A description and analysis of New Zealand's spiny dogfish (*Squalus acanthias*) fisheries and recommendations on appropriate methods to monitor the status of the stocks

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New Zealand Fisheries Assessment Report 2004/61
December 2004

Published by Ministry of Fisheries
Wellington
2004

ISSN 1175-1584

Citation:
Manning, M.J.; Hanchet, S.M.; Stevenson, M.L. (2004).
A description and analysis of New Zealand's spiny dogfish (*Squalus acanthias*) fisheries and recommendations on appropriate methods to monitor the status of the stocks.
New Zealand Fisheries Assessment Report 2004/61. 135 p.

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

EXECUTIVE SUMMARY

Manning, M.J.; Hanchet, S.M.; Stevenson, M.L. (2004). A description and analysis of New Zealand's spiny dogfish (*Squalus acanthias*) fisheries and recommendations on appropriate methods to monitor the status of the stocks.

***New Zealand Fisheries Assessment Report 2004/61.* 135 p.**

This report presents the results of a study of New Zealand's spiny dogfish (*Squalus acanthias*) fisheries funded by the Ministry of Fisheries under research project SPD2002-01 Objective 1 "Characterisation of spiny dogfish fisheries". The project's specific objective was to characterise New Zealand's spiny dogfish fisheries by analysis of existing catch and effort data and data from other sources and to make recommendations on appropriate methods to monitor the status of the major fishstocks. A characterisation of the commercial fisheries, standardised commercial catch-per-unit-effort (CPUE) indices, and the length composition of the commercial catch are presented. Trawl survey relative biomass estimates and scaled length-frequency distributions are also collated and presented and compared with the commercial CPUE indices. Recommendations on appropriate methods to monitor the status of the stocks in the major fisheries, including an assessment of current information needs, are made.

Spiny dogfish catch and effort and landings data spanning the 1989–90 to 2000–01 fishing years were extracted from the Ministry of Fisheries catch-effort and landings database and merged using a novel procedure. Analysis of the groomed unmerged and groomed and merged datasets led to the following conclusions being drawn on the composition of New Zealand's major spiny dogfish fisheries. Spiny dogfish is caught throughout the New Zealand Exclusive Economic Zone (NZ EEZ), both in and offshore and by foreign and domestic vessels in all QMAs, although the bulk of the catch is caught in southern waters (94%; SPD 3, 4, 5, 6, and 7) by the domestic fleet (78% by New Zealand vessels across all areas and fishing years). Catches from the northern QMAs (SPD 1, 9, and 10) are likely to include an unknown amount of misreported catches of the congeneric, northern spiny dogfish (*S. mitsukurii*). The total reported catch has increased steadily throughout the fishing years in the time series.

The composition of the catch varies markedly by QMA. The catch in each of the major southern QMAs, SPD 3, 4, 5, 6, and 7, may be characterised by a single or a small set of fisheries dominating the catch. The catch in SPD 3 is dominated by the target and bycatch setnet catch, although bycatch taken in the inshore mixed-species fishery for barracouta, flatfish, red cod, and other species is also important. The catch in SPD 4 is dominated by bycatch taken in the target ling bottom longline fishery, although bycatch taken in bottom trawl fisheries on the Chatham Rise contribute to a small extent. The catch in SPD 5 is dominated by bycatch taken in bottom and midwater trawl fisheries for jack mackerel and squid species by large foreign charter vessels (i.e., trawl vessels greater than 28 m in overall length and recording catch-effort data on Trawl Catch Effort Processing Returns); in no other QMA do foreign vessels contribute to the catch as greatly. The catch in SPD 6 is dominated by bycatch taken in the target ling bottom longline fishery. The catch in SPD 7 is dominated by bycatch taken in the bottom and midwater trawl fisheries for spawning hoki off the west coast of the South Island (statistical areas 034 and 035) and in Cook Strait (statistical areas 017 and 018) and the target setnet fishery in Tasman and Golden Bays. The inshore mixed-species fishery off the west coast of the South Island is a minor component of the catch in SPD 7. Trends in reporting types between the QMAs reflect the reporting regimes of those fisheries that dominate the catch in each QMA.

Discarded catches are an important component of the total catch. Discarded catches increased rapidly throughout the 1990s, from about 10–20% of the total catch in the early 1990s, to about 60% of the total catch throughout the late 1990s and beyond. The discarding rate appears reasonably stable over the last few fishing years in the time series. We suggest that rather than reflecting an actual increase in the amount of discarded catch, the trend in the discarding rate reflects a change in reporting practises, with fishers in the later years of the time series more accurately recording discarded catches of spiny

dogfish than in the past. A quantitative analysis of discarding rates and estimation of total removals from the stocks is an important topic of future research for spiny dogfish in New Zealand waters.

Generalised linear models were fitted to 10 stable catch and effort series identified in the groomed and merged dataset assuming normal errors, a log-link, and using a stepwise model selection procedure. These were: the target setnet catch by core vessels in SPD 3 (model 1), all setnet fishing by core vessels in SPD 3 (model 2), the bottom trawl catch by core vessels in SPD 3 (model 3), the bottom trawl catch by core Korean vessels on the Chatham Rise (SPD 3 and 4; model 4), the bottom trawl catch by all core vessels on the Chatham Rise (SPD 3 and 4; model 5), the bottom longline bycatch by core vessels on the Chatham Rise (SPD 3 and 4; model 6), the bottom trawl bycatch by core vessels in SPD 5 (model 7), the bottom longline bycatch by core vessels in SPD 6 (model 8), the bottom trawl bycatch by core vessels in SPD 7 excluding the Cook Strait (model 8), and the bottom trawl bycatch by core vessels in SPD 7 and 8 excluding the Cook Strait (model 9).

All models fitted the data moderately well, explaining between 21.8% (model 1) and 55% (model 4) of the deviance in the datasets they were fitted to. Canonical year effects were obtained from each of the models fitted. Of all the fitted models, only the setnet indices from the east coast of the South Island (models 1 and 2) showed any evidence of a decline. In contrast, the indices calculated for the Chatham Rise (models 4, 5, and 6), showed a large increase, although models 4 and 5 are very erratic over the first half of the time series due to a relative lack of data. The indices calculated for the Stewart-Snares shelf (model 7), sub-Antarctic (model 8), and west coast of the South Island (models 9 and 10) were all either erratic or showed no trend.

The usefulness of the commercial CPUE, commercial catch length composition data, trawl survey relative biomass estimates, and trawl survey catch length composition data for monitoring the major fisheries was evaluated. The proportion of the total catch represented, between-year fluctuations, precision, and consistency with trends from the different trawl survey series were considered. The major fisheries were defined as those fisheries accounting for more than 10% of the total catch, namely the east coast of the South Island (SPD 3), the Chatham Rise (SPD 4 and the eastern edge of SPD 3), the Stewart-Snares shelf (SPD 5), and the west coast of the South Island (SPD 7).

Following this analysis, we recommend that the east coast South Island fishery (SPD 3) should be monitored using the commercial setnet CPUE (model 2), and a quantitative stock assessment should be attempted once existing information needs have been met; we recommend that the Chatham Rise fishery (SPD 3 and 4) should be monitored using the Chatham Rise trawl survey and the length composition of the commercial catch; we recommend that the Stewart-Snares shelf fishery (SPD 5) should be monitored using the bottom-trawl CPUE and the size composition of the commercial catch; we recommend that the west coast South Island fishery (SPD 7) should be monitored using the west coast South Island inshore trawl survey and the size composition of the commercial catch.

We recommend that for each of the major fisheries, estimates of historical removals should be calculated and the potential effects of bias caused by the increase in reported discards on the CPUE indices presented in this paper, in particular those calculated for the east coast of the South Island and the Stewart-Snares shelf, should be evaluated. We also recommend that the frequency and intensity of catch-sampling of spiny dogfish by the Ministry of Fisheries Scientific Observer Programme be increased.

1. INTRODUCTION

Spiny dogfish (*Squalus acanthias*) are found throughout the southern half of the New Zealand Exclusive Economic Zone (EEZ) up to East Cape and Manukau Harbour on the east and west coasts of the North Island respectively. They are schooling, demersal carnivores, taking a wide variety of prey species. Although they have been reliably recorded from bottom-trawl catches in waters greater than 1000 m in depth in the New Zealand EEZ (Anderson et al. 1998), they seem to be most common in waters between 50 and 500 m in depth. A related species, the northern spiny dogfish (*S. mitsukurii*), is mainly restricted to North Island waters, overlapping with its congeneric in the central west coast area and around the Chatham Islands. Although the two species have different species codes for reporting purposes, some misidentification and misreporting may occur, particularly in Quota Management Areas (QMAs) SPD 1, 9, and 10. Current spiny dogfish QMAs are plotted in Figure 1.

The New Zealand spiny dogfish supports one of the largest inshore commercial fisheries in terms of tonnage landed. Best estimates of total annual landings for the fishing years 1980–81 to 1995–96 range from about 1800 to about 8100 t (Table 1). Total annual recorded landings have ranged from 6555 t to 10 433 t since the 1996–97 fishing year (Table 2). Actual catches and total removals from the stocks may be considerably higher.

Most spiny dogfish are taken as bycatch in the jack mackerel, barracouta, hoki, red cod, and arrow squid fisheries in depths from 100 to 500 m, but are also caught by inshore trawlers, setnetters, and longliners targeting flatfish, snapper, tarakihi, and gurnard. The highest catches have been recorded in QMAs SPD 3, 5, 6, and 7. Most of the catch in the early 1980s was taken by factory trawlers in SPD 5 and 6 (ca. 1000 to 2000 t per annum), but in recent years most of the catch has been taken in SPD 3 (ca. 3500 t per annum), and to a lesser extent SPD 7 (ca. 1400 t per annum), by factory trawlers and the inshore fleet equally. Since 1 October 1992, spiny dogfish in SPD 3, 5, and 6 have been managed by competitive quotas: 4075 t in SPD 3, 3600 t in SPD 5 & 6 combined, and a nominal catch limit of 10 t in SPD 10. Other than in SPD 3, in comparatively few fishing years have the catch limits in these areas been approached or exceeded. These catch limits are now considered obsolete.

Spiny dogfish were introduced into the QMS on 1 October 2004. Despite their catch history and cosmopolitan distribution in the New Zealand EEZ and extensive study overseas, particularly in the northern hemisphere, spiny dogfish in New Zealand waters have been little studied. Hanchet (1986, 1988) studied aspects of the distribution and abundance, reproductive biology, growth, and life-history characteristics of spiny dogfish off the east coast of the South Island. Regional catch histories were compiled, biological data reviewed, and biomass indices from trawl surveys tabulated by Hanchet & Ingerson (1997). A more comprehensive analysis of the New Zealand fisheries, incorporating data from the Ministry of Fisheries Scientific Observer Programme (MFish SOP) and catch-per-unit-effort (CPUE) analyses, was attempted by Walker et al. (1999), although they were unable to relate trends in CPUE to relative abundance of spiny dogfish.

This report presents the results of a study of spiny dogfish in New Zealand waters funded by the Ministry of Fisheries under research project SPD2002-01 Objective 1 "Characterisation of spiny dogfish fisheries". The specific objective of the project was to characterise New Zealand's spiny dogfish fisheries by analysis of existing commercial catch and effort data and data from other sources, and make recommendations on appropriate methods to monitor or assess the status of the major fishstocks. We present a characterisation of the spiny dogfish fisheries derived from a dataset linking fishing effort and landed catches recorded by the Ministry of Fisheries reporting regime using a novel procedure. The CPUE time series presented by Walker et al. (1999) are recomputed and updated. Abundance indices and estimated scaled length frequency distributions for recent trawl surveys are presented and summarised. Estimated scaled length-frequency distributions for the commercial catch calculated by Phillips (2004) from data collected by the MFish SOP since the 1996–97 fishing year are summarised. Recommendations on appropriate methods to monitor the status of the stocks and current information needs to assess the major fisheries are presented.

After a description of our methods (Section 2), we present each of the major topics we cover (fisheries characterisation, CPUE analyses, commercial catch length composition, trawl survey relative biomass, and length-frequency distributions; Sections 3–6) as a separate section within our report, where each set of results is presented and first discussed. We then attempt to draw these sections together by making recommendations for the future monitoring of the stocks (Section 7), and assessing existing information needs which must be met in order to carry out a quantitative assessment of the stocks (Section 8). We end by summarising our conclusions and recommendations (Section 9). All fishing methods, form types, species, and vessel flag nationality codes used in tables and figures are defined in Appendix A.

Table 1: Best estimates of total annual landings (t) of spiny dogfish by fishing year, 1980–81 to 1995–96 from Annala et al. (2003). Annual landings data are from Fisheries Statistics Unit (FSU) and Licensed Fish Receiver Returns (LFRRs); discards are reported from Catch Effort Landing Returns (CELRs) and Catch Landing Returns (CLRs). Numbers in parantheses are probably underestimates.

	FSU				Best
Fishing year	Inshore	Deepwater	LFRR	Discards	estimate
1980–81	–	(196)	–	–	196
1981–82	–	1 881	–	–	1 881
1982–83	(107)	2 568	–	–	2 675
1983–84	309	2 949	–	–	3 258
1984–85	303	3 266	–	–	3 569
1985–86	311	2 802	–	–	3 113
1986–87	870	2 277	2 608	–	3 147
1987–88	834	3 877	4 823	–	4 823
1988–89	(351)	(500)	3 573	(16)	3 589
1989–90	(14)	(0)	2 952	321	3 273
1990–91	–	–	5 983	333	6 316
1991–92	–	–	3 274	521	3 795
1992–93	–	–	4 157	616	4 773
1993–94	–	–	6 150	1 063	7 213
1994–95	–	–	4 793	628	5 421
1995–96	–	–	6 230	1 920	8 150

Table 2: Reported landings (t) of spiny dogfish by QMA and fishing year, 1996–97 to 2001–02 from Annala et al. (2003). The data are the sum of the LFRR returns and discards recorded on CELR and CLR returns. Caches of spiny dogfish by QMA are not available before the 1996–97 fishing year.

