeniformes	Actinopterygii	Chordata		1	1
TRE	0.01563	3.0640	PEL	NL	M	PISC	3.8	Pseudocaranx dentex	Pseudocaranx	Carangidae	Perciformes	Actinopterygii	Chordata	1		
TRS			BATDEM	NL	L		3.5	Trachyscorpia capensis	Trachyscorpia	Scorpaenidae	Scorpaeniformes	Actinopterygii	Chordata			1
TRU	0.02000	3.0000	DEM	NL	VL	INV	3.3	Latris lineata	Latris	Latrididae	Perciformes	Actinopterygii	Chordata		1	
TRX			BATDEM	NL	M	BEN INV	3.5	Trachonurus gagates	Trachonurus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	
TSQ	0.27770	1.4130	PEL	NL	H	PISC	3.44	Todarodes filippovae	Todarodes	Ommastrephidae	Teuthida	Cephalopoda	Mollusca		1	1
TTA			DEM	DD	L	BEN INV	4.5	Typhlonarke tarakea	Typhlonarke	Narkidae	Torpediniformes	Elasmobranchii	Chordata		1	
TUB			BENPEL	NL	M	JELLY	3.4	Tubbia tasmanica	Tubbia	Centrolophidae	Perciformes	Actinopterygii	Chordata		1	1
TUR	0.00571	3.2389	DEM	NL	VL	BEN INV	3.06	Colistium nudipinnis	Colistium	Pleuronectidae	Pleuronecteformes	Actinopterygii	Chordata	1		

Appendix 1 continued

spec	a	b	HAB	RL	R	FEED	TL	Species	Genus	Family	Order	Class	Phylum	H	C	S
TVI			BENPEL	NL	L	BEN INV	3.5	Trachonurus villosus	Trachonurus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	
VCO			BATPEL	NL	M	BEN INV	3.58	Antimora rostrata	Antimora	Moridae	Gadiformes	Actinopterygii	Chordata		1	1
VNI	0.06750	3.0558	BATDEM	NL	M	BEN INV	3.9	Ventrifossa nigromaculata	Ventrifossa	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
WAR	0.01020	3.1624	BENPEL	NL	M	JELLY	3.3	Seriolella brama	Seriolella	Centrolophidae	Perciformes	Actinopterygii	Chordata	1		1
WHR			BATDEM	NL	L	BEN INV	3.5	Trachyrincus longirostris	Trachyrincus	Macrouridae	Gadiformes	Actinopterygii	Chordata			1
WHX	0.06750	3.0558	BATDEM	NL	L	BEN INV	3.5	Trachyrincus aphyodes	Trachyrincus	Macrouridae	Gadiformes	Actinopterygii	Chordata		1	1
WIT	0.00761	3.0728	BATDEM	NL	M	BEN INV	3.5	Arnoglossus scapha	Arnoglossus	Bothidae	Pleuronecteformes	Actinopterygii	Chordata	1	1	1
WLP			REEF	NL	M	INV	3.3	Lepidoperca tasmanica	Lepidoperca	Serranidae	Perciformes	Actinopterygii	Chordata		1	
WRA	0.04410	3.0000	DEM	LC	VL	BEN INV	3.54	Dasyatis thetidis	Dasyatis	Dasyatidae	Rajiformes	Elasmobranchii	Chordata	1		
WWA	0.01788	3.0837	BATPEL	NL	M	JELLY	3.4	Seriolella caerulea	Seriolella	Centrolophidae	Perciformes	Actinopterygii	Chordata		1	1
YBF	0.00354	3.3268	DEM	NL	M	BEN INV	3.06	Rhombosolea leporina	Rhombosolea	Pleuronectidae	Pleuronecteformes	Actinopterygii	Chordata	1		
YBO	0.01650	3.0000	BATDEM	NL	M	INV	3.5	Pentaceros decacanthus	Pentaceros	Pentacerotidae	Perciformes	Actinopterygii	Chordata		1	
YCO	0.01020	3.0463	DEM	NL	H	BEN INV	3.87	Parapercis gilliesi	Parapercis	Pinguipedidae	Perciformes	Actinopterygii	Chordata		1	1
YEM	0.00024	3.2000	BENPEL	NL	M	DET	2.5	Aldrichetta forsteri	Aldrichetta	Mugilidae	Perciformes	Actinopterygii	Chordata	1		
ZDO			BATPEL	NL	M	PISC	4	Zenion leptolepis	Zenion	Zeniontidae	Zeiformes	Actinopterygii	Chordata		1	
ZEL			BATPEL	NL	L	PISC	4.5	Zu elongatus	Zu	Trachipteridae	Lampriformes	Actinopterygii	Chordata		1	

Appendix 2: Voyage codes and other summary details for each inshore trawl survey series.

