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This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

In Memoriam

Michael Manning (1973–2009) started his fisheries career in 1998 as a stock assessment technician for the Seafood Industry Council. There he developed and managed biological catch sampling programmes for commercial vessels and undertook fish ageing and data management. He started working with NIWA in 2001, and concurrently did a Master of Science degree at the University of Auckland. During more than seven years with NIWA, Michael significantly developed his science and analytical skills and made a major contribution to fisheries research, particularly to the monitoring, ageing, and stock assessment of inshore and pelagic species. He was also involved in tagging experiments on great white sharks and was a regular participant in various fisheries surveys on *Kaharoa* and *Tangaroa*. Michael was an enthusiastic presenter, making numerous presentations to fisheries assessment working groups as well as university courses and schools. He left NIWA early in 2009 to take up an exciting position with the Oceanic Fisheries Programme of the Secretariat of the Pacific Community in Noumea, New Caledonia. Michael was an extremely enthusiastic and larger-than-life character who was always keen to participate and upskill in a wide range of activities. He had enormous potential to develop his fisheries assessment career and the move to Noumea was a great step along this path. Losing him is a tragic loss to the fisheries community.

EXECUTIVE SUMMARY

Manning, M.J. (2009). Updated relative abundance indices and catch-at-length estimates for spiny dogfish (*Squalus acanthias*) in SPD 3 and 5 to the end of the 2005–06 fishing year.

***New Zealand Fisheries Assessment Report 2009/61.* 90 p.**

This report presents updated relative abundance indices and catch-at-length estimates for spiny dogfish (*Squalus acanthias*) in SPD 3 and 5 derived from standardised commercial catch-per-unit-effort data collected from the start of the 1989–90 to the end of the 2005–06 fishing year. Supporting updated fishery characterisations for both fishstocks and catch-at-length estimates for SPD 5 calculated from Ministry of Fisheries Observer Programme collected data are also presented. The commercial catch and effort data are processed using Starr's effort restratification and landed catch allocation algorithm. An average recovery rate of 66% was achieved for SPD 3 and of 53% for SPD 5. Changes in product form to greenweight conversion factors were accounted for in the updated analysis presented.

Trends in the fisheries in time and space

- There remains weak evidence of seasonality in the SPD 3 catch, with about half of the catch caught from January to May. Catches continue to be recorded from all statistical areas, but most of the catch continues to be caught in inshore statistical areas 018, 020, 022, and 024. Bottom-trawl and setnet fishing continue to account for most of the catch by fishing method, but the relative importance of the setnet catch, in particular the target setnet catch, has declined markedly over the data time series. The setnet catch has dropped from 50–60% of the total annual catch over the early- to mid-1990s to 12–18% of the total annual catch since 2000–01. The target setnet catch has dropped dramatically over the data series, from 54% of the total catch in 1989–90 to 5% during the 2005–06 fishing year.

- The SPD 5 fishery continues to be dominated by bottom-trawl fishing (63% of the total catch over all fishing years in the dataset), although there are lesser but consistent contributions to the catch from midwater-trawl, setnet, and bottom-longline fishing methods (19%, 12%, and 6% of the total catch over all fishing years respectively). The recent steady increase in the total catch is associated with increased reported landings by trawl vessels.

- There is a stronger seasonal effect in the SPD 5 catch, with 71% of the total catch in the SPD 5 data series caught during the summer and autumn months of December to April. The seasonal peak in catch is associated chiefly with catches by large (i.e., more than 28 m in overall length) bottom- and midwater-trawl vessels completing TCEPR reporting forms and targeting squids and jack mackerels (*Trachurus* spp.) on the Stewart-Snares shelf (statistical areas 025 to 030).

- Statistical area 028 on the southern end of the Stewart-Snares shelf and statistical area 030 northwest of Stewart Island are the two most important statistical areas in SPD 5, being associated with nearly half of the total SPD 5 catch over the data time series.

- Hotspots of high nominal catch rates are apparent in some fishing years in SPD 5 and appear to persist from one fishing year to the next on the Stewart-Snares shelf. Some attenuation and movement along the shelf of areas of high catch rate are noted, but the reasons for this are unclear. One possible explanation is that these changes reflect changes in fishing effort and behaviour and another is that they reflect changes in spatial patterns in spiny dogfish from one year to the next. These explanations are not mutually exclusive and are confounded given that the data are fishery-dependent and fishing effort is not randomly distributed across the continental shelf.

Composition of the SPD 5 catch

- The sampled length-frequency data are thought to be generally representative of the catch, but some inconsistencies between the sampled vessels and the fleet as a whole are noted. Precision is generally moderate to low, with mean-weighted coefficients of variation ranging between 25.8 and 35.9% and averaging 32.2% over the length-frequency data series.

- Trends in the scaled length distributions are similar to those identified previously with some minor differences. As before, males typically range between about 45–90 cm in total length though there are very few males smaller than 55 cm and larger than 80 cm present in the catch in any fishing year. The male distributions typically appear unimodal. There is weak evidence of mode progression between some years; e.g., a male mode centred around 55–57 cm in 2001–02 is centred around 60 cm in 2002–03. The female distributions generally exhibit more structure, with females typically between about 50 to over 100 cm in total length. There are two modes present in most years that appear to peak at about 55–60 cm and at about 85 cm. These length-frequency modes, when evident, almost certainly contain multiple age classes.

- As before, there is no evidence of newborn or very young dogfish in the catch. Possible explanations include the possible unavailability of newborn or very young dogfish to the commercial fishery as well as the probable (un-) selectivity of the commercial trawl gear for dogfish of this size. There is no obvious trend in male to female sex ratios by fishing year calculated from the scaled length-frequency distributions.

SPD 3 and 5 stock status

- Eight standardised CPUE log-linear models were fitted to the processed SPD 3 and 5 datasets (SPD 3: CPUE models 1.1 to 1.4; SPD 5: CPUE models 1.5 to 1.8).

- If standardised CPUE model fits 1.1 to 1.4 are accepted as valid, then it appears that the SPD 3 "stock" indexed by the model fits has declined to be now somewhere around a third of its relative biomass at the start of the data series. However, there are major changes in the fleet and in fishing patterns during this time that are of concern, although the standardisation process should account for these changes.

- The lack of catch-composition data from the SPD 3 fisheries inhibits our ability to interpret these indices. The paucity of biological data collected from the SPD 3 fisheries by the MFish Observer Programme during the Hector's dolphin interaction surveillance in the Canterbury Bight and Pegasus Bay represents an important lost opportunity, not only for spiny dogfish but also for the other species caught in the inshore mixed species elasmobranch fishery in this area.

- If standardised CPUE model fits 1.5 to 1.8 are accepted as valid, it appears that the relative abundance of the SPD 5 "stock" has been distributed around one with moderate variability from one fishing year to the next over the data series. It seems reasonable to assume for now that the interannual variation in the standardised indices is likely to be caused by factors other than removals due to fishing.

1. INTRODUCTION

1.1 Overview

Spiny dogfish (*Squalus acanthias*) is a small- to moderate-sized benthopelagic squaloid shark found in temperate marine waters around the globe. In the New Zealand region, it is found throughout the southern half of the New Zealand Exclusive Economic Zone (EEZ) north to Manukau Harbour and East Cape on the west and east coasts of the North Island. It was introduced into the New Zealand Quota Management System (QMS) on 1 October 2004 and is now managed as seven separate Quota Management Areas (QMAs; "fishstocks"): SPD 1, 3–5, 7–8, and 10 (Figure 1). This spatial stratification is different from that used by Manning et al. (2004), who analysed spiny dogfish data collected before its admission into the QMS. Of the seven QMAs now in existence, Fishstocks SPD 3, 5, and 7 have consistently accounted for most of the total reported landed catch (84% over the 1989–90 to 2005–06 fishing years; Table 1 and Figure 2).

New Zealand spiny dogfish has been little studied despite supporting one of New Zealand's largest inshore fisheries in terms of tonnage landed. Some fundamental aspects of its biology have received some attention, such as study of its distribution, diet, reproductive biology, and growth by Hanchet (1986, 1988, 1991), but other aspects of its biology relevant to the management of its fisheries in the New Zealand EEZ have received little attention. Stock structure in particular remains poorly understood. The true number of biological stock units in the New Zealand EEZ and how well the seven QMAs relate to these are unknown. Until completion of the analysis presented by Manning et al. (2004), no abundance indices had been evaluated for monitoring the status of the stock (or stocks) in any spiny dogfish QMA.

1.2 Relevant earlier work

Manning et al. (2004) comprehensively reviewed the New Zealand spiny dogfish fisheries, including fisheries characterisations, a review of available trawl-survey data, and calculation of standardised catch-per-unit-effort (CPUE) analyses using the then novel data processing algorithms devised by Starr (2003) to develop and evaluate monitoring methods for each spiny dogfish QMA. This analysis superseded earlier attempts at developing monitoring methods by Walker et al. (1999) and Hanchet & Ingerson (1997) and was complemented by an analysis of commercial catch-at-length and survey proportions-at-length data presented by Phillips (2004). Following Manning et al.'s (2004) and Phillips's (2004) analyses, the New Zealand Inshore Fishery Assessment Working Group (Inshore FAWG) concluded that Fishstock SPD 3 would be best monitored by a standardised setnet CPUE index based on core vessels fishing in inshore statistical areas in SPD 3, and that SPD 5 would be best monitored by a standardised bottom-trawl CPUE index based on core vessels fishing in all statistical areas in SPD 5 and by the length composition and sex ratio of the commercial catch using data collected by the Ministry of Fisheries Observer Programme (MFish OP) and that the standardised CPUE indices should be updated every four years. As the Manning et al. analysis was based on catch-effort and landings collected from the start of the 1989–90 (1 October 1989) to the end of the 2000–01 (30 September 2001) fishing year, updating these CPUE series is now due.

1.3 Aims of this analysis

The aim of the analysis I present in this report is to update the standardised CPUE indices developed by Manning et al. (2004) for the SPD 3 and 5 fisheries to the end of the 2005–06 fishing year. As in this earlier analysis, I use the effort restratification and landed catch allocation algorithm originally devised by Starr (2003) with some minor modifications. I also review and analyse spiny dogfish length-frequency and sex data collected in the SPD 5 fishery by the MFish OP to the end of the

(a) SPD QMAs

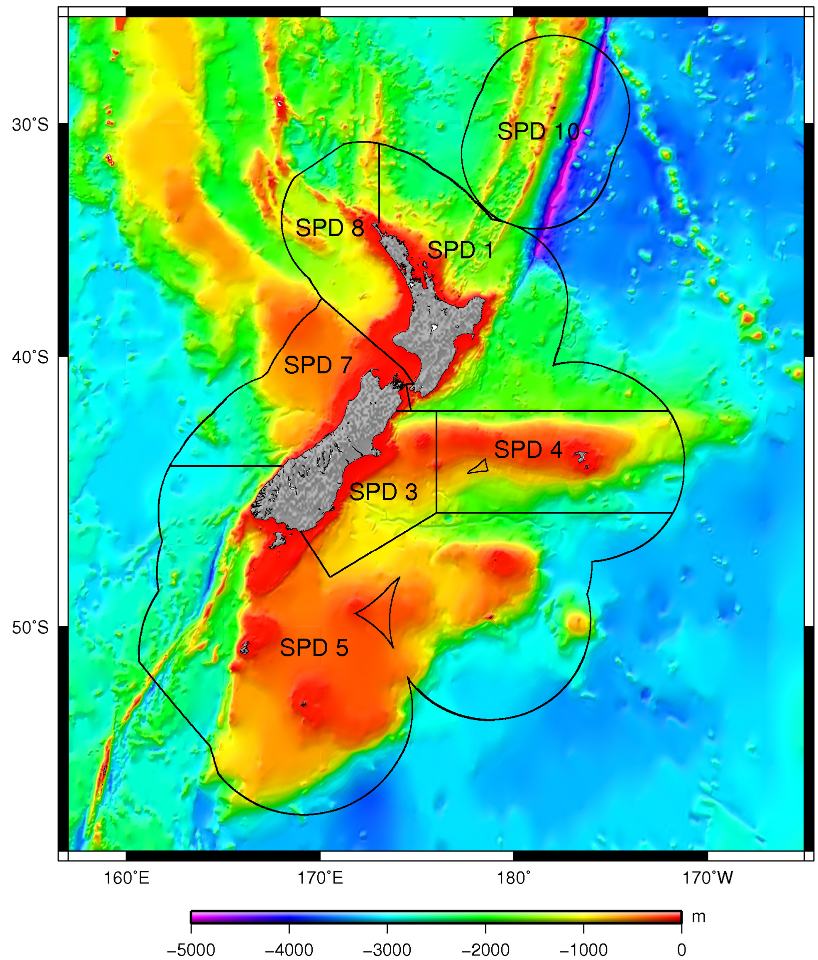


Figure 1: New Zealand fisheries management areas referred to in this report. Panel (a): spiny dogfish quota management areas (QMAs; SPD 1, 3–4, 5, 7–8, & 10). The QMAs do not necessarily contain individual biological stock units or populations. Panel (b): New Zealand fisheries statistical areas. Panel (c): New Zealand fisheries statistical areas in the Auckland region. Panel (d): New Zealand fisheries statistical areas in the Tasman Bay-Golden Bay region. Some QMA boundaries overlap multiple statistical areas. (Continued on p. 7.)

2005–06 fishing year and update the fishery characterisations presented by Manning et al. (2004) to aid as far as possible interpretation of the standardised CPUE analysis. This work was funded by the New Zealand Ministry of Fisheries as research project SPD2005/01 (“Abundance of spiny dogfish in SPD 3 & 5”) and fulfils Reporting Requirement 1 of Specific Objectives 1 (“To update standardised catch-per-unit-effort time series for SPD 3 and 5”) and 2 (“To analyse the information on size composition and sex ratio collected by observers on commercial trawlers in SPD 5”) of that project.

1.4 Structure of this report

Following a general discussion of my methods, I present and discuss my results in separate sections. I first present the results of applying the data processing algorithms, then present the updated fishery characterisations, then the scaled length-frequency analysis, and finally the standardised CPUE model

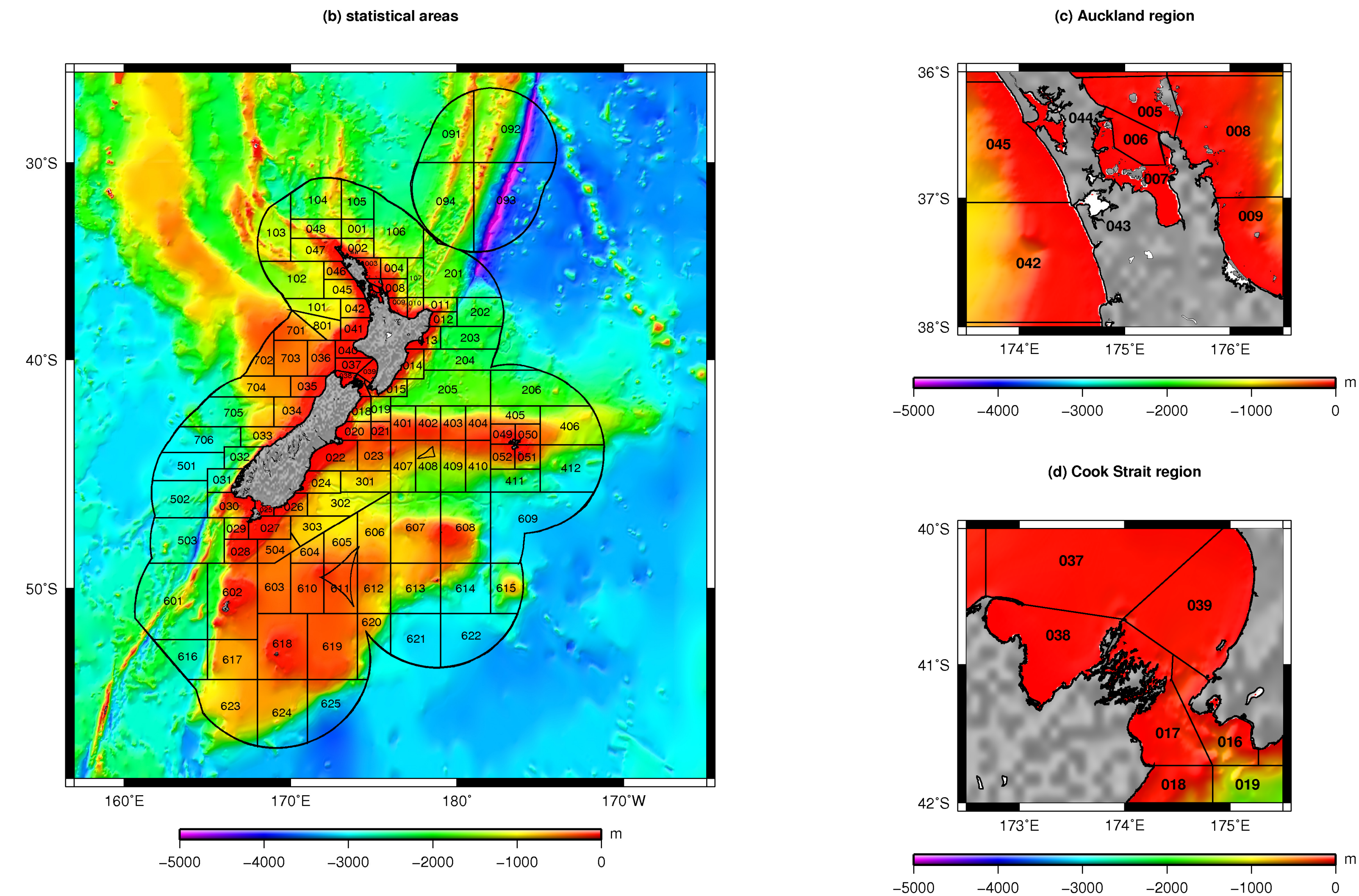


Figure 1: (continued)

fits. I end the main body of the report by attempting to summarise and synthesise the results and their implications. Supporting results which would otherwise have cluttered up my presentation are attached as appendices.

2. METHODS

2.1 The data

2.1.1 Catch-effort and landings data

These data consist of all fishing and landing events associated with two sets of fishing trips stored in the MFish catch-effort and landings database *warehou* (Ministry of Fisheries 2004) for each of the SPD 3 and 5 fishstock analyses (four different datasets in total). The data associated with the first set of trips for each fishstock were intended for use in revising and updating the corresponding earlier fishery characterisation analysis. Data associated with the second set of trips were intended for use in the corresponding standardised CPUE analysis. The catch-effort and landings data records are stored within the database on separate tables that are linked by unique trip key codes. In this report I use the MFish database nomenclature and have set valid database field and table names in italic type; e.g., the *primary_method* field in the *fishing_events* table in the *warehou* database. See Ministry of Fisheries (2004) for further information on the structure of the *warehou* database.

The two datasets for the SPD 3 analysis were defined as follows. Valid trips for the characterisation analysis were defined as all fishing trips (strictly, unique database trip keys) where an associated *landing_event* exists in the database with a recorded *landing_date* between 1 October 1989 and 30 September 2006 (inclusive; the 1989–90 to 2005–06 fishing years) and a recorded *green_weight* greater than zero for the SPD 3 stock. Valid trips for the standardised CPUE analysis were defined as those fishing trips where:

(a) at least one *fishing_event* table record exists where the *primary_method* is SN (setnet); and

(b) the *start_stats_area_code* is in the range 018–027 & 301–303 (valid statistical areas for SPD 3); and

(c) the *target_species* is SPD (spiny dogfish); or

(d) at least one associated *estimated_subcatch* table record exists where the *catch_weight* is greater than zero for *species_code* SPD between 1 October 1990 and 30 September 2006.

The logic is (a && b) && (c || d), where && = "and" and || = "or".

The two datasets for the SPD 5 analysis were defined as follows. Valid trips for the characterisation analysis were defined as all fishing trips (strictly, unique database trip keys) where an associated *landing_event* exists in the database with a recorded *landing_date* between 1 October 1989 and 30 September 2006 (inclusive; the 1989–90 to 2005–06 fishing years) and a recorded *green_weight* greater than zero for the SPD 5 stock. Valid trips for the standardised CPUE analysis were defined as those fishing trips where:

(a) the *start_stats_area_code* is in the range 025–032, 501–504, & 601–625 (valid statistical areas for SPD 5) between 1 October 1990 and 30 September 2006; and

(b) at least one *fishing_event* table record exists where the *primary_method* is BT (bottom trawl) or MW (midwater trawl).

Table 1: The total reported landed spiny dogfish catch by fishing year and QMA (Ministry of Fisheries Science Group 2007). *, New Zealand Fisheries Statistics Unit data (1983–86); †, New Zealand QMS data (1986–87 to 2005–06).

	SPD 1		SPD 3		SPD 4		SPD 5	
Year	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC
1983–84*	40	–	409	–	347	–	2265	–
1984–85*	33	–	557	–	481	–	2350	–
1985–86*	24	–	892	–	411	–	1554	–
1986–87†	82	–	1048	–	162	–	1031	–
1987–88†	59	–	1664	–	172	–	658	–
1988–89†	357	–	1510	–	168	–	778	–
1989–90†	50	–	2243	–	136	–	243	–
1990–91†	143	–	2987	–	513	–	1722	–
1991–92†	77	–	1801	–	66	–	571	–
1992–93†	59	–	2128	–	218	–	839	–
1993–94†	85	–	3165	–	358	–	1179	–
1994–95†	131	–	2883	–	363	–	643	–
1995–96†	245	–	2558	–	969	–	1299	–
1996–97†	189	–	2428	–	1287	–	884	–
1997–98†	217	–	5042	–	917	–	651	–
1998–99†	533	–	3148	–	1048	–	2150	–
1999–00†	343	–	3309	–	994	–	1352	–
2000–01†	374	–	4355	–	1075	–	1601	–
2001–02†	234	–	4249	–	1788	–	4221	–
2002–03†	255	–	3553	–	1010	–	3034	–
2003–04†	255	–	3557	–	1009	–	3037	–
2004–05†	234	331	2707	4794	838	1626	2479	3700
2005–06†	186	331	3831	4794	1055	1626	2298	3700

	SPD 7		SPD 8		SPD 10		Total	
	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC
1983–84*	119	–	79	–	0	–	3259	–
1984–85*	90	–	58	–	0	–	3569	–
1985–86*	120	–	112	–	0	–	3113	–
1986–87†	501	–	323	–	0	–	3147	–
1987–88†	1402	–	868	–	0	–	4823	–
1988–89†	633	–	143	–	0	–	3589	–
1989–90†	521	–	80	–	0	–	3273	–
1990–91†	883	–	67	–	0	–	6315	–
1991–92†	1031	–	249	–	0	–	3795	–
1992–93†	1163	–	366	–	0	–	4773	–
1993–94†	2212	–	214	–	0	–	7213	–
1994–95†	1205	–	196	–	0	–	5421	–
1995–96†	1205	–	201	–	0	–	6477	–
1996–97†	1517	–	242	–	1	–	6548	–
1997–98†	2389	–	1206	–	0	–	10422	–
1998–99†	1902	–	75	–	0	–	8856	–
1999–00†	1505	–	32	–	0	–	7535	–
2000–01†	1310	–	70	–	0	–	8785	–
2001–02†	961	–	83	–	0	–	11536	–
2002–03†	772	–	104	–	0	–	8728	–
2003–04†	773	–	104	–	0	–	8735	–
2004–05†	842	1902	121	307	0	10	7221	12670
2005–06†	832	1902	108	307	0	10	8310	12670

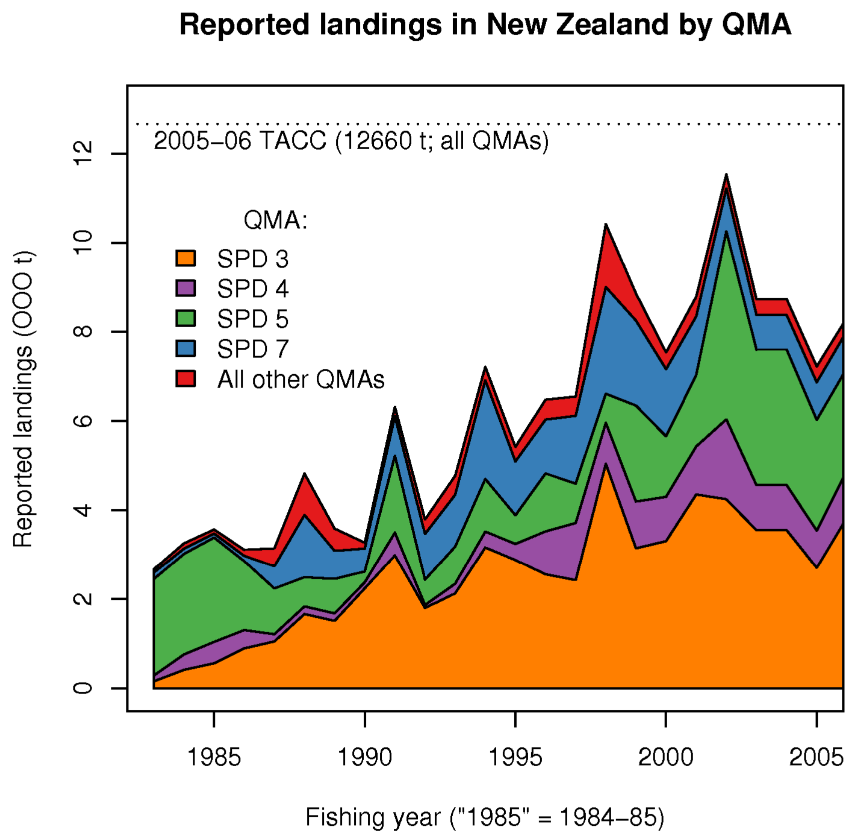


Figure 2: Total reported spiny dogfish landings by QMA, 1982–83 to 2005–06.

Here the logic is (a && b).

All fishing and landing events associated with each trip set were then extracted from the corresponding database tables. Landing event records for all spiny dogfish fishstocks were returned. Although the characterisation and CPUE datasets for each fishstock were defined differently, they were processed using the same methods.

2.1.2 MFish OP data

Spiny dogfish length-frequency data and associated station records were extracted from MFish research databases *obs_lfs* (Sanders & Mackay 2004) and *obs* (Sanders & Mackay 2005) to facilitate the SPD 5 length-frequency and sex-ratio analysis. Database *obs_lfs* was searched for all observed fishing trips where spiny dogfish length-frequency records were recorded from 1 October 1989 to 30 September 2006. All spiny dogfish length frequency and trawl catch records were then extracted for these trips. Station data for all trawls during each identified observed trip, whether spiny dogfish were caught or not, were extracted from *obs* along with all spiny dogfish processing records.

2.2 Data processing

2.2.1 Starr's data processing algorithm

The catch-effort and landings data extracts were processed using Starr's (2003) restratification and landed catch allocation algorithm as implemented by Manning et al. (2004) with refinements by Blackwell et al. (2006), Manning & Sutton (2007), and Starr (2007). The algorithm is designed to facilitate analysis of MFish catch-effort data collected using Catch Effort Landing Returns (CELRs). It is designed to overcome the main limitation of the CELR reporting form, which is that fishers are required to report only the top five species in their catches. This often results in under- or non-reporting of species that make up only a minor component of the catch, but that are nonetheless landed and counted against quota. A further benefit of the procedure is that it allows catch-effort and landings data collected using different form types (e.g., CELRs, TCEPRs, CLRs, etc.) to be combined for a single fishstock. An overview of the algorithm is given here.

2.2.2 The major steps in the algorithm

The basic unit of data within the procedure is the fishing trip and the major steps in the algorithm are as follows.

Step 1: The fishing effort and landings data are first groomed separately. Outlier values in each variable that fail a range check are corrected using median imputation. This involves replacing missing or outlier values with a median value that is calculated over some subset of the data. While this may lead to underestimates of the variance for a given variable, this uses the data to "fix itself" rather than merely dropping cases containing missing or outlier data, maximising the amount of data available for analysis while eliminating missing or implausible values (see discussion of outliers in Section 2.2.3 below).

Step 2: The fishing effort within each valid trip is then restratified by statistical area, method, and target species.

Step 3: The greenweight landings for each fishstock for each trip are then allocated to the effort strata. The greenweight landings are mapped to the effort strata using the relationship between the statistical area for each effort stratum and the statistical areas contained within each fishstock.

Step 4: The greenweight landings are then allocated to the effort strata using the total estimated catch in each effort stratum as a proportion of the total estimated catch for the trip. If estimated catches are not recorded for the trip although a landing was recorded for the trip, then the total fishing effort in each effort stratum as a proportion of the total fishing effort for the trip is used to allocate the greenweight landings.

A relatively recent innovation, the algorithm has been used in a number of published and unpublished fisheries characterisation and CPUE analyses presented to different MFish Fisheries Assessment Working Groups since its creation. Manning et al. (2004) used Starr's method in their analysis of New Zealand's spiny dogfish fisheries and I follow their implementation with some modifications in this analysis. The two most important differences between their analysis and this one are how the identification of outlier values is treated and how changes in spiny dogfish processed state to greenweight conversion factors are dealt with. I refer readers requiring more detail on the algorithm to either Manning et al. (2004) or Starr (2003, 2007).

2.2.3 Identification of outlier values

MFish catch-effort and landings datasets typically contain “outlier” values. These are observations that are unusual in some sense, or that are missing, or are otherwise invalid (e.g., miscodes). The causes are many and varied, and manifest a bewilderingly diverse pathology, but are likely due to three main reasons: (i) transcription errors by the fisher recording the data initially, (ii) transcription errors at the point of data capture by MFish (“key punching” errors), or (iii) true internal database errors. Fortunately, the number and strangeness of outlier values in New Zealand catch-effort and landings data appears to have diminished since 2000–01 due to stricter database administration by MFish, but analysis of historic MFish catch-effort and landings data requires a strategy to identify and deal with existing outliers stored in the database. Manning et al. (2004) used range checks that were defined *a priori* for particular variable, gear method, and reporting form partitions of their dataset using their knowledge of what was likely to define non-erroneous data for a given variable. This approach is inherently subjective, and in this analysis, following Starr (2003), I defined outliers to be

$$o_{ij} = \begin{cases} \text{True; if and only if } x_{ij} < \left(1/p_1\right)q_1 \text{ or } x_{ij} > p_2 q_2 \\ \text{False; otherwise} \end{cases}, \tag{1}$$

where o_{ij} is a logical flag (true or false value) indicating that the jth value for variable i is an outlier. The variables q_1 and q_2 are reference quantiles of the univariate distribution of x ($q_1 = 0.10$ and $q_2 = 0.90$ in this analysis) and p_1 and p_2 are multipliers specifying how far from these reference quantiles x_{ij} needs to be to be deemed to be an outlier. This approach has less of the subjectivity inherent in *a priori* range checks and has the advantage of being easy to implement and generalise within a computer program. Other techniques for automatically identifying outlier values within an analysis, including the jackknife and variations thereof, were not investigated in this analysis.

2.2.4 Changes in product state to fish greenweight conversion factors over time

Processed product weights in New Zealand fisheries are converted to greenweight catches using a set of multiplicative constants referred to as species and product-form specific “conversion factors”. Product form conversion factors for spiny dogfish have changed several times since the full implementation of the QMS (Table 2; Denise Nicholson, MFish, pers.comm.). This means that different amounts of greenweight catch are associated with the same amount of processed catch for a given product form in the database *warehou*. I first standardised these changes in this analysis by incorporating the catch-consistency checking algorithm designed by Blackwell et al. (2005) within my main data-processing algorithm. The checking algorithm systematically compares the different catch weights recorded for a particular fishing trip (estimated, processed, and landed greenweight catches, see Duckworth (2002) for definitions) against one another and returns the single most consistent catch value for each trip (Figure 3). This systematically accounts for conversion factor changes over time. Failure to account for conversion factor changes affects the relative abundance indices obtained from the standardised CPUE regression model fits to the data (see, for example, Maunder & Punt (2004) for a discussion of this issue). Following a request by the Inshore Fisheries Assessment Working Group, I have also investigated a simpler correction algorithm. This is

$$g_{\mathrm{i}}^{*} = \left(\frac{c_{i,\,\mathrm{current}}}{c_{i,\,\mathrm{old}}} \right) \times g_i\,, \tag{2}$$

where g_i is the greenweight recorded for the ith landing record, $c_{i,\,\mathrm{old}}$ is the recorded (historic) conversion factor for the product state in the ith landing record, $c_{i,\,\mathrm{current}}$ is the current conversion factor for that product state, and g_i^* is the corrected greenweight for the ith record.

Step one:

If (land $\approx$ cf_old $\times$ proc || land $\approx$ cf_old $\times$ est || land $\approx$ est && land ! $\approx$ proc)
then use = (cf_new / cf_old) $\times$ land
else go to step two

Step two:

If (land $\approx$ proc)
then use = cf_new $\times$ land
else go to step three

Step three:

If (est $\approx$ proc || est $\approx$ cf_old $\times$ proc)
then use = cf_new $\times$ proc
else go to step four

Step four:

Reject record

Figure 3: Catch-consistency checking algorithm implemented by Blackwell et al. (2005). "land", landed catch; "proc", processed catch; "est", estimated catch; "cf_old", product form conversion factor in use when the record was created; "cf_new", product form conversion factor in use currently; "&&", and; "||", or; "!", not; "≈", approximately.

2.3 Standardised CPUE model structure and fitting procedure

Standardised CPUE indices were obtained by fitting Generalised Linear Models (GLMs) (McCullagh & Nelder 1989) to the groomed and restratified dataset using the methods of Dunn (2002) and Manning et al. (2004). Two different response variables were used: (i) catch-per-unit-effort per effort stratum; and (ii) catch per effort stratum. Choosing catch only as the response allows the model to fit a non-linear relationship between catch and effort if such a relationship exists. Where CPUE was modelled as the response, in the SPD 3 (setnet) model fits it was typically defined as catch per 1000 m of net set per effort stratum, and in the SPD 5 (bottom trawl) model fits as catch per hour fished per effort stratum. All model fits were restricted to effort strata associated with a consistent presence in the corresponding data set, so-called core vessel subsets. The definition of core vessel varied from model to model. Dataset definitions and other summary model attributes are listed in Table 5.

The generalised linear model fitting algorithm, *glm* (Chambers & Hastie 1991), implemented in the *R* statistical programming language (R Development Core Team 2006) was used to fit all models. Model selection was carried out using a stepwise model selection algorithm, *stepCPUE* (R.I.C.C. Francis, NIWA, pers. comm.). *stepCPUE* generates a final regression model iteratively from a simple model with a single predictor variable, *fishing year*, as the base model in each fit. The reduction in residual deviance relative to the null deviance, R^2, is calculated for each additional term added to the base model. The term that results in the greatest reduction in residual deviance is added to the base model if this results in an improvement in residual deviance of more than 1%. The algorithm repeats this process until no new terms can be added. A stopping rule of 1% change in residual deviance was used as this results in a relatively parsimonious model with moderate explanatory power. An alternative model selection algorithm, *stepAIC* (Venables & Ripley 2002), was investigated using both Akaike's Information Criterion (AIC) (Akaike 1973) and Schwarz's Bayesian Information Criterion (BIC) (Schwarz 1978) as model fit evaluation criteria, but did not produce noticeably different results. The stepwise search was made only by adding terms to the base model in all fits ("forwards"; regardless of the algorithm used).

Table 2: Past and present valid spiny dogfish conversion factors stored in MFish database *warehou* on 31 March 2007 (Source: Denise Nicholson, MFish, pers. comm.). CF, conversion factor. *, use of state code not regulated; –, ongoing until further notice.

State code	Description	Start date	End date	CF
ACC	Accidental loss	*	*	1.000
CHK	Cheeks	1994-10-01	–	0.000
CLA	Claspers	*	*	0.000
DIS	Discarded	*	*	1.000
DRE	Dressed	1990-10-01	1992-09-30	2.000
DRE	Dressed	1992-10-01	–	2.700
EAT	Eaten	*	*	1.000
FIL	Fillets: skin-on	1990-10-01	1992-09-30	2.700
FIL	Fillets: skin-on	1992-10-01	–	4.100
FIN	Fins	1993-10-01	–	30.000
FIT	Fish tails	1997-12-04	–	0.000
FLP	Flaps	1994-10-01	–	0.000
GBP	Gut by-product	2000-06-23	–	0.000
GGU	Gilled and gutted	*	*	1.200
GRE	Green (or whole)	1990-10-01	–	1.000
GUT	Gutted	1990-10-01	–	1.100
HDS	Heads	1994-10-01	–	0.000
HGT	Headed, gutted and tailed	*	*	2.000
HGU	Headed and gutted	1990-10-01	1992-09-30	2.000
HGU	Headed and gutted	1992-10-01	–	2.700
LIB	Livers by-product	1997-12-04	–	0.000
LIV	Livers	1993-10-01	–	3.850
LUG	Lugs or collars	1994-10-01	–	0.000
MEA	Fish meal	1990-10-01	–	5.600
MEA	Fish meal	*	*	5.556
MEB	Fish meal by-product	1997-12-04	–	0.000
MIN	Mince	*	*	0.000
OIL	Oil	1990-10-01	–	0.000
ROE	Roe	1990-10-01	–	0.000
SHF	Shark fins	1997-12-04	–	0.000
SKF	Fillets: skin-off	1999-10-01	–	5.000
SUR	Surimi	1990-10-01	–	4.300
SWB	Sounds or swim bladders	1994-10-01	–	0.000
TRU	Trunked	*	*	2.000

Up to eight predictor variables were offered to each model: *fishing year*, *statistical area*, *month*, *target species*, *vessel key*, *fishing duration*, and *effort number*. Descriptions of each variable are given in Table 3. All continuous variables were offered as third-order polynomial functions and all variables were groomed during the restratification process. The number of effort variables that may sensibly be offered to the model is limited by the resolution of the effort strata (the unique vessel-statistical area-method-target species combinations). Effort variables other than the eight listed in Table 3 were not investigated. Density (continuous variables) and mosaic (discrete) plots were produced for the predictor variables offered in each fit to test whether changes in these distributions have occurred over time that may have affected the CPUE indices calculated. The models were fitted as Gaussian GLMs with an identity link. Log-normally distributed errors were assumed and were achieved by fitting to the natural log of CPUE per effort stratum and by taking the natural log of continuously distributed effort variables before fitting the regression model (mean estimates for the levels of categorical variables are, by definition, on the same scale as the response; lognormally distributed here). Effort strata with a zero catch or CPUE response were dropped. CPUE was first defined as kilogrammes of spiny dogfish caught per 1 km of net set per effort stratum in the SPD 3 model fits and as kilogrammes

Table 3: Types and descriptions of predictor variables offered to the standardised CPUE models. As not all predictor variables are defined for all fishing methods, not all of the predictor variables listed here were necessarily offered to each of the models fitted.