												QMA
Fishing year	1	2	3	4	5	6	7	8	9	10	Other	Total
1996–97	30	159	2 428	1 287	764	120	1 517	235	7	1	1	6 555
1997–98	52	165	5 042	917	428	223	2 389	1 172	34	0	11	10 433
1998–99	45	488	3 148	1 048	1 996	154	1 902	74	<1	0	<1	8 424
1999–00	15	328	3 309	994	1 163	189	1 505	25	7	0	5	7 540
2000–01	38	336	4 355	1 075	1 389	212	1 310	54	16	0	28	8 811
2001–02	11	221	4 247	1 788	3 734	487	960	70	12	0	–	11 530

(A) SPD QMAs

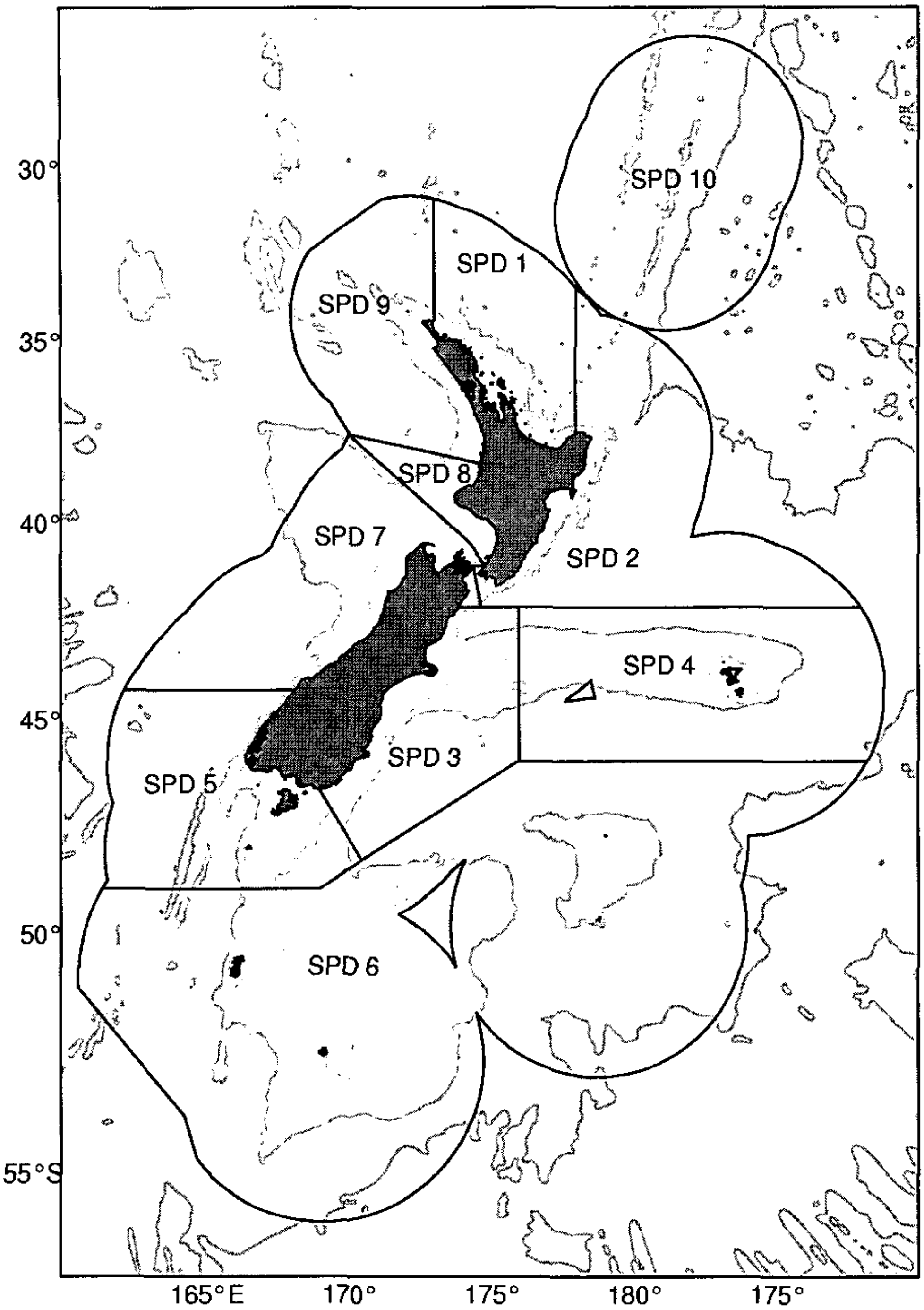

Figure 1: Maps of the New Zealand EEZ showing (A) the boundaries of current spiny dogfish QMAs and (B) New Zealand fisheries statistical areas. Insets showing the statistical areas in the Auckland and Cook Strait regions are also provided in (B). The 200 m, 1000 m, and 5000 m isobaths are overlaid in grey on both (A) and (B). Note the overlap between QMAs of certain statistical areas (e.g., statistical area 032 overlaps QMAs SPD5 and 7).

(B) New Zealand fisheries statistical areas

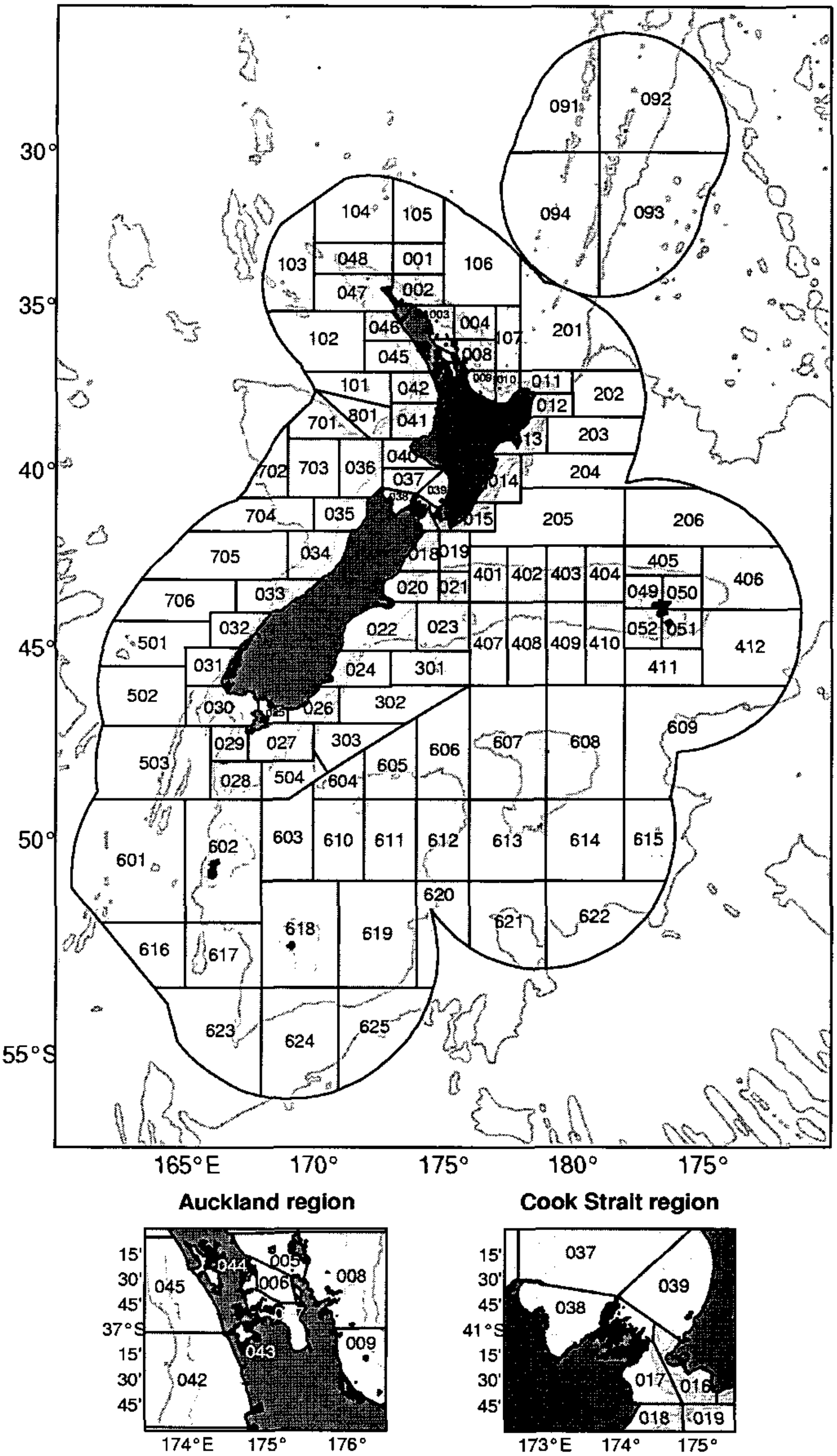

Figure 1: (continued)

2. METHODS

2.1 References to fishing and calendar years

The fishing year extends from 1 October in any calendar year to 30 September in the following calendar year (e.g., the 1996–97 fishing year = 1 October 1996 to 30 September 1997). Where fishing years are given as single numbers rather than as a range (e.g., in figure labels), the number given refers to the largest calendar year component in the fishing year; e.g., 97 = the 1996–97 fishing year. References to calendar years rather than fishing years are stated explicitly (e.g., "... the 1996 calendar year...").

2.2 The fisheries characterisation and CPUE dataset

Spiny dogfish catch-effort and landings data were extracted from the Ministry of Fisheries (MFish) catch-effort and landings database *warehou* (Duckworth 2002). All trips that reported landings of spiny dogfish from 1 October 1989 to 30 September 2001 and all associated fishing events for these trips were extracted (MFish catch-effort reports 4986 and 5026), including 72 767 landing event records and 389 071 fishing event records. A total of 62 226 unique trip keys were present in the landing event extract, and of these, 61 943 unique trip keys were also present in the fishing event extract. The discrepancy between the numbers of unique trip keys in the landings and fishing events extracts is due to a misapplication of trip keys within the database (K. Duckworth, pers. comm.); landing events with no corresponding effort data were dumped. The landings and fishing events records extracted included data recorded on Catch Effort Landing Returns (CELRs), Trawl Catch Effort Processing Returns (TCEPRs), and Catch Landing Returns (CLRs). Vessel registration data for each vessel within the sets of extracted catch-effort and landings records were obtained and matched with each record using anonymous vessel key numbers allocated by MFish. The landings data were then allocated to the effort data using a novel merging procedure devised by Starr (2003).

2.3 Overview of Starr's procedure

Starr's (2003) procedure is designed to facilitate analysis of MFish catch-effort data collected using CELRs. The procedure is designed to overcome the main limitation of the CELR system, which is that fishers are required to report only the top five species in their catches, resulting in the frequent non-reporting of species which make up only a minor component of the catch. A further benefit of the procedure is that it allows catch-effort and landings data collected using different form types, i.e. CELRs, TCEPRs, and CLRs, to be combined for a single fishstock. Given that spiny dogfish are taken mainly as bycatch in New Zealand waters, and that the dataset extracted from *warehou* includes fishing and landing events recorded on CELRs, TCEPRs, and CLRs, it was anticipated that the procedure would allow the maximum amount of information to be extracted from the dataset while avoiding the limitations and likely biases imposed by studying bycatch catch-effort data recorded on multiple form types. We believe that Paul & Sanders (2001) were the first to investigate merging catch-effort and landings data; however their approach was implemented manually, unlike Starr's (2003), which is algorithmic and can be therefore implemented as a computer program.

Starr's (2003) procedure links the valid landings from a given valid fishing trip with the corresponding valid fishing effort for that trip. The basic unit of data within the procedure is the fishing trip and the major steps in the procedure are as follows.

- The fishing effort and landings data are first groomed separately. Outlier values failing range checks are corrected using median imputation.
- The fishing effort within each valid trip are then restratified by statistical area, method, and target species.

- 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.

- 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 of spiny dogfish 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 step-by-step summary of the procedure followed in this analysis is given in Appendix B. The data were stored in a custom-built Microsoft Access database before analysis and the procedure was implemented using SQL statements and the "R" statistical programming language (R Development Core Team 2003). A comparison of the groomed merged and unmerged landed catch, and a "recovery rate", defined as the percentage of the groomed unmerged landed catch retained in the merged landings and effort dataset, is presented in Table 3. The descriptive and catch-per-unit-effort analyses described below were performed on subsets of the groomed and merged dataset.

2.4 Commercial catch-per-unit-effort analyses

2.4.1 Catch-per-unit-effort datasets

Walker et al. (1999) identified two catch and effort series in their data that were reasonably data-rich, consistent in time and space, and where the rate of discarded catch was relatively low. These were the setnet target fishery for spiny dogfish off the east coast of the South Island and the bottom-trawl bycatch fishery for spiny dogfish on the Chatham Rise by Korean charter vessels. Walker et al. (1999) were unable to relate trends in CPUE in either of these fisheries to spiny dogfish abundance, however.

In this study, we recomputed the CPUE analyses presented by Walker et al. (1999), using the groomed and merged landings and effort dataset described above and revised definitions of catch-per-unit-effort. Furthermore, following our descriptive analysis of the groomed and merged landings and effort dataset, we identified eight additional catch and effort series that seemed reasonably consistent in time and space and fitted CPUE models to these data. The datasets analysed by associated QMA were:

Model	*Dataset*	*QMA(s)*	*Where identified*
1	Target setnet fishery off the east coast of the South Island	SPD 3	Walker et al. (1999)
2	Bycatch setnet fishery off the east coast of the South Island	SPD 3	This study
3	Bycatch bottom-trawl fishery off the east coast of the South Island	SPD 3	This study
4	Bycatch bottom-trawl fishery on the Chatham Rise by Korean vessels	SPD 3 & 4	Walker et al. (1999)
5	Bycatch bottom-trawl fishery on the Chatham Rise (all vessels)	SPD 3 & 4	This study

Model	*Dataset*	*QMA(s)*	*Where identified*
6	Bycatch bottom-longline fishery on the Chatham Rise	SPD 3 & 4	This study
7	Bycatch bottom-trawl fishery on the Stewart-Snares shelf	SPD 5	This study
8	Bycatch bottom-longline fishery on the sub-Antarctic plateaus	SPD 6	This study
9	Bycatch bottom-trawl fishery off the west coast of the South Island	SPD 7	This study
10	Bycatch bottom-trawl fishery off the west coasts of the North and South Islands	SPD 7 & 8	This study

Note that all models were fitted to core-vessel subsets of these datasets. Core vessels were defined as vessels with a presence in the fisheries of some minimum number of years. No threshold was placed on fishing activity for those years that vessels were active in the fisheries. Descriptions of the models fitted, including the definitions of CPUE and core vessels and any restrictions placed on statistical areas when defining the data subsets, are given in Table 4.