Survey series	Voyage code	Month	No. stations
Bay of Plenty			
	IKA6106/07	Mar–May	
	IKA6108	Aug/Sep	
	IKA6202	Mar/Apr	
	IKA6205	Aug/Sep	
	IKA6207	Dec	
	IKA6301	Jan	
	IKA6404	Oct	
	IKA6507	Sep/Oct	
	IKA6510	Dec	
	IKA6709	May	
	IKA6714/15	Jul	
	IKA6727	Dec	
	IKA6820	Jul	
	IKA8003	Mar/Apr	
	IKA8102	Mar/Apr	
	KAH8303	Feb/Mar	63
	KAH8506	Feb/Mar	87
	KAH8711	May	36
	KAH9004	Feb/Mar	63
	KAH9202	Feb/Mar	89
	KAH9601	Feb/Mar	80
	KAH9902	Feb/Mar	78
West coast NI	KAH8612	Oct	79
	KAH8715	Oct/Nov	56
	KAH8918	Nov/Dec	92
	KAH9111	Nov/Dec	108
	KAH9410	Oct	75
	KAH9615	Oct/Nov	124
	KAH9915	Oct	100
Hauraki Gulf			
	IKA6405	Nov	21
	IKA6509	Nov/Dec	35
	IKA8010	Nov	30
	IKA8011	Dec	26
	KAH8421	Oct/Nov	85
	KAH8517	Nov	80
	KAH8613	Nov	54
	KAH8716	Nov	43
	KAH8810	Oct/Nov	71
	KAH8917	Nov	81
	KAH9016	Nov	73
	KAH9017	Nov/Dec	81
	KAH9212	Nov	73
	KAH9311	Nov	73
	KAH9411	Oct/Nov	70
	KAH9720	Oct/Nov	49
	KAH0012	Nov	48
East coast SI			
	KAH9105	May	55
	KAH9205	May/Jun	80
	KAH9306	May/Jun	74
	KAH9606	May/Jun	121
	KAH9618	Dec/Jan	118
	KAH9704	Dec/Jan	138
	KAH9809	Dec/Jan	120
	KAH9917	Dec/Jan	120
West coast SI			
	KAH9204	Mar/Apr	79
	KAH9404	Mar/Apr	78
	KAH9504	Mar/Apr	80
	KAH9704	Mar/Apr	80

Appendix 2: Voyage codes and other summary details for each middle depth trawl survey series. * - stations sampled outside main survey strata.

Survey series	Voyage code	Month	No stations
Scampi	KAH9301*	Jan	57 (SCI 1), 37 (SCI 2)
	KAH9401*	Jan	49 (SCI 1), 41 (SCI 2)
	KAH9501*	Jan	60 (SCI 1), 48 (SCI 2)
	KAH9604	Apr	55 (SCI 1)
	DRY9601	Sep	12 (SCI 1)
	DRY9602	Oct	14 (SCI 1)
	KAH9801	Jan	40 (SCI 1)
	KAH9906	May	4 (SCI 2)
	KAH9910	Jul	5 (SCI 2)
	KAH9914	Oct	5 (SCI 2)
	KAH9916	Dec	5 (SCI 2)
	KAH0001*	Feb	23 (SCI 1)
	KAH0002	Feb	6 (SCI 2)
	KAH0005	Apr	5 (SCI 2)
	KAH0102	Jan/Feb	12 (SCI 1)
	KAH0203	Apr	14 (SCI 1)
	KAH0301	Feb/Mar	11 (SCI 2)
	KAH0401	Jan/Feb	12 (SCI 2)
	KAH0501	Feb/Mar	12 (SCI 2)
	KAH0604	Mar/Apr	12 (SCI 2)
Chatham Rise hoki	SHI8301	Mar	127
	SHI8304	Nov/Dec	85
	SHI8602	Jun/Jul	107
	AEX8903	Nov/Dec	118
	TAN9106	Jan/Feb	186
	TAN9212	Dec–Feb	195
	TAN9401	Jan	165
	TAN9501	Jan/Feb	136
	TAN9601	Dec/Jan	93
	TAN9701	Jan	105
	TAN9801	Jan	130
	TAN9901	Jan	142
	TAN0001	Dec/Jan	134
	TAN0101	Dec/Jan	144
	TAN0201	Dec/Jan	169
	TAN0301	Dec/Jan	125
	TAN0401	Dec/Jan	110
	TAN0501	Dec/Jan	133
	TAN0601	Dec/Jan	117
	TAN0701	Dec/Jan	129
Sub-Antarctic	SHI8201	Mar/Apr	219
	SHI8302	Apr	119
	SHI8303	Oct/Nov	186
	SHI8601	Jun	58
	AEX8902	Oct/Nov	126
	AEX9001	Jul/Aug	122
	AEX9002	Nov/Dec	181
	TAN9105	Nov/Dec	155
	TAN9204	Apr/May	93
	TAN9211	Nov/Dec	162
	TAN9304	May/Jun	101
	TAN9310	Nov/Dec	143
	TAN9605	Mar/Apr	102
	TAN9805	Apr/May	77
	TAN0012	Nov/Dec	109
	TAN0118	Nov/Dec	110
	TAN0219	Nov/Dec	111
	TAN0317	Nov/Dec	86
	TAN0414	Nov/Dec	96
	TAN0515	Nov/Dec	99

Appendix 2: Voyage codes and other summary details for deepwater trawl survey series.

Survey series	Voyage code	Month	No stations
Orange roughy (Chatham Rise)			
	BUC8401	Jul	132
	BUC8501	Jul	127
	BUC8601	Jul	145
	BUC8701	Jun–Aug	292
	COR8801	Jul/Aug	154
	COR8802	Sep/Oct	129
	COR8901	Jul/Aug	240
	COR9002	Jun–Aug	281
	TAN9206	Jun/Jul	281
	TAN9406	May/Jul	120