Variable type	Variable name	Data type	Description
Response	CPUE	Continuous	Catch-per-unit-effort (bottom trawl models: kilogrammes of spiny dogfish caught per hour fished per effort stratum; set net models: kilogrammes of spiny dogfish caught per kilometre of net set per effort stratum)
Response	Catch	Continuous	Catch of spiny dogfish per effort stratum (kg)
Predictor	Fishing year	Categorical	Calculated from the landing date for each fishing trip and assigned to each effort stratum during the grooming and restratification procedure
Predictor	Statistical area	Categorical	New Zealand fisheries statistical areas
Predictor	Month	Categorical	Calendar month at the start date of the first fishing event in each effort stratum
Predictor	Target species	Categorical	Recorded target species per effort stratum
Predictor	Vessel key	Categorical	Unique vessel number per effort stratum
Predictor	Fishing duration	Continuous	Total fishing time per effort stratum in hours (hours)
Predictor	Effort number	Continuous	Total number of trawl shots per effort stratum
Predictor	Effort height	Continuous	Median headline height per effort stratum (m)
Predictor	Effort width	Continuous	Median wingspread per effort stratum (bottom- or midwater trawl fishing) (m) *or* median net mesh width per effort stratum (setnet fishing) (m)
Predictor	Net length	Continuous	Total amount of net set per effort stratum (km)

of spiny dogfish caught per hour fished per effort stratum in the SPD 5 model fits. However, as discussed, all models were refitted with the effort denominator offered to the model as a predictor variable (i.e., where the response variable was log catch per effort stratum, not log-CPUE).

The model indices are presented in a canonical form following Dunn (2002). Goodness of model fit was investigated using standard regression diagnostic plots. For each model, a plot of residuals against fitted values and a plot of residuals against quantiles of the standard normal distribution was produced to check for departures from the regression assumptions of homoscedasticity and normality of errors in link-space. Plots of the expected catch rate for each variable in the final model holding all other variables fixed at median values are also produced to check for the sensitivity of the model results to particular predictor variable values.

I test whether the models are monitoring abundance using the criteria developed by Dunn et al. (2000). This involves involve examining the relationship between CPUE and abundance by considering data adequacy, model fit, and model validation. For model validation, I compare the CPUE indices computed for each model fit with spiny dogfish relative biomass estimates from research trawl surveys of the east-coast of the South Island by RV *Kaharoa* (1991–2000; 2007) and of the Stewart-Snares shelf by RV *Tangaroa* (1993–1996) (Table 4).

Table 4: Spiny dogfish relative biomass estimates from research trawl surveys of the east coast of the South Island by RV *Kaharoa* (1990–2000 & 2007; winter and summer series) and of the Stewart–Snares shelf (STEW) by RV *Tangaroa* (1993–1996). Coefficients of variation (c.v.s) and references are provided.

QMA	Series	Trip code	Date	Biomass (t)	c.v. (%)	Reference
SPD 3	ECSI	KAH9105	May–Jun, 1991	12 873	22	Beentjes & Wass (1994)
	(*Winter*)	KAH9205	May–Jun, 1992	10 787	26	Beentjes (1995a)
		KAH9306	May–Jun, 1993	13 949	17	Beentjes (1995b)
		KAH9406	May–Jun, 1994	14 530	10	Beentjes (1998a)
		KAH9606	May–Jun, 1996	35 169	15	Beentjes (1998b)
		KAH0705	May–Jun, 2007	35 386	28	Beentjes (unpub. results)
	ECSI	KAH9618	Dec–Jan, 1996–97	35 776	28	Stevenson (1997)
	(*Summer*)	KAH9704	Dec–Jan, 1997–98	29 765	25	Stevenson & Hurst (1998)
		KAH9809	Dec–Jan, 1998–99	22 842	16	Stevenson & Beentjes (1999)
		KAH9917	Dec–Jan, 1999–00	49 832	37	Stevenson & Beentjes (2001)
		KAH0014	Dec–Jan, 2000–01	30 508	34	Stevenson & Beentjes (2002)
SPD 5	STEW	TAN9301	Feb–Mar, 1993	36 023	13	Hurst & Bagley (1994)
		TAN9402	Feb–Mar, 1994	36 328	17	Bagley & Hurst (1995)
		TAN9502	Feb–Mar, 1995	91 364	29	Bagley & Hurst (1996a)
		TAN9604	Feb–Mar, 1996	89 818	29	Bagley & Hurst (1996b)

2.4 Length-frequency analysis

2.4.1 The data

Spiny dogfish length and sex data have been collected at sea from bottom-longline and bottom- and midwater-trawl catches in the New Zealand EEZ by the MFish OP since the start of the 1996–97 fishing year. Measurements from over 88 000 individuals had been collected from throughout the EEZ by the end of the 2005–06 fishing year. Spiny dogfish data are usually collected using the MFish OP sampling design for bycatch species, where observers are requested to collect a random sample (in practice, usually an approximately simple random sample) of unsorted fish directly from the catch in each sampled trawl or line set during each observed trip (Sutton 2002). Sampling effort within an observed trip is usually allocated as follows. Observers are requested to collect a sample of 100 sexed dogfish per trawl for 10 trawls or sets per observed trip and to spread their sampling effort throughout a longer trip by sampling one trawl every 2–4 days (Sutton 2002).

2.4.2 Post-stratification of the data using tree-based regression partitioning

The aim of this analysis is to update the scaled length-frequency distributions calculated by Phillips (2004) for the SPD 5 fishery with all the data collected to the end of the 2005–06 fishing year. His analysis was based on data collected over the 1996–97 to 2000–01 fishing years and he used a tree-based regression algorithm to identify length-frequency strata for his analysis. Sensible post-stratification of these kinds of datasets is a potentially useful variance reduction technique. I use the same algorithm and repeat the partitioning exercise in this analysis to test whether the new data available for my updated analysis might suggest that different strata should be used in my scaled length frequency calculations.

Table 5: Descriptions of the CPUE datasets and models fitted. The QMA and the definition of each model dataset (fishing method, target species, statistical areas, reporting form type) and the model response variable are noted. The core vessel subset definitions for each dataset (where "core vessels" are defined by a minimum number of years present in the dataset and a minimum number of associated non-zero effort strata per year) and the response and predictor variables offered to each model are also noted. "P(*x*, 3)", variable *x* offered as a third-order polynomial.

		Data set definitions				Core vessel subset definitions	
QMA	Model	Method	Target species	Statistical areas	Form type	Min. years	Min. non-zero effort strata per year
SPD 3	1.1	SN	SPD	018–027	CELR	5	10
	1.2	SN	SPD	018–027	CELR	5	10
	1.3	SN	ELE, GSH, SCH, SPD, SPO	018–027	CELR	5	10
	1.4	SN	ELE, GSH, SCH, SPD, SPO	018–027	CELR	5	10
SPD 5	1.5	BT	All[1]	025–030, 504	CELR and TCEPR	3	3
	1.6	BT	All[1]	025–030, 504	CELR and TCEPR	3	3
	1.7	BT	ESO, FLA, GUR, LSO, SPD, STA	025–030, 504	CELR	3	3
	1.8	BT	ESO, FLA, GUR, LSO, SPD, STA	025–030, 504	CELR	3	3

		Model variables	
QMA	Model	Response	Predictors offered
SPD 3	1.1	Catch per 1000 m net set	Fishing year + vessel key + month + stat. area + P(fishing duration, 3) + P(vessel exp., 3)
	1.2	Catch	Fishing year + vessel key + month + stat. area + P(fishing duration, 3) + P(vessel exp., 3) + P(net set, 3)
	1.3	Catch per 1000 m net set	Fishing year + vessel key + month + stat. area + P(fishing duration, 3) + P(vessel exp., 3) + target species
	1.4	Catch	Fishing year + vessel key + month + stat. area + P(fishing duration, 3) + P(vessel exp., 3) + P(net set, 3) + target species
SPD 5	1.5	Catch per hour fished	Fishing year + vessel key + month + stat. area + target species + P(effort number, 3) + form type
	1.6	Catch	Fishing year + vessel key + month + stat. area + target species + P(effort number, 3) + P(fishing duration, 3) + form type
	1.7	Catch per hour fished	Fishing year + vessel key + month + stat. area + target species + P(effort number, 3)
	1.8	Catch	Fishing year + vessel key + month + stat. area + target species + P(effort number, 3) + P(fishing duration, 3)

[1] "All" = ESO, FLA, GUR, LSO, SPD, STA, BAR, HAK, HOK, LIN, SQU, SWA, WWA, and OTH ("other"; i.e.,. all other target species that exist in the dataset)

I use the `rpart` recursive partitioning and regression tree model fitting algorithm implemented in version 2.4.1 of the `R` statistical programming language (R Development Core Team 2006) to carry out the post-stratification of the updated length-frequency dataset. The algorithm grows and prunes a regression tree model of the response variable, mean length per observed tow in this analysis, given the predictors offered using the methods of Breiman et al. (1984). This involves attempting to predict the outcome of the predictors by dividing the model space defined by the predictors into mutually exclusive regions in which the value of the response is as homogeneous as possible. This is achieved by splitting each predictor in a binary fashion, choosing the split so that it maximises the homogeneity in each subset. The binary split is performed on one predictor variable at a time, and thus the order of variables used at the splits (nodes) is an indicator of variable importance to the model. It is possible for the algorithm to grow a tree that describes the data very well, but is over elaborate and has little meaning in the real world (e.g., a difference in mean length of only a fraction of a centimetre across a split in a given predictor). A model cost-complexity measure ("cross validation"; see Breiman et al. (1984) for a description in full) is therefore used to prune back the tree. I measure the ability of the model fitted to explain the data using the proportion of residual deviance explained (R^2).

2.4.3 Calculating scaled length-frequency distributions using `Catchatage`

Description

`Catchatage` is a package of `R` functions (R Development Core Team 2005) developed and maintained by NIWA (Bull & Dunn 2002). It computes biomass estimates and scaled length-frequency distributions by sex and by stratum for trawl survey and market-sampling data using the calculations of Bull & Gilbert (2001) and Francis (1989). If passed a set of length-at-age data, it can construct an age-length key, which can then be applied to scaled length-frequency distributions to compute scaled age-frequency distributions, also by sex and stratum. A "direct-age" subroutine also exists, where individual age observations are weighted up to stratum catch totals using specified length-at-age and weight-at-length relationships. The coefficients of variation (c.v.) for each length and age-class and the overall mean-weighted c.v. for each length and age-frequency distribution are computed using a bootstrapping routine (Efron & Tibshirani 1993): fish length (or age) records are resampled within each station (or sample), stations (or samples) are resampled within each stratum, and the length-at-age data used to construct an age-length key are simply resampled, all with replacement. The bootstrap length- and age-frequency distributions are computed from each resample and the c.v.s for each length- and age-class and mean-weighted c.v.s for each length and age distribution computed from the bootstrap distributions.

Analysis performed

`Catchatage` was used to calculate scaled length-frequency distributions by sex for the commercial catch in SPD 5 over the 1996–97 to 2004–05 fishing years. Data from the 2005–06 fishing year were not available when this analysis was carried out. Strata derived from the results of the tree-based regression analysis were used to partition the data. Stratum catch totals were derived from cross-tabulations of the groomed, restratified, and merged catch-effort and landings dataset described in Section 4 that were scaled to the total reported landings for SPD 5 over these fishing years (see Table 1). Bootstrapped c.v.s for each length class and mean-weighted c.v.s for each distribution were calculated from 1000 iterations of the resampling algorithm. The weight-at-length relationships were parameterised using estimates calculated from a regression of log-transformed length and weight data collected during a research trawl survey of the Stewart-Snares shelf by RV *Tangaroa* in February-March 1995 (voyage code TAN9502; Bagley & Hurst (1996a)). These data ($n_{\text{male}} = 503$ and $n_{\text{female}} = 548$; male length range = 44.9–96.8 cm TL and female length range = 43.4–104.4 cm TL) were used as they span most of the length range of both sexes in the commercial catch and MFish observers do not typically collect individual fish weight data. Observations of fish deemed to be unusually light or heavy at length were dropped before fitting the regression models. The relationships are

$$\textit{males}: \; w = 3.90\times10^{-6}(l^{3.02}) \,, \tag{3}$$

$$\textit{females}: \; w = 1.00\times10^{-6}(l^{3.37}) \text{, and} \tag{4}$$

$$\textit{unsexed fish}: \; w = 0.70\times10^{-6}(l^{3.45}) \,, \tag{5}$$

where l is fish length in centimetres and w is fish weight in kilogrammes. The analysis was restricted to data from bottom (BT) and midwater (MW) trawls. The bottom longline data were deemed to be too sparse to be useful and were dropped. Data from BT and MW trawls where more than three spiny dogfish were measured only were retained in the analysis. Data associated with strata with fewer than three sampled stations were also dropped. The representativeness of the length-frequency data is also considered.

3. DATA PROCESSING

Here I summarise the results of applying the data processing algorithms to the different datasets. The numbers of unique trip keys and the total number of effort strata in each dataset are given in Table 6. The "recovery rate" (the percentage of groomed but unmerged landed catch retained in the groomed and merged catch-effort and landings dataset) and the effect of applying the catch-consistency checking algorithm is given in Table 7. The value of the imputation grooming routine is illustrated by comparing the distribution of bottom-trawl effort width (trawl wingspread in this context; see MFish (2004) for a discussion of the meaning of this and other effort variables in other contexts) in the SPD 5 CPUE dataset before and after grooming in Figure 4. Extreme values thought to be errors are removed and replaced with values that are typical of each vessel, producing a distribution with a more plausible shape. A total of 91% of the groomed landed catch was retained in the groomed and merged dataset, which is gratifyingly high. Recall that trips with fishing effort recorded in statistical areas that straddle multiple QMA boundaries and with landings recorded from multiple spiny dogfish QMAs were dropped from the analysis. Where effort straddles multiple stock boundaries but landings from only a single QMA are recorded, the assumption is made that fishing took place on the recorded QMA side of the statistical area boundary line during the fishing trip and that trip's data are retained in the analysis.

Table 6: Summarising the catch-effort and landings datasets.

Cross-tabulations of the numbers of unique trip keys in the fishing and landing event tables in each unprocessed dataset. *F*, fishing events table; *L*, landing events table. The off-diagonals in the cross-tabulations are equal (indicated by "–").

	QMA					
Dataset		SPD 3			SPD 5	
Characterisation		*F*	*L*		*F*	*L*
	F	57 897	–	*F*	5 845	–
	L	57 897	58 056	*L*	5 845	5 900
CPUE		*F*	*L*		*F*	*L*
	F	26 774	–	*F*	22 815	–
	L	26 520	26 520	*L*	15 775	15 775

Numbers of unique trip key and effort strata in the processed datasets.

		N	
QMA	Dataset	Unique trip keys	Effort strata
SPD 3	Characterisation	24 737	31 251
	CPUE	45 075	60 959
SPD 5	Characterisation	20 312	33 742
	CPUE	4 069	8 995

Table 7: Summarising the results of applying the data processing algorithms to the SPD 3 & 5 characterisation tables. The QMR landings and corresponding TACCs are listed by fishing year. For comparison, the total greenweight landings by fishstocks for all trips in the valid trip sets defined for each analysis are provided. The groomed and merged landings (i.e., after removing improper destination state codes, trips fishing in straddled statistical areas and reporting more than one fishstock per landing, etc.) and the "most consistent" landed catch calculated after a comparison of the estimated, processed, and reported greenweight landings for each trip are also provided. RR, recovery rate or the proportion of raw greenweight landings retained in the groomed and merged landed catch. All landings are in tonnes.

	Fish.			Raw greenweight landings by fishstock in valid trip set						Groomed		"Consistent"	
QMA	year	QMR	TACC	SPD1	SPD3	SPD4	SPD5	SPD7	SPD8	Landings	RR	landings	CR
SPD 3	1990	2243	–	–	1865	91	132	157	31	1152	0.62	1662	1.44
	1991	2987	–	–	2684	449	530	103	44	1701	0.63	2292	1.35
	1992	1801	–	< 1	1760	49	334	258	46	1408	0.80	1866	1.33
	1993	2128	–	–	2072	155	624	176	105	1304	0.63	1578	1.21
	1994	3165	–	–	2945	74	685	230	78	2100	0.71	2248	1.07
	1995	2883	–	< 1	2429	40	365	189	75	1585	0.65	1721	1.09
	1996	2558	–	–	2615	376	1063	239	19	1966	0.75	2079	1.06
	1997	2428	–	–	2507	272	459	121	21	2126	0.85	2183	1.03
	1998	5042	–	–	5138	359	190	178	102	2190	0.43	2217	1.01
	1999	3148	–	–	3182	416	1374	147	52	2859	0.90	2889	1.01
	2000	3309	–	< 1	3380	613	881	173	1	2913	0.86	2964	1.02
	2001	4355	–	5	4411	489	891	198	5	2918	0.66	3003	1.03
	2002	4249	–	3	5313	413	2845	230	21	3013	0.57	3073	1.02
	2003	3553	–	–	4856	480	1791	163	15	2772	0.57	2823	1.02
	2004	3557	–	1	4183	322	974	95	3	2519	0.60	2540	1.01
	2005	2707	4794	10	2861	394	1046	142	3	1614	0.56	1629	1.01
	2006	3831	4794	9	3814	483	1056	84	11	1847	0.48	1853	1.00
SPD 5	1990	243	–	–	560	65	203	73	13	96	0.47	107	1.11
	1991	1722	–	–	773	197	1543	57	31	211	0.14	278	1.32
	1992	571	–	< 1	318	19	533	187	118	199	0.37	294	1.48
	1993	839	–	4	572	74	795	106	59	356	0.45	441	1.24
	1994	1179	–	–	876	45	1076	144	53	220	0.20	233	1.06
	1995	643	–	–	488	21	493	84	52	123	0.25	155	1.26
	1996	1299	–	–	525	237	1403	101	14	364	0.26	366	1.01
	1997	884	–	–	341	182	858	34	2	421	0.49	424	1.01
	1998	651	–	1	221	142	452	48	2	390	0.86	390	1.00
	1999	2150	–	–	689	117	2117	171	28	1367	0.65	1368	1.00
	2000	1352	–	–	722	202	1263	69	–	1085	0.86	1094	1.01
	2001	1601	–	–	876	385	1399	135	6	1221	0.87	1236	1.01
	2002	4221	–	1	1696	134	3886	117	15	2846	0.73	2890	1.02
	2003	3034	–	–	833	88	2733	65	11	2036	0.74	2051	1.01
	2004	3037	–	–	546	59	1834	36	3	1221	0.67	1233	1.01
	2005	2479	3700	< 1	675	73	2469	124	6	1302	0.53	1355	1.04
	2006	2298	3700	–	1076	285	2314	96	11	1067	0.46	1090	1.02

The relationship between the total estimated catch and the total recorded landed catch for each trip in the groomed but unmerged datasets is plotted in Figure 5. Here most values fall about the expected one-to-one line, but a number of trips fall into a region where the total estimated catch is a fraction of the total landed catch divided by valid spiny dogfish conversion factors. Given that spiny dogfish catches are usually processed (i.e., trunked) at sea rather than landed green (i.e., unprocessed), this suggests that some fishers have probably recorded estimates of the processed (i.e., trunk) catch weight on their catch-effort reporting forms rather than an estimate of the unprocessed catch as they are instructed, although fishing trips where this is likely to have occurred are relatively few (less than 5%; scores 2–3, Table 8; trips with a consistency score of 4 were dropped from the analysis). Time series of different catch types including the QMR catches from Table 1 and the total estimated and landed catches in the characterisation dataset (with and without the application of the catch-consistency checking algorithm) are plotted in Figure 6. A rigorous comparison of different methods of correcting for conversion factor changes over time is recommended in the next analysis.

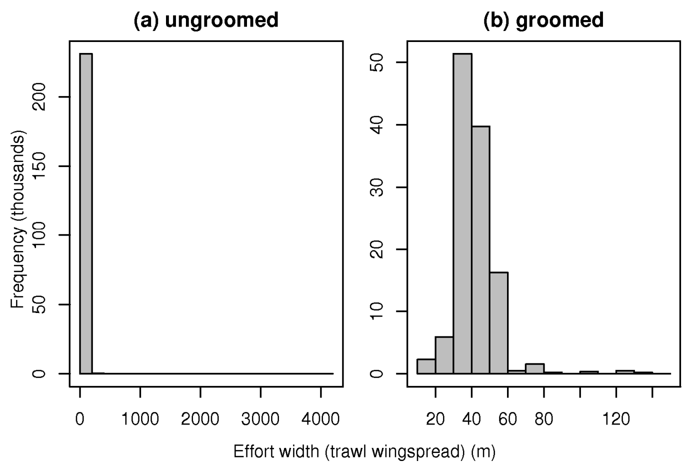


Figure 4: The effect of applying median imputation on outlier values in the effort width (trawl wingspread) variable associated with bottom-trawls by vessels using TCEPR reporting forms in the SPD 5 CPUE dataset.

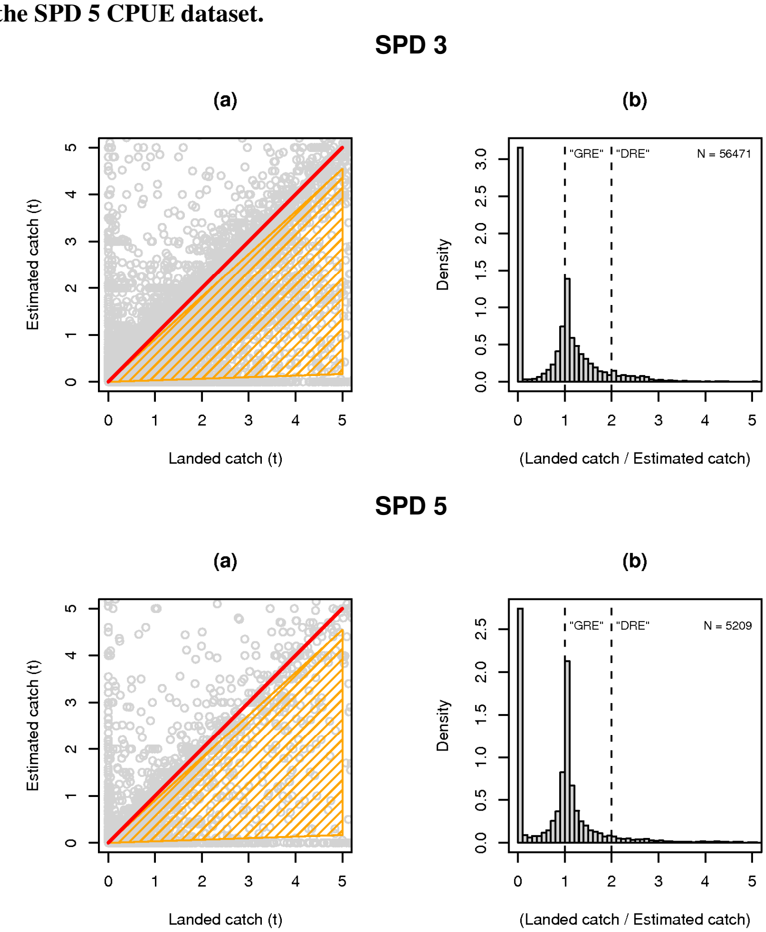


Figure 5: The relationship between the total estimated and landed spiny dogfish catch for each fishing trip in the groomed but unmerged SPD 3 & 5 catch-effort and landings datasets (characterisation datasets). The expected one-to-one relationship is indicated by the grey line. The shaded region is the total landed catch divided by the recorded conversion factor(s) per fishing trip (i.e., the imputed processed catch). Points that fall in this region suggest fishing trips where fishers have recorded processed (e.g., dressed, fins) rather than greenweight catch estimates on their catch-effort forms.

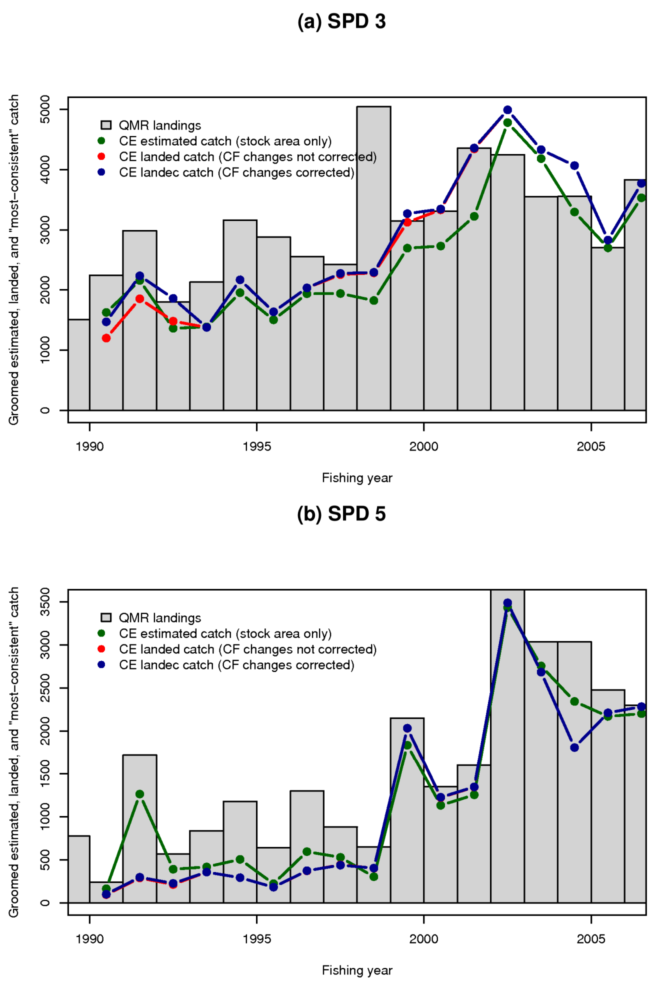


Figure 6: Four of the different catch types considered in the SPD 3 & 5 analyses. The grey bars are the QMR catch. The lines are: (a) the estimated catch; (b) the groomed but otherwise unprocessed greenweight landed catch; and (c) the "most-consistent" landed catch derived by considering changes in conversion factor and comparing the total estimated, total greenweight, and total processed catch for each fishing trip in the data. See Figure 3 for a description of the comparison algorithm.

Table 8: Results of applying the catch-consistency checking algorithm to the groomed landings table. The frequencies of occurrence of the consistency scores calculated by applying the checking algorithm described by Blackwell et al. (2005) to each dataset in this analysis are tabulated. CHAR, characterisation dataset; CPUE, catch-effort standardisation dataset.

Stock	Dataset	Score	Frequency
SPD 3	CHAR	1	31 891
		2	9 783
		3	4 616
		4	10 174
		Total	56 464
	CPUE	1	11 427
		2	1 637
		3	1 807
		4	1 882
		Total	16 753
SPD 5	CHAR	1	1 323
		2	2 017
		3	316
		4	1 538
		Total	5 194
	CPUE	1	626
		2	1 270
		3	143
		4	1 035
		Total	3 074

4. FISHERY CHARACTERISATIONS

Manning et al. (2004) described both the SPD 3 and 5 fisheries over the 1989–90 to 2000–01 fishing years. I update their analysis with data available to the end of the 2005–06 fishing year. The aim of the updated fishery characterisation is to test whether fishing patterns (or at least the fishing events data captured by the catch-effort and landings reporting system) have changed since the last analysis to aid the interpretation of the standardised CPUE indices that I present below.

4.1 SPD 3

A series of plots of the groomed and merged SPD 3 landed catch conditioning on different explanatory variables is first presented. Estimates of the retained and discarded catch are plotted in Figure 7(b). The catch is plotted by month and fishing year, by statistical area and fishing year, by recorded fishing method and fishing year, and by recorded target species in Figure 8. The catch is plotted by reporting form type, fishing method, and fishing year in Figure 9. The catch is plotted by fishing method, target species, and reporting form type for CELR- and TCEPR-associated effort strata only in Figure 10. The catch is plotted by fishing method, fishing year, statistical area, and reporting form type for CELR- and TCEPR-associated effort strata only in Figure 11. The catch is plotted by fishing method, fishing year, statistical area, and target species for all form types in Figure 12. Finally, the catch is plotted by fishing method, month of the fishing year, and fishing year in Figure 13. Cross-tabulations of the groomed and merged landed catch are given in Appendix A.

The reported catch has risen steadily over the data series, from less than 1000 t during the late 1980s, to an average annual catch of 2944 t per year over the 1990s. The catch peaked at 5042 t during the 1997–98 fishing year. Since the start of the 2000–01 fishing year, the catch has averaged 3709 t per year. A TACC of 4794 t was introduced at the start of the 2004–05 fishing year, but has not yet been caught (see Table 1). However, there is some evidence of a possible change in reporting practices over the data series. The proportion of reported discarded catch in the total annual SPD 3 catch increases rapidly over the 1990s, which Manning et al. (2004) interpreted as a change in reporting practice rather than in the true spiny dogfish catch, but drops extremely rapidly after spiny dogfish was admitted into the QMS at the start of the 2004–05 fishing year. The implications of these trends for how accurately the reported SPD 3 catch in Table 1 indexes true total removals are unknown.

Patterns in the catch are generally consistent with Manning et al.'s (2004) earlier analysis, but there are some interesting patterns that have emerged since their analysis. There remains some evidence of seasonality in the catch, with about half of the catch caught over the five months from January to May (but only 52% of the total catch across all fishing years 1989–90 to 2005–06, Table A1, Appendix A). Catches continue to be recorded from all statistical areas, but most of the catch continues to be taken in inshore statistical areas 018, 020, 022, and 024 (94% across all fishing years 1989–90 to 2005–06, Table A2, Appendix A). Statistical area 022 containing the Canterbury Bight is the single most important statistical area, accounting for 36% of the total catch over the 1989–90 to 2005–06 fishing years (Table A2, Appendix A). The catch in area 022 has increased rapidly since the 2000–01 fishing year and seems to be driven by an increase in catches by smaller (less than or equal to 28 m in overall length) bottom trawl vessels completing CELRs targeting red cod and by larger (over 28 m in overall length) bottom trawl vessels completing TCEPR reporting forms and targeting barracouta, red cod, and squids over this time.

Bottom-trawl and setnet fishing continue to account for most of the catch by fishing method. However, the relative importance of the setnet catch, in particular the target setnet catch, has declined markedly over the data time series. Manning et al. (2004) found that bottom trawling accounted for 57% and setnet fishing for 40% of the total catch over the 1989–90 to 2000–01 fishing years. However, in the new characterisation dataset analysed in this study, bottom trawl fishing accounts for 65% of the total

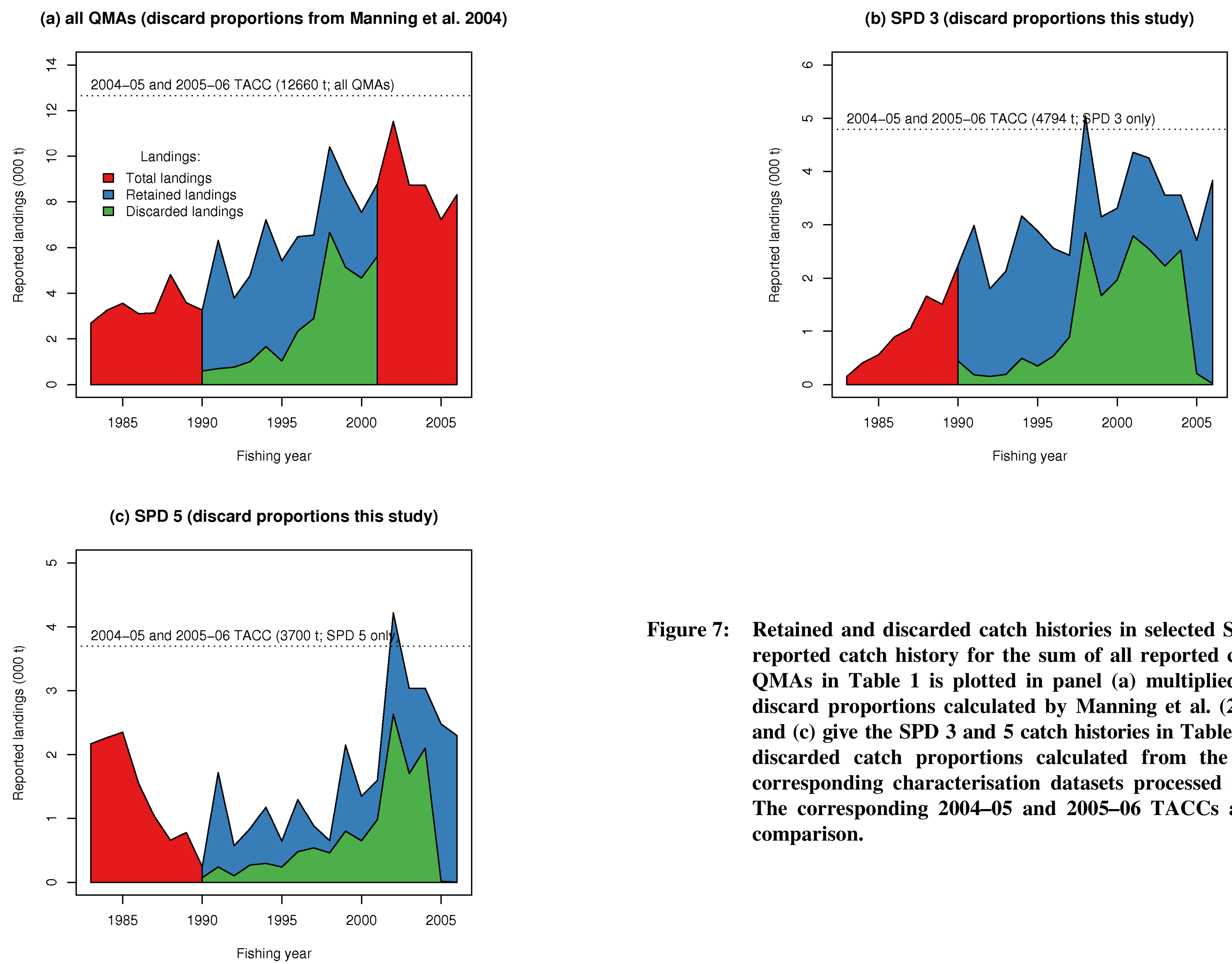


Figure 7: Retained and discarded catch histories in selected SPD QMAs. The reported catch history for the sum of all reported catch in all SPD QMAs in Table 1 is plotted in panel (a) multiplied by the annual discard proportions calculated by Manning et al. (2004). Panels (b) and (c) give the SPD 3 and 5 catch histories in Table 1 multiplied by discarded catch proportions calculated from the catches in the corresponding characterisation datasets processed in this analysis. The corresponding 2004–05 and 2005–06 TACCs are overlaid for comparison.