2.4.2 Model structures

Estimates of relative year effects in each CPUE model were obtained from a stepwise multiple regression method in which the data were modelled using a lognormal generalised linear model following Dunn (2002). A forward stepwise multiple-regression fitting algorithm (Chambers & Hastie 1991) implemented in the "R" statistical programming language (R Development Core Team 2003) was used to fit all models. The algorithm generates a final regression model iteratively and used the *fishing year* term as the initial or base model in all cases. The reduction in residual deviance relative to the null deviance, R^2, is calculated for each single 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 would result in an improvement in the residual deviance of more than 1%. The algorithm then repeats this process, updating the model, 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. Alternative stopping rules or error structures were not investigated.

All models were fitted to a dataset consisting of all non-zero effort strata by a subset of "core" vessels in each fishery. Core vessels were defined as vessels active in each fishery for at least three (models 1–2, and 4–8) or five years (models 3, and 9–10) or more over the 1989–90 to 2000–01 fishing year time series; the definition of core vessels for each model is given in Table 4.

Following Dunn (2002), all model indices are presented in a canonical form. Model fits were 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 were produced to check for departures from the regression assumptions of homoscedasticity and normality of errors in log-space (i.e., log-normal errors). A plot of the expected log catch rate for each variable in the final model holding all other variables fixed at median values was also produced.

Table 3: Comparison of merged and unmerged groomed landed catches by QMA and fishing year. A "recovery rate", the merged groomed landed catch as a percentage of the unmerged groomed landed catch, is provided.

(A) Groomed unmerged catches (t) by QMA and fishing year

											QMA	
Fishing year	1	2	3	4	5	6	7	8	9	10	Other	Total
1989–90	28	12	1 208	56	97	< 1	326	40	0	0	74	1 840
1990–91	74	11	1 881	213	286	7	706	32	0	2	0	3 212
1991–92	39	20	1 486	39	202	24	741	172	0	1	0	2 724
1992–93	45	7	1 385	63	360	7	829	248	0	1	2	2 947
1993–94	48	33	2 214	275	299	7	1 571	182	0	< 1	29	4 657
1994–95	72	41	1 686	244	220	26	839	119	< 1	0	5	3 252
1995–96	67	173	2 078	621	416	152	1 462	161	14	0	20	5 165
1996–97	29	158	2 329	1 156	456	118	1 503	143	7	1	15	5 915
1997–98	51	145	2 286	814	408	220	1 124	273	34	0	16	5 372
1998–99	45	489	3 042	1 103	2 068	152	1 752	74	< 1	0	8	8 733
1999–00	15	326	3 343	926	1 241	191	1 509	25	7	0	1	7 585
2000–01	38	337	4 379	1 149	1 391	214	1 321	54	17	0	26	8 927
Total	551	1 752	27 317	6 658	7 444	1 118	13 682	1 525	80	5	196	60 328

(B) Groomed and merged catches (t) by QMA and fishing year

											QMA	
Fishing year	1	2	3	4	5	6	7	8	9	10	Other	Total
1989–90	18	10	999	45	66	< 1	272	25	0	0	0	1 435
1990–91	52	7	1 553	146	222	7	682	14	0	1	0	2 682
1991–92	34	14	1 322	26	142	24	649	113	0	1	0	2 326
1992–93	34	6	1 270	58	159	7	761	180	0	1	0	2 477
1993–94	37	32	1 898	268	140	3	1 466	86	0	0	0	3 930
1994–95	61	40	1 588	236	101	25	717	40	< 1	0	0	2 808
1995–96	51	126	1 830	513	179	150	1 181	59	< 1	0	0	4 089
1996–97	21	100	2 020	1 074	245	112	1 227	34	< 1	0	0	4 832
1997–98	35	128	2 057	729	233	150	949	52	< 1	0	0	4 332
1998–99	31	436	2 364	971	801	122	1 635	21	< 1	0	0	6 381
1999–00	10	292	2 600	730	393	113	1 369	21	6	0	0	5 533
2000–01	11	277	3 500	941	570	152	1 213	35	16	0	0	6 715
Total	394	1 467	23 001	5 736	3 250	867	12 121	680	23	2	0	47 540

(C) "Recovery rate" (%) by QMA and fishing year

											QMA	
Fishing year	1	2	3	4	5	6	7	8	9	10	Other	Total
1989–90	65	82	83	80	69	100	83	63	0	0	0	78
1990–91	69	60	83	69	78	100	97	42	0	27	0	84
1991–92	88	72	89	67	70	100	88	66	0	57	0	85
1992–93	75	84	92	93	44	100	92	72	0	89	0	84
1993–94	77	98	86	98	47	51	93	47	0	0	0	84
1994–95	84	98	94	97	46	94	86	34	100	0	0	86
1995–96	76	73	88	83	43	99	81	37	< 1	0	0	79
1996–97	74	63	87	93	54	95	82	24	4	0	0	82
1997–98	67	89	90	90	57	68	84	19	< 1	0	0	81
1998–99	70	89	78	88	39	81	93	28	100	0	0	73
1999–00	65	90	78	79	32	59	91	82	78	0	0	73
2000–01	29	82	80	82	41	71	92	65	98	0	0	75
Total	72	84	84	86	44	78	89	45	28	39	0	79

Table 4: **Descriptions of catch-per-unit-effort models fitted to subsets of the groomed and merged dataset. The corresponding QMA(s), a description of the data subset, the definitions of core vessels and catch-per-unit-effort, and any restrictions placed on statistical areas are given for each model. See Appendix B for a description of how catches in statistical areas overlapping adjacent QMAs were handled during data grooming and merging.**

Model	QMA(s)	Data subset	Definition of core vessels [1]	Definition of catch-per-unit-effort	Statistical areas
1	SPD 3	All non-zero target setnet effort strata by core vessels	3 years	Catch per 1000 m net set per effort stratum ($kg.1000\ m^{-1}$)	018, 019, 020, 021, 022, 023, 024, 025, 026, 027
2	SPD 3	All non-zero setnet effort strata (all target species) by core vessels	3 years	Catch per 1000 m net set per effort stratum ($kg.1000\ m^{-1}$)	018, 019, 020, 021, 022, 023, 024, 025, 026, 027
3	SPD 3	All non-zero bottom-trawl effort strata by core vessels in inshore statistical areas	5 years	Catch per hour fished per effort stratum ($kg.hour^{-1}$)	018, 020, 022, 024
4	SPD 3 & 4	All non-zero bottom-trawl effort strata by core Korean vessels on the Chatham Rise	3 years	Catch per hour fished per effort stratum ($kg.hour^{-1}$)	019, 021, 023, 049, 050, 051, 052, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412
5	SPD 3 & 4	All non-zero bottom-trawl effort strata by all core vessels on the Chatham Rise	3 years	Catch per hour fished per effort stratum ($kg.hour^{-1}$)	019, 021, 023, 049, 050, 051, 052, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412
6	SPD 3 & 4	All non-zero bottom-longline effort strata by core vessels on the Chatham Rise	3 years	Catch per 1000 hooks set per effort stratum ($kg.1000\ hooks^{-1}$)	019, 021, 023, 049, 050, 051, 052, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412
7	SPD 5	All non-zero bottom-trawl effort strata by core vessels	3 years	Catch per hour fished per effort stratum ($kg.hour^{-1}$)	All statistical areas in SPD 5
8	SPD 6	All non-zero bottom-longline effort strata by core vessels	3 years	Catch per 1000 hooks set per effort stratum ($kg.1000\ hooks^{-1}$)	All statistical areas in SPD 6
9	SPD 7	All non-zero bottom-trawl effort strata by core vessels excluding Cook Strait	5 years	Catch per hour fished per effort stratum ($kg.hour^{-1}$)	032, 033, 034, 035, 036, 037, 038, 039, 040, 702, 703, 704, 705, 706
10	SPD 7 & 8	All non-zero bottom-trawl effort strata by core vessels excluding Cook Strait	5 years	Catch per hour fished per effort stratum ($kg.hour^{-1}$)	032, 033, 034, 035, 036, 037, 038, 039, 040, 041, 702, 703, 704, 705, 706, 801

[1] Vessels active in the fishery for *x* years or more

2.4.3 Description of the variables offered to each model

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 the variables are given in Table 5. Note that all continuous predictor variables were offered to the models as third-order polynomial functions. Note also that all models other than models 6 and 8 were fitted to the complete time series of data in each data subset; i.e., all data in fishing years 1989–90 to 2000–01 (12 years in variable *fishing year*). Due to insufficient data in the first two years of the time series, models 6 and 8 were fitted to the latter 10 years of data in their respective data subsets; i.e., all data in fishing years 1991–92 to 2000–01 (10 levels in variable *fishing year*). All variables offered to the models were groomed during the data merging procedure using range checks to identify outliers and median imputation to replace missing or outlier values. This process is described in full in Appendix B.

2.5 The length composition of the commercial catch

Spiny dogfish length frequency data collected from commercial catches sampled between 1 October 1996 and 30 September 2001 by the Ministry of Fisheries Scientific Observer Programme (MFish SOP) were extracted from Ministry of Fisheries database *obs_lfs* (Sanders & Mackay 1999). Since 1 October 1996, MFish scientific observers have been requested to collect length-frequency samples of up to 100 fish per sex per tow or set for up to 10 tows or sets per trip when present on fishing trips where spiny dogfish are caught (see Sutton 2002). Tree-based regression methods were used by Phillips (2004) to post-stratify the observer-collected length-frequency data before calculating scaled length-frequency distributions. Phillips (2004) also analysed the extent and representativeness of the observer sampling effort and compared the length-frequency distributions to those presented for selected trawl surveys of the New Zealand EEZ. We summarise his results and conclusions in Section 5.

2.6 Trawl survey relative biomass estimates and scaled length-frequency distributions for spiny dogfish

Spiny dogfish relative biomass and scaled length-frequency distributions computed from data gathered during RV *Kaharoa* and RV *Tangaroa* research trawl surveys of the New Zealand EEZ during the calendar years 1990 to 2003 were collated (Table 6). Data from 51 trawl surveys from 9 separate trawl survey series were identified: the east coast North Island series (4 surveys; RV *Kaharoa*), the summer east coast South Island series (5 surveys; RV *Kaharoa*), the winter east coast South Island series (5 surveys; RV *Kaharoa*), the Chatham Rise series (12 surveys; RV *Tangaroa*), the Stewart Island–Snares shelf series (4 surveys; RV *Tangaroa*), the spring sub-Antarctic series (7 surveys; RV *Tangaroa*), the autumn sub-Antarctic series (4 surveys; RV *Tangaroa*), the west coast South Island series (6 surveys; RV *Kaharoa*), and the west coast North Island series (4 surveys; RV *Kaharoa*).

All trawl surveys followed the same general survey design: a two-stage, stratified, randomised trawl survey design following Francis (1989). Readers interested in particular survey designs (e.g., gear descriptions, stratum definitions, other data collected, etc.) are referred to the references given in Table 6. If length-frequency data were collected during a given trawl survey but scaled length-frequency distributions were not presented in the corresponding reference, scaled length-frequency distributions were computed using the "TrawlSurvey" analysis program (Vignaux 1994) and the same set of available trawl station data and stratum definitions as those specified in the corresponding reference. Note that the relative biomass estimates for the west coast North Island series were recomputed using all available trawl strata, as not all trawl survey strata were used in the original analysis presented for these results.

Table 5: Types and descriptions of the variables offered to the CPUE models. The number of levels in each categorical variable in each data subset are given in parentheses. Note that all continuous variables other than CPUE were offered to the models as third-order polynomial functions. This is indicated by "P, 3" in parentheses. Note also that all models other than models 6 and 8 were fitted to the complete time series of data in each data subset (i.e., fishing years 1989–90 to 2000–01 inclusive). Due to insufficient data, models 6 and 8 were fitted to the latter 10 years of data (i.e., fishing years 1991–92 to 2000–01 inclusive).

			Offered to model:									
Variable	Type	Description	1	2	3	4	5	6	7	8	9	10
CPUE	Continuous	Catch-per-unit-effort (see Table 4 for definitions). Note that all models were fitted to ln(CPUE); i.e., log-normal errors were assumed in all models.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fishing year	Categorical	Calculated from the landing date for each fishing trip and assigned to each effort stratum during the data grooming and merging procedure.	Yes (12)	Yes (12)	Yes (12)	Yes (12)	Yes (12)	Yes (10)	Yes (12)	Yes (10)	Yes (12)	Yes (12)
Statistical area	Categorical	Inshore and offshore statistical areas in each data subset (see Table 4 for restrictions placed on statistical areas in each model dataset).	Yes (8)	Yes (10)	Yes (4)	Yes (12)	Yes (18)	Yes (17)	Yes (9)	Yes (16)	Yes (14)	Yes (16)
Month	Categorical	Calendar month at the start date of the first fishing event included in each effort stratum.	Yes (12)	Yes (12)	Yes (12)	Yes (11)	Yes (12)	Yes (12)	Yes (12)	Yes (12)	Yes (12)	Yes (12)
Target species	Categorical	Recorded target species per effort stratum.	No (–)	Yes (42)	Yes (49)	Yes (12)	Yes (19)	Yes (8)	Yes (27)	No (–)	Yes (34)	Yes (34)
Vessel key	Categorical	Unique vessel number per effort stratum.	Yes (27)	Yes (62)	Yes (84)	Yes (11)	Yes (36)	Yes (10)	Yes (33)	Yes (6)	Yes (60)	Yes (62)
Fishing duration	Continuous	Total fishing time per effort stratum in hours.	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)
Effort number	Continuous	Total number of fishing events per effort stratum. Not defined for models 1 and 2, equal to the total number of lines set per stratum for models 6 and 8, and equal to the total number of tows per stratum for models 3–5, 7, and 9–10.	No (–)	No (–)	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)	Yes (P,3)

Table 6: Trawl survey relative biomass estimates for spiny dogfish for all RV *Kaharoa* and RV *Tangaroa* trawl surveys carried out during the calendar years 1991 to 2003. Vessel: KAH, RV *Kaharoa*; TAN, RV *Tangaroa*. Whether spiny dogfish length-frequency data were collected during each survey is noted: Y, yes; N, no.

QMA	Area	Vessel	Trip code	Date	Fishing year	Biomass (t)	c.v. (%)	LF data	Reference
SPD 2	East coast North Island [1]	KAH	KAH9304	Feb–Mar 1993	1992-93	963	78	N	Kirk & Stevenson (1996)
			KAH9402	Feb–Mar 1994	1992-94	988	47	N	Stevenson & Kirk (1996)
			KAH9502	Feb–Mar 1995	1994-95	658	25	N	Stevenson (1996a)
			KAH9602	Feb–Mar 1996	1995-96	1 026	51	N	Stevenson (1996b)
SPD 3	East coast South Island (*Winter*) [2]	KAH	KAH9105	May–Jun 1991	1990-91	12 873	22	N	Beentjes & Wass (1994)
			KAH9205	May–Jun 1992	1991-92	10 787	26	Y	Beentjes (1995a)
			KAH9306	May–Jun 1993	1992-93	13 949	17	Y	Beentjes (1995b)
			KAH9406	May–Jun 1994	1993-94	14 530	10	Y	Beentjes (1998a)
			KAH9606	May–Jun 1996	1995-96	35 169	15	Y	Beentjes (1998b)
	East coast South Island (*Summer*) [2]	KAH	KAH9618	Dec–Jan 1996–97	1996-97	35 776	28	Y	Stevenson (1997)
			KAH9704	Dec–Jan 1997–98	1997-98	29 765	25	Y	Stevenson & Hurst (1998)
			KAH9809	Dec–Jan 1998–99	1998-99	22 842	16	Y	Stevenson & Beentjes (1999)
			KAH9917	Dec–Jan 1999–00	1999-00	49 832	37	Y	Stevenson & Beentjes (2001)
			KAH0014	Dec–Jan 2000–01	2000–01	30 508	34	Y	Stevenson & Beentjes (2002)
SPD 4	Chatham Rise [3]	TAN	TAN9106	Dec–Feb 1991–92	1991–92	2 390	14	N	Horn (1994a)
			TAN9212	Dec–Feb 1992–93	1992–93	2 220	11	Y	Horn (1994b)
			TAN9401	Jan–Feb 1994	1993–94	3 449	13	Y	Schofield & Horn (1994)
			TAN9501	Jan–Feb 1995	1994–95	2 841	21	Y	Schofield & Livingston (1995)
			TAN9601	Dec–Jan 1995–96	1995–96	4 969	11	Y	Schofield & Livingston (1996)
			TAN9701	Jan 1997	1996–97	9 570	14	Y	Schofield & Livingston (1997)
			TAN9801	Jan 1998	1997–98	5 724	17	Y	Bagley & Hurst (1998)
			TAN9901	Jan 1999	1998–99	8 551	13	Y	Bagley & Livingston (2000)
			TAN0001	Dec–Jan 1999–00	1999–00	8 905	9	Y	Stevens et al. (2001)
			TAN0101	Dec–Jan 2000–01	2000–01	9 586	9	Y	Stevens et al. (2002)
			TAN0201	Dec–Jan 2001–02	2001–02	6 334	8	Y	Stevens & Livingston (2003)
			TAN0301	Dec–Jan 2002–03	2002–03	6 191	17	Y	Livingston et al. (2004)

[1] The east coast North Island series was reviewed by Stevenson & Hanchet (2000a)
[2] The winter series was reviewed by Beentjes & Stevenson (2000) and the summer series by Beentjes & Stevenson (2001)
[3] The Chatham Rise series was reviewed by Livingston et al. (2002)

Table 6: (continued)

QMA	Area	Vessel	Trip code	Date	Fishing year	Biomass (t)	c.v. (%)	LF data	Reference
SPD 5	Stewart-Snares shelf [1]	TAN	TAN9301	Feb–Mar 1993	1992–93	36 023	13	Y	Hurst & Bagley (1994)
			TAN9402	Feb–Mar 1994	1993–94	36 328	17	Y	Bagley & Hurst (1995)
			TAN9502	Feb–Mar 1995	1994–95	91 364	29	Y	Bagley & Hurst (1996a)
			TAN9604	Feb–Mar 1996	1995–96	89 818	29	Y	Bagley & Hurst (1996b)
SPD 6	Sub-Antarctic (*Spring*) [2]	TAN	TAN9105	Nov–Dec 1991	1991–92	8 502	55	Y	Chatterton & Hanchet (1994)
			TAN9211	Nov–Dec 1992	1992–93	1 150	15	Y	Ingerson et al. (1995)
			TAN9310	Nov–Dec 1993	1993–94	1 585	21	Y	Ingerson & Hanchet (1995)
			TAN0012	Nov–Dec 2000	2000–01	4 173	12	Y	O'Driscoll et al. (2002)
			TAN0118	Nov–Dec 2001	2001–02	8 528	31	Y	O'Driscoll & Bagley (2003a)
			TAN0219	Nov–Dec 2002	2002–03	3 505	19	Y	O'Driscoll & Bagley (2003b)
			TAN0317	Nov–Dec 2003	2003–04	2 317	17	Y	O'Driscoll & Bagley (2004)
SPD 6	Sub-Antarctic (*Autumn*) [2]	TAN	TAN9204	Apr–May 1992	1991–92	0 926	30	N	Schofield & Livingston (1994a)
			TAN9304	May–Jun 1993	1992–93	0 440	38	N	Schofield & Livingston (1994b)
			TAN9605	Mar–Apr 1996	1995–96	0 207	56	N	Colman (1996)
			TAN9805	Apr–May 1998	1997–98	1 532	36	N	Bagley & McMillan (1999)
SPD 7	West coast South Island [3]	KAH	KAH9204	Mar–Apr 1992	1991–92	3 919	15	N	Drummond & Stevenson (1995a)
			KAH9404	Mar–Apr 1994	1993–94	7 145	7	N	Drummond & Stevenson (1995b)
			KAH9504	Mar–Apr 1995	1994–95	8 370	10	N	Drummond & Stevenson (1996)
			KAH9701	Mar–Apr 1997	1996–97	5 275	13	Y	Stevenson (1998)
			KAH0004	Mar–Apr 2000	1999–00	4 777	12	Y	Stevenson (2002)
			KAH0304	Mar–Apr 2003	2002–03	4 446	15	Y	Stevenson (2004)
SPD 9	West coast North Island [4]	KAH	KAH9111	Oct 1991	1991–92	443*	34	N	Drury & Hartill (1993)
			KAH9410	Oct 1994	1994–95	381*	30	N	Langley (1995)
			KAH9615	Oct 1996	1996–97	634*	68	N	Morrison (1998)
			KAH9915	Nov 1999	1999–00	106*	15	N	Morrison & Parkinson (2001)

[1] The Stewart-Snares shelf series was reviewed by Hurst & Bagley (1997)
[2] The spring and autumn sub-Antarctic series were reviewed by O' Driscoll & Bagley (2001)
[3] The west coast South Island series was reviewed by Stevenson & Hanchet (2000b)
[4] The west coast North Island series was reviewed by Morrison et al. (2001)
* Values differ from Morrison et al. (2001) as all strata in SPD 9 were used to calculate relative biomass for this analysis.

3. CHARACTERISATION OF THE FISHERIES

Descriptions of New Zealand's spiny dogfish fisheries based on analysis of the groomed merged and unmerged datasets are given below. An overview is provided for all QMAs and separate descriptions for each of QMAs SPD 3, 4, 5, 6, and 7. We begin by comparing the unmerged and merged datasets.

3.1 Comparing the groomed unmerged and merged datasets

As noted above, the total groomed unmerged catch, the total groomed merged catch, and a recovery rate by QMA and fishing year are presented in Table 3. The recovery rate is 79% across all fishing years and QMAs, ranges from 73% (1999–2000) to 86% (1994–95) across all fishing years in the time series, but ranges from 28% (SPD 9) to 89% (SPD 7) across the QMAs. Catches in the "Other" QMA category (i.e., landings from outside the NZ EEZ or where no QMA was recorded), were dropped entirely during the data grooming and merging procedure.

The variable recovery rate across QMAs for all fishing years is a function of the algorithm employed to deal with catches in statistical areas straddling adjacent QMAs in the merging procedure (see Appendix B). Fishing trips with effort recorded in straddling statistical areas where only one of the adjacent fishstocks was recorded in the corresponding landing record were retained in the analysis. Fishing trips where more than one fishstock was recorded were dropped. QMAs such as SPD 5 containing a large number of statistical areas which straddle adjacent fishstocks thus yielded a poor recovery of the catch in the merged dataset.

Given that the merged dataset contains a groomed subset of the available landed catch, we concentrate on relative trends in catch between groups in this dataset, extrapolating to the fisheries at large. We follow Annala et al. (2003) and define the total catch, i.e., the total removals from the stocks, as the sum of the undiscarded and discarded landed catch. We also follow Annala et al. (2003) and make the simplifying assumption that all discarded fish are returned to the water dead, although no data are available to test this hypothesis.

3.2 Overview

We describe current best estimates of the total catch and present revised best estimates of the total catch for the fishing years 1989–90 to 2000–01. We describe how spiny dogfish catches are recorded, overall trends in reporting rates, and overall trends in the composition of the catch.

3.2.1 Current and revised best estimates of the total catch

The current best estimates of the total catch for the fishing years 1980–81 to 2001–02 given by Annala et al. (2003) are plotted in Figure 2. The best estimates for the fishing years 1980–81 to 1986–87 are the sum of the FSU data for each fishing year (see Table 1). The best estimates for the fishing years 1987–88 to 2001–02 are the sum of the LFRR records and recorded discards on CELR and CLR forms for each fishing year (see Table 2). However, grooming the landings data revealed a number of CELR and CLR landings records that were highly implausible, artificially inflating the recorded catch in some fishing years substantially. These records were revised during grooming and we present the total groomed, unmerged landed catches for the fishing years 1989–90 to 2000–01 as revised best estimates for these fishing years (Figure 3).

Catches by fishing year and QMA in both the unmerged and merged datasets are compared in Table 7. In both datasets, catches in the southern QMAs (SPD 3, 4, 5, 6, and 7) dominate, accounting for 93% of the total catch by weight in the unmerged dataset and 94% of the catch by weight in the merged dataset across all the fishing years in the time series. SPD 3 alone accounts for nearly half of the catch (45% of the total catch in the unmerged dataset and 48% of the total catch in the merged dataset), followed by SPD 7 (23% of the total catch in the unmerged dataset and 25% of the total catch in the merged dataset) and SPD 4 (11% of the total catch in the unmerged dataset and 12% of the total catch in the merged dataset). Catches in the northern QMAs, SPD 1, 2, 8, 9, and 10, are negligible. Differences in percentages of catch by fishing year and QMA between the datasets are due to variable recovery rates between fishing years and QMAs as described below. These differences are generally small and we assume that there is no bias between the datasets.

The range of spiny dogfish in New Zealand waters is known to extend as far north as the Manukau Harbour and East Cape on the east and west coasts of the South Island (SPD 1 and 9). Although spiny dogfish have been reliably recorded from trawl surveys in these waters (e.g., Stevenson & Hanchet 2000a, Morrison & Parkinson 2001), biomass estimates are generally imprecise and erratic (Section 6). Nevertheless, as the biomass estimates produced are generally low compared to roughly comparable trawl surveys of more southern waters in the New Zealand EEZ, the areas surveyed probably represent the northern edge of their range, although this is not well defined. Although this is untested, catches from the northern QMAs, in particular SPD 1, 9, and 10, may be in part misreportings of catches of the congeneric, *Squalus mitsukurii*.

Table 7: Comparison of catches by fishing year and QMA for all data in (A) the groomed unmerged dataset and (B) the groomed and merged dataset. Catches by QMA and fishing year are given as a percentage of the total catch for each fishing year. Catches by fishing year and statistical area for selected QMAs are given in Table C2 in Appendix C. "Other", landings of spiny dogfish caught outside the NZ EEZ or where the fishstock was unspecified; these were dropped during the data grooming and merging procedure.