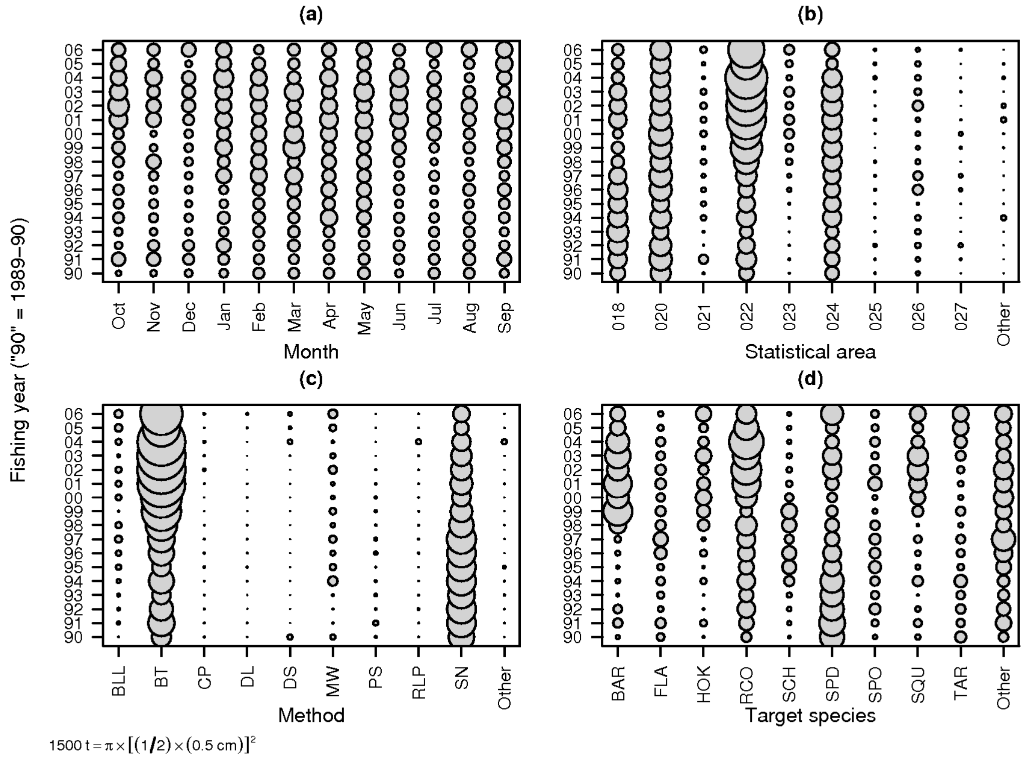


Figure 8: **The SPD 3 groomed and merged landed catch by: (a) month and fishing year; (b) statistical area and fishing year; (c) method and fishing year; and (d) target species and fishing year. Circle areas are proportional to the amount of catch in each factor level and fishing year combination and are equivalent from panel to panel. Circle areas are equivalent to the same amount of catch from plot to plot.**

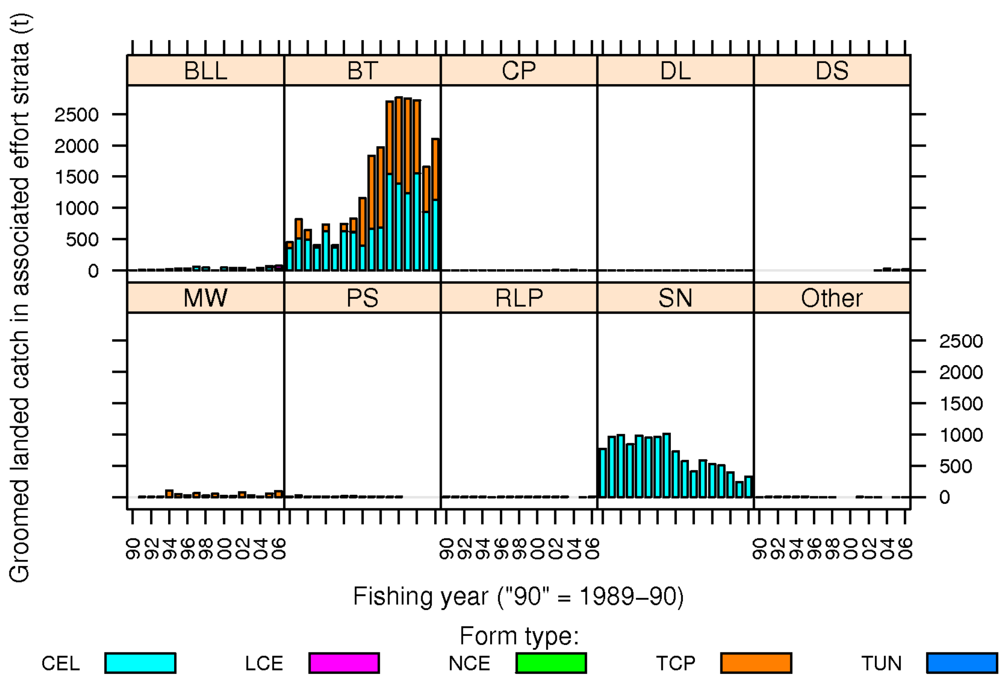


Figure 9: **The SPD 3 groomed and merged landed catch by reporting form type, fishing year, and fishing method. The form type and fishing method codes used are given in Appendix F.**

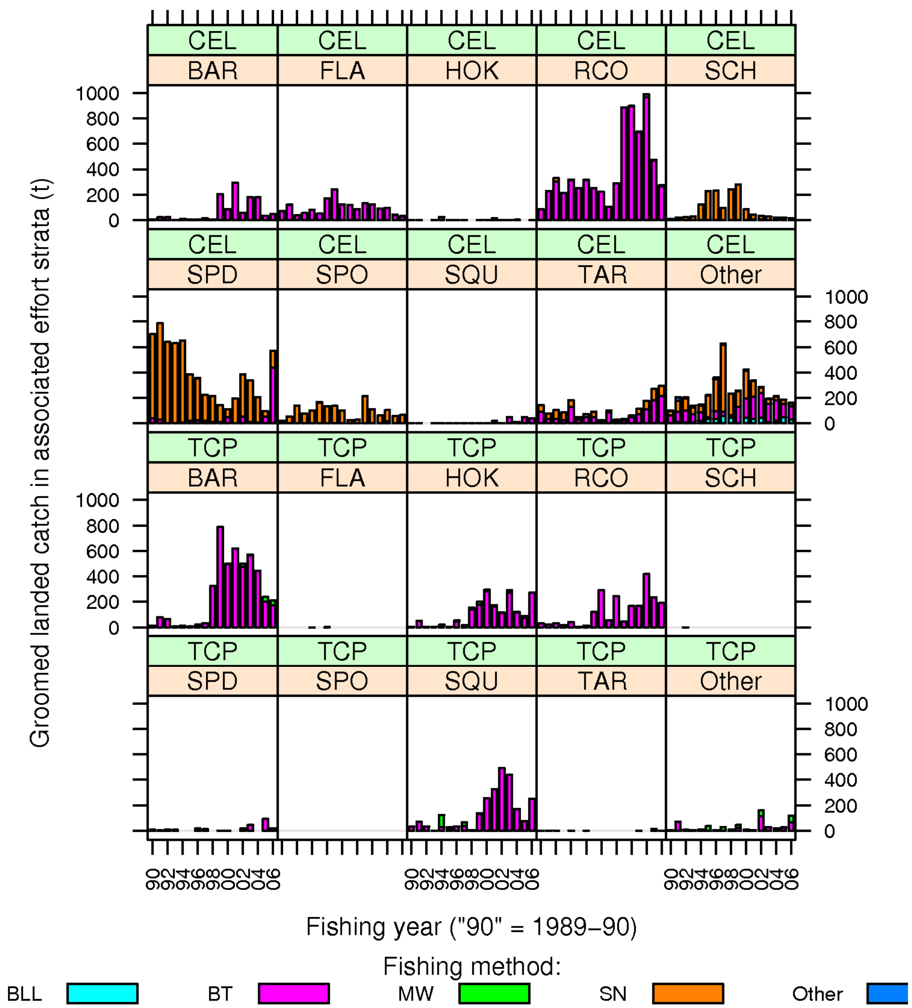


Figure 10: The SPD 3 groomed and merged landed catch by fishing method, fishing year, target species, and reporting form type. The fishing method, target species, and form type codes used are given in Appendix F.

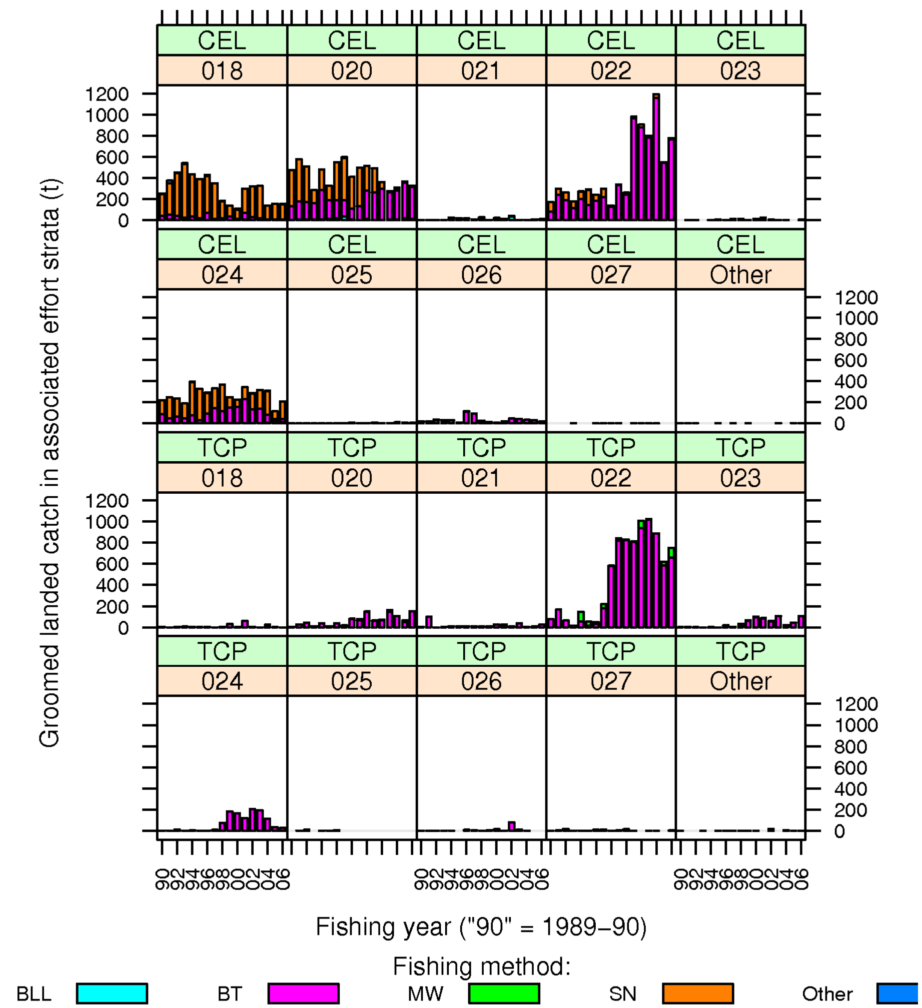


Figure 11: The SPD 3 groomed and merged landed catch by fishing method, fishing year, fisheries statistical area, and reporting form type. The fishing method and target species codes used are given in Appendix F.

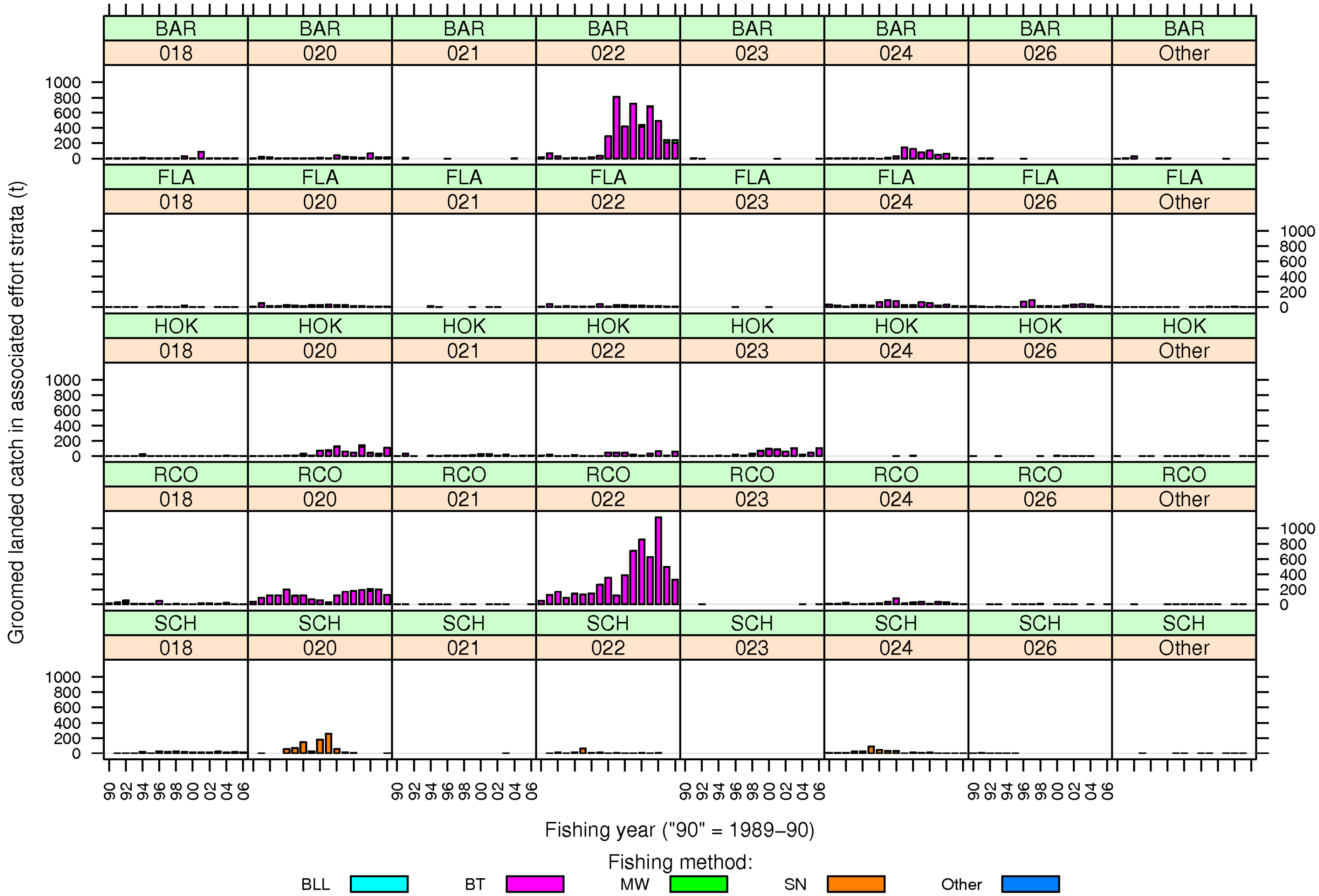


Figure 12: The SPD 3 groomed and merged catch by fishing method, fishing year, statistical area, and target species for the 1989–90 to 2005–06 fishing years. The fishing method and target species used are given in Appendix F.

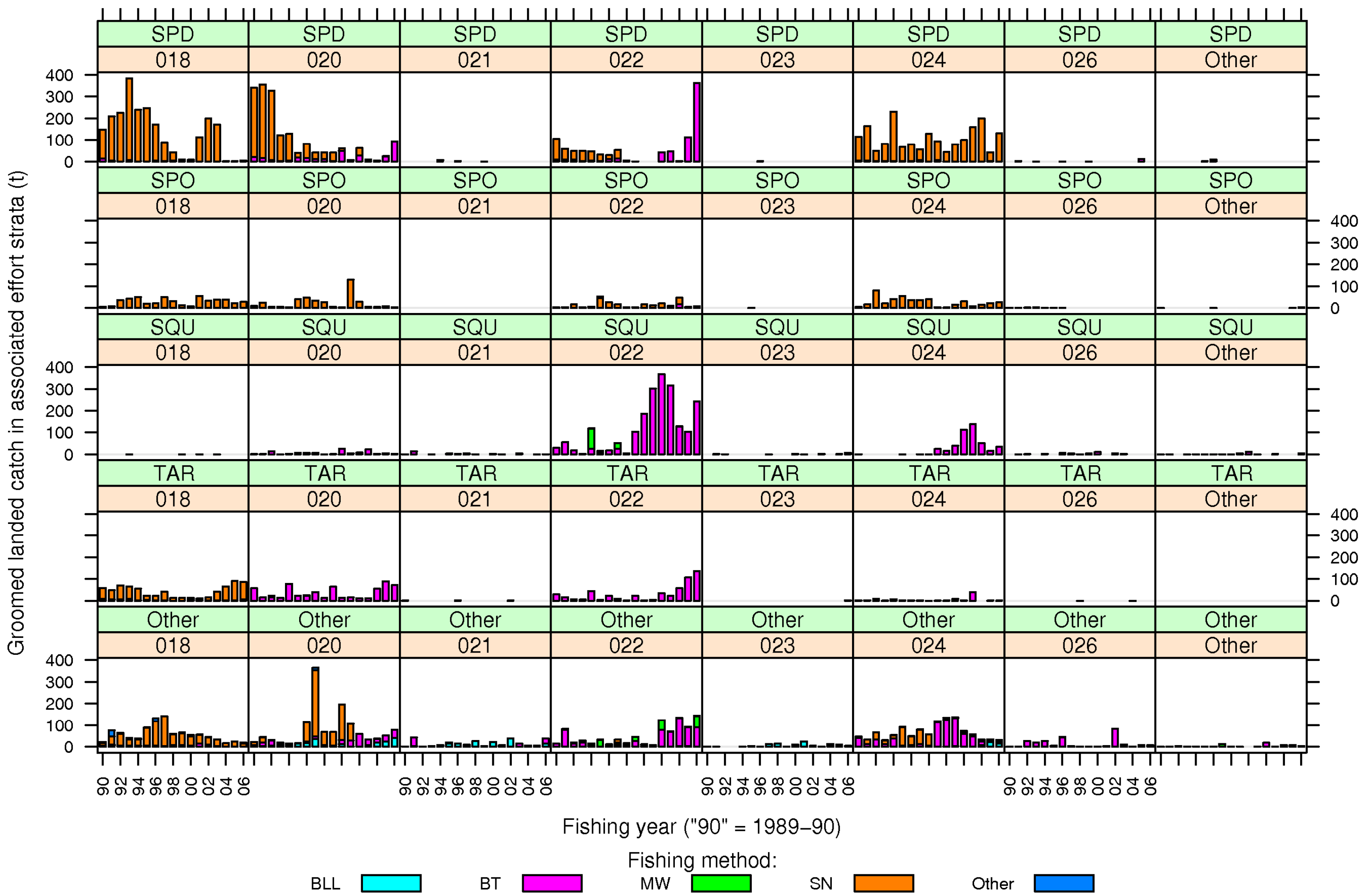


Figure 12: **(continued)**

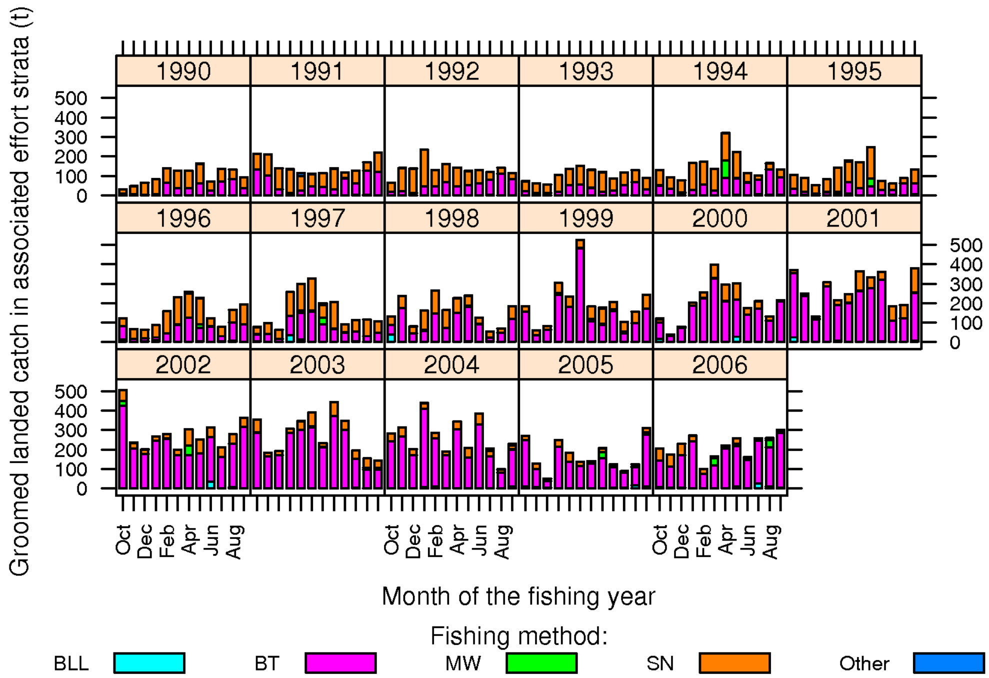


Figure 13: The SPD 3 groomed and merged catch by fishing method, month of the fishing year (October to September), and fishing year, 1989–90 to 2005–06. The fishing method codes used are give in Appendix F.

catch and setnet fishing 31% over the 1989–90 to 2005–06 fishing years (Table A3, Appendix A). This has been driven by an increase in the bottom trawl catch, in particular, as noted above, by vessels targeting red cod and barracouta and to a lesser extent hoki and squids, and a four-fold decrease in the setnet catch since the late 1990s. The setnet catch has dropped from between 50% to 60% of the total annual catch over the early- to mid-1990s to between 12% and 18% of the total annual catch since 2000–01. The target setnet catch in particular has dropped dramatically over the data series, from 54% of the total catch in 1989–90 to 5% during the 2005–06 fishing year.

Historically, most of the target setnet catch was caught in statistical areas 018 (Kaikoura), 020 (southern Cook Strait), and 024 (Pegasus Bay) with a lesser contribution from statistical area 022 (Canterbury Bight). Recent declines in the target setnet catch are greatest in statistical areas 018, 020, and 022, where the target setnet catch has largely disappeared in recent years. However, the target setnet catch in area 024 (Timaru), although somewhat variable from fishing year to fishing year, appears to have remained reasonably steady over the data series. Declines in the spiny dogfish catch by setnet vessels targeting other species are less clear. Spiny dogfish catches by setnet vessels targeting school shark have always been relatively low, with the exception of a small peak in the catch over the mid- to late-1990s that has now disappeared. Catches by setnet vessels targeting rig appear low and variable from year to year but remain reasonably steady over the time series.

New, higher-resolution bottom-longline (LCERs, the Line Catch Effort Return), setnet (NCELR, the Netting Catch Effort Landing Return), and trawl (TCERs, the Trawl Catch Effort Return) catch-effort reporting forms have been implemented by MFish to replace the use of CELRs for these method types for fishing vessels that meet particular criteria. LCERs were introduced on 1 October 2004, NCELRs on 1 October 2006, and TCERs on 1 October 2007. These forms differ from the CELR form chiefly in that fishing activity is recorded on a set by set or trawl by trawl basis rather than being aggregated across multiple sets or trawls. Precise position fixes must be recorded for each set or trawl, and space is provided to record the estimated catch of the top eight rather than only the top five species in the catch. However, the amount of catch associated with LCERs in the characterisation dataset is minimal, and the amount of catch associated with NCELRs and TCERs in the dataset produced by the Ministry of Fisheries for this analysis is non-existent, and as a result we lack the ability to investigate spatial trends in catch below the level of statistical areas in SPD 3 in this analysis.

A very small amount of catch was associated with a single tuna surface longlining trip targeting southern bluefin tuna in 2002–03.

4.2 SPD 5

As with the SPD 3 description above, a series of plots of the groomed and merged SPD 5 landed catch conditioning on different explanatory variables is presented. Estimates of the retained and discarded catch are plotted in Figure 7(c). The catch is plotted by month and fishing year, by statistical area and fishing year, by recorded fishing method and fishing year, and by recorded target species in Figure 14. The catch is plotted by reporting form type, fishing method, and fishing year in Figure 15, and by fishing method, target species, and reporting form type for CELR- and TCEPR-associated effort strata only in Figure 16. The catch is plotted by fishing method, fishing year, statistical area, and reporting form type for CELR- and TCEPR-associated effort strata only in Figure 17. The catch is plotted by fishing method, fishing year, statistical area, and target species for all form types in Figure 18. And finally, the catch is plotted by fishing method, month of the fishing year, and fishing year in Figure 19. Cross-tabulations of the groomed and merged landed catch are also given in Appendix A.

The catch has risen steadily since the late 1990s, exceeding 2000 t every year since the start of the 2001–02 fishing year (Table 1). The greatest annual catch was in 2001–02, with over 4200 t landings reported during that year (see Table 1). A TACC of 3700 t was introduced at the start of the 2004–05 fishing year and remains unchanged at this time. The TACC has not been caught since its introduction (Table 1). As with SPD 3, there is some evidence of a possible change in reporting practices in the SPD 5 catch over the data series. As with SPD 3, the proportion of reported discarded catch in the total annual SPD 5 catch increases rapidly over the 1990s, but drops extremely rapidly after spiny dogfish was admitted into the QMS at the start of the 2004–05 fishing year. The implications of these trends for how accurately the reported SPD 5 catch in Table 1 indexes true total removals are unknown.

Trends within the catch are broadly consistent with those identified in Manning et al.'s (2004) earlier analysis. The SPD 5 fishery continues to be dominated by bottom-trawl fishing (63% of the total catch over all fishing years; Table A8, Appendix A), although there are lesser but consistent contributions to the catch associated with midwater-trawl, setnet, and bottom-longline fishing methods (19%, 12%, and 6% of the total catch over all fishing years respectively; Table A8, Appendix A). The recent steady increase in the total catch is associated with increased reported landings by trawl vessels. Evidence of a more distinct seasonal effect in the catch than in SPD 3 also exists, with 71% of the total catch over all fishing years in the data series caught during the summer and autumn months of December to April (inclusive; Table A6, Appendix A). There is some variation in the precise start and end of this "season" between fishing years, however (c.f., 1996–97 and 1998–99, for example). The seasonal peak in catch is associated chiefly with catches by large bottom- and midwater-trawl vessels completing TCEPR reporting forms (i.e., over 28 m in overall length) and targeting squids and jack mackerels (*Trachurus* spp.) on the Stewart-Snares shelf (statistical areas 025 to 030). There is also a notable increase in the targeted spiny dogfish catch reported by bottom-trawl vessels in areas 025 and 030, during 2004–05 and 2005–06, which may be due to a change in reporting practices associated with the introduction of spiny dogfish into the QMS at the start of the 2004–05 fishing year.

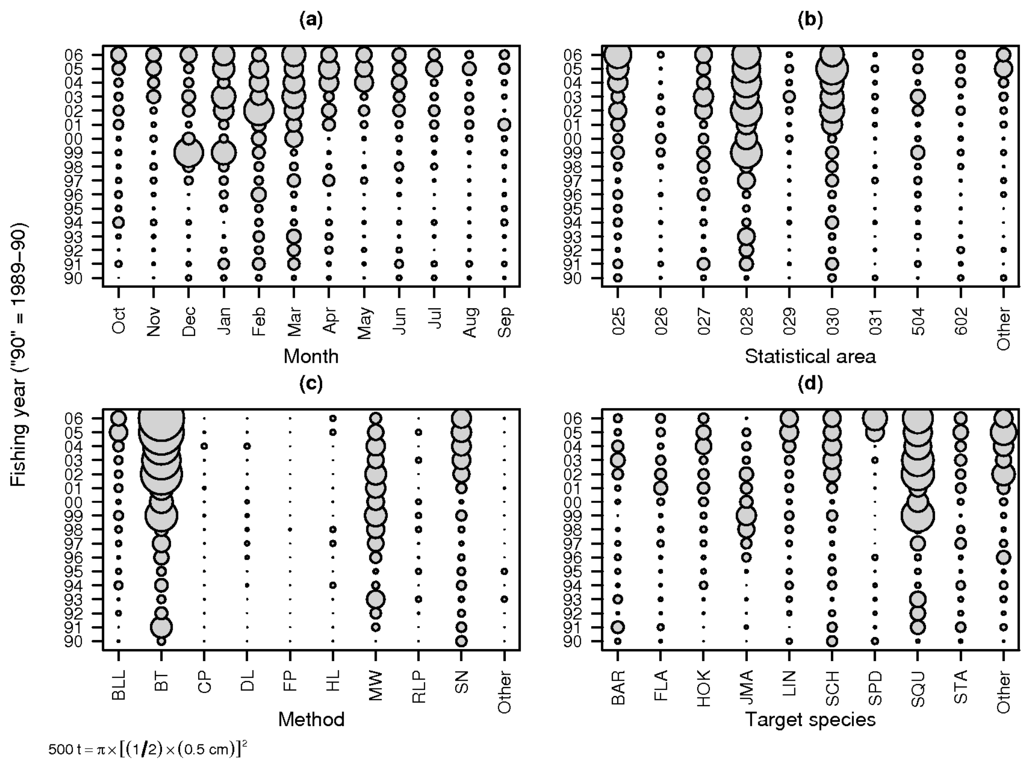


Figure 14: The SPD 5 groomed and merged landed catch by: (a) month and fishing year; (b) statistical area and fishing year; (c) method and fishing year; and (d) target species and fishing year. Circle areas are proportional to the amount of catch in each factor level and fishing year combination and are equivalent from panel to panel. Circle areas are equivalent to the same amount of catch from plot to plot.

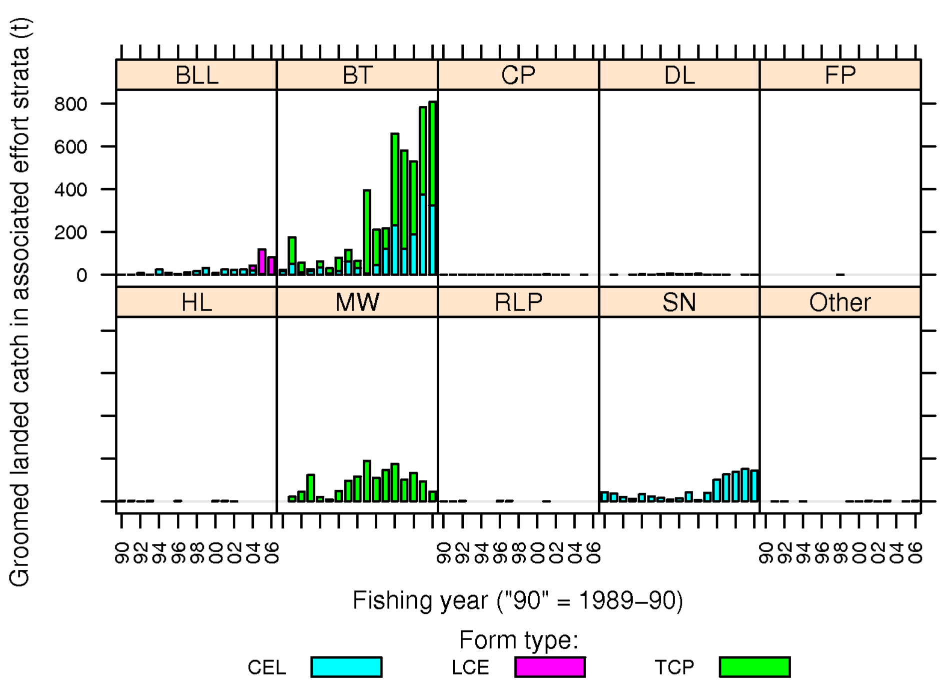


Figure 15: The SPD 5 groomed and merged landed catch by reporting form type, fishing year, and fishing method. The form type and fishing method codes used are given in Appendix F.

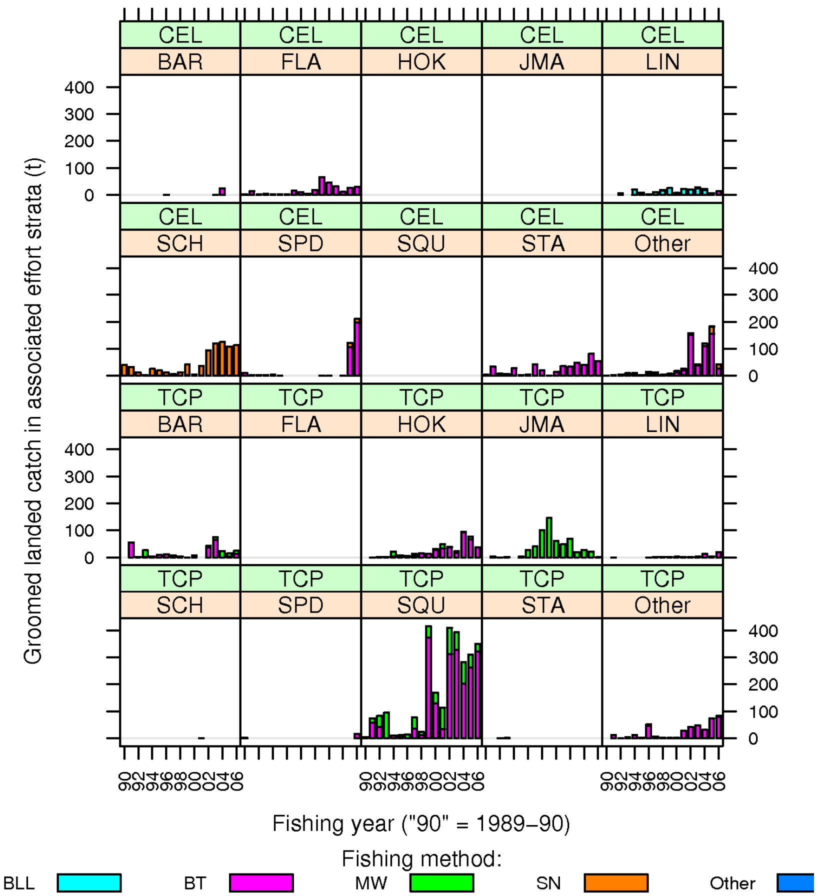


Figure 16: The SPD 5 groomed and merged landed catch by fishing method, fishing year, target species, and reporting form type. The fishing method, target species, and form type codes used are given in Appendix F.

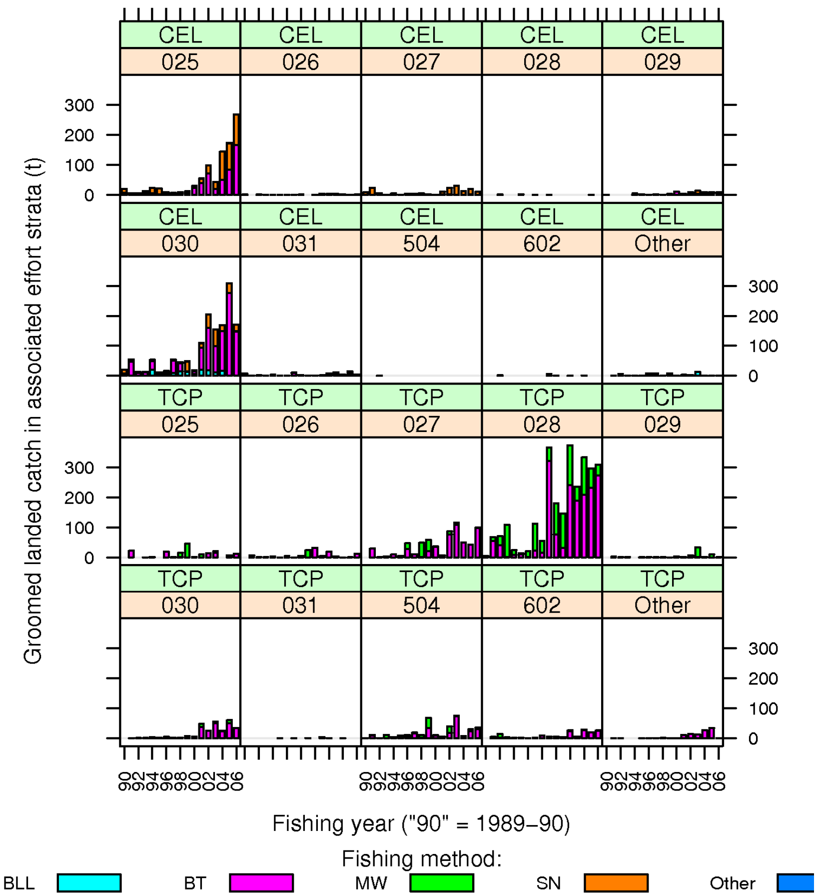


Figure 17: The SPD 5 groomed and merged landed catch by fishing method, fishing year, fisheries statistical area and reporting form type. The fishing method and form type codes used are given in Appendix F.

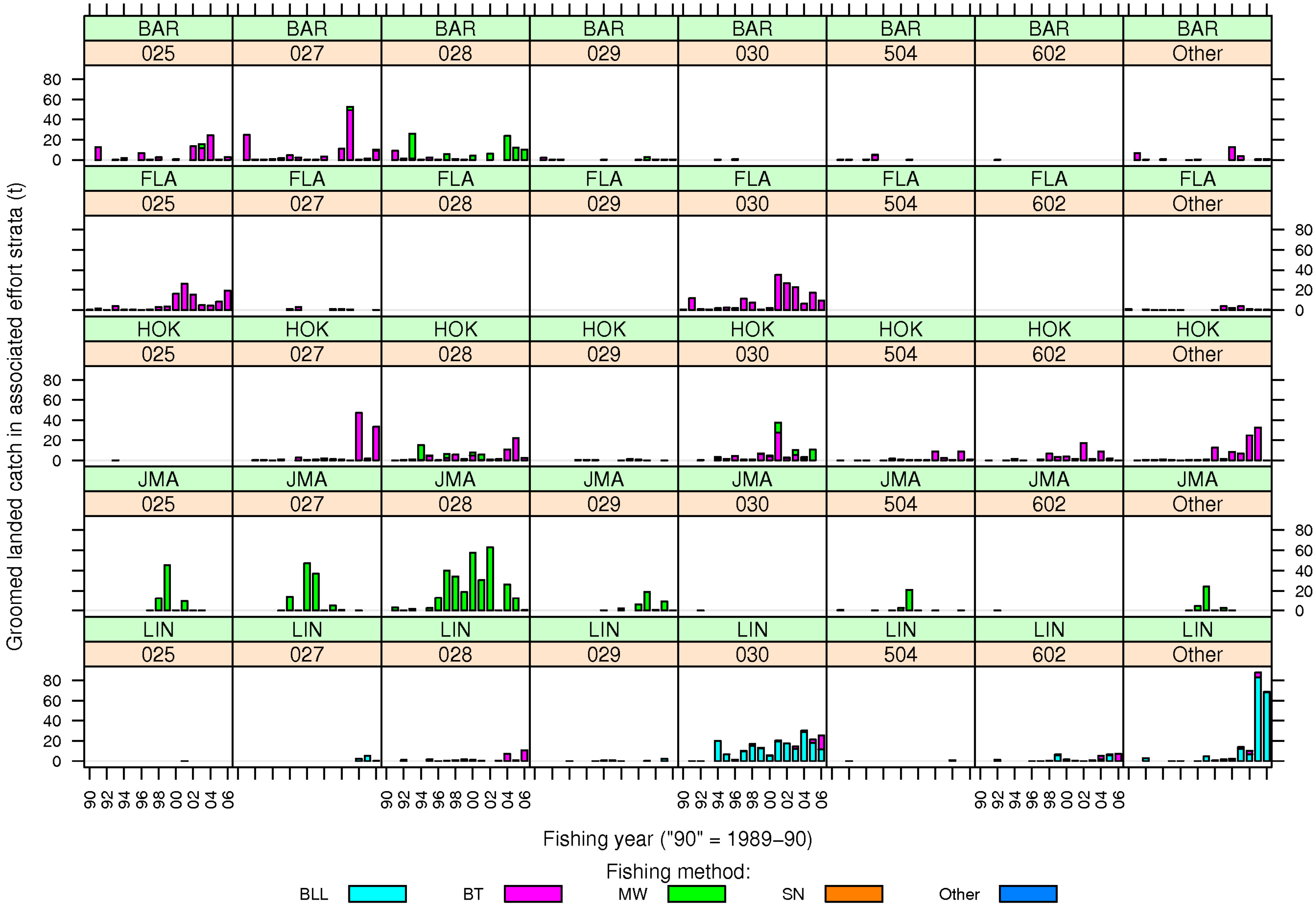


Figure 18: The SPD 5 groomed and merged catch by fishing method, fishing year, statistical area, and target species for the 1989–90 to 2005–06 fishing years. The fishing method and target species codes used are given in Appendix F.