(A) Groomed unmerged catches by fishing year and QMA

	QMA											Total
Fishing year	1	2	3	4	5	6	7	8	9	10	Other	catch (t)
1989–90	2	1	66	3	5	<1	18	2	0	0	4	1 840
1990–91	2	<1	59	7	9	<1	22	1	0	<1	0	3 212
1991–92	1	1	55	1	7	1	27	6	0	<1	0	2 724
1992–93	2	<1	47	2	12	<1	28	8	0	<1	<1	2 947
1993–94	1	1	48	6	6	<1	34	4	0	<1	1	4 657
1994–95	2	1	52	8	7	1	26	4	<1	0	<1	3 252
1995–96	1	3	40	12	8	3	28	3	<1	0	<1	5 165
1996–97	<1	3	39	20	8	2	25	2	<1	<1	<1	5 915
1997–98	1	3	43	15	8	4	21	5	1	0	<1	5 372
1998–99	1	6	35	13	24	2	20	1	<1	0	<1	8 733
1999–00	<1	4	44	12	16	3	20	<1	<1	0	<1	7 585
2000–01	<1	4	49	13	16	2	15	1	<1	0	<1	8 927
Total	1	3	45	11	12	2	23	3	<1	<1	<1	60 328

(B) Groomed and merged catches by fishing year and QMA

	QMA											Total
Fishing year	1	2	3	4	5	6	7	8	9	10	Other	catch (t)
1989–90	1	1	70	3	5	<1	19	2	0	0	0	1 435
1990–91	2	<1	58	5	8	<1	25	1	0	<1	0	2 682
1991–92	1	1	57	1	6	1	28	5	0	<1	0	2 326
1992–93	1	<1	51	2	6	<1	31	7	0	<1	0	2 477
1993–94	1	1	48	7	4	<1	37	2	0	0	0	3 930
1994–95	2	1	57	8	4	1	26	1	<1	0	0	2 808
1995–96	1	3	45	13	4	4	29	1	<1	0	0	4 089
1996–97	<1	2	42	22	5	2	25	1	<1	0	0	4 832
1997–98	1	3	47	17	5	3	22	1	<1	0	0	4 332
1998–99	<1	7	37	15	13	2	26	<1	<1	0	0	6 381
1999–00	<1	5	47	13	7	2	25	<1	<1	0	0	5 533
2000–01	<1	4	52	14	8	2	18	1	<1	0	0	6 715
Total	1	3	48	12	7	2	25	1	<1	<1	0	47 540

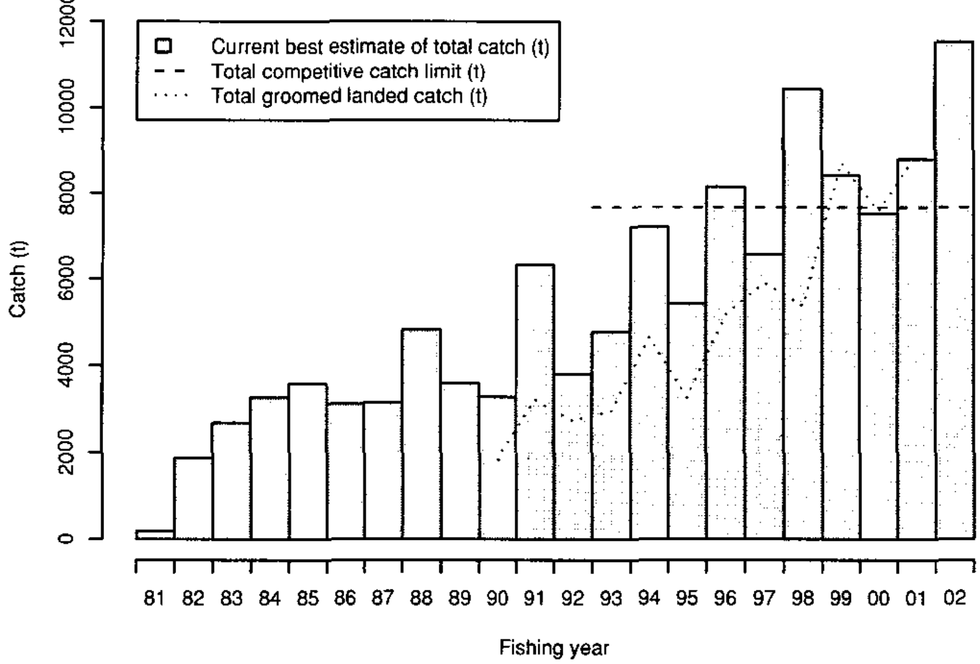

Figure 2: Current best estimates of the total commercial landings of spiny dogfish by fishing year for the fishing years 1980–81 ("81") to 2001–02 ("02"). The best estimates for the fishing years 1980–81 to 1986–87 are the sum of the FSU data for each fishing year (Table 1). The best estimates for the fishing years 1987–88 to 2001–02 are the sum of the LFRR returns and recorded discards from CELR and CLR forms for each fishing year (Tables 1–2). Revised best estimates for the 1989–90 to the 2000–01 fishing years are the groomed landed catches presented in this paper (dotted line; see Table 3(A) and Figure 3).

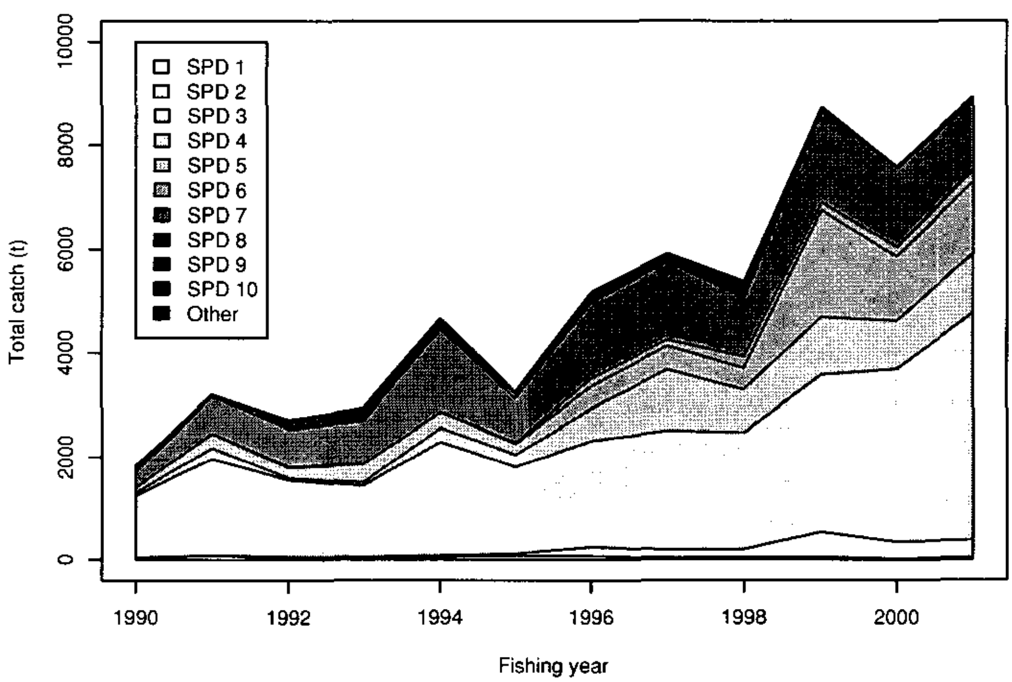

Figure 3: Groomed landed unmerged catches by QMA and fishing year for the fishing years 1989–90 to 2000–01. The groomed landed unmerged catches are revised best estimates for the total commercial landings of spiny dogfish for these fishing years, i.e., the total removals from the stocks.

3.2.2 Trends in discarding rates

Total groomed unmerged landings, discarded unmerged landings, and discarding rates defined as discarded landings as percentages by weight of total landings are tabulated by fishing year and QMA in Table 8. The discarded and undiscarded landings and discarding rates are plotted in Figure 4. The discarding rate is 45% across all fishing years and QMAs, and ranges from 11% (1990–91) to 64% (2000–01) by fishing year, and from 0% (SPD 10) to 78% (SPD 6 and 9) by QMA. Figure 4 suggests that the discarding rate is increasing over time in all QMAs, although the magnitude of the trend varies between QMAs. The trend is most apparent in the relatively data-rich southern QMAs (SPD 2, 3, 4, 5, 6, and 7) and less well defined in relatively data-poor northern QMAs (SPD 1, 8, 9, and 10). The final panel in Figure 4 suggests that the overall discarding rate varied between 10–20% of total landings during the 1989–90 to 1995-96 fishing years, increased to about 60–65% of total landings thereafter, and appears to have remained reasonably stable since the 1998–99 fishing year.

We suggest that rather than reflecting an increase in the amount of spiny dogfish catch that is discarded, this reflects a change in the reporting of discarded catches of spiny dogfish, i.e., an increase in the amount of discarded spiny dogfish that is reported. In any case, discarded catches are a very substantial component of total removals from the stocks and appear to be driving the increase in total catch observed throughout the 1990s (Figure 4). Although a quantitative analysis of discarding rates is beyond the scope of this paper, a rigorous analysis of discarding rates and estimation of the total removals from the stocks is an important topic of future research on spiny dogfish in New Zealand waters (see Section 8).

3.2.3 How spiny dogfish catches are recorded

Total groomed unmerged landings are tabulated by fishing year, form type, and QMA in Table 9. The groomed and merged catch is tabulated by fishing year, form type, and QMA in Table 10. The percentage of the catch in each dataset recorded on CLR forms is plotted by fishing year and QMA in Figure 5. Some trends are apparent, although, as with the discarded catch, these are less well defined in the relatively data-poor northern QMAs and in those southern QMAs where total groomed unmerged landings are low (e.g., before the 1993–94 fishing year in SPD 6).

The distributions of landings by form type generally separate into three general types: "mostly CELR" (i.e., about three-quarters or more of the landed catch was recorded on CELR forms), "mostly CLR" (i.e., about three-quarters or more of the landed catch was recorded on CLR forms), and "50:50" (i.e., approximately equal amounts of catch were recorded on each form type). We deem the catch in SPD 1, 3, 4, 6, and 10 to be "mostly CELR", the catch in SPD 2, 5, and 9 to be "mostly CLR", and the catch in SPD 7 and 8 to be "50:50". These distributions probably reflect the reporting requirements for the types of fishing that dominate the catch in these areas. Temporal trends in the percentage of catch recorded on each form type, such as the increasing amounts of catch recorded on CLRs in SPD 3 and 7, probably reflect changes in the composition of fishing activity within these areas over the time series.

3.2.4 Reporting rates

Kendrick & Walker (2004) defined the total estimated catch expressed as a percentage by weight of the total landed catch as a "reporting rate". Low reporting rates are typical results in bycatch fisheries, where species not in the top five by weight in the catch for each tow or set are not recorded in the corresponding catch-effort record, although they may still be landed and are recorded in the landed catch. Indeed, overcoming this problem is one of the objectives of Starr's (2003) procedure. Reporting rates *sensu* Kendrick & Walker (2004) are calculated by QMA and fishing year in Table 11. Overall, the reporting rate is 77%, and ranges from 67% (1997–98) to 119% (1990–91) by fishing year across the QMAs, and from 22% (SPD 9) to 97% (SPD 5) by QMA across the fishing years. Basing our analyses solely on estimated catches may have biased our results.

Table 8: Comparison of discarded unmerged groomed landed catches by QMA and fishing year. Total unmerged groomed landed catches (A), discarded unmerged groomed landed catches (B), and discarded unmerged groomed landed catches as percentages of total catches (C) are provided

(A) Total unmerged groomed landed catches by QMA and fishing year

Fishing year	1	2	3	4	5	6	7	8	9	10	Other	QMA Total
1989–90	28	12	1 208	56	97	0	326	40	0	0	74	1 840
1990–91	74	11	1 881	213	286	7	706	32	0	2	0	3 212
1991–92	39	20	1 486	39	202	24	741	172	0	1	0	2 724
1992–93	45	7	1 385	63	360	7	829	248	0	1	2	2 947
1993–94	48	33	2 214	275	299	7	1 571	182	0	0	29	4 657
1994–95	72	41	1 686	244	220	26	839	119	0	0	5	3 252
1995–96	67	173	2 078	621	416	152	1 462	161	14	0	20	5 165
1996–97	29	158	2 329	1 156	456	118	1 503	143	7	1	15	5 915
1997–98	51	145	2 286	814	408	220	1 124	273	34	0	16	5 372
1998–99	45	489	3 042	1 103	2 068	152	1 752	74	0	0	8	8 733
1999–00	15	326	3 343	926	1 241	191	1 509	25	7	0	1	7 585
2000–01	38	337	4 379	1 149	1 391	214	1 321	54	17	0	26	8 927
Total	551	1 752	27 317	6 658	7 444	1 118	13 682	1 525	80	5	196	60 328

(B) Discarded unmerged groomed landed catches by QMA and fishing year

Fishing year	1	2	3	4	5	6	7	8	9	10	Other	QMA Total
1989–90	3	2	218	2	44	0	41	14	0	0	0	324
1990–91	5	0	104	4	82	1	149	8	0	0	0	353
1991–92	3	1	112	5	69	22	311	30	0	0	0	553
1992–93	6	3	69	32	140	3	168	199	0	0	0	619
1993–94	2	21	277	116	64	2	456	120	0	0	0	1 059
1994–95	2	22	132	77	43	19	247	76	0	0	0	618
1995–96	5	68	376	342	163	143	657	116	14	0	2	1 885
1996–97	4	96	610	459	321	80	888	128	7	0	2	2 595
1997–98	27	120	1 174	435	295	190	908	250	34	0	3	3 435
1998–99	9	452	1 744	662	607	119	1 440	46	0	0	1	5 080
1999–00	1	281	2 019	509	489	130	1 220	21	2	0	0	4 674
2000–01	14	236	2 613	881	796	165	949	30	5	0	23	5 712
Total	81	1 302	9 448	3 523	3 113	874	7 432	1 038	63	0	32	26 906

(C) Discarding rates by QMA and fishing year

Fishing year	1	2	3	4	5	6	7	8	9	10	Other	QMA Total
1989–90	11	17	18	4	46	100	13	34	0	0	0	18
1990–91	7	0	6	2	29	11	21	24	0	0	0	11
1991–92	9	3	8	13	34	90	42	18	0	0	0	20
1992–93	13	47	5	51	39	43	20	80	0	0	0	21
1993–94	5	65	13	42	21	34	29	66	0	0	0	23
1994–95	2	52	8	31	20	74	29	64	98	0	5	19
1995–96	7	39	18	55	39	94	45	72	100	0	11	36
1996–97	15	61	26	40	70	68	59	89	93	0	16	44
1997–98	53	83	51	53	72	86	81	92	100	0	16	64
1998–99	20	92	57	60	29	78	82	63	0	0	16	58
1999–00	9	86	60	55	39	68	81	84	35	0	0	62
2000–01	37	70	60	77	57	77	72	56	29	0	87	64
Total	15	74	35	53	42	78	54	68	78	0	16	45

Table 9: Total unmerged groomed landed catches (t) by form type (CEL, CLR), QMA, and fishing year. CEL, percentage of total landings recorded on Catch Effort Landing Returns; CLR, percentage of total landings recorded on Catch Landing Returns. The catch-effort data associated with landings data recorded on CLRs are recorded on Trawl Catch Effort Processing Returns (TCEPRs).

	SPD 1			SPD 2			SPD 3			SPD 4			SPD 5			SPD 6		
Fishing year	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)
1989–90	96	0	28	100	0	12	73	27	1 208	7	93	56	54	45	97	–	–	0
1990–91	78	22	74	45	55	11	65	35	1 881	1	99	213	28	72	286	0	100	7
1991–92	100	0	39	90	10	20	78	23	1 486	33	64	39	17	83	202	88	17	24
1992–93	89	9	45	100	14	7	90	10	1 385	62	37	63	9	91	360	100	14	7
1993–94	90	8	48	55	42	33	77	23	2 214	87	13	275	31	69	299	43	43	7
1994–95	100	0	72	2	98	41	83	17	1 686	73	27	244	30	70	220	96	8	26
1995–96	100	1	67	12	88	173	84	16	2 078	80	20	621	10	90	416	99	1	152
1996–97	93	3	29	3	97	158	76	24	2 329	61	39	1 156	21	79	456	90	10	118
1997–98	96	4	51	6	94	145	51	49	2 286	55	45	814	19	81	408	67	33	220
1998–99	82	18	45	2	98	489	36	64	3 042	67	33	1 103	4	96	2 068	68	32	152
1999–00	87	20	15	6	94	326	35	65	3 343	49	51	926	5	95	1 241	40	60	191
2000–01	76	24	38	21	79	337	50	50	4 379	53	47	1 149	17	83	1 391	50	50	214
Total	91	9	551	11	89	1 752	61	39	27 317	59	41	6 658	13	87	7 444	67	33	1 118

	SPD 7			SPD 8			SPD 9			SPD 10			Other			Total		
Fishing year	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)
1989–90	70	30	326	68	32	40	–	–	0	–	–	0	100	0	74	71	29	1 840
1990–91	84	15	706	41	62	32	–	–	0	100	0	2	–	–	0	62	38	3 212
1991–92	63	37	741	15	85	172	–	–	0	100	0	1	–	–	0	65	35	2 724
1992–93	82	18	829	13	88	248	–	–	0	100	0	1	0	100	2	71	30	2 947
1993–94	64	36	1 571	38	62	182	–	–	0	–	–	0	0	100	29	68	32	4 657
1994–95	57	43	839	33	66	119	–	–	0	–	–	0	100	0	5	70	30	3 252
1995–96	34	66	1 462	42	59	161	0	100	14	–	–	0	85	15	20	60	40	5 165
1996–97	39	61	1 503	22	79	143	0	100	7	100	0	1	80	20	15	56	44	5 915
1997–98	22	78	1 124	13	87	273	0	100	34	–	–	0	81	12	16	41	59	5 372
1998–99	23	77	1 752	28	72	74	–	–	0	–	–	0	100	0	8	29	71	8 733
1999–00	39	61	1 509	84	16	25	43	57	7	–	–	0	61	39	1	32	68	7 585
2000–01	44	56	1 321	50	52	54	53	47	17	–	–	0	100	0	26	43	57	8 927
Total	46	54	13 682	27	73	1 525	16	84	80	100	0	5	80	20	196	50	50	60 328

Table 10: Total groomed landed catches (t) in the groomed and merged dataset by form type (CEL, CLR), QMA, and fishing year. CEL, percentage of total landings recorded on Catch Effort Landing Returns; CLR, percentage of total landings recorded on Catch Landing Returns. The catch-effort data associated with landings data recorded on CLRs are recorded on Trawl Catch Effort Processing Returns (TCEPRs).

	SPD 1			SPD 2			SPD 3			SPD 4			SPD 5			SPD 6		
Fishing year	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)
1989–90	100	0	18	90	0	10	87	13	999	2	96	45	79	21	66	0	0	0
1990–91	98	0	52	71	29	7	75	25	1 553	2	99	146	35	65	222	0	100	7
1991–92	100	0	34	86	14	14	86	14	1 322	35	65	26	21	80	142	88	17	24
1992–93	100	0	34	83	17	6	97	3	1 270	67	33	58	17	83	159	100	14	7
1993–94	100	0	37	56	44	32	87	13	1 898	88	12	268	66	34	140	100	0	3
1994–95	100	0	61	2	98	40	86	14	1 588	75	25	236	66	34	101	100	0	25
1995–96	100	2	51	6	94	126	91	9	1 830	92	8	513	22	78	179	100	0	150
1996–97	95	5	21	3	97	100	84	16	2 020	65	35	1 074	36	64	245	95	6	112
1997–98	97	3	35	5	95	128	56	44	2 057	61	39	729	28	72	233	98	2	150
1998–99	94	6	31	2	98	436	46	54	2 364	76	24	971	10	90	801	84	16	122
1999–00	80	20	10	7	93	292	43	57	2 600	55	45	730	15	85	393	68	32	113
2000–01	91	9	11	26	74	277	62	38	3 500	65	35	941	39	61	570	70	30	152
Total	98	2	394	11	89	1 467	71	29	23 001	67	33	5 736	28	72	3 250	86	14	867

	SPD 7			SPD 8			SPD 9			SPD 10			Other			Total		
Fishing year	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)	CEL (%)	CLR (%)	Total (t)
1989–90	79	21	272	100	4	25	0	0	0	0	0	0	–	–	0	83	17	1 435
1990–91	87	13	682	93	7	14	0	0	0	0	0	0	–	–	0	71	29	2 682
1991–92	72	28	649	22	78	113	0	0	0	100	0	1	–	–	0	75	25	2 326
1992–93	84	16	761	17	83	180	0	0	0	100	0	1	–	–	0	81	19	2 477
1993–94	67	33	1 466	80	20	86	0	0	0	0	0	0	–	–	0	79	21	3 930
1994–95	61	39	717	80	20	40	0	0	0	0	0	0	–	–	0	77	23	2 808
1995–96	41	59	1 181	100	0	59	0	0	0	0	0	0	–	–	0	72	28	4 089
1996–97	39	61	1 227	82	18	34	0	0	0	0	0	0	–	–	0	65	35	4 832
1997–98	23	77	949	54	44	52	0	0	0	0	0	0	–	–	0	49	51	4 332
1998–99	24	76	1 635	67	29	21	0	0	0	0	0	0	–	–	0	38	62	6 381
1999–00	40	60	1 369	86	14	21	50	33	6	0	0	0	–	–	0	41	59	5 533
2000–01	46	54	1 213	63	37	35	56	50	16	0	0	0	–	–	0	56	44	6 715
Total	50	50	12 121	53	47	680	57	43	23	100	0	2	–	–	0	60	40	47 540

Table 11: Comparison of landed and estimated catches in the groomed and merged dataset. Total landed catches by fishing year and QMA are given in (A), total estimated catches by fishing year and QMA are given in (B), and the total estimated catch as a percentage of the total landed catch by fishing year (C) and QMA are given.

(A) Total landed catches in the groomed and merged dataset

	QMA											
Fishing year	1	2	3	4	5	6	7	8	9	10	Other	Total
1989–90	18	10	999	45	66	0	272	25	0	0	0	1 435
1990–91	52	7	1 553	146	222	7	682	14	0	0	0	2 682
1991–92	34	14	1 322	26	142	24	649	113	0	1	0	2 326
1992–93	34	6	1 270	58	159	7	761	180	0	1	0	2 477
1993–94	37	32	1 898	268	140	3	1 466	86	0	0	0	3 930
1994–95	61	40	1 588	236	101	25	717	40	0	0	0	2 808
1995–96	51	126	1 830	513	179	150	1 181	59	0	0	0	4 089
1996–97	21	100	2 020	1 074	245	112	1 227	34	0	0	0	4 832
1997–98	35	128	2 057	729	233	150	949	52	0	0	0	4 332
1998–99	31	436	2 364	971	801	122	1 635	21	0	0	0	6 381
1999–00	10	292	2 600	730	393	113	1 369	21	6	0	0	5 533
2000–01	11	277	3 500	941	570	152	1 213	35	16	0	0	6 715
Total	394	1 467	23 001	5 736	3 250	867	12 121	680	23	2	0	47 540

(B) Total estimated catches in the groomed and merged dataset

	QMA											
Fishing year	1	2	3	4	5	6	7	8	9	10	Other	Total
1989–90	10	5	1 104	58	69	0	185	18	0	0	0	1 449
1990–91	33	2	1 656	128	731	0	636	12	0	0	0	3 198
1991–92	21	9	1 019	15	144	21	541	101	0	0	0	1 870
1992–93	16	1	1 010	52	105	5	767	98	0	0	0	2 054
1993–94	18	12	1 503	237	148	3	1 402	33	0	0	0	3 358
1994–95	20	22	1 272	184	105	6	633	36	0	0	0	2 278
1995–96	35	47	1 388	350	164	11	953	35	0	0	0	2 984
1996–97	11	152	1 579	708	239	97	604	11	0	0	0	3 402
1997–98	9	102	1 588	368	108	101	572	35	0	0	0	2 883
1998–99	11	357	1 885	668	684	94	846	8	0	0	0	4 553
1999–00	4	228	2 133	509	282	84	787	17	0	0	0	4 044
2000–01	6	208	2 488	617	362	114	795	17	4	0	0	4 611
Total	195	1 147	18 625	3 892	3 142	537	8 720	421	5	1	0	36 685

(C) Total estimated catches as a percentage of total landed catches in the groomed and merged dataset

	QMA											
Fishing year	1	2	3	4	5	6	7	8	9	10	Other	Total
1989–90	57	54	110	129	104	74	68	70	0	0	0	101
1990–91	64	25	107	87	330	2	93	90	0	100	0	119
1991–92	61	64	77	56	101	86	83	89	0	0	0	80
1992–93	46	21	79	90	66	72	101	54	0	13	0	83
1993–94	50	39	79	88	106	95	96	38	0	0	0	85
1994–95	34	55	80	78	104	24	88	88	100	0	0	81
1995–96	68	38	76	68	92	7	81	60	100	0	0	73
1996–97	53	152	78	66	98	87	49	33	88	0	0	70
1997–98	26	80	77	50	47	67	60	68	0	0	0	67
1998–99	36	82	80	69	85	77	52	38	0	0	0	71
1999–00	43	78	82	70	72	75	57	82	9	0	0	73
2000–01	53	75	71	66	64	75	66	48	24	0	0	69
Total	49	78	81	68	97	62	72	62	22	30	0	77

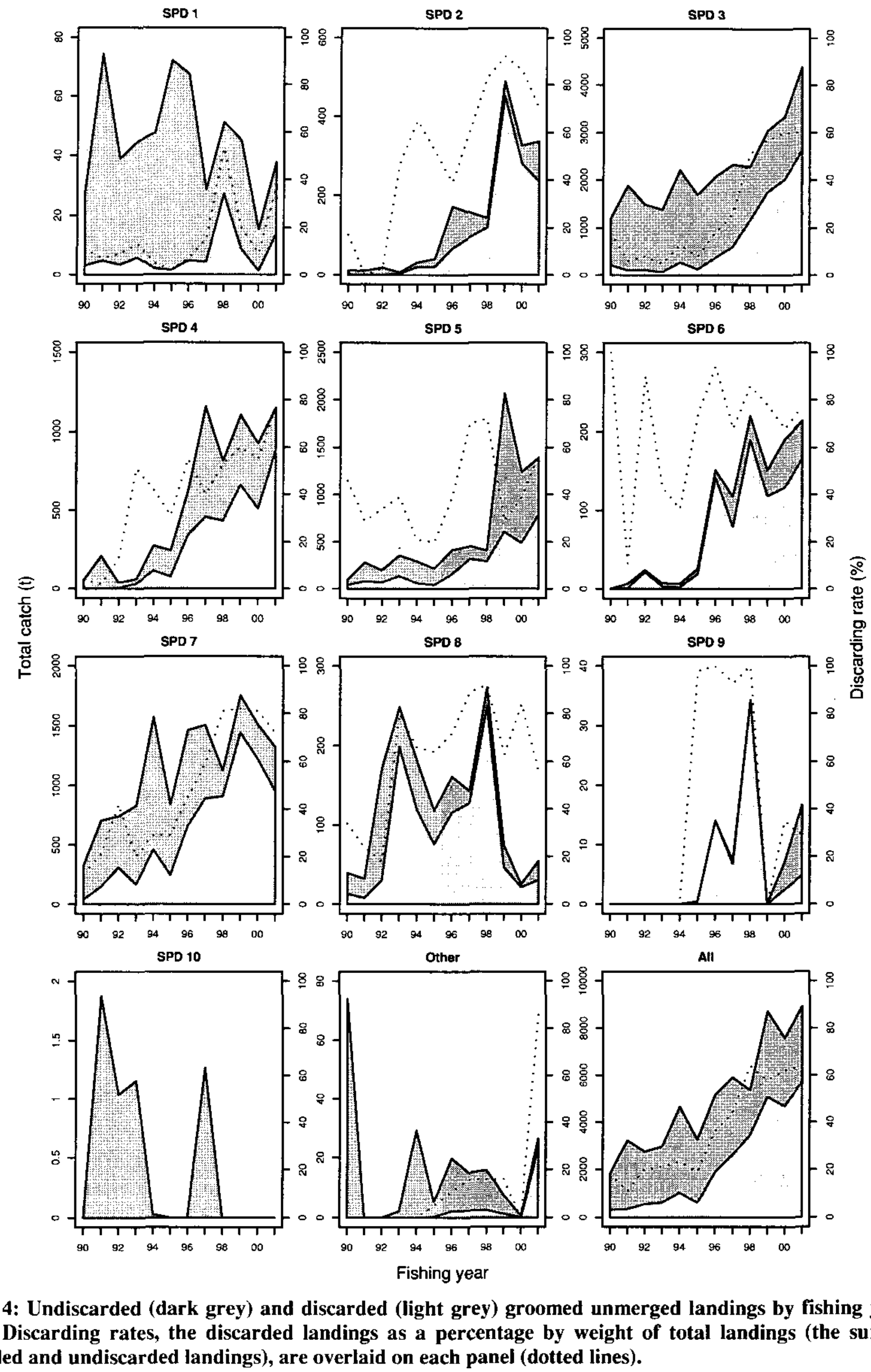

Figure 4: Undiscarded (dark grey) and discarded (light grey) groomed unmerged landings by fishing year and QMA. Discarding rates, the discarded landings as a percentage by weight of total landings (the sum of the discarded and undiscarded landings), are overlaid on each panel (dotted lines).