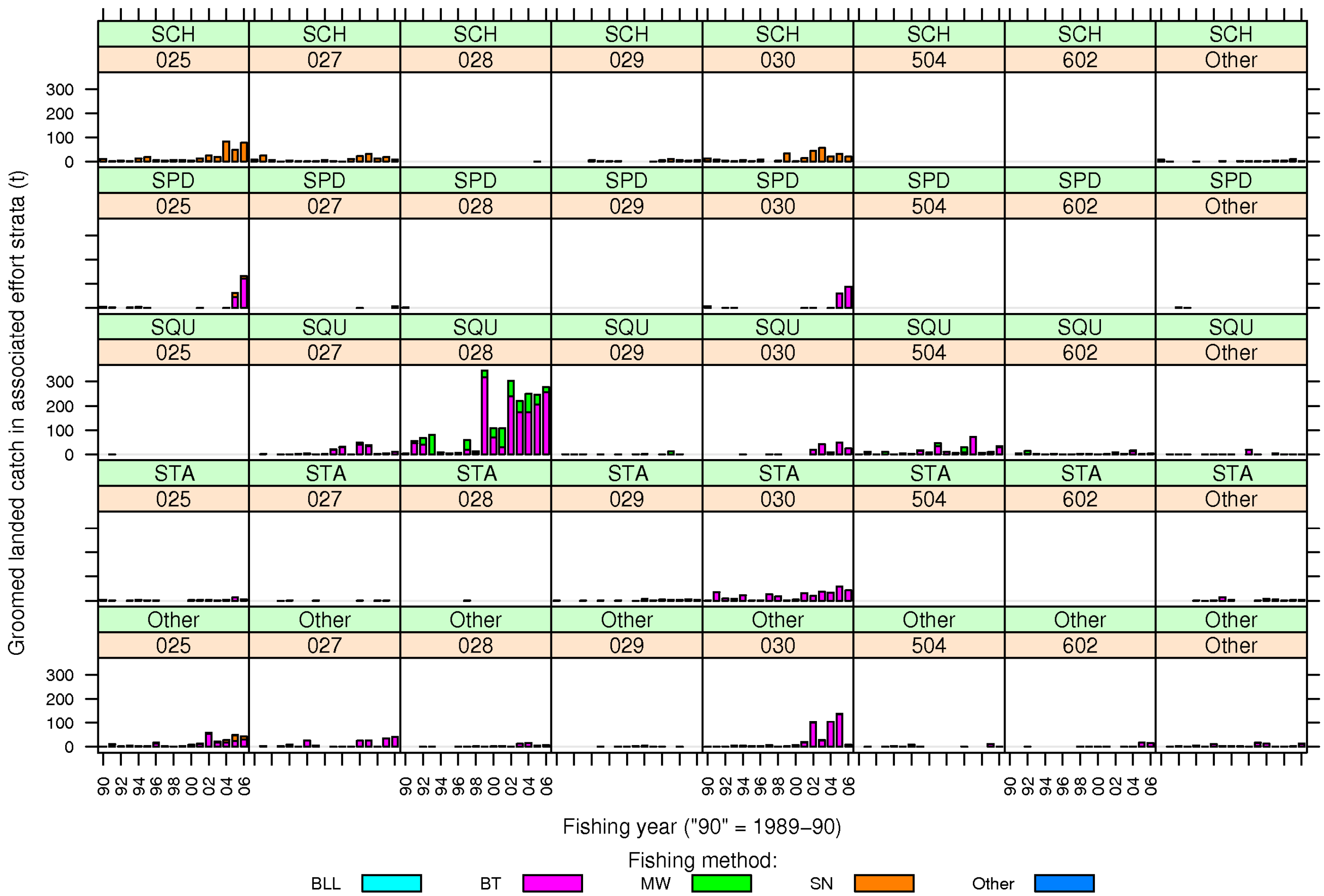


Figure 18: **(continued)**

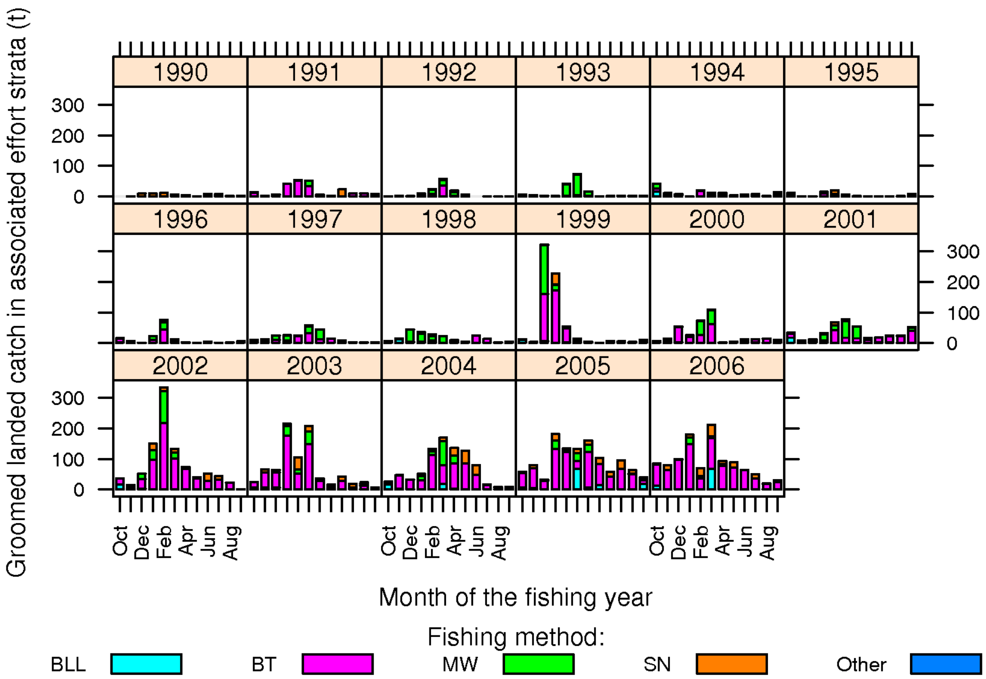


Figure 19: The SPD 5 groomed and merged catch by fishing method, month of the fishing year (October to September), and fishing year, 1989–90 to 2005–06. The fishing method codes used are give in Appendix F.

Statistical area 028 on the southern end of the Stewart-Snares shelf and area 030 northwest of Stewart Island are the two most important statistical areas, being associated with nearly half of the total SPD 5 catch over the data time series (36% from 028 and 23% from 030 over all fishing years; Table A7, Appendix A). Areas 025 and 027, northeast and southeast of Stewart Island respectively, are the next most important, being associated with one quarter of the total catch (14% from 025 and 11% from 027 over all fishing years; Table A7, Appendix A). With the exception of area 504 (associated with 5% of the total catch over all fishing years), contributions from other statistical areas are negligible. Interestingly, most of the catch in statistical areas 025 and 030 to the north of Stewart Island are associated with smaller bottom-trawl vessels completing CELR reporting forms, whereas the catch in areas 027, 028, and 504 to the south are associated with larger bottom- and midwater-trawl vessels completing TCEPRs. This probably reflects the greater fishing depths on the continental slope prosecuted by the larger trawl vessels and their greater endurance in the prevailing weather conditions on the southern end of the Stewart-Snares shelf.

The large amount of catch recorded on TCEPR reporting forms facilitates investigating patterns in catch on a smaller spatial scale than the level of individual statistical areas. Nominal median log spiny dogfish catch rate surfaces for the 1989–90 to 2005–06 fishing years are plotted by fishing year in Figure 20. Hotspots of high nominal catch rates are apparent in some fishing years and appear to persist from one fishing year to the next on the Stewart-Snares shelf. Some attenuation and movement along the shelf of areas of high catch rate are noted, but the reasons for this are unclear. One possible explanation is that these changes reflect changes in fishing effort and behaviour and another is that they reflect changes in spatial patterns in spiny dogfish from one year to the next. These explanations are not mutually exclusive and are confounded given that the data are fishery-dependent and fishing effort is not randomly distributed across the shelf. Interestingly, as noted above, the greatest amount of spiny dogfish catch is by large TCEPR-using bottom- and midwater-trawl vessels targeting jack mackerels and squids in area 028 on the southern end of the Stewart-Snares shelf; however in many

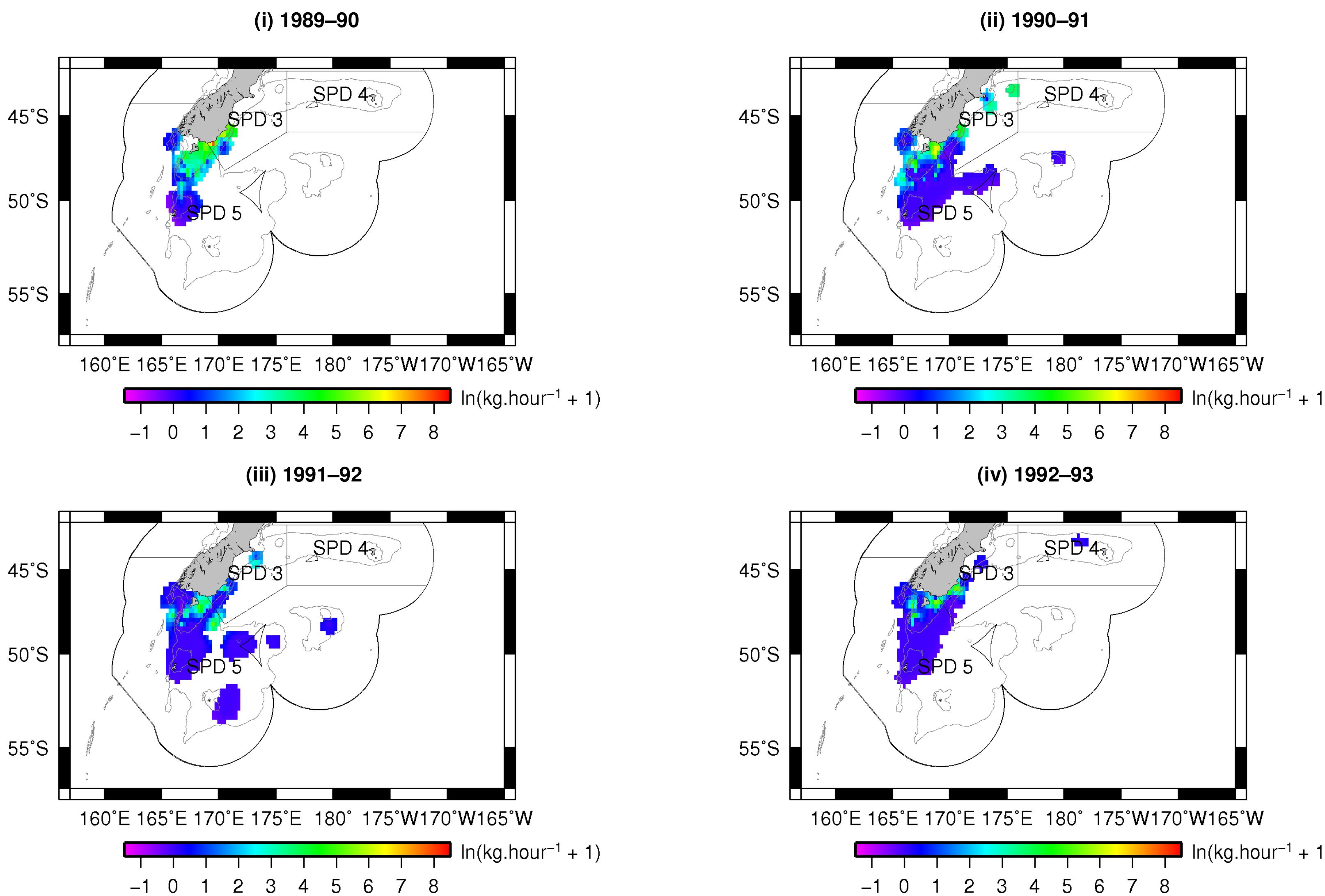


Figure 20: **Median log catch-rate surfaces from bottom- and midwater-trawl vessels completing TCEPR reporting forms in groomed but unmerged fishing events associated with the SPD 5 characterisation dataset, 1989–90 (i) to 2005–06 (xvii). Catch rates are defined as the median of the natural log of the estimated catch of spiny dogfish per hour fished plus one and are plotted on a 0.25° longitude by 0.25° latitude grid. Only those grid squares with three or more associated fishing events were included in the surface calculations. The surfaces were calculated using the algorithm of Smith & Wessel (1990).**

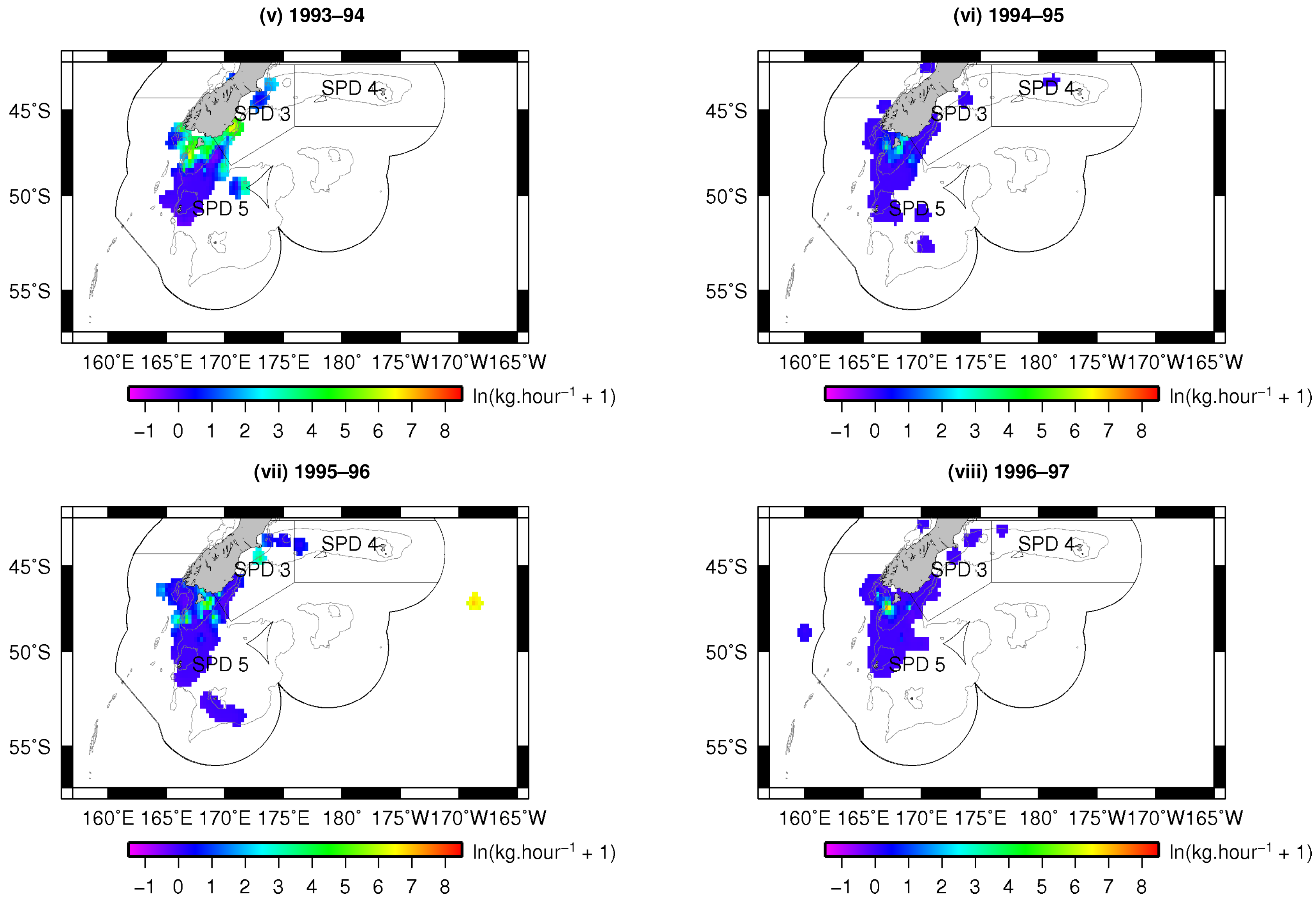
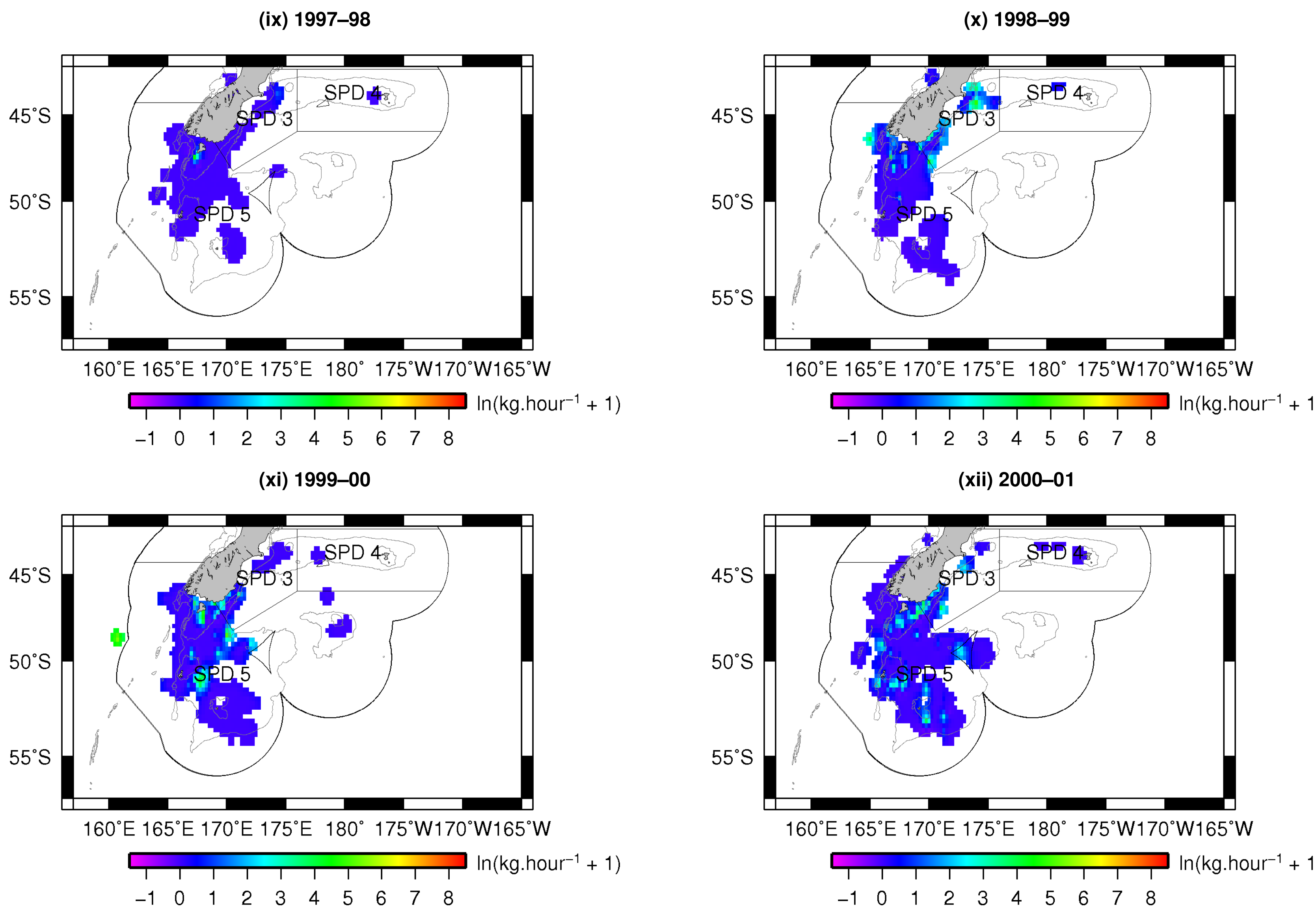


Figure 20: (continued)



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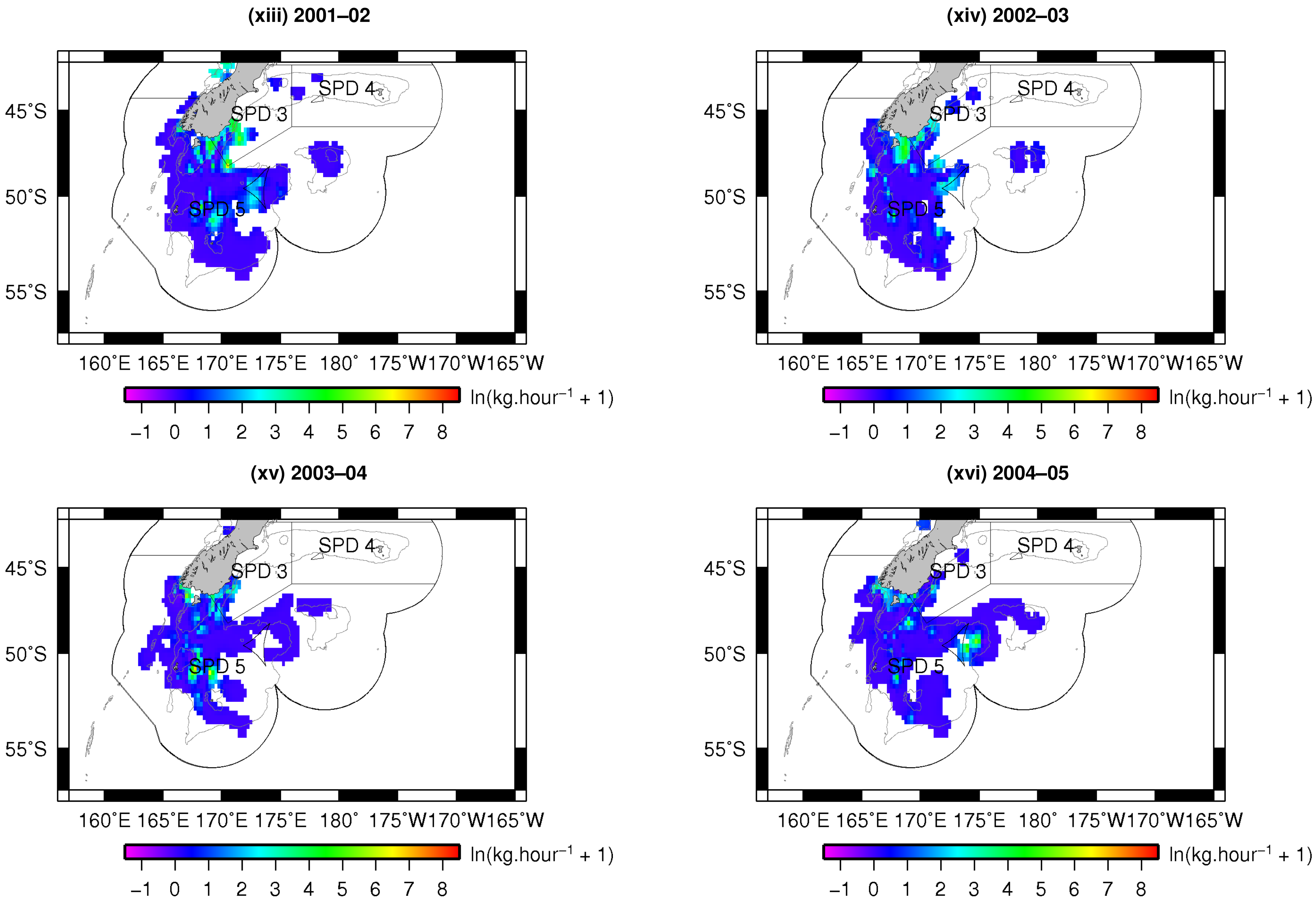

Figure 20: (continued)

(xvii) 2005–06

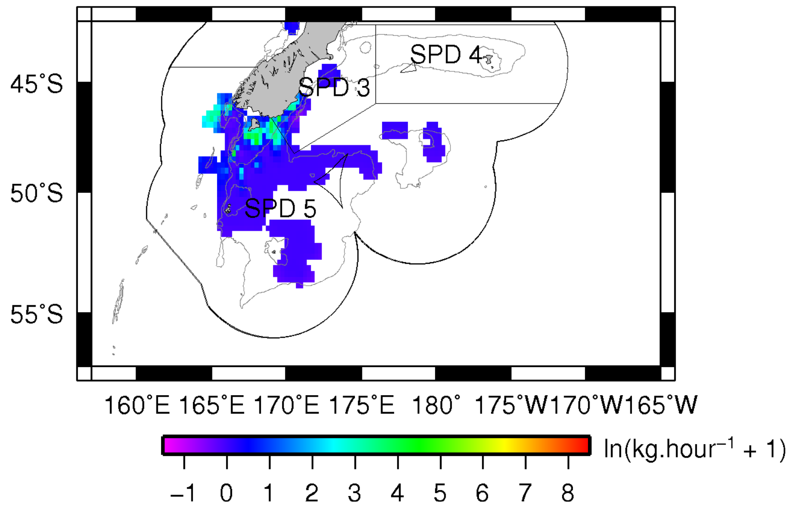

Figure 20: (continued)

years this area seems to be adjacent to rather than encompassing that part of the shelf where nominal log trawl catch rates are highest.

Nevertheless, trachurid mackerels and nototodarid squids form part of the natural diet of spiny dogfish in the New Zealand region (Hanchet 1991, M. Dunn, unpublished results from Chatham Rise trophic study, Ministry of Fisheries project ENV2007/06). Spiny dogfish, trachurid mackerels, and nototodarid squids have been grouped together following quantitative analysis of their associations in other areas such as the Chatham Rise (Bull et al. 2001) and have often been caught together in research bottom trawls on the Stewart-Snares shelf (Hurst & Bagley 1994, 1997, Bagley & Hurst 1995, 1996a, 1996b). Spiny dogfish is likely to naturally associate with these species in this area.

5. THE LENGTH COMPOSITION OF THE SPD 5 CATCH

5.1 Sample composition and representativeness

The length-frequency data collected by the MFish OP from the large vessel (TCEPR) bottom- and midwater trawl fleet over the 1996–97 to 2004–05 fishing years in SPD 5 are tabulated in Table 9. Most of the data have been collected from the Southland (FMA 5) fisheries management area within the SPD 5 QMA, encompassing the Stewart-Snares shelf. The representativeness of the sample data is assessed in a series of plots similar to those presented by Manning (2007) and Manning et al. (2008) in other recent studies of this type. First, each sampled trip was matched with the corresponding catch-effort and landings database records in the *warehou* database. Here records were matched using concatenations of the unique vessel identification keys held in each database and the corresponding landing date records. Of 106 sampled fishing trips in the MFish OP LF dataset in this study, 89% (94 trips) could be matched with the *warehou* records. Successful and unsuccessful matches are also tabulated in Table 9. All trips sampled after the start of the 2001–02 fishing year could be matched to the corresponding *warehou* data.

After the matching up exercise, temporal summaries of the total, fleet, and sampled catch by fishing year are given in Figure 21. Fishing behaviour of the fleet and sampled vessels is compared in Figure 22, where proportions of the estimated spiny dogfish catch and the numbers of trawls by statistical area and fishing year (Figure 22 panel A) and by target species and fishing year (Figure 22 panel B) are plotted. There is generally good agreement between the catch and numbers of trawls by statistical area between the sampled fleet and the fleet as a whole in most fishing years, especially in the latter half of the data time series (e.g., the 2001–02 fishing year and later). In the first half of the time series, there is noticeable over-representation of statistical area 028 in the catch and proportions of trawls of the sampled fleet compared with the fleet as a whole (e.g., 1996–97 and 1998–99 to 2000–01). Trends are less obvious in the target species plot, but it appears that catch and trawls by vessels targeting squids are somewhat over-represented in the sampled fleet compared with the fleet as a whole, and hoki is often but not always under-represented. The extent to which the inconsistencies noted between the sampled fleet and the fleet as a whole are a problem is unknown.

Table 9: Composition of the length-frequency data collected by the MFish OP over the 1996–97 to 2004–05 fishing years aboard the large (TCEPR) bottom- (BT) and midwater-trawl (MW) fleet in SPD 5 (raw data). The numbers of length-frequency observations collected data are tabulated by fishing method (BT, MW) and by the fisheries management areas within the QMA. SOI, Auckland Islands (FMA 6A); SOU, Southland (FMA 5); SUB, Subantarctic (FMA 6). The numbers of sampled fishing trips which could be matched to the corresponding *warehou* catch-effort and landings data are also provided.

	Length-frequency observations collected						Matching of sampled fishing trips to *warehou*	
	BT			MW				
Fishing year	SOI	SOU	SUB	SOI	SOU	SUB	Matched	Unmatched
1996–97	–	1143	–	–	610	42	4	2
1997–98	–	1679	434	–	1432	39	8	4
1998–99	–	1470	9	–	1999	54	11	2
1999–00	–	1657	605	–	1724	–	13	1
2000–01	511	3916	213	–	2944	–	19	2
2001–02	–	2304	24	6	1701	5	11	1
2002–03	17	3172	135	–	1011	21	12	–
2003–04	–	959	943	–	299	–	7	–
2004–05	–	2400	40	–	116	–	9	–

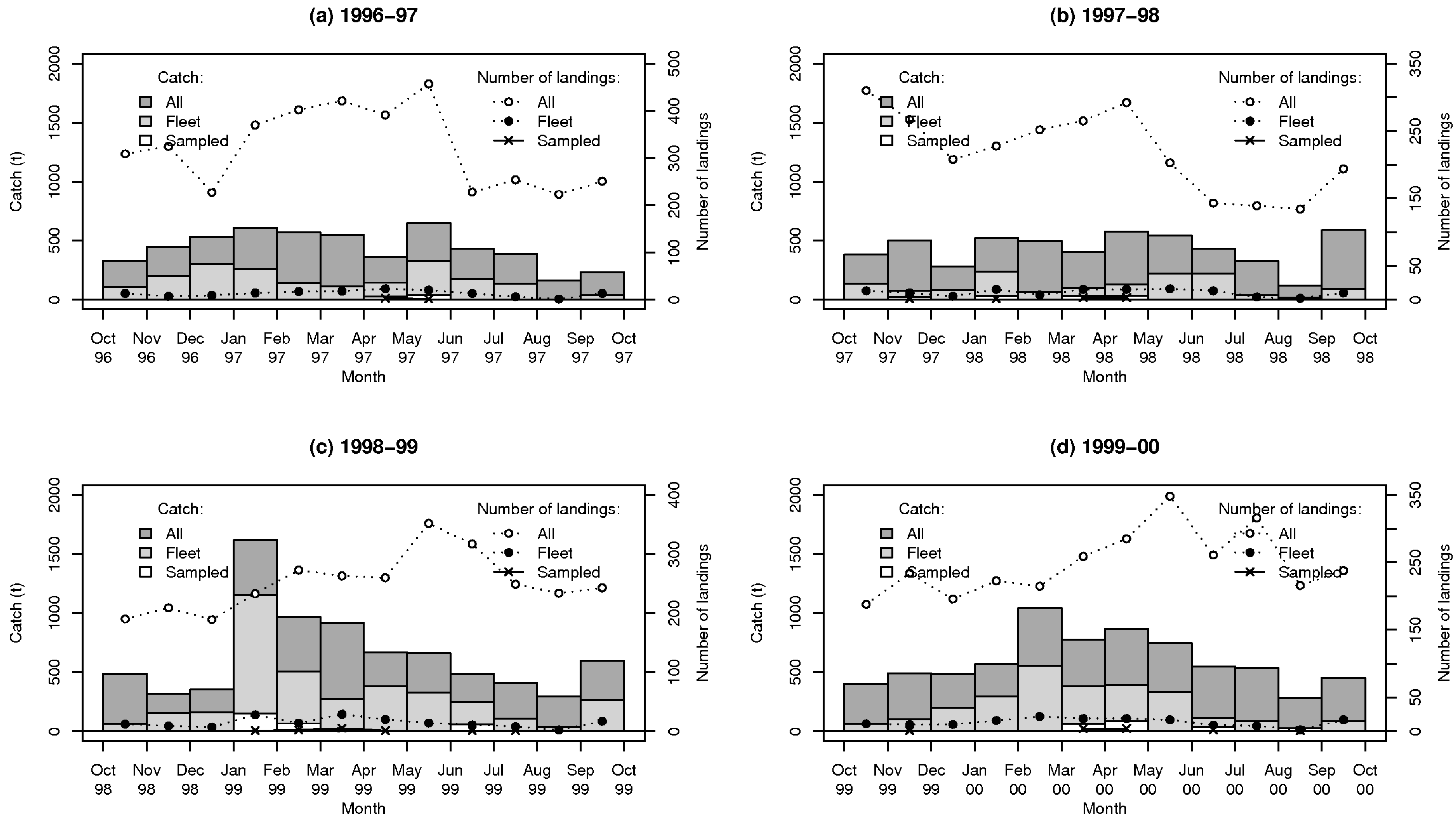

Figure 21: Summaries of fishing and observer sampling activity in SPD 5, 1996–97 (panel a) to 2004–05 (panel i). Histograms of the total reported landed catch in SPD 5 (dark-grey bars), the total reported landed catch by bottom- and midwater-trawl vessels completing TCEPR reporting forms in SPD 5 (mid-grey bars), and the bottom and midwater-trawl fleet sampled by the MFish OP (white bars) are overlaid. The numbers of landings per month by each fleet sector (all, fleet, sampled fleet) are also overlaid.

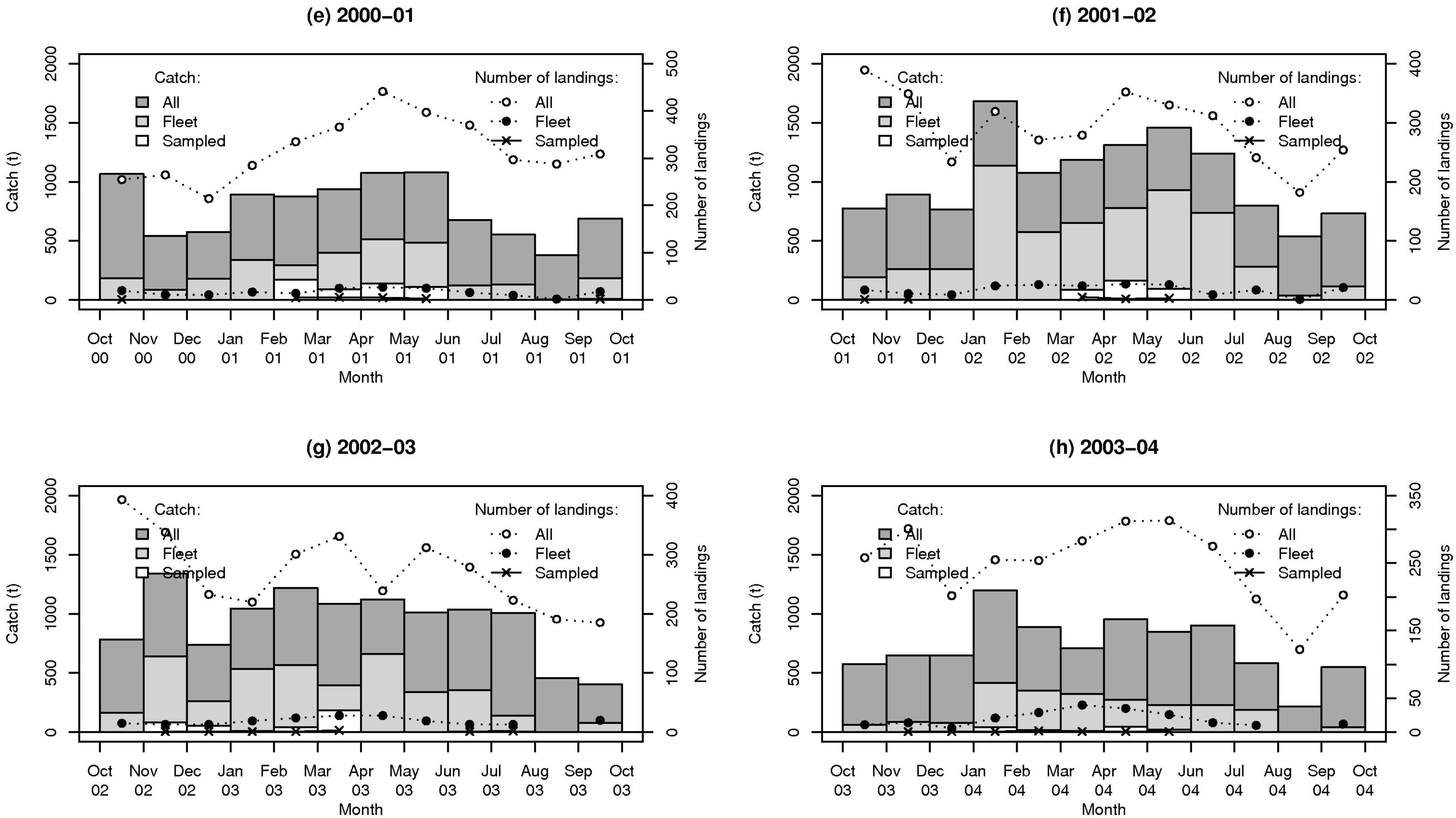

Figure 21: (continued)

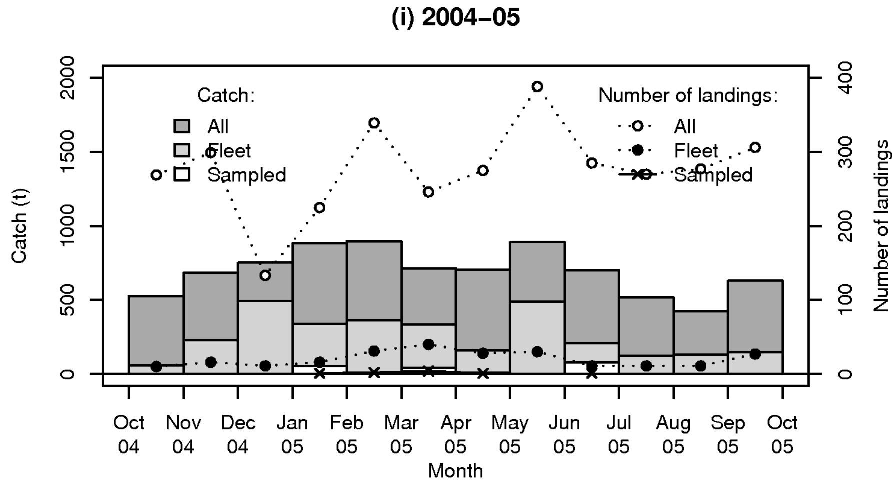

Figure 21: (continued)

5.1.1 Post-stratification of the length-frequency data

Results of fitting the regression tree model to the updated length-frequency stratification dataset are plotted in Figures 23 and 24. Figure 23(a) shows the result of offering the model tow start depth (“depth_s”), tow start longitude (“long_s”), tow start latitude (“lat_s”), the day of the fishing year (“day_fishing_year”), and fishing gear type (“fish_gear”) as predictors of mean spiny dogfish length per sampled tow and restricting the tree complexity parameter to 0.02. Fishing gear type, fishing depth, day of the fishing year, and the longitude and latitude at the start of each tow were all included within a tree with seven leaves. Figure 23(b) contains a diagnostic plot for this fit where relative error is plotted as a function of the complexity parameter (which determines the size of the tree) using cross-validation (i.e., resampling) methods. This shows that the gain (reduction) in relative error drops rapidly as the size of the tree grows beyond three leaves and is negligible (more appropriately asymptotic) for trees of five leaves or larger, suggesting that the seven leaf tree is inappropriately complex (i.e., over-fit). Figure 24 shows the result of refitting the tree algorithm restricting the complexity parameter to 0.05 to produce a smaller tree with three leaves and adequate relative error. Fishing gear type and the day of the fishing year remain as predictors in the model.

5.1.2 Scaled length-frequency calculations

Scaled length-frequency distributions were calculated separately for each fishery assuming a stratification scheme derived from the three-leaf regression tree results. Selecting three strata allowed each stratum to be adequately populated in nearly all fishing years given the constraints discussed in Subsection 2.4.3 above (i.e., no fewer than three sampled tows per stratum, no fewer than three sampled fish measured per sampled tow, no unsexed fish). The strata assumed were: (i) where gear method is midwater-trawling (“MW-ALL”); (ii) where gear method is bottom-trawling and the day of the fishing year is less than or equal to 28 February (the 150th day of the fishing year; “BT-EARLY”); and (iii) where gear method is bottom-trawling and the day of the fishing year is 1 March or later (“BT-LATE”). Summaries of the sample data included in each analysis are given in Table 10. The scaled length-frequency distributions are plotted by sex in Figure 25. The bootstrapped coefficients of variation for each length class are overlaid. Mean-weighted coefficients of variation for each distribution by sex and by stratum as well as pooled over all strata are given in Table 11. Data

(a) statistical area

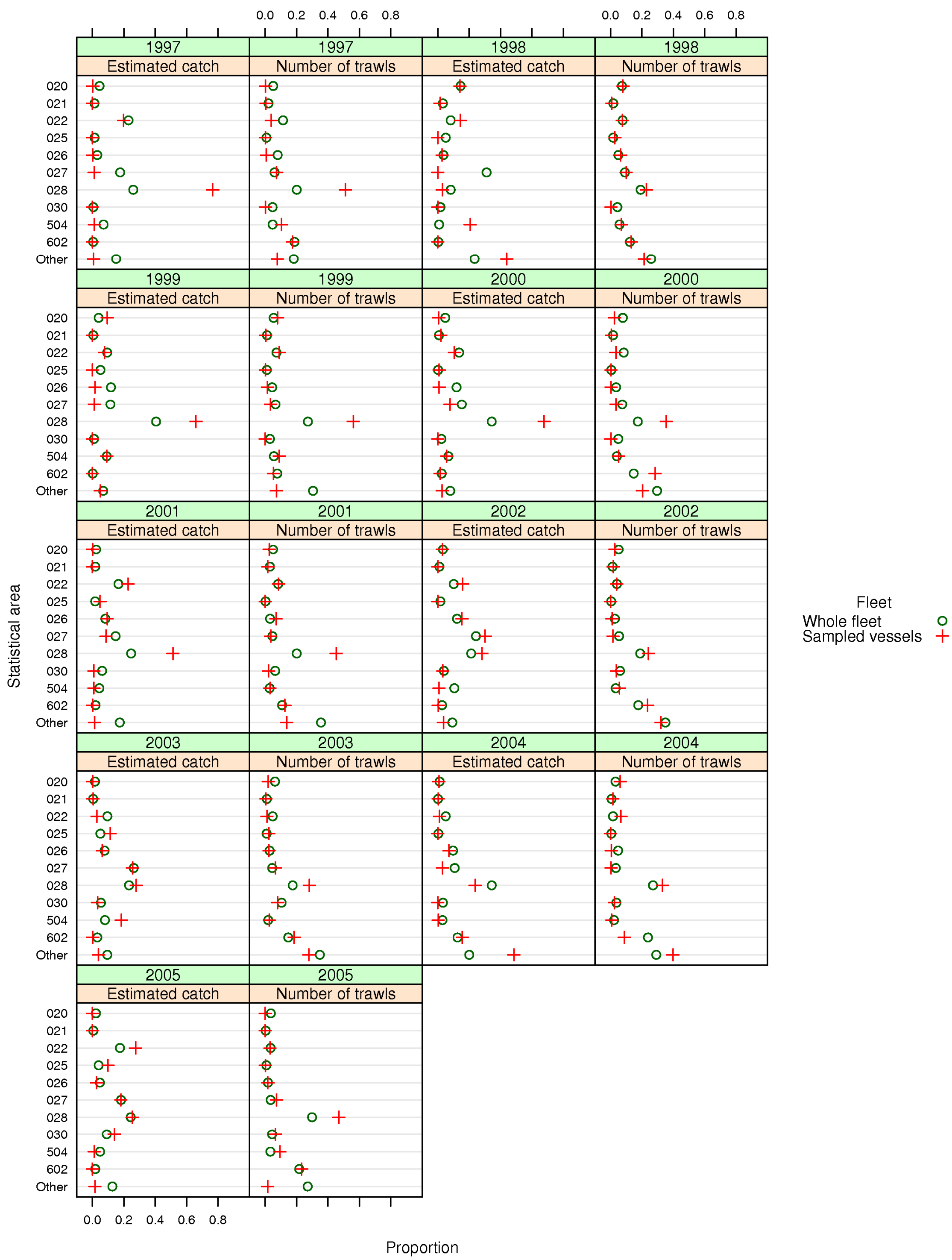

Figure 22: Comparing the sampled and the fleet catch as a whole by two covariates. Proportions of the estimated spiny dogfish catch and of the number of trawl shots by (a) statistical area and (b) target species for all vessels in the bottom- and midwater-trawl TCEPR fleet in SPD 5 area compared with the corresponding proportions by the sampled fleet sector.

(b) target species

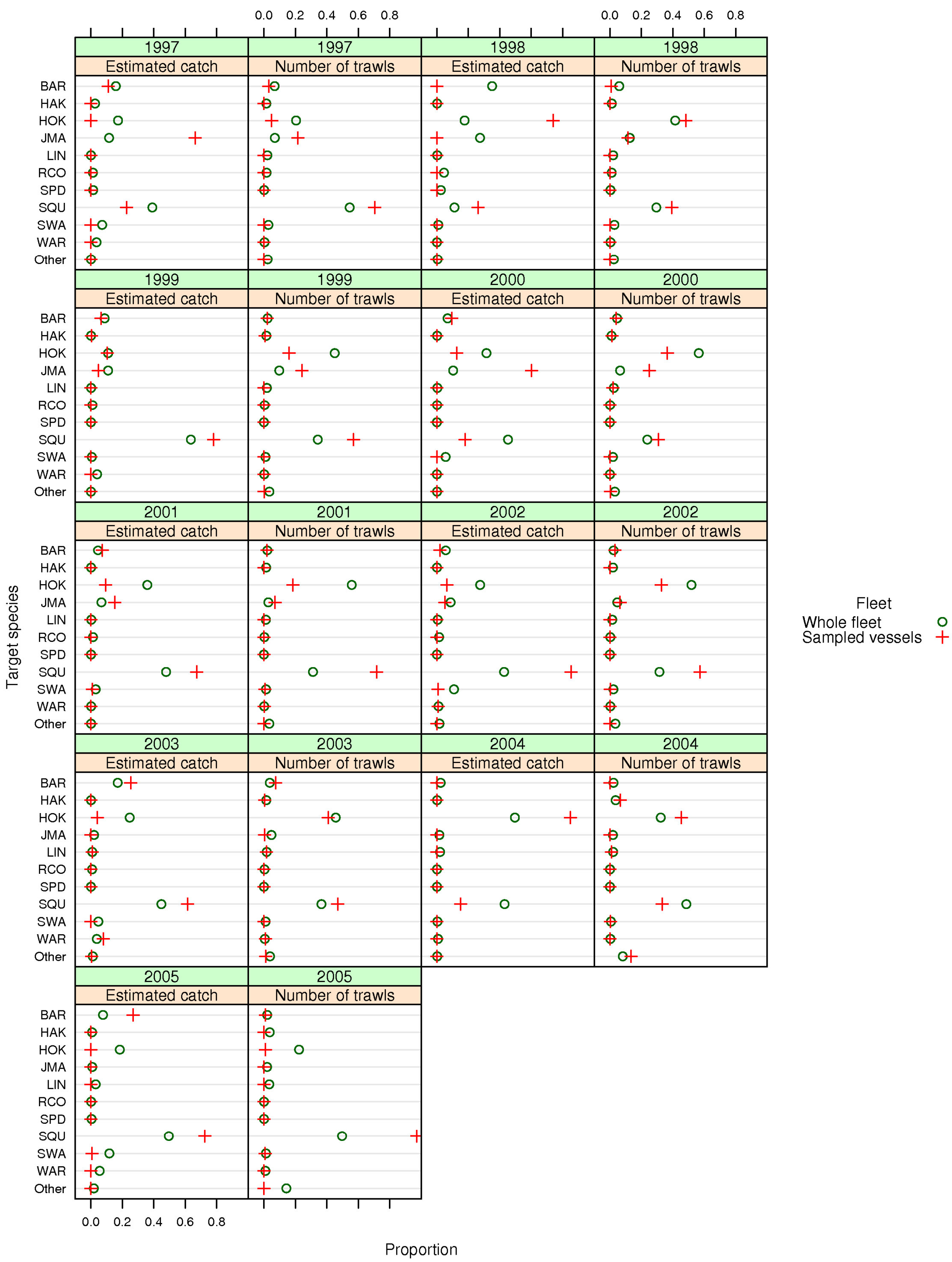

Figure 22: (continued)

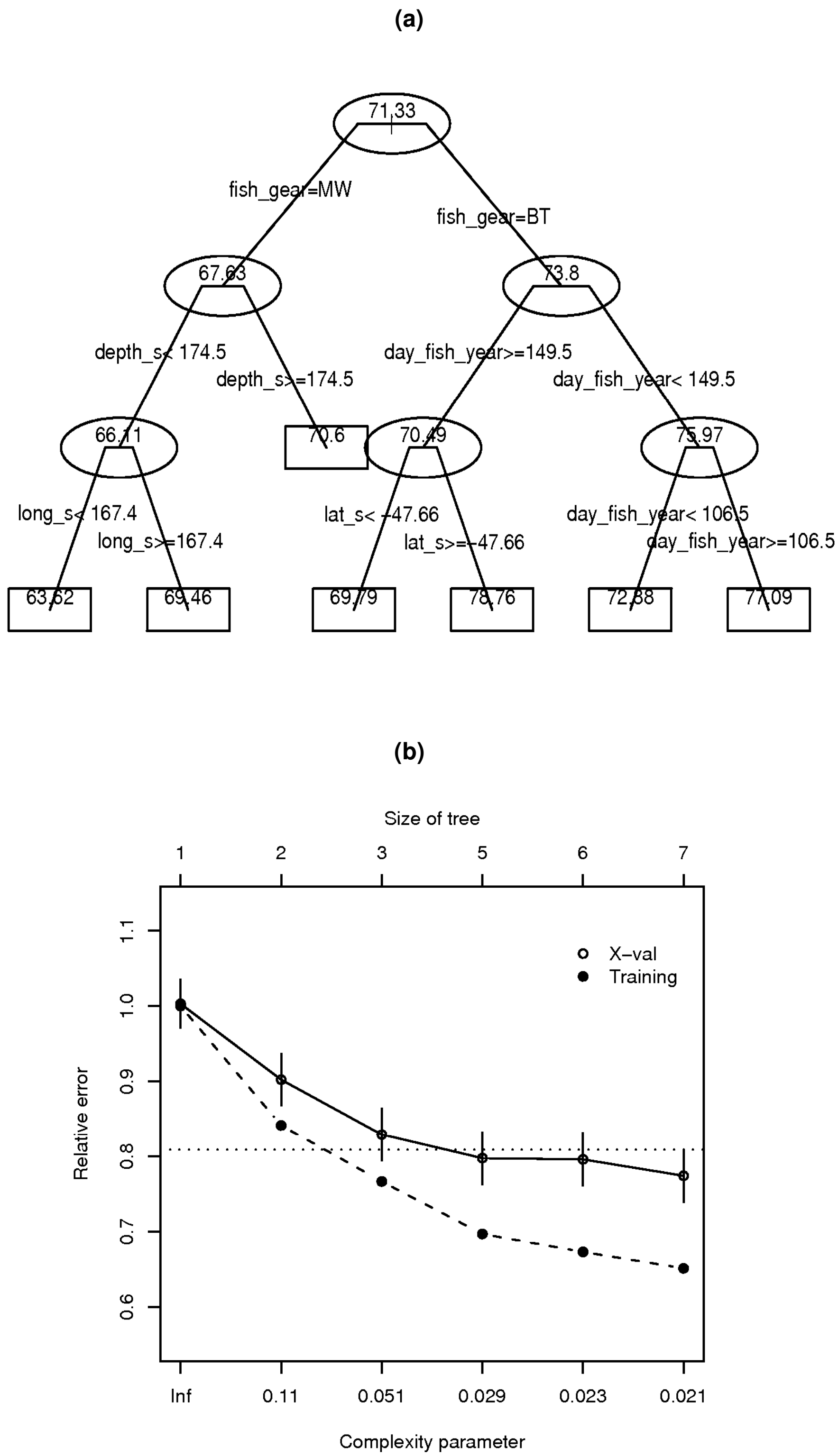

Figure 23: Results of tree regression partitioning of the length-frequency dataset. Panel (a) contains the regression tree drawn after offering the tree regression model tow start depth, tow start longitude, tow start latitude , the day of the fishing year, and fishing gear type (BT or MW) as predictors of mean spiny dogfish length in the sampled tows but restricting the complexity parameter to 0.02. Panel (b) contains a tree-regression diagnostic plot for the same fit where relative error is plotted as a function of the complexity parameter or the size of the tree.

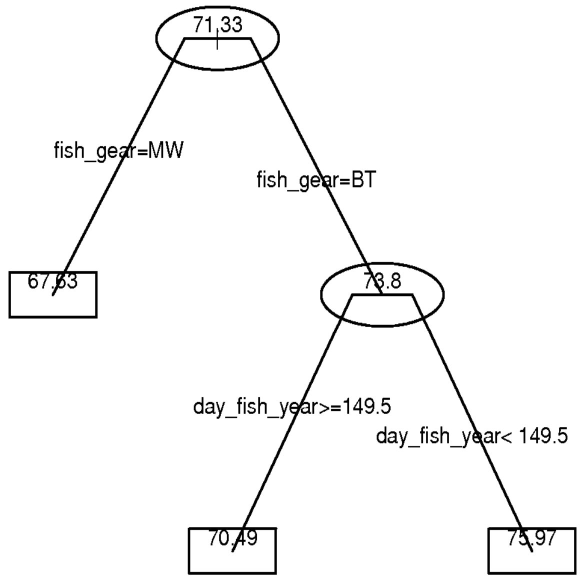

Figure 24: Results of tree regression partitioning of the length-frequency dataset. Regression tree drawn after offering the tree regression model tow start depth, tow start longitude, tow start latitude , the day of the fishing year, and fishing gear type (BT or MW) as predictors of mean spiny dogfish length in the sampled tows but restricting the complexity parameter to 0.05

associated with the BT-EARLY stratum in 1996–97 and the BT-LATE stratum in 2003–04 did not exceed the constraints assumed in the analysis and distributions for these strata were not calculated.

Trends apparent in the scaled length distributions presented here are similar to those described by Manning et al. (2004) with some minor differences. As before, males typically range between about 45 and 90 cm in total length, though there are very few males smaller than 55 cm and larger than 80 cm present in any fishing year. The male distributions typically appear unimodal, although there is weak evidence of more than one mode in some years and mode progression between some years; e.g., a male mode centred around 55–57 cm in 2001–02 is centred around 60 cm in 2002–03. The female distributions generally exhibit more structure, with females typically between about 50 to over 100 cm in total length. There are two modes present in most years appearing to peak at about 55 to 60 cm and at about 85 cm. Given the apparent longevity and relatively slow growth of spiny dogfish in New Zealand waters (unvalidated age estimates produced by Hanchet (1986) suggest the New Zealand spiny dogfish can reach their middle-twenties at least and true longevity is likely to be older), it is likely that individual length-frequency modes, when evident, correspond to multiple age classes. The spikiness apparent in the distributions calculated by Phillips (2004) is reduced in the distributions calculated in this analysis. The reduction is thought to be due to the simpler stratification scheme and constraints adopted here. Hanchet (1988) reported that the average size of newborn spiny dogfish off the east coast of the South Island was 24 cm at a mother length of 85 cm. As before, there is no evidence of newborn or very young dogfish in the catch. Possible explanations include the possible unavailability of newborn or very young dogfish to the commercial fishery as well as the probable (non-) selectivity of the commercial trawl gear for dogfish of this size. There is no obvious trend in male to female sex ratios by fishing year calculated from the scaled length-frequency distributions (Figure 26).

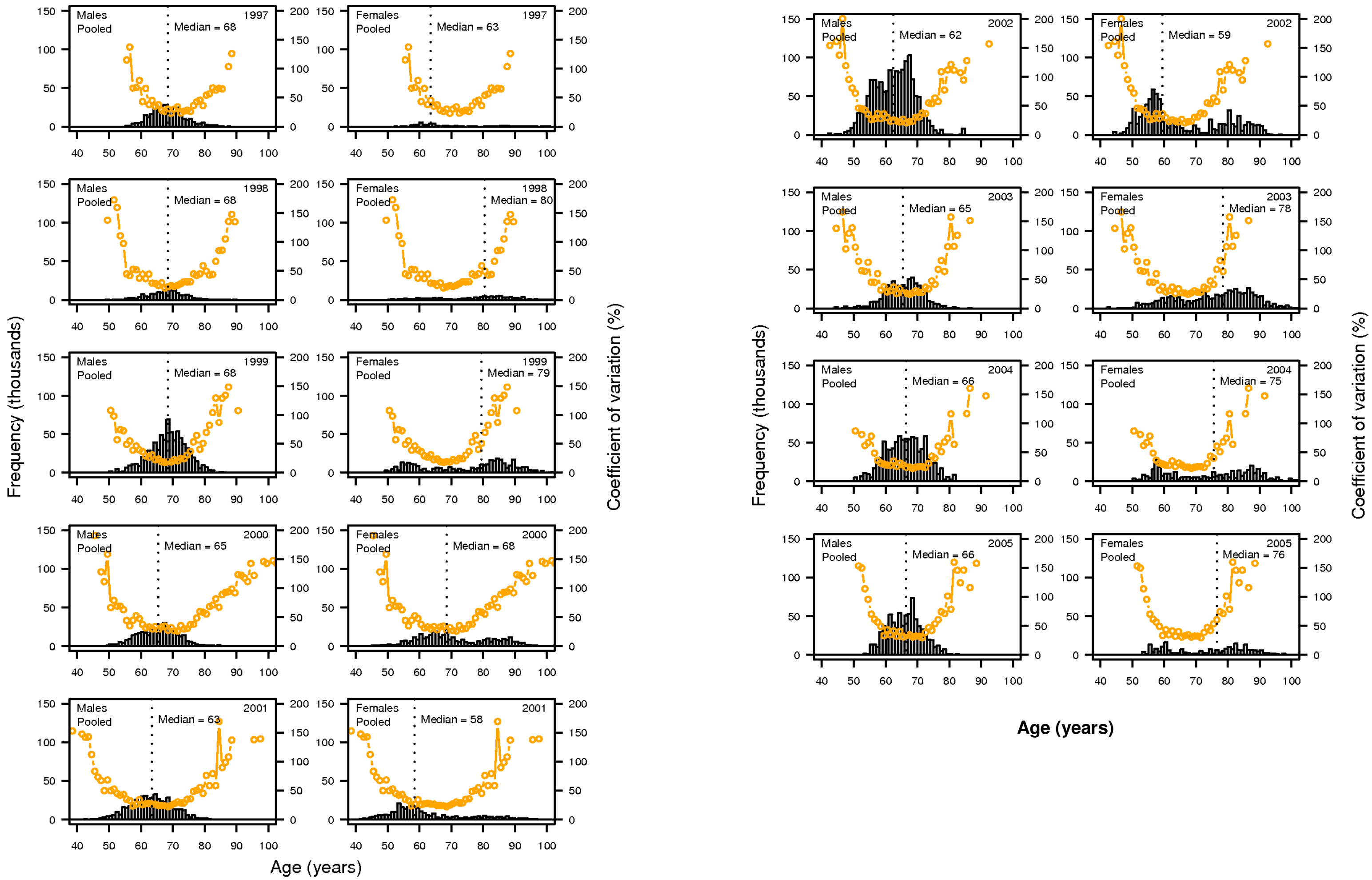

Figure 25: Scaled length-frequency distributions of the bottom- and midwater-trawl TCEPR fleet catch in SPD 5 by sex and by fishing year pooled across the strata assumed in each analysis, 1995–96 to 2004–05. Median lengths (dashed lines) and bootstrapped coefficients of variation (dotted lines) are overlaid for comparison.

Table 10: Summaries of the data included in each scaled length-frequency analysis, 1996–97 to 2004–05. "–", stratum not adequately populated during that fishing year so all associated data dropped.

Fishing	BT-EARLY			BT-LATE			MW-ALL			Total		
year	n_{Trips}	n_{Tows}	n_{Fish}	n_{Trips}	n_{Tows}	n_{Fish}	n_{Trips}	n_{Tows}	n_{Fish}	n_{Trips}	n_{Tows}	n_{Fish}
1996–97	–	–	–	2	10	1143	4	9	652	6	19	1795
1997–98	5	15	1274	3	28	832	5	18	1461	13	61	3567
1998–99	5	26	1160	3	4	317	7	48	2019	15	78	3496
1999–00	3	4	373	6	17	1774	5	18	1619	14	39	3766
2000–01	12	44	4153	4	4	388	8	39	2923	24	87	7464
2001–02	3	10	989	6	18	1339	4	16	1706	13	44	4034
2002–03	6	29	2697	5	10	627	4	10	1007	15	49	4331
2003–04	4	21	1802	–	–	–	2	15	299	6	36	2101
2004–05	5	18	1817	3	17	608	1	8	115	9	43	2540

Table 11: Percentage mean-weighted coefficients of variation for the scaled length-frequency distributions calculated by sex, strata, and fishing year. –, stratum not adequately populated during that fishing year.

		Analysis stratum			
Fishing year	Sex	BT-EARLY	BT-LATE	MW-ALL	Pooled
1996–97	Male	–	42.3	43.6	35.7
	Female	–	98.5	92.5	82.5
	All fish	–	43.4	41.1	34.4
1997–98	Male	42.5	43.8	39.6	32.0
	Female	41.8	91.8	62.5	53.6
	All fish	36.0	44.4	40.6	33.2
1998–99	Male	57.6	63.7	29.5	29.1
	Female	53.3	103.5	66.7	49.8
	All fish	43.5	61.3	32.2	28.9
1999–00	Male	110.1	31.3	56.5	36.3
	Female	49.6	63.6	86.2	57.5
	All fish	56.6	30.7	32.9	25.8
2000–01	Male	49.8	98.0	31.7	30.1
	Female	54.9	100.3	71.7	57.6
	All fish	44.4	87.9	30.5	28.9
2001–02	Male	57.9	34.3	40.0	31.2
	Female	79.9	71.8	78.4	62.0
	All fish	57.5	36.5	41.9	35.0
2002–03	Male	57.0	94.3	41.1	34.5
	Female	50.4	91.0	82.2	44.7
	All fish	42.6	80.6	41.5	32.4
2003–04	Male	38.9	–	57.6	36.6
	Female	59.9	–	106.2	61.5
	All fish	38.6	–	57.4	35.9
2004–05	Male	44.7	77.7	78.0	38.7
	Female	64.5	96.6	148.9	58.8
	All fish	40.4	77.6	77.7	35.7

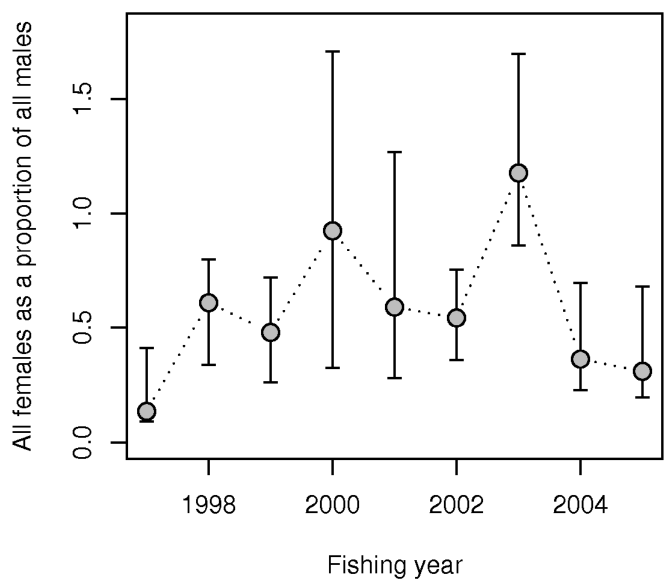

Figure 26: Male to female sex ratios in the scaled length-frequency series. Sex ratios are plotted as all females present in each scaled length distribution as a proportion of all males present in the same distributions. The error bars are 95% confidence intervals calculated from the corresponding bootstrap distributions.

Mean-weighted coefficients of variation for all fish pooled across all strata range between 25.8% and 35.9% and average 32.2%. These results are generally better than those obtained by Phillips (2004) for the same fishing years (i.e., 1996–97 to 2000–01).

6. THE STANDARDISED CPUE MODEL FITS

Eight different standardised model fits are presented in this report (referred to as models 1.1 to 1.8) (Figures 27 & 28, Table 12). An earlier set of six model runs (designated models 0.1 to 0.6) was presented to a meeting of the Inshore Fisheries Assessment Working Group (Inshore FAWG) in Wellington on 19 April 2007, but is not included in this report. Models 1.1 to 1.6 were presented to the Inshore FAWG on 7 November 2007. Models 1.7 and 1.8 have not been presented to the Inshore FAWG, but I have included these results in this report as a crude sensitivity on the canonical year effects produced by further restricting the dataset that models 1.5 and 1.6 were fitted to.

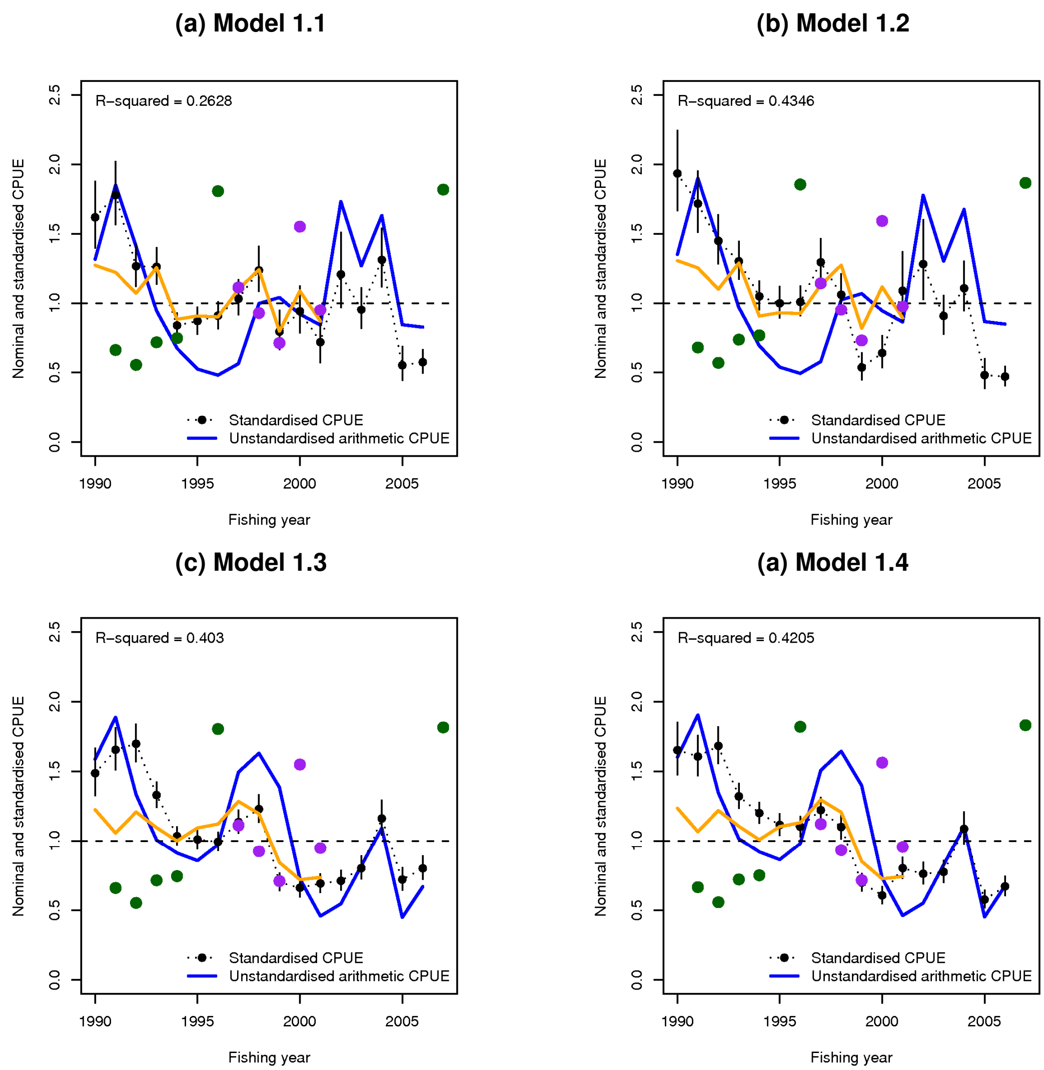

Figure 27: Relative abundance indices derived from standardised CPUE model fits 1.1–1.4 (SPD 3; black dots). The error bars are 95% lognormal confidence intervals. The nominal CPUE (blue lines), the old CPUE indices produced by Manning et al. (2004) (orange lines), and trawl survey relative biomass estimates from the ECSI winter (green dots) and summer (green dots) survey series by RV *Kaharoa* (1991–2000; 2007) have been overlaid on the corresponding panels for comparison (see Table 4). The nominal CPUE and trawl survey relative biomass indices have been rescaled so that all three series can be displayed on the same plot. R^2, the reduction of residual deviance relative to the null deviance explained by each fitted model.

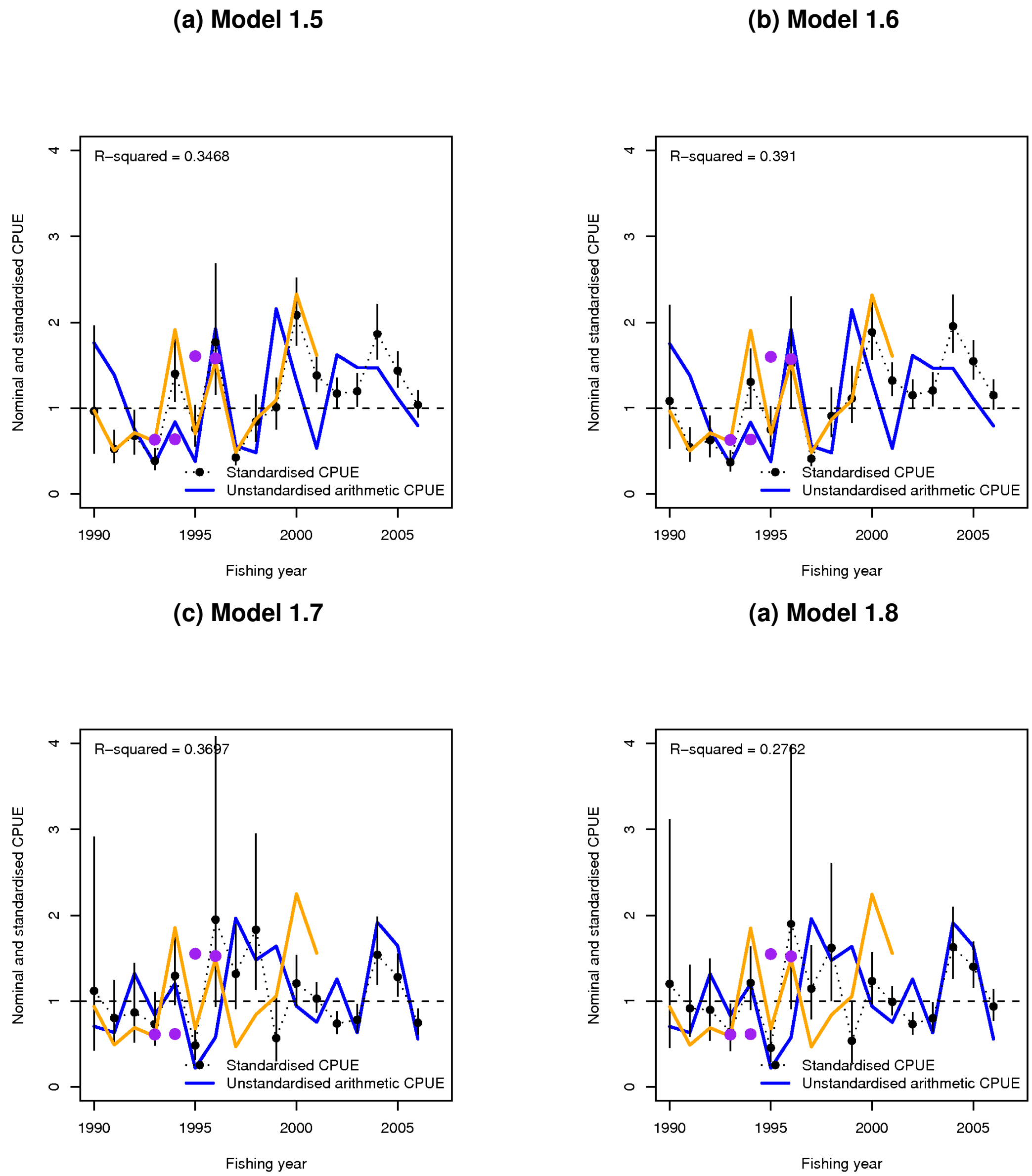

Figure 28: Standardised CPUE relative abundance indices derived from model fits 1.5–1.8 (SPD 5; black dots). The error bars are 95% lognormal confidence intervals. The nominal CPUE (blue lines), the old CPUE indices produced by Manning et al. (2004) (orange lines), and trawl survey relative biomass estimates from the SCSI survey series by RV *Tangaroa* (1993–2006) have been overlaid on the corresponding panels for comparison (see Table 4). The nominal CPUE and trawl survey relative biomass indices have been rescaled so that all three series can be displayed on the same plot. R^2, the reduction in residual deviance relative to the null deviance explained by the model.

Table 12: Predictor variables included by the fitting algorithm in each model. The variables are given in the order they were included by the fitting algorithm. The reduction in residual deviance relative to the null deviance (R^2) explained during each step is noted. The predictor variables offered to each model are specified in Table 5.