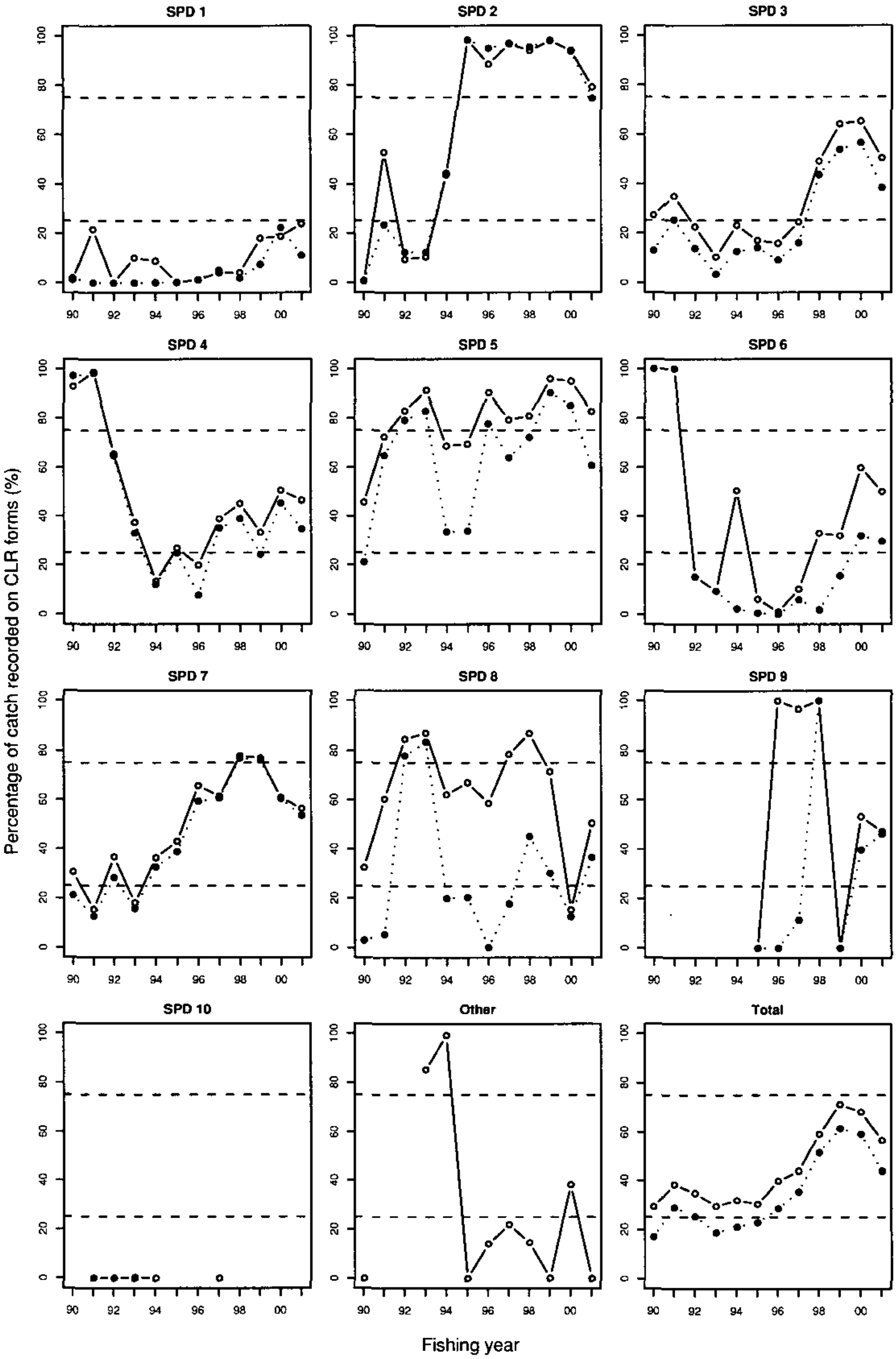

Figure 5: Landings recorded on CLR forms (percentage by weight of total landings) by fishing year and QMA for the groomed unmerged (white circles and solid line) and merged (black circles and dotted line) datasets. The 25% and 75% lines are drawn on each panel.

3.3 Trends in the composition of the catch

Here we attempt to define the catch in terms of where, when, how, and by whom the catch was caught. Cross-tabulations of the groomed and merged catch by fishing year and month (Table C1), by fishing year and statistical area (Table C2), by fishing year and method (Table C3), by fishing year and target species (Table C4), and by fishing year and vessel flag nationality (Table C5) are presented in Appendix C for all the data and separately for QMAs SPD 3, 4, 5, 6, and 7. The catch is plotted by fishing year and month, by fishing year and QMA, and by fishing year and fishing method in Figure 6. The data are further plotted by fishing year, form type, target species, and fishing method in Figure 7; by fishing year, form type, QMA, and fishing method in Figure 8; and by fishing year, form type, vessel flag nationality, and QMA in Figure 9, revealing structure within the data.

The distribution of catch by fishing year and month (Figure 6, panel A) suggests some level of seasonality in the catch overall, with 44% of the total catch (Table C1(A), Appendix C) caught during the winter and early spring months of June, July, August, and September; i.e., nearly one-half of the total catch is caught during one-third of the fishing year. As noted above, SPD 3 and 7 dominate the catch by QMA (Figure 6, panel B).

The distribution of catch by fishing year and method (Figure 6, panel C) suggests that virtually all of the catch is caught by four methods, namely bottom longlining, bottom trawling, midwater trawling, and setnet fishing. These methods account for about 11%, 47%, 16%, and 26% respectively of the total catch (Table C3(A), Appendix C). All other fishing methods accounting for less than 1% of the total catch (Table C3(A), Appendix C). The data also suggest a shift over time in those methods that account for most of the catch, with the bottom longline catch negligible before the 1993–94 fishing year, the midwater trawl catch negligible before the 1992–93 fishing year, and the setnet catch high throughout the early 1990s, peaking during the 1993–94 fishing year, and declining after the 1995–96 fishing year.

The distribution of catch by fishing year and target species (Figure 6, panel C) suggests that spiny dogfish are caught mainly as bycatch of target fishing for other species, principally barracouta, hoki, ling, and red cod, although spiny dogfish caught in target fishing for flatfish, jack mackerels, and squid species are also important. Spiny dogfish caught in target fishing for barracouta, hoki, ling, and red cod account for 52% (11%, 20%, 12%, and 15%, respectively) of the total catch; spiny dogfish taken in fisheries for all other species, including flatfish, jack mackerels, and squid, account for less than half (48%) of the total catch (Table C4(A), Appendix C). Target fishing for spiny dogfish accounts for only about 15% of the total catch over all fishing years, but accounted for as much as 48% of the total catch in the early 1990s. The target spiny dogfish catch declined rapidly after the 1995–96 fishing year, matching the decline in the setnet catch noted above. A moratorium on targeting spiny dogfish was issued by the Ministry of Fisheries at the start of the 1992–93 fishing year. There are also temporal shifts in the importance of other target species, with bycatch taken in hoki and ling fisheries increasingly important after the mid 1990s.

3.3.1 SPD 3

The groomed and merged catch in SPD 3 is summarised in Figures 10–13. There is some evidence of seasonality in the catch, with most of the catch caught over the summer and autumn months of January to May (53% across all fishing years; Table C1(B)). Catches are recorded from all statistical areas, but most of the catch is taken in the inshore statistical areas 018, 020, 022, and 024 (94% across all fishing years; Table C2(A)), with relatively little catch caught in statistical areas further offshore. These patterns are consistent from fishing year to fishing year, although the catch in statistical area 022 during the 2000–01 fishing year was roughly double that of any preceding fishing year.

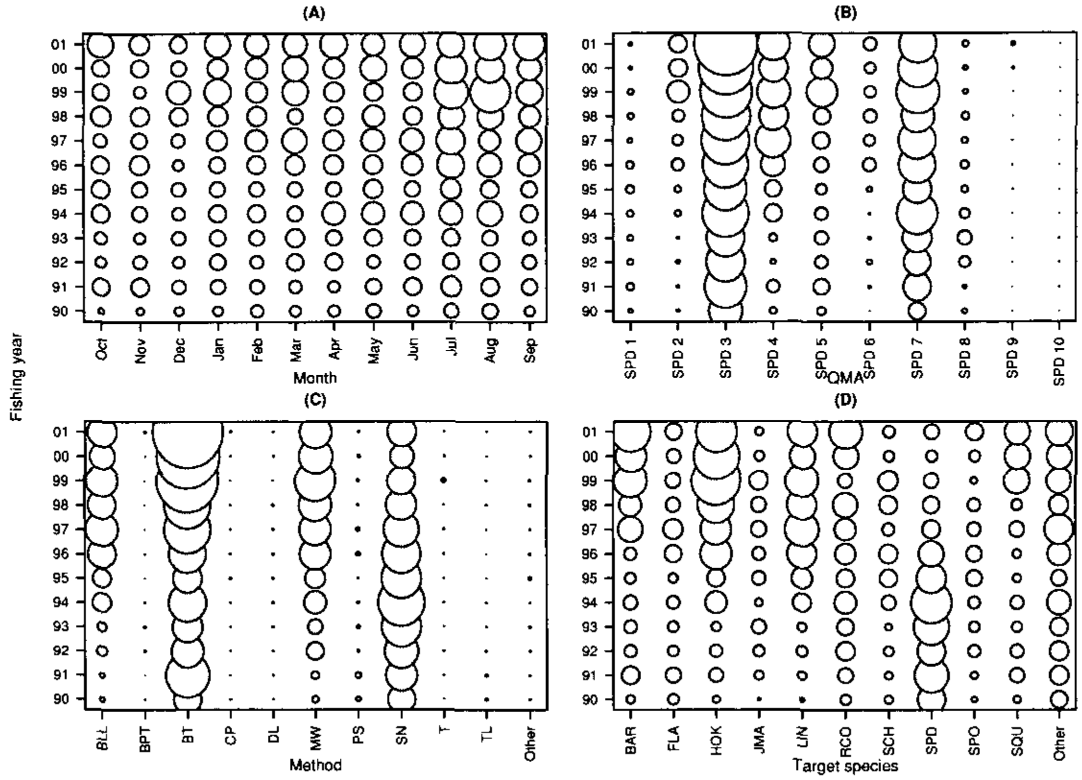

Figure 6: All groomed and merged catches (A) by month and fishing year, (B) by QMA and fishing year, (C) by method and fishing year, and (D) by target species and fishing year. Circle areas are proportional to the amount of catch in each factor level and fishing year combination and are equivalent from plot to plot. The value in catch of a circle 1 cm in diameter is 5000 t. Method and target species codes are defined in Appendix A.

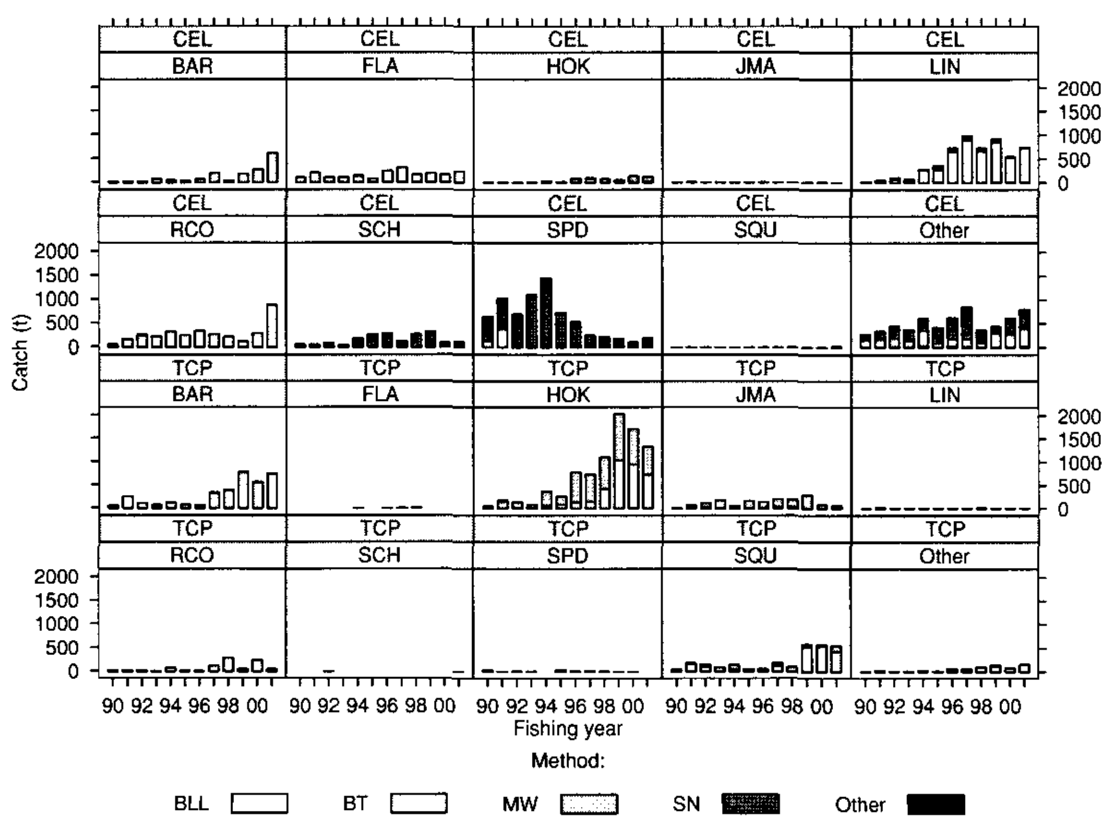

Figure 7: All groomed and merged catches by fishing year, catch-effort records form type, target species, and fishing method for the fishing years 1989–90 to 2000–01. Form type, fishing method, and target species codes are defined in Appendix A.