	Model 1.1		Model 1.2		Model 1.3		Model 1.4	
Step	Variable	R^2	Variable	R^2	Variable	R^2	Variable	R^2
1	Fishing year	0.109	Fishing year	0.075	Fishing year	0.045	Fishing year	0.038
2	Vessel key	0.228	Vessel key	0.399	Vessel key	0.336	Vessel key	0.382
3	Month	0.263	Month	0.425	Month	0.390	Month	0.420
4	–	–	P(Fishing duration, 3)	0.435	Target species	0.403	–	–
5	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–

	Model 1.5		Model 1.6		Model 1.7		Model 1.8	
Step	Variable	R^2	Variable	R^2	Variable	R^2	Variable	R^2
1	Fishing year	0.037	Fishing year	0.041	Fishing year	0.056	Fishing year	0.058
2	Vessel key	0.243	Vessel key	0.248	Vessel key	0.221	Vessel key	0.191
3	Month	0.281	P(Fishing duration, 3)	0.344	Month	0.294	Month	0.256
4	P(Effort number, 3)	0.313	Month	0.374	P(Effort number, 3)	0.358	P(Effort number, 3)	0.276
5	Target species	0.333	Target species	0.391	Target species	0.370	–	–
6	Statistical area	0.347	–	–	–	–	–	–

6.1 Exploring the CPUE datasets

Attributes of each model fit presented, including the definition of the dataset fitted to, the definition of the response variable (whether catch or CPUE, and if CPUE, what the chosen unit of effort is), and the predictor variables offered to the stepwise model selection algorithm are given in Table 5. All models were fitted to core vessel subsets. The SPD 3 models were fitted to core vessel subsets that consisted of all effort strata associated with vessels that had been active in the fishery for five years or more with no fewer than 10 associated positive (non-zero) effort strata in any given fishing year. The SPD 5 models were fitted to core vessel subsets that consisted of vessels with three or more fishing years with three or more associated non-zero effort strata in any given fishing year. All models were fitted to the positive (i.e., non-zero) effort strata only. Tabular summaries of each model dataset are given in Appendix B along with box (continuous variables) and mosaic plots (discrete variables) of all variables offered to each model. Visualisations of the fleet composition in each dataset are given in Appendix C.

6.1.1 Models 1.1 and 1.2

Distributions of nominal ln(CPUE), vessel experience, month, median net mesh width, total amount of net set, total fishing duration or gear soak time, and associated statistical area per effort stratum are plotted by fishing year for the dataset to which CPUE models 1.1 and 1.2 were fitted in Figure B1. Many of the trends identified in the SPD 3 characterisation above are also apparent here. Nominal natural log CPUE drops slightly then recovers over the data series. However, there has been a radical shift in the relative importance of the different statistical areas in the dataset and in fleet composition. The change in fleet composition is apparent in both the vessel experience density and dataset vessel catch by year plots, with several formerly high-catch vessels appearing to leave the fishery during the 1997–98 to 2000–01 fishing years. Only a single high-catch vessel remains in the dataset at the end of the data series. The catch associated with area 018 (Kaikoura), formerly of greatest relative importance during the early years of the data series, is of minimal importance after 2000–01. The catch associated with statistical area 024 (Timaru), formerly of minimal importance, is associated with most of the catch after 2000–01. These trends presumably represent vessels that formerly fished in area 018 leaving the fishery with vessels fishing in area 024 remaining in the fishery. The number of effort strata in the dataset by fishing year accordingly drops sharply after 1996–97. However, the total amount of net set per effort stratum appears to remain reasonably steady at 1.2 to 2.0 km over the data series and median net mesh width at about 175 to 180 mm or approximately 7 inches.

6.1.2 Models 1.3 and 1.4

Distributions of nominal ln(CPUE), vessel experience, month, median net mesh width, total amount of net set, total fishing duration or gear soak time, associated statistical area and target species per effort stratum are plotted by fishing year for the dataset to which CPUE models 1.3 and 1.4 were fitted in Figure B2. Similar trends are apparent to those identified in the dataset to which models 1.1 and 1.2 were fitted but are generally somewhat weaker. Nominal ln(CPUE) declines then peaks during 1997–98, and then subsequently declines. These perturbations are of similar magnitude to those in the previous dataset. Although there are twice as many vessels in this dataset as in the model 1.1 and 1.2 dataset, no new vessels enter after 1997–98. Even though in absolute terms more data are available than for the previous fits, there is a similar proportional decrease in the amount of data in the second (i.e., post-1997–98) half of this dataset. Median net mesh width, total amount of net set, and total fishing duration per effort stratum appear static across the dataset at similar values. Statistical areas 018 and 024 are the most important proportionally with the greatest relative amounts of associated effort strata (although a comparison based on total amount of net set might be more appropriate). However, the amount of effort strata associated with area 018 appears to drop and the amount of effort associated with area 024 increases over the dataset. Unlike the previous fits, associated target species is included in this dataset. Somewhat unsurprisingly, spiny dogfish (“SPD”) is the most important target species (i.e., has the greatest number of associated effort strata), but drops in importance during the late 1990s and thereafter, reflecting the demise of the target fishery. Most effort strata are associated with rig (“SPO”) and school shark (“SCH”) setnet effort subsequently.

6.1.3 Models 1.5 and 1.6

Distributions of nominal ln(CPUE), vessel experience, month, median net wingspread, median net headline height, total number of trawls, total fishing duration or the total time the trawl gear was at fishing depth in hours, statistical area, and target species per effort stratum are plotted by fishing year for the dataset to which models 1.5 and 1.6 were fitted in Figure B3. Nominal ln(CPUE) drops very slightly over the early- to mid-1990s, rises again over the late 1990s, then drops and rises once more towards the end of the series. Although new vessels enter the dataset frequently, as with the other datasets in this analysis, the fleet continuous to age steadily. Most (80%; Table B1) effort strata are contained in the second half of the data series (1999–2000 to 2005–06). The seasonality effect identified in the SPD 5 fishery characterisation above is less obvious to me here. Median wingspread, median headline height, the total number of trawls, and the total fishing duration per effort stratum all appear to have risen slightly over the 1990s then dipped, which may represent either a corresponding change in the fleet or in fishing patterns or both. Most effort strata area associated with statistical areas 025 (eastern Foveaux Strait), 028 (southern Stewart-Snares shelf), and 030 (Puysegur Canyon), consistent with the results of the fishery characterisation. There seems to be no large change in the relative importance of the different statistical areas over the time series in the dataset, however. Flatfishes (“FLA”), squids (“SQU”), and giant stargazer (“STA”) are the most important target species.

6.1.4 Models 1.7 and 1.8

Distributions of nominal ln(CPUE), vessel experience, month, median net wingspread, median net headline height, total number of trawls, total fishing duration or the total time the trawl gear was at fishing depth in hours, statistical area, and target species per effort stratum are plotted by fishing year for the dataset to which models 1.5 and 1.6 were fitted in Figure B4. There is a similar trend in nominal ln(CPUE) in this dataset to the dataset to which models 1.5 and 1.6 were fitted, although the very slight drop early in the data series is flat here. There are similar trends in the fishing covariate variables (median net wingspread, median net headline height, total number of trawls, and total fishing duration per effort stratum). Statistical areas 025 (eastern Foveaux Strait) and 030 (Puysegur canyon) are of even greater relative importance. Of the target species included in these fits, most effort strata are associated with the generic flatfishes code ("FLA") and giant stargazer ("STA"). Effort strata associated with larger vessels completing TCEPR forms and targeting squids and other continental slope species were dropped from these fits. Median net headline height and wingspread are accordingly typically somewhat less here than in the two previous fits. Average median headline height per effort stratum drops from 3.1 m to 2.1 m; average median wingspread from 27.1 m to 19.5 m; and average median fishing duration from 16.8 hours to 15.9 m over the corresponding datasets.

6.2 Canonical year effects and stock status

The canonical year effects from model fits 1.1 to 1.4 are plotted in Figure 27. The year effects from models 1.5 to 1.8 are plotted in Figure 28. Variables selected by the fitting algorithm are given in order of inclusion along with the proportion of null deviance explained for each fit in Table 12. Diagnostic goodness-of-fit residual and expected log catch-rate (i.e., log catch or log CPUE depending on model definitions) plots for each predictor variable included in each model are given in Appendix D. I note that the diagnostic plots in Appendix C suggest that the regression assumptions of homoscedasticity and normality of errors (in link space) have plausibly been met. Predicted log catch-rates calculated by varying each predictor variable included in each fit separately in turn while holding all other variables constant at their median values also appear plausible. In all cases the models explain acceptable amounts of the null deviance (model 1.1, 0.26; model 1.2, 0.43; model 1.3, 0.40; model 1.4, 0.42; model 1.5, 0.35; model 1.6, 0.39; model 1.7, 0.37; model 1.8, 0.28).

The standardisation in model fits 1.1 and 1.2 flattens out the nominal arithmetic CPUE in the mid 1990s. There is a discrepancy between the new indices presented here and the old indices calculated by Manning et al. (2004) during the early 1990s. This is due to the consideration of changes in product form conversion factors in this analysis, which was not done in the earlier analysis. Consistency between the two series in the mid 1990s is good for both models 1.1 and 1.2, but diverges in the late 1990s and beyond for model 1.2 where ln(catch) rather than ln(CPUE) is the response variable. Consistency between the standardised CPUE indices and the trawl survey relative biomass indices from the winter ECSI series (from both the original set of indices from 1992 to 1997 as well as the single point from the revised series from 2007 available at the time of writing) is poor. Interestingly, consistency with the summer ECSI relative biomass indices is generally much better. Similar trends are apparent in the model 1.3 and 1.4 results. Although there is generally better agreement between the old and the new standardised CPUE indices in the late 1990s and later in the model 1.4 results where ln(catch) was the response (c.f., model 1.2). If the results of the CPUE standardisations are accurate, then it appears that the SPD 3 "stock" indexed by the model fits has declined to be now somewhere around a third of its relative biomass at the start of the data series. However, there are major changes in the fleet and in fishing patterns during this time that are of concern, even though the standardisation process should account for these changes. No fishery-dependent stock composition data are available to compare with the results of the CPUE standardisations[1]. However, comparison of the fishery-independent stock composition data from both the summer and winter ECSI survey series (see the sources referred to in Table 4) suggest that the survey catches over the survey series (both summer and winter) are made up of a broad length range of size classes and therefore presumably a broad range of age classes. Although the selectivities of the survey and the commercial fisheries in SPD 3 (however defined) are almost certainly different, it seems reasonable to assume that the length (and presumably the age) range of the commercial catch *may* be similarly broad and therefore that the apparent decline in stock (relative) abundance is due to fishing rather than recruitment failure.

The standardisation in model fits 1.5 and 1.6 increases the value of the 1993–94 index substantially as well as generally lifting up the indices from the 1998–99 fishing year and later. Consistency between the indices calculated by Manning et al. (2004) and those in these fits is good. Consistency between the updated standardised CPUE indices and the trawl survey relative biomass indices from the Stewart-Snares shelf series is poor. In contrast to fits 1.5 and 1.6, the standardisation in fits 1.7 and 1.8 has no effect on the 1993–94 index, but pulls up the 1995–96 index and drops the 1998–99 index substantially. There is good consistency between the nominal arithmetic and the standardised ln(CPUE) from the 1999–2000 fishing year and later. There is also more divergence between the old and the updated standardised indices in these fits, but this is not that surprising given the changes in the data definitions and other assumptions in models 1.7 and 1.8 compared with the old model fits and in models 1.5 and 1.6. However, there is no obvious trend in the revised standardised indices. If we accept the models as valid but consider the width of the year effect error bars, it appears that the relative abundance of the SPD 5 stock has been distributed around one with moderate variability from one fishing year to the next over the data series. It seems reasonable to assume for now that the interannual variation in the standardised indices is likely to be caused by factors other than removals due to fishing. However, the standardised indices for the three fishing years from 2003–04 to 2005–06 drop in all four SPD 5 model fits.

7. CONCLUSIONS

Trends in the fisheries in time and space

- Patterns in the SPD 3 and 5 catches are generally consistent with Manning et al.'s (2004) earlier analysis, but there are some interesting patterns that have emerged since the last analysis.

- There remains weak evidence of seasonality in the SPD 3 catch, with about half of the catch caught over the five months from January to May. Catches continue to be recorded from all statistical areas, but most of the catch continues to be caught in inshore statistical areas 018, 020, 022, and 024. Bottom-trawl and setnet fishing continue to account for most of the catch by fishing method, but the relative importance of the setnet catch, in particular the target setnet catch, has declined markedly over the data time series. The setnet catch has dropped from between 50 and 60% of the total annual catch over the early to mid 1990s to 12–18% of

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[1] Industry-funded at-sea catch-sampling programmes have been running off the east and south coasts of the South Island in the mixed-species elasmobranch setnet fisheries there since at least 1992 to meet quota owners' obligations under the terms of the rig, school shark, and elephantfish Adaptive Management Programmes. However, these sampling programmes have been focused on those species and what spiny dogfish data has been collected has been sparse and of limited value. No MFish-funded catch sampling programme has been carried out in these fisheries during this time, either. Although substantial numbers of MFish OP observer days have been allocated to these fisheries since the early 2000s to support monitoring of interactions between these fisheries and Hector's dolphin (*Cephalorhynchus hectori*), no data of any elasmobranch, or indeed any, species in the catch have been collected by the MFish OP during these deployments.

the total annual catch since 2000–01. The target setnet catch has dropped dramatically over the data series, from 54% of the total catch in 1989–90 to 5% during the 2005–06 fishing year.

- The SPD 5 fishery continues to be dominated by bottom-trawl fishing (63% of the total catch over all fishing years in the dataset), although there are lesser but consistent contributions to the catch associated with midwater-trawl, setnet, and bottom-longline fishing methods (19%, 12%, and 6% of the total catch over all fishing years respectively). The recent steady increase in the total catch is associated with increased reported landings by trawl vessels.

- There is a stronger seasonal effect in the SPD 5 catch, with 71% of the total catch in the SPD 5 data series caught during the summer and autumn months of December to April. The seasonal peak in catch is associated chiefly with catches by large bottom- and midwater-trawl vessels completing TCEPR reporting forms (i.e., over 28 m in overall length) and targeting squids and jack mackerels (*Trachurus* spp.) on the Stewart-Snares shelf (statistical areas 025 to 030).

- Statistical area 028 on the southern end of the Stewart-Snares shelf and area 030 northwest of Stewart Island are the two most important statistical areas in SPD 5, being associated with nearly half of the total SPD 5 catch over the data time series.

- Hotspots of high nominal catch rates are apparent in some fishing years in SPD 5 and appear to persist from one fishing year to the next on the Stewart-Snares shelf. Some attenuation and movement along the shelf of areas of high catch rate are noted, but the reasons for this are unclear. One possible explanation is that these changes reflect changes in fishing effort and behaviour and another is that they reflect changes in spatial patterns in spiny dogfish from one year to the next. These explanations are not mutually exclusive and are confounded given that the data are fishery-dependent and fishing effort is not randomly distributed across the continental shelf.

Composition of the SPD 5 catch

- The sampled length-frequency data are thought to be generally representative of the catch, but some inconsistencies between the sampled vessels and the fleet as a whole are noted. Precision is generally moderate to low, with mean-weighted coefficients of variation ranging between 25.8 and 35.9% and averaging 32.2% over the length-frequency data series.

- Trends in the scaled length distributions are similar to those identified previously with some minor differences. As before, males typically range between about 45 and 90 cm in total length though there are very few males smaller than 55 cm and larger than 80 cm present in the catch in any fishing year. The male distributions typically appear unimodal. There is weak evidence of mode progression between some years; e.g., a male mode centred around 55–57 cm in 2001–02 is centred around 60 cm in 2002–03. The female distributions generally exhibit more structure, with females typically between about 50 to over 100 cm in total length. There are two modes present in most years that appear to peak at about 55–60 cm and at about 85 cm. These length-frequency modes, when evident, almost certainly contain multiple age classes.

- As before, there is no evidence of newborn or very young dogfish in the catch. Possible explanations include the possible unavailability of newborn or very young dogfish to the commercial fishery as well as the probable (un-) selectivity of the commercial trawl gear for dogfish of this size. There is no obvious trend in male to female sex ratios by fishing year calculated from the scaled length-frequency distributions.

SPD 3 and 5 stock status

- If we accept standardised CPUE model fits 1.1 to 1.4 as valid, then it appears that the SPD 3 "stock" indexed by the model fits has declined to be currently somewhere around a third of its relative biomass at the start of the data series. However, there are major changes in the fleet and in fishing patterns during this time that are of concern, even though the standardisation process should account for these changes.

- The lack of catch-composition data from the SPD 3 fisheries inhibits our ability to interpret these statistics, however. The paucity of biological data collected from the SPD 3 fisheries by the MFish OP during the Hector's dolphin interaction surveillance in the Canterbury Bight and Pegasus Bay represents a lost opportunity, not only for spiny dogfish but also for the other species in the inshore mixed species elasmobranch fishery in this area.

- If we accept standardised CPUE model fits 1.5 to 1.8 as valid but consider the width of the year effect error bars, it appears that the relative abundance of the SPD 5 "stock" has been distributed around one with moderate variability from one fishing year to the next over the data series. It seems reasonable to assume for now that the interannual variation in the standardised indices is likely to be caused by factors other than removals due to fishing.

- There is evidence of at least two apparent major changes in the proportion of discarded spiny dogfish catch in the total reported catch in both SPD 3 and 5. In both SPD 3 and 5, there is an increase in the proportion of discarded catch throughout the 1990s, which is followed by an apparently extremely rapid decline following admission of spiny dogfish into the QMS at the start of the 2004–05 fishing year. The implications of these trends for how accurately the reported catches index true total removals and hence interpretation of the CPUE year effects calculated is unknown.

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Appendix A: Cross-tabulations of the groomed and merged catch for SPD 3 and 5

A.1 SPD 3

Table A1: The groomed and merged catch by fishing year and month. The catch in each cell is a proportion of the total catch for that fishing year (source: Table 1). "0.00", proportions rounded to zero; "–", true zeros.

	Month (proportions)												
Fish year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Catch (kg)
1990	0.03	0.04	0.05	0.07	0.11	0.10	0.10	0.13	0.06	0.11	0.11	0.08	1 227
1991	0.12	0.12	0.08	0.08	0.06	0.06	0.06	0.08	0.06	0.07	0.09	0.12	1 824
1992	0.04	0.09	0.08	0.14	0.08	0.10	0.09	0.08	0.08	0.07	0.09	0.07	1 653
1993	0.06	0.05	0.04	0.08	0.11	0.12	0.10	0.10	0.07	0.09	0.10	0.07	1 265
1994	0.07	0.05	0.04	0.09	0.09	0.07	0.17	0.12	0.06	0.06	0.09	0.07	1 845
1995	0.07	0.06	0.04	0.06	0.10	0.13	0.12	0.17	0.05	0.04	0.06	0.09	1 440
1996	0.07	0.04	0.04	0.05	0.09	0.13	0.15	0.13	0.07	0.04	0.09	0.11	1 786
1997	0.04	0.05	0.03	0.13	0.15	0.17	0.10	0.10	0.05	0.06	0.06	0.05	1 966
1998	0.07	0.12	0.04	0.08	0.14	0.08	0.12	0.12	0.07	0.03	0.04	0.09	1 950
1999	0.07	0.02	0.03	0.12	0.09	0.21	0.07	0.07	0.08	0.04	0.06	0.10	2 464
2000	0.05	0.02	0.03	0.08	0.11	0.16	0.12	0.12	0.07	0.09	0.05	0.09	2 441
2001	0.11	0.08	0.04	0.09	0.06	0.07	0.11	0.10	0.11	0.06	0.06	0.11	3 341
2002	0.15	0.07	0.06	0.08	0.08	0.06	0.09	0.07	0.09	0.06	0.08	0.11	3 419
2003	0.11	0.06	0.06	0.09	0.11	0.12	0.07	0.13	0.11	0.06	0.05	0.04	3 294
2004	0.09	0.10	0.06	0.14	0.09	0.06	0.11	0.07	0.12	0.06	0.03	0.07	3 190
2005	0.13	0.06	0.03	0.12	0.09	0.07	0.07	0.10	0.06	0.04	0.06	0.15	2 021
2006	0.08	0.07	0.09	0.10	0.04	0.06	0.09	0.10	0.06	0.10	0.10	0.12	2 613
Total	0.09	0.06	0.05	0.10	0.09	0.10	0.10	0.10	0.08	0.06	0.07	0.09	37 740

Table A2: The groomed and merged catch by fishing year and statistical area. The catch in each cell is a proportion of the total catch for that fishing year (source: Table 1). "0.00", proportions rounded to zero; "–", true zeros.

	Statistical area (proportions)										
Fish year	018	020	021	022	023	024	025	026	027	Other	Catch (kg)
1990	0.21	0.39	0.00	0.21	0.00	0.18	0.00	0.01	0.00	0.00	1 227
1991	0.21	0.33	0.06	0.25	0.00	0.14	0.00	0.01	0.00	0.00	1 824
1992	0.28	0.33	0.00	0.20	0.00	0.15	0.01	0.02	0.01	0.00	1 653
1993	0.43	0.23	0.00	0.15	0.00	0.15	0.00	0.03	0.00	0.00	1 265
1994	0.24	0.28	0.02	0.23	0.00	0.21	0.00	0.02	0.00	–	1 845
1995	0.27	0.23	0.02	0.24	0.00	0.23	0.00	0.00	0.00	0.00	1 440
1996	0.24	0.33	0.01	0.16	0.01	0.16	0.00	0.07	0.01	0.00	1 786
1997	0.18	0.31	0.01	0.26	0.01	0.17	0.00	0.05	0.01	0.00	1 966
1998	0.09	0.25	0.02	0.37	0.02	0.23	0.00	0.01	0.00	0.00	1 950
1999	0.07	0.23	0.00	0.48	0.03	0.18	0.00	0.01	0.00	0.00	2 464
2000	0.04	0.27	0.02	0.45	0.04	0.16	0.00	0.01	0.01	0.00	2 441
2001	0.11	0.17	0.01	0.54	0.03	0.14	0.00	0.01	0.00	–	3 341
2002	0.09	0.13	0.01	0.56	0.02	0.15	0.00	0.04	0.00	0.01	3 419
2003	0.10	0.13	0.01	0.55	0.03	0.16	0.00	0.02	0.00	0.00	3 294
2004	0.05	0.13	0.00	0.65	0.01	0.13	0.00	0.01	0.00	0.00	3 190
2005	0.08	0.22	0.01	0.58	0.03	0.07	0.00	0.02	–	0.00	2 021
2006	0.06	0.19	0.02	0.59	0.04	0.09	0.00	0.01	0.00	0.00	2 613
Total	0.14	0.23	0.01	0.43	0.02	0.15	0.00	0.02	0.00	0.00	37 740

Table A3: The groomed and merged catch by fishing year and fishing method. The catch in each cell is a proportion of the total catch for that fishing year (source: Table 1). "0.00", proportions rounded to zero; "–", true zeros.

	Fishing method (proportions)										
Fish year	BLL	BT	CP	DL	DS	MW	PS	RLP	SN	Other	Catch (kg)
1990	0.00	0.37	0.00	0.00	–	–	0.00	0.00	0.63	0.00	1 227
1991	0.01	0.45	0.00	0.00	–	0.00	0.02	0.00	0.53	0.00	1 824
1992	0.00	0.39	0.00	0.00	–	0.00	0.00	0.00	0.60	0.00	1 653
1993	0.01	0.32	0.00	0.00	–	0.00	0.01	0.00	0.67	0.00	1 265
1994	0.01	0.40	0.00	0.00	–	0.06	0.00	0.00	0.53	0.00	1 845
1995	0.02	0.28	0.00	0.00	–	0.03	0.00	0.00	0.66	0.00	1 440
1996	0.02	0.42	0.00	0.00	–	0.02	0.01	0.00	0.54	0.00	1 786
1997	0.03	0.42	0.00	0.00	–	0.03	0.01	0.00	0.51	0.00	1 966
1998	0.02	0.59	0.00	0.00	–	0.01	0.00	0.00	0.37	0.00	1 950
1999	0.00	0.75	0.00	0.00	–	0.02	0.00	0.00	0.23	–	2 464
2000	0.02	0.81	0.00	0.00	–	0.01	0.00	0.00	0.17	–	2 441
2001	0.01	0.81	0.00	0.00	–	0.00	0.00	0.00	0.18	0.00	3 341
2002	0.01	0.81	0.00	0.00	–	0.02	0.00	0.00	0.16	0.00	3 419
2003	0.00	0.84	0.00	0.00	0.00	0.01	–	0.00	0.15	0.00	3 294
2004	0.01	0.85	0.00	0.00	0.01	0.00	–	–	0.12	–	3 190
2005	0.03	0.82	0.00	0.00	0.00	0.03	–	0.00	0.12	0.00	2 021
2006	0.03	0.81	0.00	0.00	0.01	0.04	–	0.00	0.12	0.00	2 613
Total	0.01	0.65	0.00	0.00	0.00	0.02	0.00	0.00	0.31	0.00	37 740

Table A4: The groomed and merged catch by fishing year and target species. The catch in each cell is a proportion of the total catch for that fishing year (source: Table 1).

	Target species (proportions)										
Fish year	BAR	FLA	HOK	RCO	SCH	SPD	SPO	SQU	TAR	Other	Catch (kg)
1990	0.02	0.06	0.00	0.09	0.01	0.58	0.02	0.03	0.12	0.09	1 227
1991	0.06	0.07	0.03	0.14	0.01	0.43	0.03	0.04	0.04	0.15	1 824
1992	0.05	0.02	0.00	0.22	0.01	0.39	0.09	0.02	0.06	0.13	1 653
1993	0.01	0.04	0.00	0.18	0.02	0.50	0.06	0.00	0.07	0.11	1 265
1994	0.01	0.04	0.02	0.20	0.07	0.35	0.05	0.07	0.10	0.09	1 845
1995	0.01	0.04	0.00	0.18	0.16	0.27	0.12	0.02	0.03	0.18	1 440
1996	0.02	0.10	0.03	0.18	0.13	0.21	0.07	0.02	0.04	0.21	1 786
1997	0.02	0.12	0.01	0.19	0.05	0.12	0.07	0.03	0.05	0.33	1 966
1998	0.17	0.06	0.08	0.26	0.12	0.11	0.05	0.00	0.01	0.12	1 950
1999	0.40	0.05	0.08	0.07	0.11	0.06	0.01	0.06	0.04	0.12	2 464
2000	0.24	0.04	0.12	0.22	0.03	0.05	0.01	0.10	0.01	0.18	2 441
2001	0.27	0.04	0.06	0.28	0.01	0.06	0.06	0.10	0.01	0.10	3 341
2002	0.16	0.04	0.03	0.31	0.01	0.12	0.03	0.14	0.02	0.13	3 419
2003	0.23	0.03	0.09	0.26	0.01	0.12	0.02	0.15	0.03	0.07	3 294
2004	0.20	0.03	0.04	0.44	0.01	0.06	0.03	0.06	0.06	0.08	3 190
2005	0.13	0.02	0.04	0.35	0.01	0.09	0.03	0.06	0.14	0.11	2 021
2006	0.10	0.01	0.10	0.18	0.01	0.23	0.03	0.11	0.11	0.12	2 613
Total	0.15	0.04	0.05	0.24	0.04	0.18	0.04	0.07	0.05	0.13	37 740

Table A5: The groomed and merged catch by fishing year, target species (SPD, spiny dogfish; Other, all other target species), fishing method (BLL, bottom longline; BT, bottom trawl; MW, midwater trawl; SN, setnet; Other, all other fishing methods) and reporting form type (CELR, LCER, NCELR, TCEPR, TLCER). The catch in each cell is a proportion of the total catch for that fishing year (source: Table 1). "0.00", proportions rounded to zero; "–", true observed zeros.

(i) CELRs

	BLL		BT		MW		SN		Other	
Fish year	SPD	Other	SPD	Other	SPD	Other	SPD	Other	SPD	Other
1990	–	0.00	0.03	0.26	–	–	0.54	0.09	–	0.00
1991	0.00	0.01	0.02	0.27	–	–	0.41	0.11	0.00	0.02
1992	–	0.00	0.00	0.30	–	–	0.38	0.22	–	0.00
1993	–	0.01	0.00	0.29	–	–	0.49	0.17	–	0.01
1994	–	0.01	0.00	0.34	–	–	0.35	0.18	–	0.00
1995	–	0.02	0.01	0.24	–	–	0.25	0.40	0.00	0.01
1996	0.00	0.02	0.01	0.34	–	–	0.18	0.36	0.00	0.01
1997	–	0.03	0.01	0.30	–	–	0.11	0.41	–	0.01
1998	–	0.02	0.01	0.20	–	–	0.10	0.27	–	0.00
1999	–	0.00	0.00	0.26	–	0.00	0.05	0.18	–	0.00
2000	–	0.02	0.02	0.26	–	–	0.03	0.14	–	0.00
2001	–	0.01	0.00	0.46	–	–	0.06	0.12	–	0.00
2002	–	0.01	0.02	0.39	–	–	0.10	0.06	–	0.00
2003	–	0.00	0.00	0.37	–	0.00	0.10	0.05	–	0.00
2004	–	0.01	0.00	0.49	–	0.00	0.06	0.06	–	0.01
2005	–	0.02	0.03	0.43	–	–	0.02	0.10	–	0.00
2006	–	0.01	0.17	0.27	–	0.00	0.05	0.07	–	0.01
Total	0.00	0.01	0.02	0.34	–	0.00	0.16	0.16	0.00	0.00

(ii) LCERs

	BLL		BT		MW		SN		Other	
Fish year	SPD	Other	SPD	Other	SPD	Other	SPD	Other	SPD	Other
1990	–	–	–	–	–	–	–	–	–	–
1991	–	–	–	–	–	–	–	–	–	–
1992	–	–	–	–	–	–	–	–	–	–
1993	–	–	–	–	–	–	–	–	–	–
1994	–	–	–	–	–	–	–	–	–	–
1995	–	–	–	–	–	–	–	–	–	–
1996	–	–	–	–	–	–	–	–	–	–
1997	–	–	–	–	–	–	–	–	–	–
1998	–	–	–	–	–	–	–	–	–	–
1999	–	–	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–	–	–
2001	–	–	–	–	–	–	–	–	–	–
2002	–	–	–	–	–	–	–	–	–	–
2003	–	–	–	–	–	–	–	–	–	–
2004	–	0.01	–	–	–	–	–	–	–	–
2005	–	0.01	–	–	–	–	–	–	–	–
2006	–	0.02	–	–	–	–	–	–	–	–
Total	–	0.00	–	–	–	–	–	–	–	–

Table A5: (continued)

(iii) NCELRs

	BLL		BT		MW		SN		Other	
Fish year	SPD	Other	SPD	Other	SPD	Other	SPD	Other	SPD	Other
1990	–	–	–	–	–	–	–	–	–	–
1991	–	–	–	–	–	–	–	–	–	–
1992	–	–	–	–	–	–	–	–	–	–
1993	–	–	–	–	–	–	–	–	–	–
1994	–	–	–	–	–	–	–	–	–	–
1995	–	–	–	–	–	–	–	–	–	–
1996	–	–	–	–	–	–	–	–	–	–
1997	–	–	–	–	–	–	–	–	–	–
1998	–	–	–	–	–	–	–	–	–	–
1999	–	–	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–	–	–
2001	–	–	–	–	–	–	–	–	–	–
2002	–	–	–	–	–	–	–	–	–	–
2003	–	–	–	–	–	–	–	–	–	–
2004	–	–	–	–	–	–	–	–	–	–
2005	–	–	–	–	–	–	–	–	–	–
2006	–	–	–	–	–	–	–	0.00	–	–
Total	–	–	–	–	–	–	–	0.00	–	–

(iv) TCEPRs

	BLL		BT		MW		SN		Other	
Fish year	SPD	Other	SPD	Other	SPD	Other	SPD	Other	SPD	Other
1990	–	–	0.01	0.07	–	–	–	–	–	–
1991	–	–	0.00	0.16	–	0.00	–	–	–	–
1992	–	–	0.01	0.09	–	0.00	–	–	–	–
1993	–	–	0.01	0.02	–	0.00	–	–	–	–
1994	–	–	–	0.06	–	0.06	–	–	–	–
1995	–	–	–	0.02	–	0.03	–	–	–	–
1996	–	–	0.01	0.06	–	0.02	–	–	–	–
1997	–	–	0.01	0.10	–	0.03	–	–	–	–
1998	–	–	–	0.39	–	0.01	–	–	–	–
1999	–	–	0.00	0.48	–	0.02	–	–	–	–
2000	–	–	0.00	0.53	–	0.01	–	–	–	–
2001	–	–	–	0.35	–	0.00	–	–	–	–
2002	–	–	0.01	0.40	–	0.02	–	–	–	–
2003	–	–	0.01	0.45	–	0.01	–	–	–	–
2004	–	–	–	0.37	–	0.00	–	–	–	–
2005	–	–	0.05	0.31	–	0.03	–	–	–	–
2006	–	–	0.01	0.36	–	0.04	–	–	–	–
Total	–	–	0.01	0.29	–	0.02	–	–	–	–

Table A5: (continued)

(v) TLCERs

Fish year	BLL		BT		MW		SN		Other		Catch (kg)
	SPD	Other	SPD	Other	SPD	Other	SPD	Other	SPD	Other	
1990	–	–	–	–	–	–	–	–	–	–	1 227
1991	–	–	–	–	–	–	–	–	–	–	1 824
1992	–	–	–	–	–	–	–	–	–	–	1 653
1993	–	–	–	–	–	–	–	–	–	–	1 265
1994	–	–	–	–	–	–	–	–	–	–	1 845
1995	–	–	–	–	–	–	–	–	–	–	1 440
1996	–	–	–	–	–	–	–	–	–	–	1 786
1997	–	–	–	–	–	–	–	–	–	–	1 966
1998	–	–	–	–	–	–	–	–	–	–	1 950
1999	–	–	–	–	–	–	–	–	–	–	2 464
2000	–	–	–	–	–	–	–	–	–	–	2 441
2001	–	–	–	–	–	–	–	–	–	–	3 341
2002	–	–	–	–	–	–	–	–	–	–	3 419
2003	–	–	–	–	–	–	–	–	–	0.00	3 294
2004	–	–	–	–	–	–	–	–	–	–	3 190
2005	–	–	–	–	–	–	–	–	–	–	2 021
2006	–	–	–	–	–	–	–	–	–	–	2 613
Total	–	–	–	–	–	–	–	–	–	0.00	37 740

A.2 SPD 5

Table A6: The groomed and merged catch by fishing year and month. The catch in each cell is a proportion of the total reported catch for that fishing year (source: Table 1). "0.00", proportions rounded to zero; "–", true zeros.

	Month (proportions)												
Fish year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Catch (kg)
1990	–	0.00	0.15	0.16	0.18	0.10	0.08	0.01	0.13	0.11	0.05	0.03	64
1991	0.06	0.01	0.03	0.18	0.24	0.22	0.02	0.01	0.10	0.04	0.05	0.03	230
1992	0.01	0.02	0.01	0.09	0.20	0.46	0.15	0.05	–	0.00	0.01	0.01	125
1993	0.04	0.03	0.01	0.01	0.26	0.47	0.11	0.01	0.01	0.02	0.02	0.02	158
1994	0.31	0.08	0.05	0.00	0.14	0.09	0.08	0.03	0.04	0.06	0.01	0.10	138
1995	0.16	0.02	0.01	0.22	0.29	0.10	0.02	0.01	0.00	0.01	0.03	0.13	69
1996	0.12	0.03	0.00	0.16	0.52	0.08	0.01	0.00	0.03	0.00	0.01	0.03	148
1997	0.04	0.05	0.11	0.11	0.11	0.26	0.20	0.06	0.03	0.01	0.01	0.01	233
1998	0.03	0.07	0.21	0.17	0.14	0.11	0.04	0.02	0.12	0.06	0.00	0.02	213
1999	0.02	0.00	0.49	0.35	0.08	0.02	0.01	0.00	0.01	0.01	0.00	0.02	659
2000	0.02	0.04	0.16	0.08	0.22	0.33	0.00	0.01	0.03	0.03	0.04	0.03	337
2001	0.08	0.02	0.03	0.08	0.16	0.18	0.13	0.04	0.04	0.06	0.06	0.12	428
2002	0.04	0.01	0.05	0.16	0.35	0.14	0.08	0.04	0.05	0.05	0.02	0.00	956
2003	0.03	0.08	0.08	0.26	0.13	0.25	0.04	0.02	0.05	0.02	0.03	0.01	829
2004	0.03	0.06	0.04	0.06	0.16	0.20	0.16	0.15	0.10	0.02	0.01	0.01	840
2005	0.05	0.07	0.03	0.16	0.12	0.12	0.14	0.09	0.05	0.08	0.06	0.03	1 144
2006	0.08	0.07	0.09	0.17	0.07	0.20	0.09	0.08	0.06	0.05	0.02	0.03	1 075
Total	0.05	0.05	0.10	0.16	0.17	0.18	0.09	0.06	0.05	0.04	0.03	0.03	7 646

Table A7: The groomed and merged catch by fishing year and statistical area. The catch in each cell is a proportion of the total catch for that fishing year (source: Table 1). "0.00", proportions rounded to zero; "–", true zeros.

	Statistical area (proportions)										
Fish year	025	026	027	028	029	030	031	504	602	Other	Catch (kg)
1990	0.30	0.02	0.14	0.08	0.00	0.33	0.12	0.01	–	–	64
1991	0.12	0.03	0.23	0.30	0.01	0.24	0.00	0.05	0.02	0.00	230
1992	0.05	0.01	0.05	0.57	0.00	0.12	0.02	0.00	0.13	0.05	125
1993	0.08	0.01	0.02	0.69	0.01	0.10	0.00	0.07	0.02	0.00	158
1994	0.18	0.02	0.10	0.17	0.03	0.42	0.03	0.03	0.01	0.00	138
1995	0.30	0.00	0.07	0.23	0.03	0.20	0.01	0.13	0.02	0.00	69
1996	0.20	0.03	0.35	0.14	0.01	0.14	0.00	0.08	0.01	0.05	148
1997	0.03	0.00	0.06	0.49	0.01	0.24	0.05	0.08	0.01	0.04	233
1998	0.11	0.03	0.26	0.26	0.01	0.22	0.01	0.05	0.05	0.00	213
1999	0.09	0.04	0.09	0.56	0.01	0.09	0.00	0.10	0.02	0.01	659
2000	0.09	0.10	0.11	0.53	0.04	0.07	0.00	0.03	0.02	0.00	337
2001	0.15	0.02	0.04	0.34	0.01	0.37	0.01	0.01	0.01	0.03	428
2002	0.12	0.02	0.12	0.39	0.02	0.24	0.01	0.04	0.03	0.02	956
2003	0.08	0.01	0.18	0.28	0.06	0.25	0.01	0.09	0.01	0.03	829
2004	0.17	0.00	0.08	0.40	0.01	0.25	0.01	0.01	0.04	0.04	840
2005	0.16	0.00	0.06	0.26	0.02	0.34	0.01	0.03	0.02	0.10	1 144
2006	0.26	0.01	0.10	0.29	0.01	0.20	0.00	0.03	0.02	0.07	1 075
Total	0.14	0.02	0.11	0.36	0.02	0.23	0.01	0.05	0.02	0.04	7 646

Table A8: The groomed and merged catch by fishing year and fishing method. The catch in each cell is a proportion of the total catch for that fishing year (source: Table 1). "0.00", proportions rounded to zero; "–", true zeros.

	Fishing method (proportions)										
Fish year	BLL	BT	CP	DL	FP	HL	MW	RLP	SN	Other	Catch (kg)
1990	0.02	0.34	0.00	–	–	0.00	–	0.00	0.64	–	64
1991	0.00	0.76	0.00	0.00	–	0.00	0.09	0.00	0.15	0.00	230
1992	0.06	0.44	0.00	–	–	0.00	0.34	0.01	0.15	0.00	125
1993	0.01	0.16	0.00	0.00	–	0.00	0.77	–	0.06	–	158
1994	0.17	0.45	0.00	0.01	–	–	0.14	–	0.23	0.00	138
1995	0.14	0.43	0.00	0.00	–	–	0.11	–	0.32	–	69
1996	0.02	0.53	0.00	0.03	–	0.00	0.32	0.00	0.10	–	148
1997	0.04	0.49	0.00	0.03	–	–	0.41	0.00	0.03	–	233
1998	0.07	0.30	0.00	0.01	0.00	–	0.54	–	0.06	–	213
1999	0.05	0.60	0.00	0.00	–	–	0.28	–	0.06	0.00	659
2000	0.02	0.62	0.00	0.01	–	0.00	0.32	–	0.02	0.00	337
2001	0.06	0.50	0.01	0.00	–	0.00	0.34	0.00	0.09	0.00	428
2002	0.02	0.69	0.00	0.00	–	0.00	0.18	–	0.10	0.00	956
2003	0.03	0.70	0.00	0.00	–	–	0.12	–	0.15	0.00	829
2004	0.05	0.63	–	–	–	–	0.16	–	0.16	–	840
2005	0.10	0.68	0.00	0.00	–	–	0.08	–	0.13	0.00	1 144
2006	0.08	0.75	–	0.00	–	–	0.04	–	0.13	0.00	1 075
Total	0.06	0.63	0.00	0.00	0.00	0.00	0.19	0.00	0.12	0.00	7 646

Table A9: The groomed and merged catch by fishing year and target species. The catch in each cell is a proportion of the total catch for that fishing year (source: Table 1). "0.00", proportions rounded to zero; "–", true zeros.

	Target species (proportions)										
Fish year	BAR	FLA	HOK	JMA	LIN	SCH	SPD	SQU	STA	Other	Total (kg)
1990	–	0.04	–	–	–	0.62	0.21	0.06	0.06	0.01	64
1991	0.24	0.06	0.00	0.02	0.00	0.14	0.01	0.32	0.15	0.06	230
1992	0.02	0.01	0.01	0.00	0.05	0.11	0.03	0.66	0.07	0.04	125
1993	0.17	0.03	0.01	0.01	–	0.02	0.02	0.60	0.05	0.08	158
1994	0.03	0.02	0.15	–	0.15	0.19	0.03	0.07	0.20	0.16	138
1995	0.13	0.04	0.11	0.04	0.13	0.29	0.01	0.16	0.04	0.07	69
1996	0.08	0.02	0.03	0.18	0.01	0.09	–	0.09	0.03	0.45	148
1997	0.04	0.06	0.06	0.17	0.05	0.03	–	0.33	0.18	0.08	233
1998	0.02	0.05	0.07	0.47	0.09	0.06	–	0.11	0.09	0.03	213
1999	0.00	0.01	0.02	0.22	0.04	0.06	–	0.63	0.00	0.01	659
2000	0.02	0.05	0.09	0.18	0.03	0.02	–	0.50	0.04	0.06	337
2001	–	0.15	0.11	0.11	0.06	0.09	0.00	0.27	0.08	0.13	428
2002	0.04	0.05	0.04	0.07	0.02	0.10	0.00	0.43	0.04	0.21	956
2003	0.09	0.04	0.03	0.02	0.04	0.14	–	0.47	0.06	0.11	829
2004	0.06	0.01	0.11	0.03	0.07	0.15	0.00	0.34	0.05	0.18	840
2005	0.01	0.02	0.07	0.02	0.11	0.09	0.11	0.27	0.07	0.22	1 144
2006	0.02	0.03	0.03	0.00	0.10	0.11	0.21	0.33	0.05	0.12	1 075
Total	0.04	0.04	0.06	0.07	0.06	0.11	0.05	0.37	0.06	0.14	7 646

Table A10 The groomed and merged catch by fishing year, target species (SPD, spiny dogfish; Other, all other target species), fishing method (BLL, bottom longline; BT, bottom trawl; MW, midwater trawl; SN, setnet; Other, all other fishing methods) and reporting form type (CELR, LCER, TCEPR). The catch in each cell is a proportion of the total catch for that fishing year (source: Table 1). "0.00", proportions rounded to zero; "–", true observed zeros. Note that unlike SPD 3, there is no SPD 5 catch associated with either NCELR or TLCER reporting forms.

(i) CELRs

	BLL		BT		MW		SN		Other	
Fish year	SPD	Other	SPD	Other	SPD	Other	SPD	Other	SPD	Other
1990	0.01	0.01	0.15	0.10	–	–	0.03	0.62	–	0.00
1991	–	0.00	–	0.21	–	–	0.01	0.15	–	0.00
1992	–	0.06	–	0.09	–	–	0.03	0.12	0.00	0.01
1993	0.00	0.01	0.01	0.09	–	–	0.01	0.05	–	0.00
1994	–	0.17	–	0.25	–	–	0.03	0.19	–	0.01
1995	–	0.14	–	0.08	–	–	0.01	0.31	–	0.00
1996	–	0.02	–	0.12	–	–	–	0.10	–	0.03
1997	–	0.04	–	0.27	–	–	–	0.03	–	0.03
1998	–	0.07	–	0.15	–	–	–	0.06	–	0.02
1999	–	0.05	–	0.01	–	–	–	0.06	–	0.01
2000	–	0.02	–	0.13	–	–	–	0.02	–	0.02
2001	–	0.06	0.00	0.28	–	–	0.00	0.09	–	0.01
2002	–	0.02	–	0.24	–	–	0.00	0.10	–	0.00
2003	–	0.03	–	0.15	–	–	–	0.15	–	0.00
2004	–	0.02	–	0.23	–	–	0.00	0.16	–	–
2005	–	0.00	0.09	0.24	–	–	0.01	0.12	–	0.00
2006	–	0.00	0.18	0.12	–	–	0.01	0.12	–	0.00
Total	0.00	0.03	0.04	0.18	–	–	0.01	0.12	0.00	0.00

(ii) LCERs

	BLL		BT		MW		SN		Other	
Fish year	SPD	Other	SPD	Other	SPD	Other	SPD	Other	SPD	Other
1990	–	–	–	–	–	–	–	–	–	–
1991	–	–	–	–	–	–	–	–	–	–
1992	–	–	–	–	–	–	–	–	–	–
1993	–	–	–	–	–	–	–	–	–	–
1994	–	–	–	–	–	–	–	–	–	–
1995	–	–	–	–	–	–	–	–	–	–
1996	–	–	–	–	–	–	–	–	–	–
1997	–	–	–	–	–	–	–	–	–	–
1998	–	–	–	–	–	–	–	–	–	–
1999	–	–	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–	–	–
2001	–	–	–	–	–	–	–	–	–	–
2002	–	–	–	–	–	–	–	–	–	–
2003	–	–	–	–	–	–	–	–	–	–
2004	–	0.03	–	–	–	–	–	–	–	–
2005	–	0.10	–	–	–	–	–	–	–	–
2006	–	0.07	–	–	–	–	–	–	–	–
Total	–	0.03	–	–	–	–	–	–	–	–

Table A10: (continued)

(iii) TCEPRs

Fish year	BLL		BT		MW		SN		Other		Catch (kg)
	SPD	Other	SPD	Other	SPD	Other	SPD	Other	SPD	Other	
1990	–	–	0.03	0.06	–	–	–	–	–	–	64
1991	–	–	–	0.54	–	0.09	–	–	–	–	230
1992	–	–	–	0.36	–	0.34	–	–	–	–	125
1993	–	–	–	0.06	–	0.77	–	–	–	–	158
1994	–	–	–	0.20	–	0.14	–	–	–	–	138
1995	–	–	–	0.35	–	0.11	–	–	–	–	69
1996	–	–	–	0.42	–	0.32	–	–	–	–	148
1997	–	–	–	0.22	–	0.41	–	–	–	–	233
1998	–	–	–	0.15	–	0.54	–	–	–	–	213
1999	–	–	–	0.59	–	0.28	–	–	–	–	659
2000	–	–	–	0.49	–	0.32	–	–	–	–	337
2001	–	–	–	0.22	–	0.34	–	–	–	–	428
2002	–	–	–	0.45	–	0.18	–	–	–	–	956
2003	–	–	–	0.55	–	0.12	–	–	–	–	829
2004	–	–	–	0.40	–	0.16	–	–	–	–	840
2005	–	–	–	0.36	–	0.08	–	–	–	–	1 144
2006	–	–	0.02	0.44	–	0.04	–	–	–	–	1 075
Total	–	–	0.00	0.41	–	0.19	–	–	–	–	7 646

Appendix B: Data summaries for all CPUE models

Table B1: Number of effort strata (n_{strata}), number of vessels (n_{vessels}), total catch (t_{catch} ; tonnes), total effort (t_{effort}), proportion of zero-catch effort strata (p_{zeros}), median catch per effort stratum (m_{catch} ; kilogrammes), median effort per effort stratum (m_{effort}), median CPUE per effort stratum (m_{CPUE}), and median log CPUE per effort stratum (m_{lnCPUE}) in the core vessel subsets to which models (a) 1.1 and 1.2, (b) 1.3 and 1.4, (c) 1.5 and 1.6, and (d) 1.7 and 1.8 were fitted. All quantities, except for the proportion of zero-catch strata, are calculated for the positive (non-zero) effort strata data subset to which these models were fitted. The proportion of zero-catch effort strata is defined as the proportion of zero-catch effort strata in the complete (i.e., positive- and zero-catch effort strata) model datasets defined in Table 5.

Core vessel subset for models 1.1 and 1.2 ("effort", total net set per effort stratum in kilometres; "CPUE", kilogrammes caught per km net set per effort stratum):

	Fishing year ("90", 1989–90; "All", all fishing years)																	
	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	All
n_{vessels}	7	8	8	9	9	7	7	8	6	4	3	2	2	3	2	2	3	11
n_{strata}	255	379	420	810	862	507	612	374	242	129	123	78	82	206	184	89	221	5573
t_{catch}	374	493	508	481	459	236	251	189	148	85	61	51	90	158	178	42	104	3911
t_{effort}	574	538	728	1030	1374	908	1055	677	299	165	134	124	105	250	221	101	255	8537
p_{zeros}	0.03	0.02	0.04	0.03	0.05	0.20	0.05	0.19	0.26	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.07
m_{catch}	714.2	499.5	396.9	277.0	253.5	234.1	201.0	215.1	294.3	340.0	354.0	484.5	880.5	677.0	819.0	422.6	312.8	0.3
m_{effort}	2.0	1.2	1.3	1.2	1.2	2.0	2.0	2.0	1.0	1.0	1.0	1.5	1.2	1.2	1.2	1.2	1.2	1.2
m_{CPUE}	472.5	455.1	312.5	252.7	174.7	150.0	145.6	131.6	272.6	332.0	372.8	323.0	733.8	564.2	687.5	358.5	269.0	458.1
m_{lnCPUE}	6.2	6.1	5.7	5.5	5.2	5.0	5.0	4.9	5.6	5.8	5.9	5.8	6.6	6.3	6.5	5.9	5.6	6.1

Core vessel subset for models 1.3 and 1.4 ("effort", total net set per effort stratum in kilometres; "CPUE", kilogrammes caught per km net set per effort stratum):

	Fishing year ("90", 1989–90; "All", all fishing years)																	
	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	All
n_{vessels}	14	17	18	20	22	23	24	24	19	14	15	17	13	13	12	11	9	31
n_{strata}	341	576	769	1222	1465	997	1122	840	656	573	399	469	410	413	377	343	397	11369
t_{catch}	388	565	600	570	716	512	648	754	566	434	158	137	131	188	225	85	135	6810
t_{effort}	744	912	1371	1725	2392	1821	2032	1538	1058	954	661	909	732	698	628	577	615	19369
p_{zeros}	0.38	0.23	0.19	0.16	0.20	0.27	0.22	0.30	0.40	0.38	0.46	0.46	0.40	0.43	0.27	0.35	0.25	0.29
m_{catch}	441.5	290.2	203.9	190.0	195.0	183.0	175.2	238.8	350.0	221.0	162.0	119.0	86.5	199.0	267.0	95.0	188.6	0.2
m_{effort}	1.5	1.3	1.5	1.5	1.5	1.8	2.0	2.0	1.5	1.5	1.5	1.5	2.0	1.2	1.2	1.2	1.2	1.5
m_{CPUE}	279.9	261.0	167.4	173.1	139.3	120.0	120.0	145.2	258.3	162.0	132.0	71.7	56.3	146.7	189.4	84.4	134.2	351.6
m_{lnCPUE}	5.6	5.6	5.1	5.2	4.9	4.8	4.8	5.0	5.6	5.1	4.9	4.3	4.0	5.0	5.2	4.4	4.9	5.9

Table B1: (continued)

Core vessel subset for models 1.5 and 1.6 ("effort", total number of hours trawled; "CPUE", kilogrammes caught per hour trawled):

	Fishing year ("90", 1989–90; "All", all fishing years)																	
	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	All
n_{vessels}	5	8	5	11	12	15	8	14	8	14	21	23	29	29	26	30	26	40
n_{strata}	8	39	33	46	66	47	24	100	43	55	149	298	341	238	197	285	290	2259
t_{catch}	7	66	24	16	54	27	60	89	38	295	195	143	490	377	368	498	404	3152
t_{effort}	95	1159	794	1084	1560	1715	762	3867	1922	3329	3607	6504	7371	6237	6101	10850	12351	69310
p_{zeros}	0.97	0.87	0.90	0.90	0.87	0.92	0.97	0.87	0.95	0.92	0.80	0.60	0.54	0.70	0.73	0.64	0.53	0.79
m_{catch}	374.6	298.4	142.9	107.1	262.0	163.0	613.3	118.9	220.0	300.0	270.9	196.5	209.8	208.0	450.0	416.9	300.5	0.3
m_{effort}	10.7	19.5	11.0	12.8	9.0	20.9	11.6	20.1	19.6	26.0	13.0	16.6	14.9	18.0	19.0	20.2	23.5	18.0
m_{CPUE}	41.3	19.8	14.1	7.0	20.8	12.2	20.9	3.0	15.2	12.4	22.2	13.8	15.1	11.5	19.1	19.5	12.6	45.5
m_{lnCPUE}	3.7	3.0	2.6	1.9	3.0	2.5	3.0	1.1	2.7	2.5	3.1	2.6	2.7	2.4	2.9	3.0	2.5	3.8

Core vessel subset for models 1.7 and 1.8 ("effort", total number of hours trawled; "CPUE", kilogrammes caught per hour trawled):

	Fishing year ("90", 1989–90; "All", all fishing years)																	
	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	All
n_{vessels}	4	5	3	8	10	10	4	4	2	3	13	17	16	18	9	13	11	18
n_{strata}	4	22	16	26	51	25	7	32	19	10	89	266	281	153	77	171	173	1422
t_{catch}	1	9	9	11	29	5	3	39	19	6	42	120	178	59	84	166	68	847
t_{effort}	51	445	218	452	804	724	173	664	419	126	1493	5263	4694	3122	1447	3352	4014	27461
p_{zeros}	0.98	0.91	0.93	0.92	0.88	0.95	0.99	0.94	0.97	0.98	0.85	0.57	0.56	0.75	0.86	0.72	0.61	0.83
m_{catch}	282.8	255.8	251.8	209.5	242.0	116.0	375.0	204.5	350.0	313.4	260.0	199.1	144.5	98.0	467.1	328.0	188.0	0.2
m_{effort}	12.5	19.9	11.0	11.6	7.5	18.5	28.0	18.6	16.0	11.0	9.5	16.5	14.5	18.0	17.5	18.0	22.0	16.5
m_{CPUE}	30.5	17.5	26.4	20.3	20.2	7.9	13.4	12.2	18.7	27.8	22.9	15.3	10.0	6.7	26.1	19.1	9.0	30.8
m_{lnCPUE}	3.4	2.9	3.3	3.0	3.0	2.1	2.6	2.5	2.9	3.3	3.1	2.7	2.3	1.9	3.3	3.0	2.2	3.4

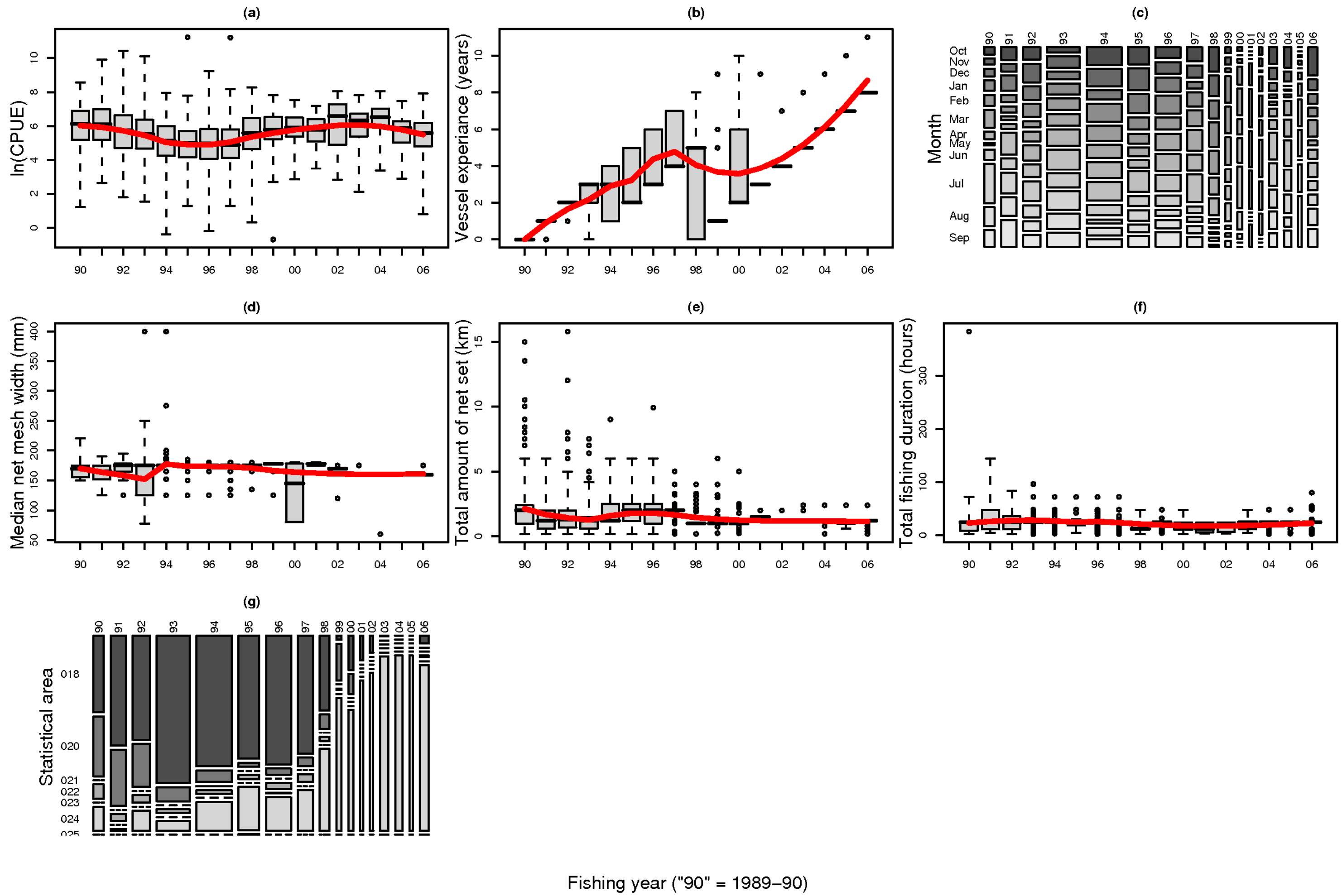


Figure B1: **Exploring the distributions of variables in the dataset to which models 1.1 and 1.2 were fitted. Boxplots of continuous variables and mosaic plots of discrete variables per effort stratum are plotted. Boxplot lower and upper hinges are drawn at the first and third quantiles. The median of each distribution is indicated by the thick solid black line. Whiskers extend upwards and downwards to three times the interquartile range. Values beyond three times the interquartile range ("outliers") are plotted as points. A loess-smoothed curve is overlaid on the continuous variable distributions.**

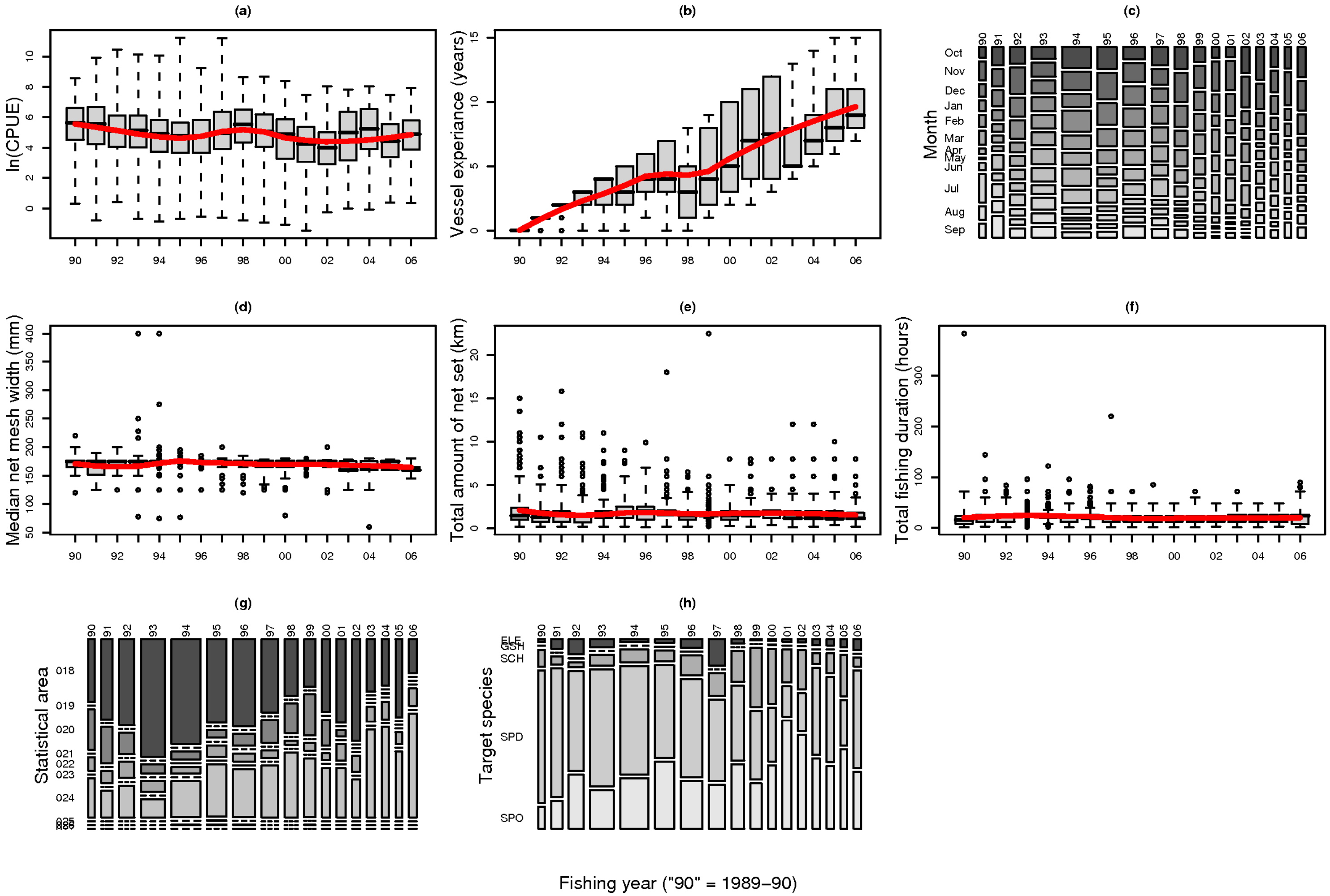


Figure B2: **Exploring the distributions of variables in the dataset to which models 1.3 and 1.4 were fitted. Boxplots of continuous variables and mosaic plots of discrete variables per effort stratum are plotted. Boxplot lower and upper hinges are drawn at the first and third quantiles. The median of each distribution is indicated by the thick solid black line. Whiskers extend upwards and downwards to three times the interquartile range. Values beyond three times the interquartile range ("outliers") are plotted as points. A loess-smoothed curve is overlaid on the continuous variable distributions.**

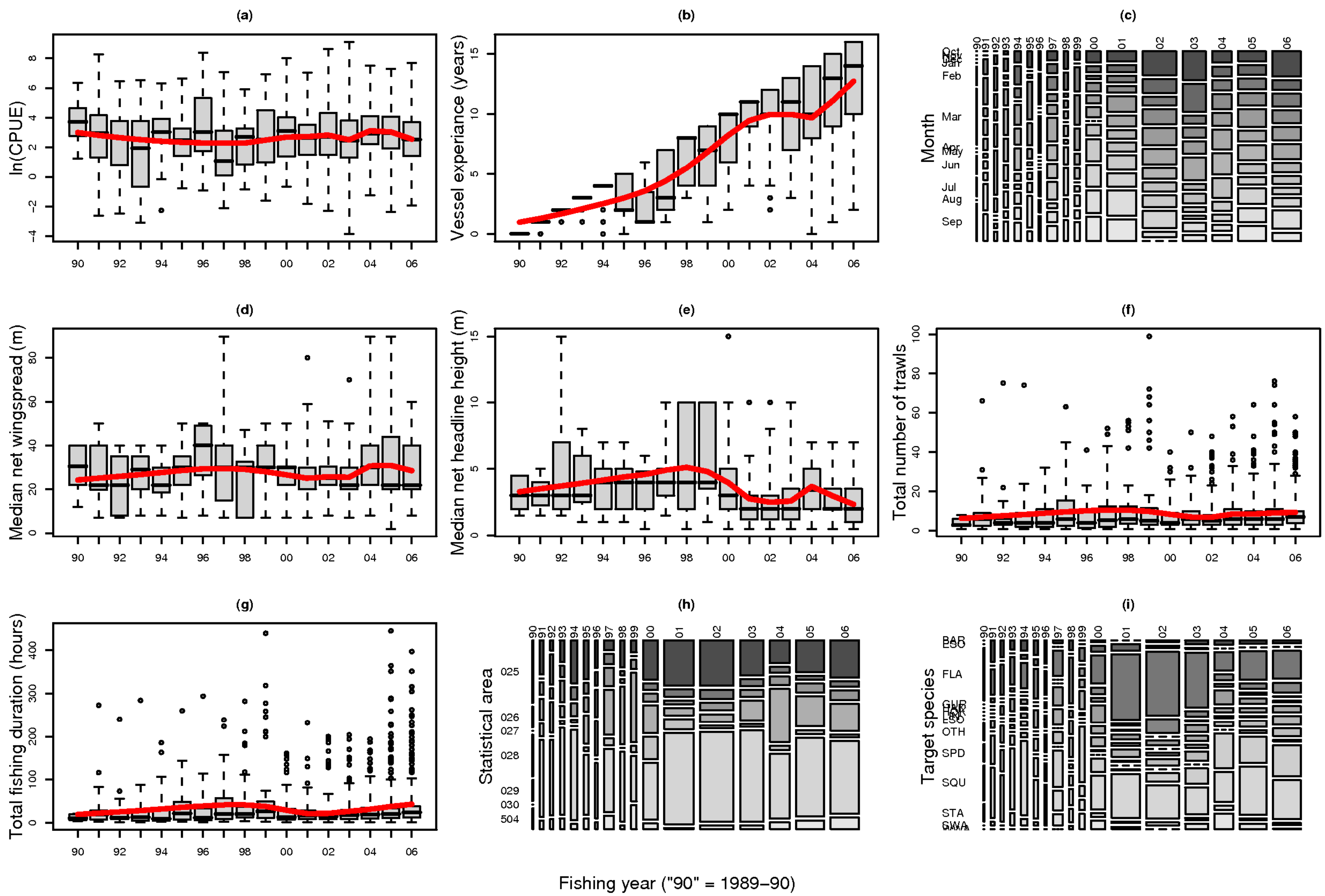


Figure B3: **Exploring the distributions of variables in the dataset to which models 1.5 and 1.6 were fitted. Boxplots of continuous variables and mosaic plots of discrete variables per effort stratum are plotted. Boxplot lower and upper hinges are drawn at the first and third quantiles. The median of each distribution is indicated by the thick solid black line. Whiskers extend upwards and downwards to three times the interquartile range. Values beyond three times the interquartile range ("outliers") are plotted as points. A loess-smoothed curve is overlaid on the continuous variable distributions.**

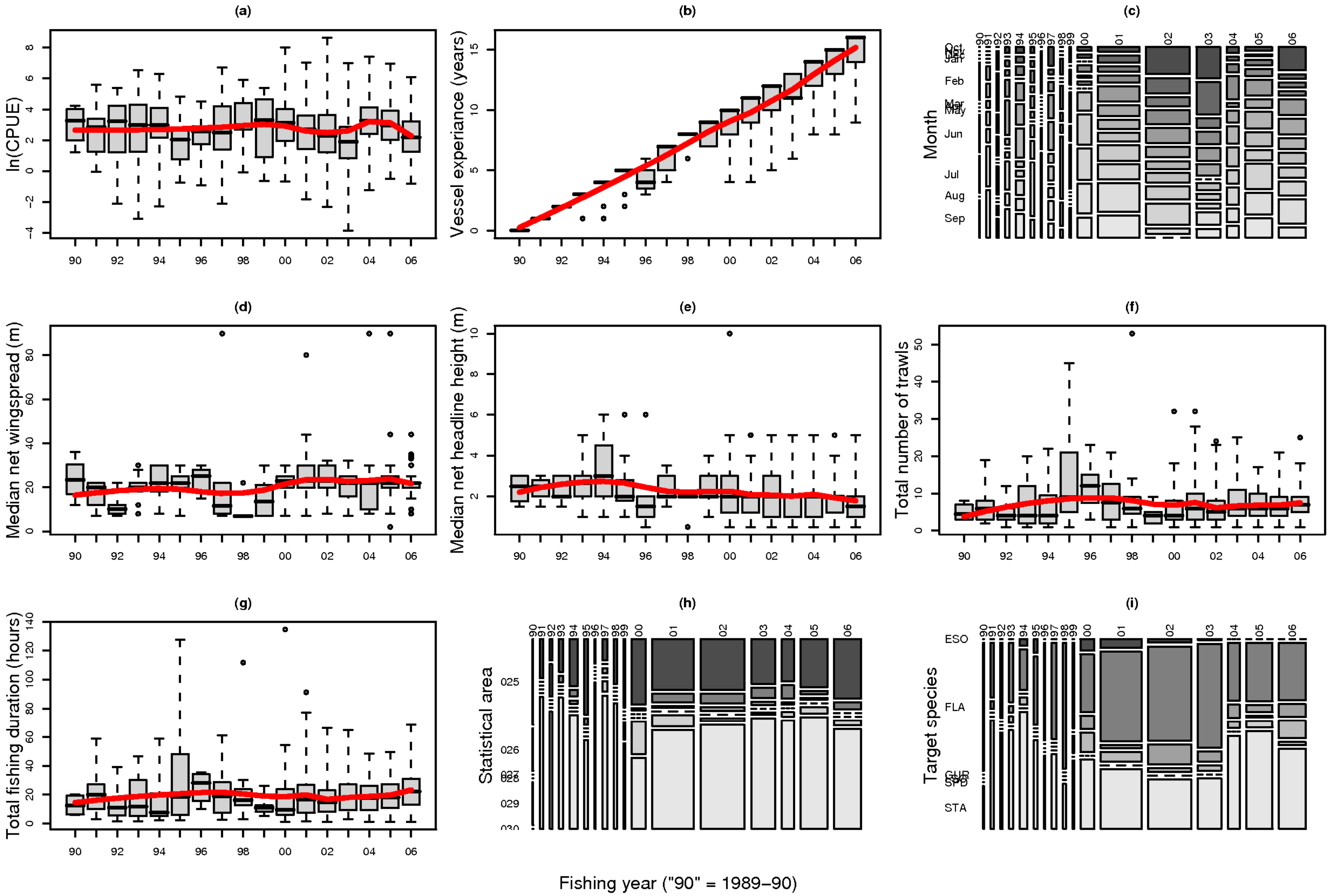
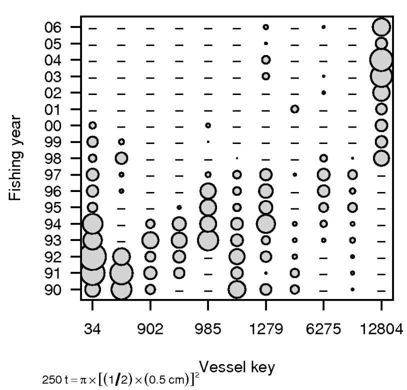


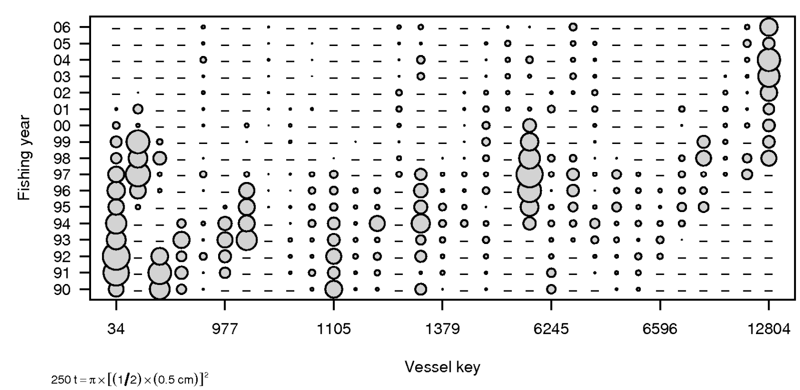
Figure B4: **Exploring the distributions of variables in the dataset to which models 1.7 and 1.8 were fitted. Boxplots of continuous variables and mosaic plots of discrete variables per effort stratum are plotted. Boxplot lower and upper hinges are drawn at the first and third quantiles. The median of each distribution is indicated by the thick solid black line. Whiskers extend upwards and downwards to three times the interquartile range. Values beyond three times the interquartile range ("outliers") are plotted as points. A loess-smoothed curve is overlaid on the continuous variable distributions.**

Appendix C: Visualising fleet composition in each model core dataset

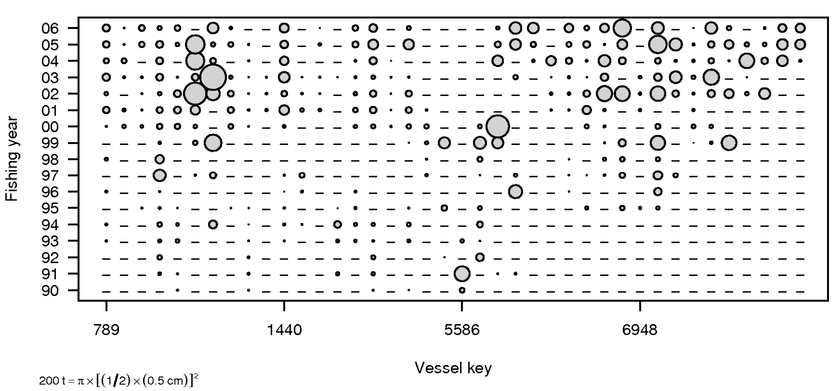
(a) models 1.1 and 1.2



(a) models 1.3 and 1.4



(a) models 1.5 and 1.6



(a) models 1.7 and 1.8

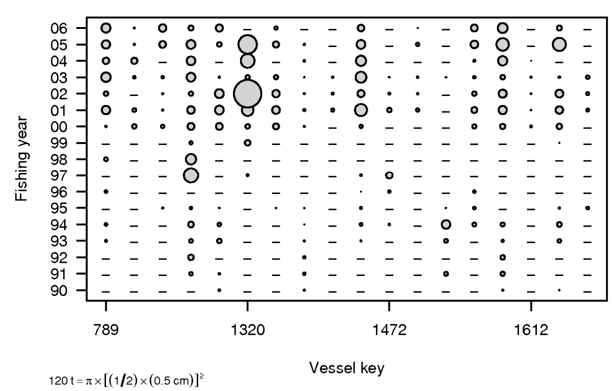


Figure C1: Catch by vessel by fishing year for each vessel in the "core" vessel data subset to which (a) models 1.1 and 1.2, (b) models 1.3 and 1.4, (c) models 1.5 and 1.6, and (d) models 1.7 and 1.8 were fitted. Vessel keys are unique numerical codes that identify each fishing vessel within the *warehou* database. "90", 1989–90 fishing year.

Appendix D: Diagnostic goodness-of-fit plots for lognormal model fits

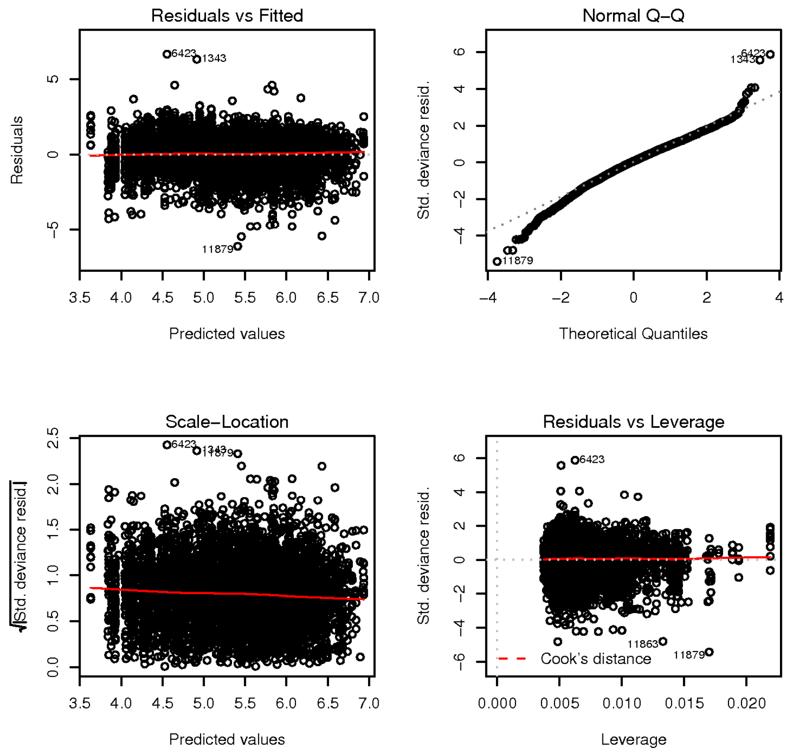


Figure D1: **Diagnostic residual goodness-of-fit plots for model 1.1.**

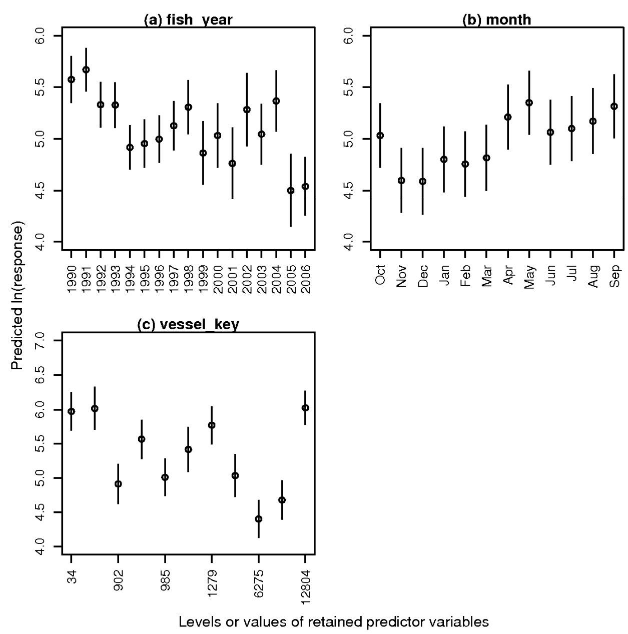


Figure D2: **Expected log catch rates for all predictor variables retained in model 1.1. These were calculated by varying each retained predictor in turn holding all other variables in the model at their median values. The width of the error bars is equal to two standard errors about the log catch rate.**

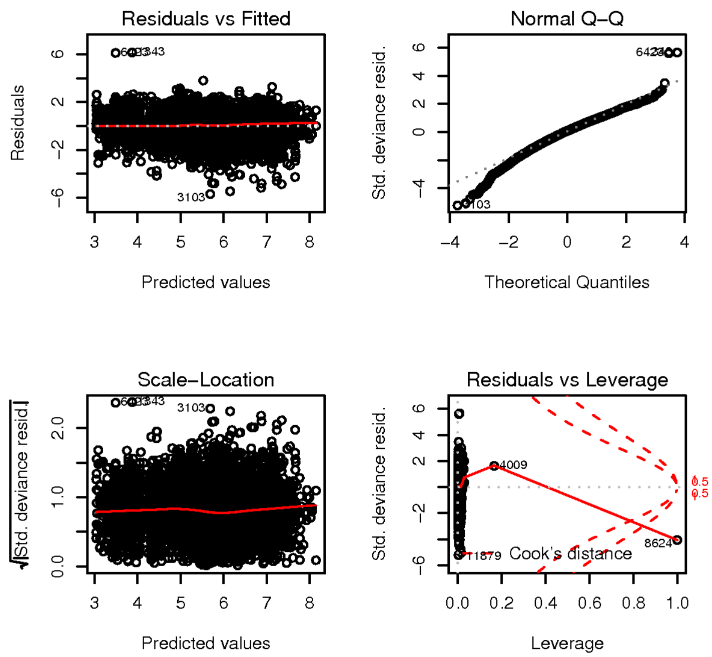


Figure D3: **Diagnostic residual goodness-of-fit plots for model 1.2.**

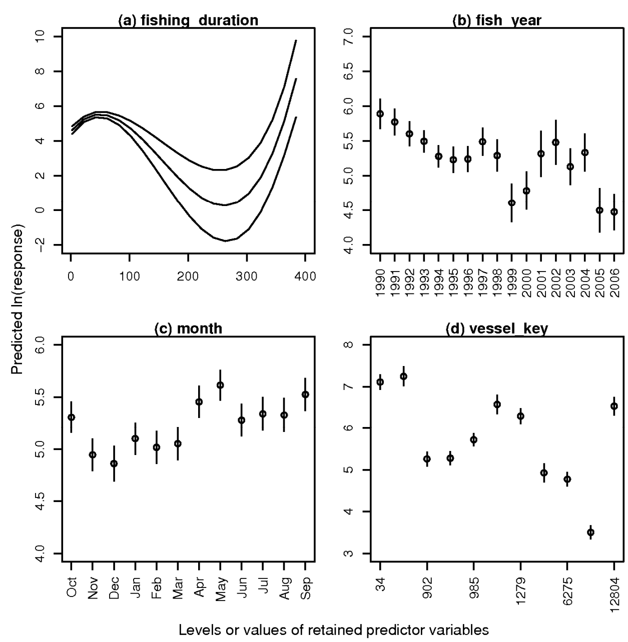


Figure D4: **Expected log catch rates for all predictor variables retained in model 1.2. These were calculated by varying each retained predictor in turn holding all other variables in the model at their median values. The width of the error bars is equal to two standard errors about the log catch rate.**

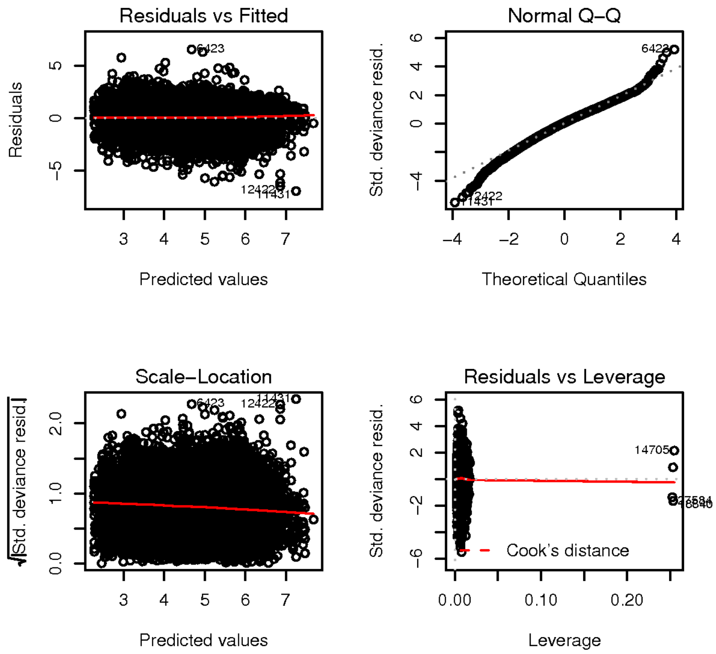


Figure D5: **Diagnostic residual goodness-of-fit plots for model 1.3.**

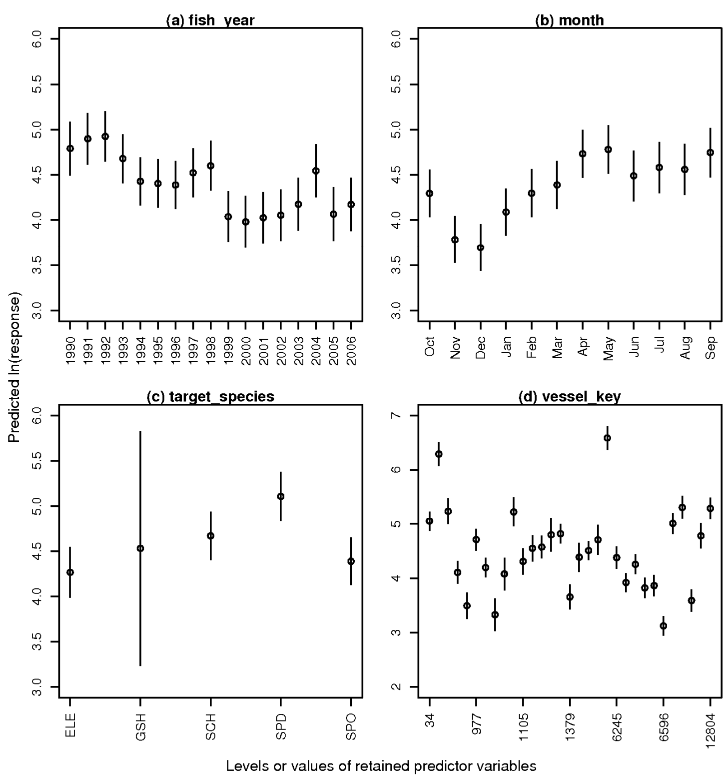


Figure D6: **Expected log catch rates for all predictor variables retained in model 1.3. These were calculated by varying each retained predictor in turn holding all other variables in the model at their median values. The width of the error bars is equal to two standard errors about the log catch rate.**

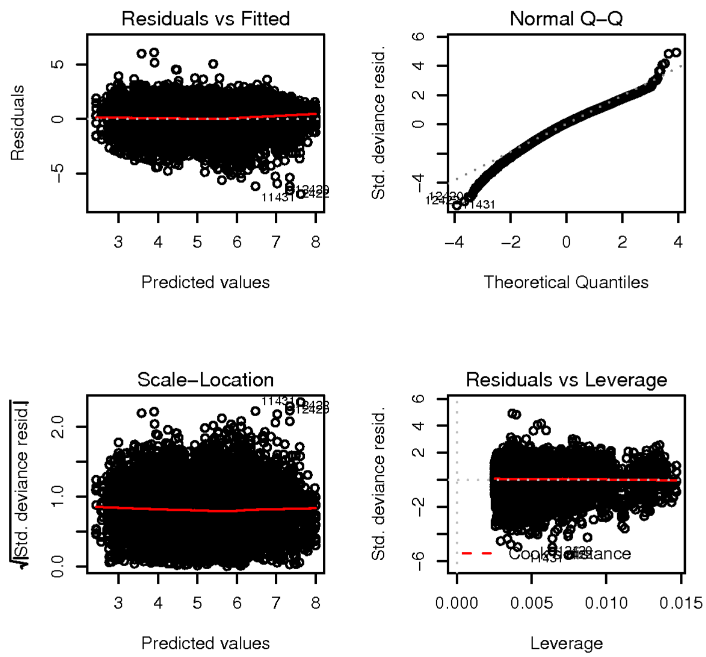


Figure D7: Diagnostic residual goodness-of-fit plots for model 1.4.

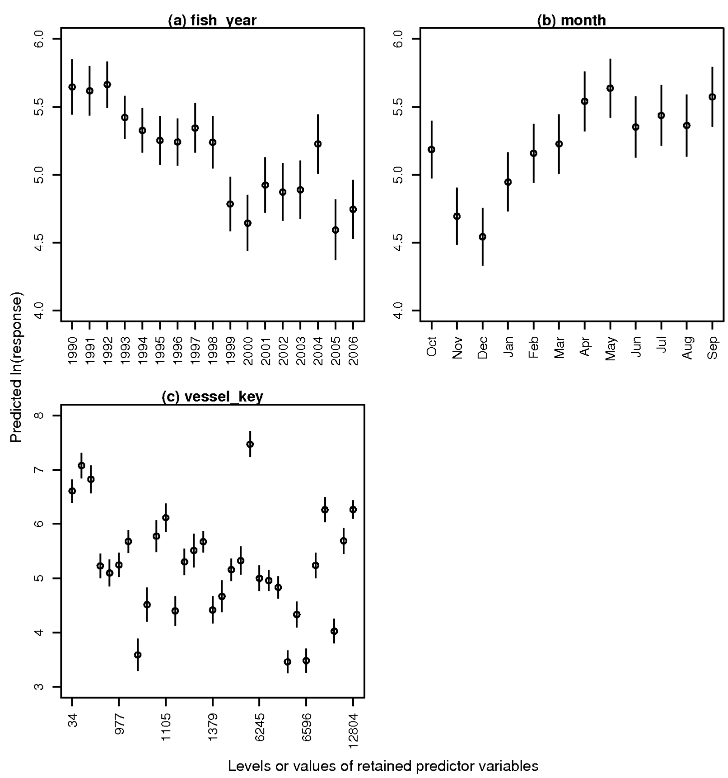


Figure D8: Expected log catch rates for all predictor variables retained in model 1.4. These were calculated by varying each retained predictor in turn holding all other variables in the model at their median values. The width of the error bars is equal to two standard errors about the log catch rate.

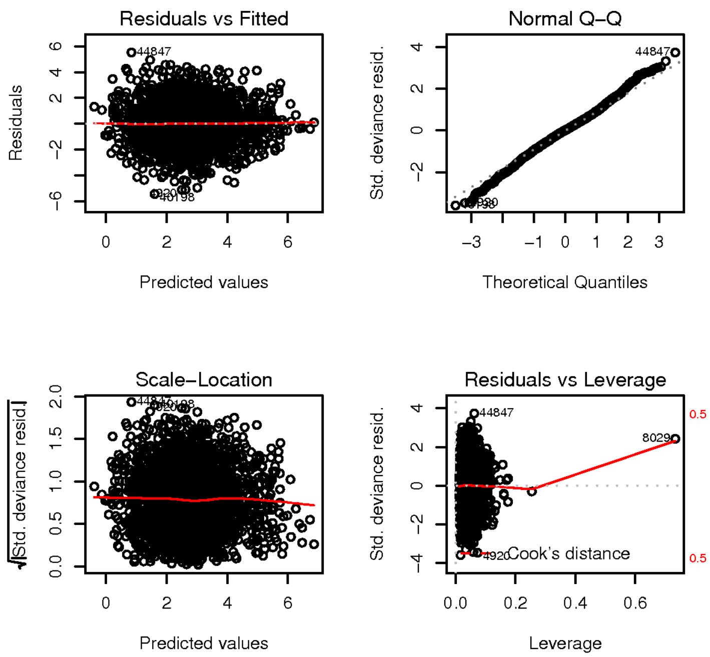


Figure D9: **Diagnostic residual goodness-of-fit plots for model 1.5.**

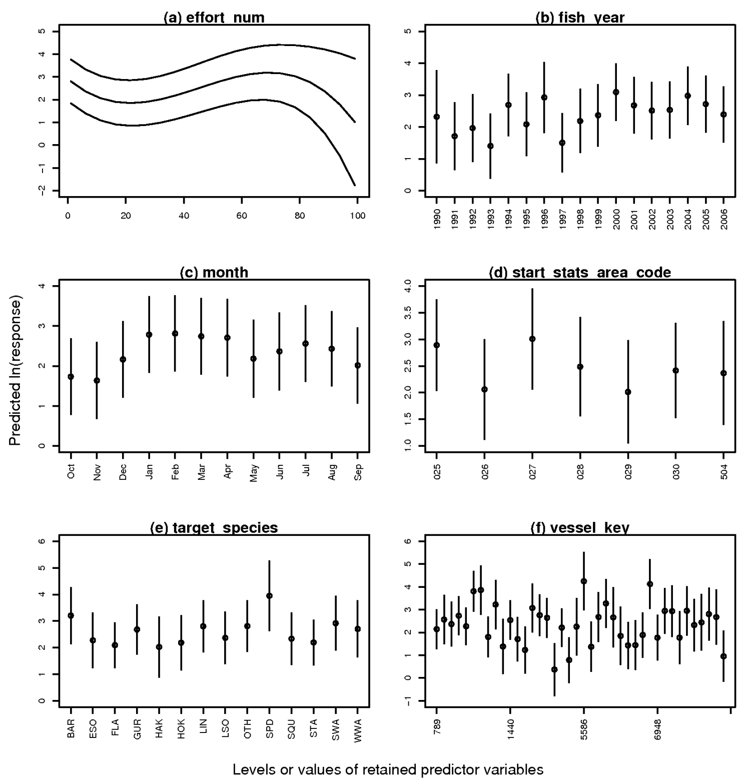


Figure D10: **Expected log catch rates for predictor variables retained in model 1.5. Expected log catch rates were calculated by varying the variable of interest and holding all other variables in the model at their median values. The width of the error bars is equal to two Standard errors about the log catch rate.**

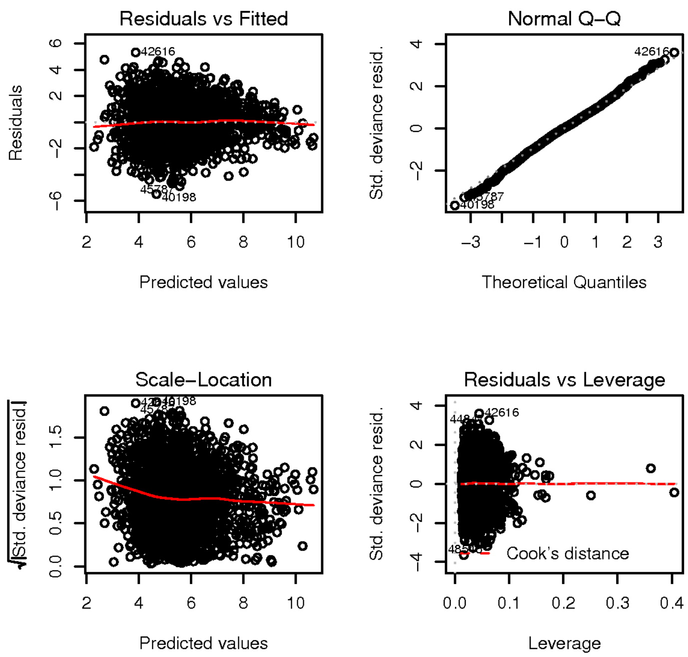


Figure D11: **Diagnostic residual goodness-of-fit plots for model 1.6.**

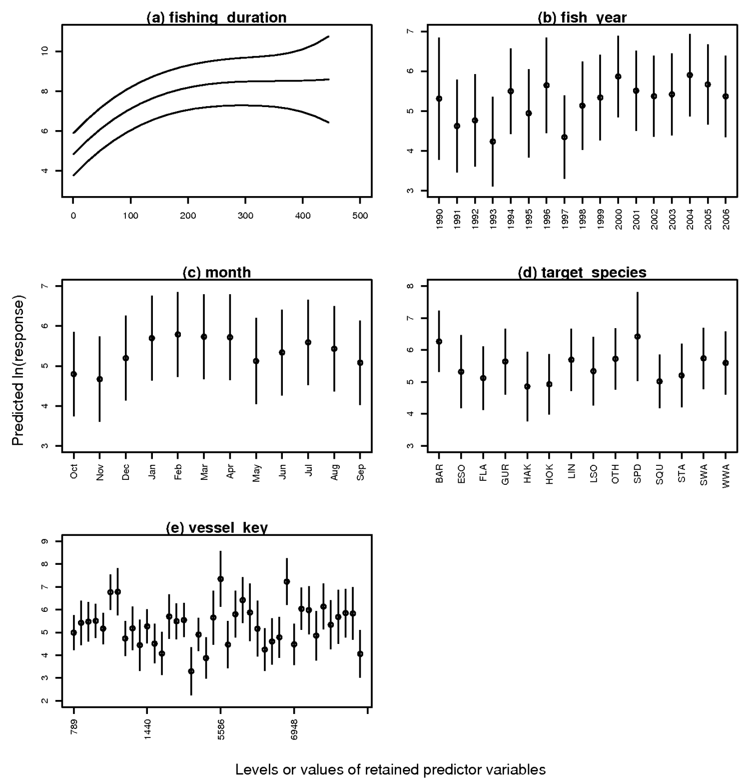


Figure D12: **Expected log catch rates for all predictor variables retained in model 1.6. These were calculated by varying each retained predictor in turn holding all other variables in the model at their median values. The width of the error bars is equal to two standard errors about the log catch rate.**

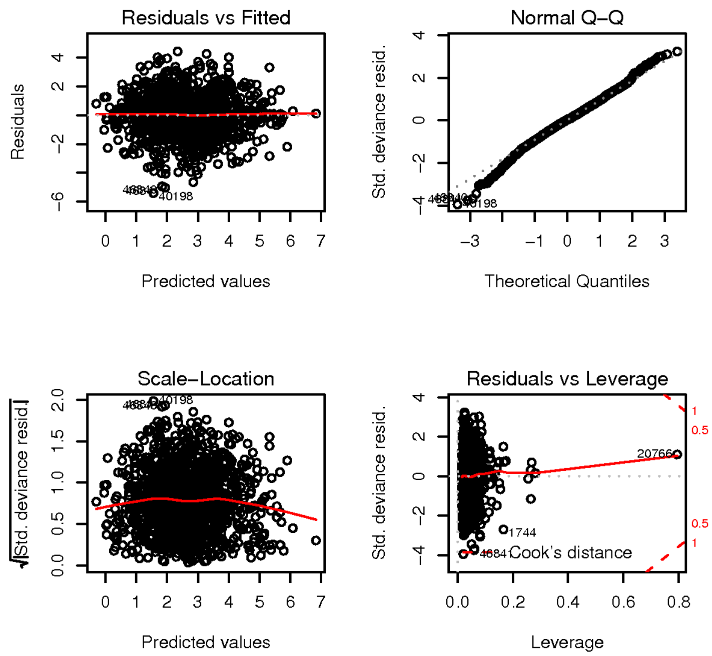


Figure D13: Diagnostic residual goodness-of-fit plots for model 1.7.

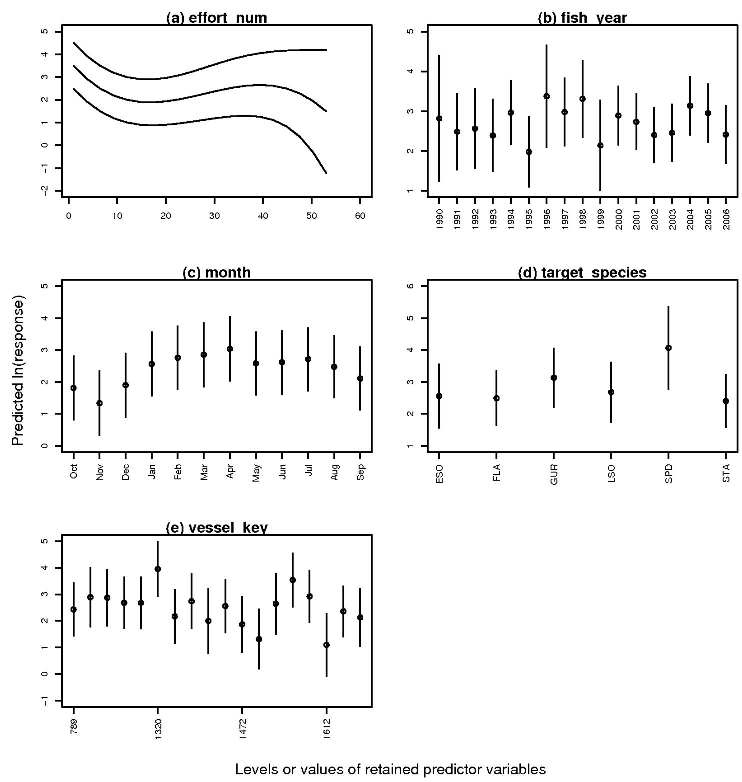


Figure D14: Expected log catch rates for all predictor variables retained in model 1.7. These were calculated by varying each retained predictor in turn holding all other variables in the model at their median values. The width of the error bars is equal to two standard errors about the log catch rate.

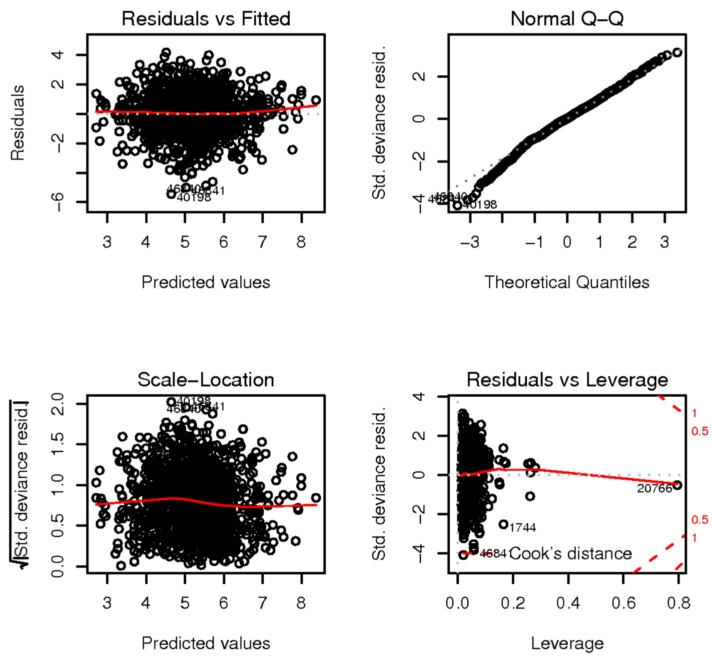


Figure D15: Diagnostic residual goodness-of-fit plots for model 1.8.

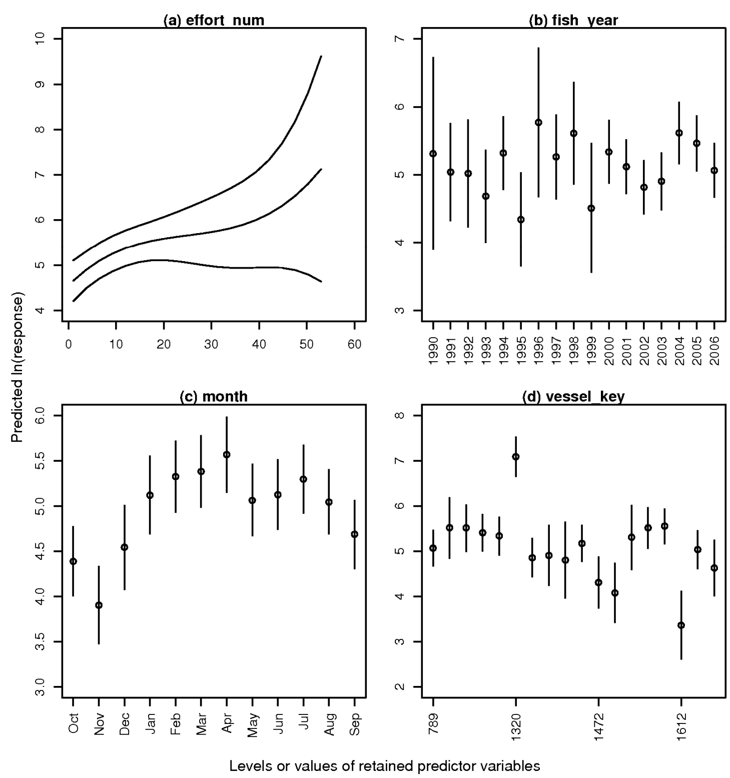


Figure D16: Expected log catch rates for all predictor variables retained in model 1.8. These were calculated by varying each retained predictor in turn holding all other variables in the model at their median values. The width of the error bars is equal to two standard errors about the log catch rate.

Appendix E: CPUE model canonical year effects

Table E1: Year effects and 95% lognormal confidence intervals for standardised model fits 1.1 to 1.8.

	Model 1.1		Model 1.2		Model 1.3		Model 1.4	
Year	Index	95% CI	Index	95% CI	Index	95% CI	Index	95% CI
1990	1.619	(1.396, 1.877)	1.934	(1.667, 2.244)	1.488	(1.327, 1.668)	1.653	(1.475, 1.852)
1991	1.779	(1.565, 2.022)	1.718	(1.511, 1.953)	1.655	(1.511, 1.814)	1.607	(1.468, 1.758)
1992	1.267	(1.123, 1.430)	1.450	(1.285, 1.636)	1.698	(1.569, 1.838)	1.683	(1.556, 1.820)
1993	1.263	(1.139, 1.401)	1.303	(1.175, 1.446)	1.330	(1.243, 1.424)	1.321	(1.234, 1.414)
1994	0.838	(0.759, 0.926)	1.050	(0.951, 1.161)	1.035	(0.973, 1.101)	1.201	(1.129, 1.277)
1995	0.869	(0.776, 0.973)	1.000	(0.893, 1.120)	1.011	(0.944, 1.083)	1.116	(1.042, 1.195)
1996	0.908	(0.815, 1.011)	1.010	(0.907, 1.125)	0.994	(0.931, 1.062)	1.103	(1.033, 1.178)
1997	1.034	(0.914, 1.169)	1.296	(1.147, 1.466)	1.137	(1.057, 1.223)	1.222	(1.138, 1.313)
1998	1.238	(1.086, 1.410)	1.062	(0.932, 1.211)	1.230	(1.135, 1.332)	1.101	(1.016, 1.193)
1999	0.794	(0.665, 0.948)	0.536	(0.448, 0.641)	0.701	(0.640, 0.766)	0.699	(0.640, 0.764)
2000	0.940	(0.786, 1.124)	0.640	(0.535, 0.766)	0.662	(0.598, 0.733)	0.607	(0.549, 0.672)
2001	0.717	(0.572, 0.900)	1.091	(0.868, 1.371)	0.693	(0.630, 0.762)	0.803	(0.731, 0.883)
2002	1.209	(0.968, 1.509)	1.283	(1.027, 1.603)	0.712	(0.644, 0.788)	0.763	(0.690, 0.844)
2003	0.953	(0.817, 1.111)	0.906	(0.776, 1.056)	0.804	(0.726, 0.890)	0.776	(0.701, 0.858)
2004	1.313	(1.121, 1.539)	1.109	(0.944, 1.302)	1.162	(1.046, 1.292)	1.087	(0.979, 1.208)
2005	0.552	(0.444, 0.686)	0.481	(0.387, 0.598)	0.721	(0.645, 0.807)	0.577	(0.517, 0.645)
2006	0.574	(0.496, 0.664)	0.470	(0.406, 0.545)	0.802	(0.722, 0.890)	0.672	(0.606, 0.746)

	Model 1.5		Model 1.6		Model 1.7		Model 1.8	
Year	Index	95% CI	Index	95% CI	Index	95% CI	Index	95% CI
1990	0.965	(0.475, 1.961)	1.083	(0.534, 2.197)	1.119	(0.430, 2.910)	1.199	(0.462, 3.114)
1991	0.523	(0.369, 0.740)	0.545	(0.385, 0.771)	0.802	(0.519, 1.240)	0.915	(0.593, 1.413)
1992	0.675	(0.468, 0.975)	0.626	(0.434, 0.904)	0.867	(0.523, 1.436)	0.897	(0.542, 1.486)
1993	0.385	(0.283, 0.525)	0.369	(0.271, 0.502)	0.730	(0.486, 1.097)	0.641	(0.427, 0.963)
1994	1.399	(1.080, 1.812)	1.304	(1.008, 1.686)	1.294	(0.961, 1.741)	1.211	(0.901, 1.628)
1995	0.761	(0.561, 1.032)	0.749	(0.553, 1.015)	0.484	(0.321, 0.730)	0.455	(0.302, 0.685)
1996	1.765	(1.162, 2.682)	1.513	(0.996, 2.298)	1.954	(0.936, 4.076)	1.900	(0.911, 3.961)
1997	0.426	(0.343, 0.529)	0.411	(0.331, 0.511)	1.315	(0.915, 1.891)	1.144	(0.796, 1.644)
1998	0.843	(0.619, 1.150)	0.907	(0.666, 1.236)	1.829	(1.135, 2.949)	1.619	(1.006, 2.606)
1999	1.010	(0.756, 1.349)	1.112	(0.835, 1.481)	0.569	(0.306, 1.058)	0.538	(0.290, 0.996)
2000	2.089	(1.733, 2.518)	1.888	(1.569, 2.272)	1.205	(0.949, 1.531)	1.231	(0.970, 1.561)
2001	1.380	(1.195, 1.592)	1.320	(1.144, 1.522)	1.028	(0.871, 1.212)	0.990	(0.840, 1.167)
2002	1.169	(1.014, 1.348)	1.150	(0.998, 1.325)	0.738	(0.622, 0.876)	0.731	(0.617, 0.866)
2003	1.195	(1.021, 1.400)	1.204	(1.029, 1.409)	0.782	(0.638, 0.958)	0.799	(0.653, 0.977)
2004	1.864	(1.572, 2.210)	1.957	(1.651, 2.320)	1.539	(1.195, 1.981)	1.628	(1.265, 2.093)
2005	1.435	(1.243, 1.656)	1.545	(1.338, 1.783)	1.279	(1.058, 1.545)	1.399	(1.160, 1.686)
2006	1.037	(0.896, 1.200)	1.148	(0.992, 1.328)	0.747	(0.616, 0.905)	0.938	(0.776, 1.133)

Appendix F: New Zealand Ministry of Fisheries codes used in figures and tables

Table F1: New Zealand Ministry of Fisheries catch-effort form type, fishing method, and target species codes used in the figures and tables above. For a complete list and description of all current reporting forms see Ministry of Fisheries (2008). For a complete list and description of all current fishing method and target species codes, contact the Ministry of Fisheries.

Catch-effort form type codes:

Code	Description
CEL	*Catch-Effort-Landing-Return (CELR)*. Used by trawl vessels less than 6 m in overall length and all non-trawl vessels other than squid-jig and tuna surface longline vessels to record catch-effort and landings data.
CLR	*Catch-Landing-Return (CLR)*. Used by fishing vessels larger than 28 m using bottom longline, surface longlining and where targeting species other than tunas, trotline, or bottom and midwater trawl fishing methods to record landings data.
LCE	*Line-Catch-Effort-Return (LCER).* Used by fishing vessels larger than 28 m in overall length and employing bottom longline, surface longlining and where targeting species other than tunas, and trot line fishing methods to record catch-effort, processing, and environmental data. Associated landings data are recorded on CLRs.
NCE	*Net-Catch-Effort-Landing-Return (NCELR)*. Used by fishing vessels larger than 6 m in overall length and employing setnet, inshore drift net, or pair set fishing methods to record catch-effort and landings data.
TCP	*Trawl-Catch-Effort-Processing-Return (TCEPR)*. Used by bottom and midwater trawl vessels greater than 28 m in overall length to record catch-effort, processing, and environmental data. Associated landings data are recorded on CLRs.
TUN	*Tuna-Longlining-Catch-Effort-Return (TLCER)*. Used by fishing vessels larger than 28 m in overall length surface longlining and targeting tunas to record catch-effort, processing, and environmental data. Associated landings data are recorded on CLRs.

Fishing method codes:

Code	Fishing method	Code	Fishing method	Code	Fishing method
BLL	Bottom longlining	DS	Danish seining	PS	Purse seining
BT	Bottom single trawling	FP	Fish trapping	RLP	Rock lobster potting
CP	Cod potting	HL	Hand lining	SN	Setnetting
DL	Drop or dahn lining	MW	Midwater single trawling		

Target species codes:

Code	Common name	Scientific name
BAR	Barracouta	*Thyrsites atun*
FLA	Flatfishes	*Colistum guntheri, C. nudipinnis, Peltorhamphus novaezelandiae, Rhombosolea flavilatus, R. leporina, R. plebeia, R. retiaria, R. topirina*
HOK	Hoki	*Macruronus novaezelandiae*
JMA	Jack mackerels	*Trachurus declivis, T. novaezelandiae, T. symmetricus murphyi*
LIN	Ling	*Genypterus blacodes*
RCO	Red cod	*Pseudophycis bachus*
SCH	School shark	*Galeorhinus australis*
SPD	Spiny dogfish	*Squalus acanthias*
SPO	Rig	*Mustelus lenticulatus*
SQU	Squids	*Nototodarus gouldi, N. sloanii*
STA	Giant stargazer	*Kathetostoma giganteum*
TAR	Tarakihi	*Nemadactylus macropterus*