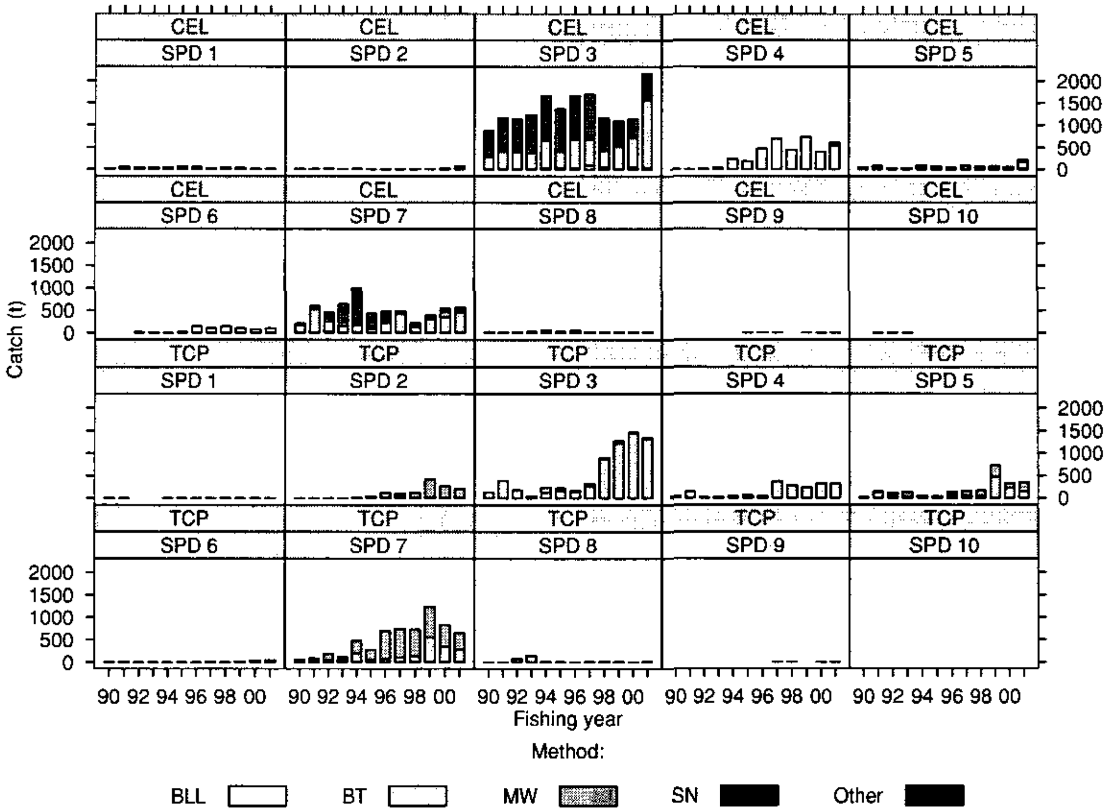

Figure 8: All groomed and merged catches by fishing year, catch-effort records form type, QMA, and fishing method for the fishing years 1989–90 to 2000–01. Form type and fishing method codes are defined in Appendix A.

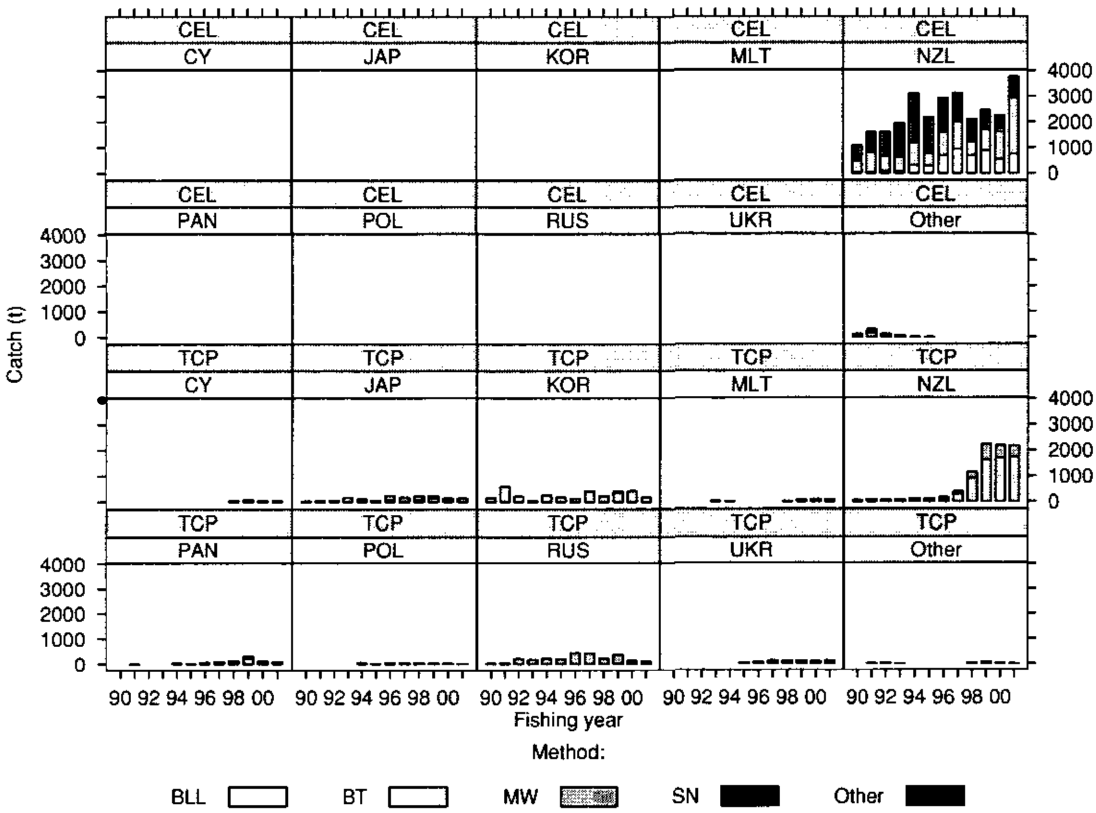

Figure 9: All groomed and merged catches by fishing year, catch-effort records form type, vessel flag nationality, and fishing method for the fishing years 1989–90 to 2000–01. Form type, vessel flag nationality, and fishing method codes are defined in Appendix A.

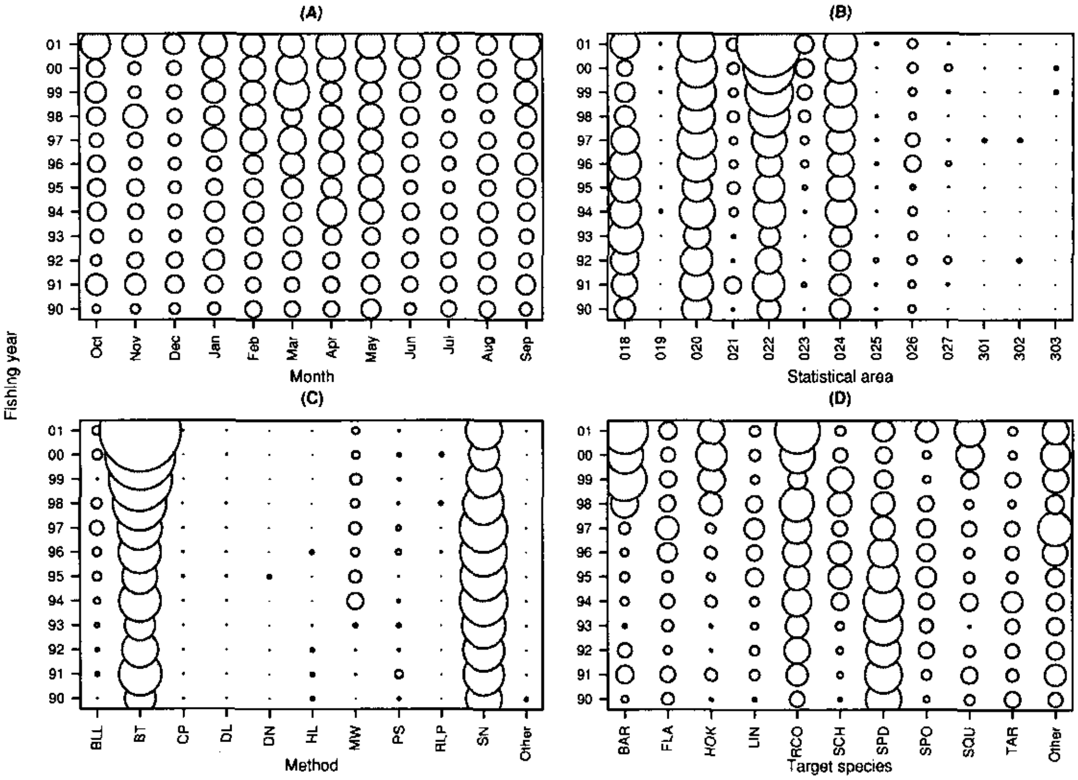

Figure 10: SPD 3 groomed and merged catches (A) by month and fishing year, (B) by statistical area and fishing year, (C) by method and fishing year, and (D) by target species and fishing year. Circle areas are proportional to the amount of catch in each factor level and fishing year combination and are equivalent from plot to plot. The value in catch of a circle 1 cm in diameter is 2500 t. Method and target species codes are defined in Appendix A.

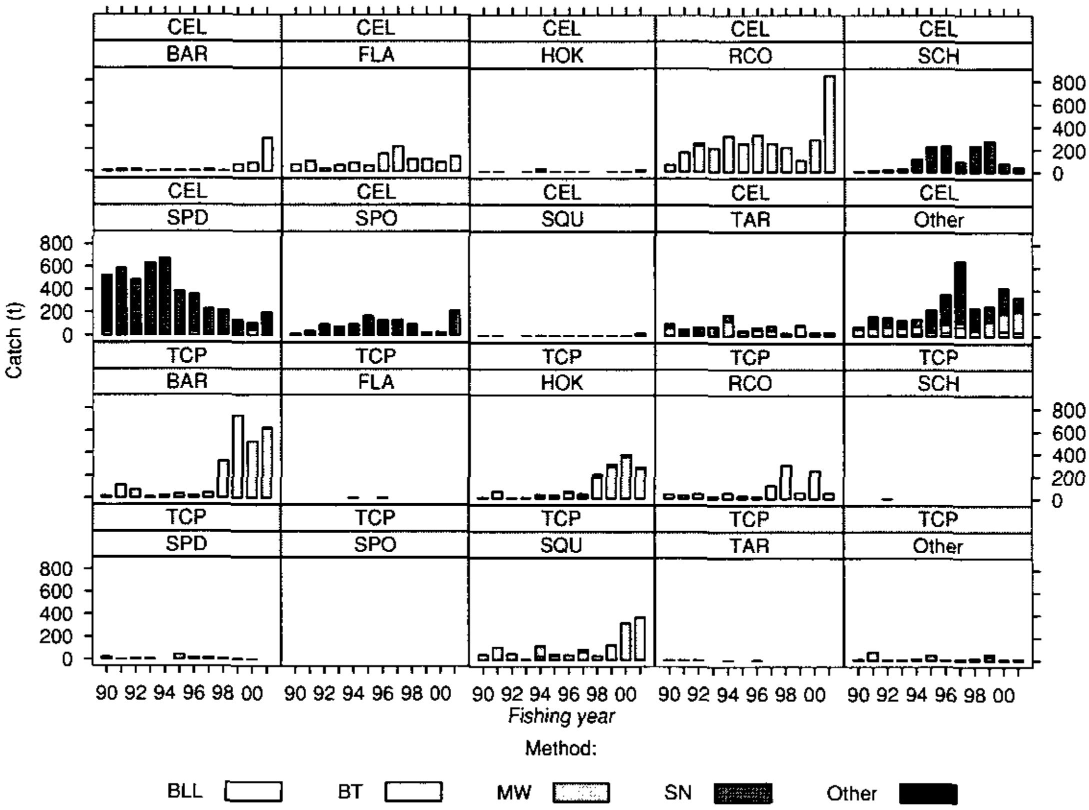

Figure 11: SPD 3 groomed and merged catches by fishing year, catch-effort records form type, target species, and fishing method for the fishing years 1989–90 to 2000–01. Form type, fishing method, and target species codes are defined in Appendix A.

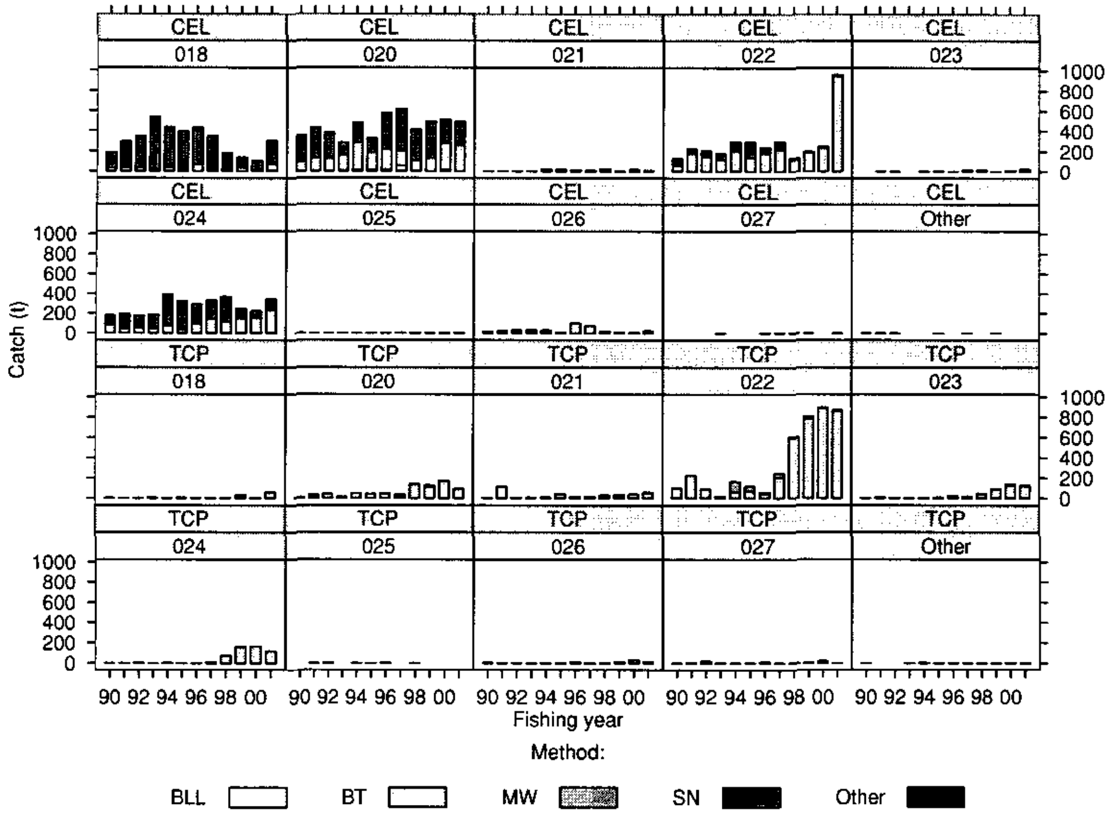

Figure 12: SPD 3 groomed and merged catches by fishing year, catch-effort records form type, statistical area, and fishing method for the fishing years 1989–90 to 2000–01. Form type and fishing method codes are defined in Appendix A.

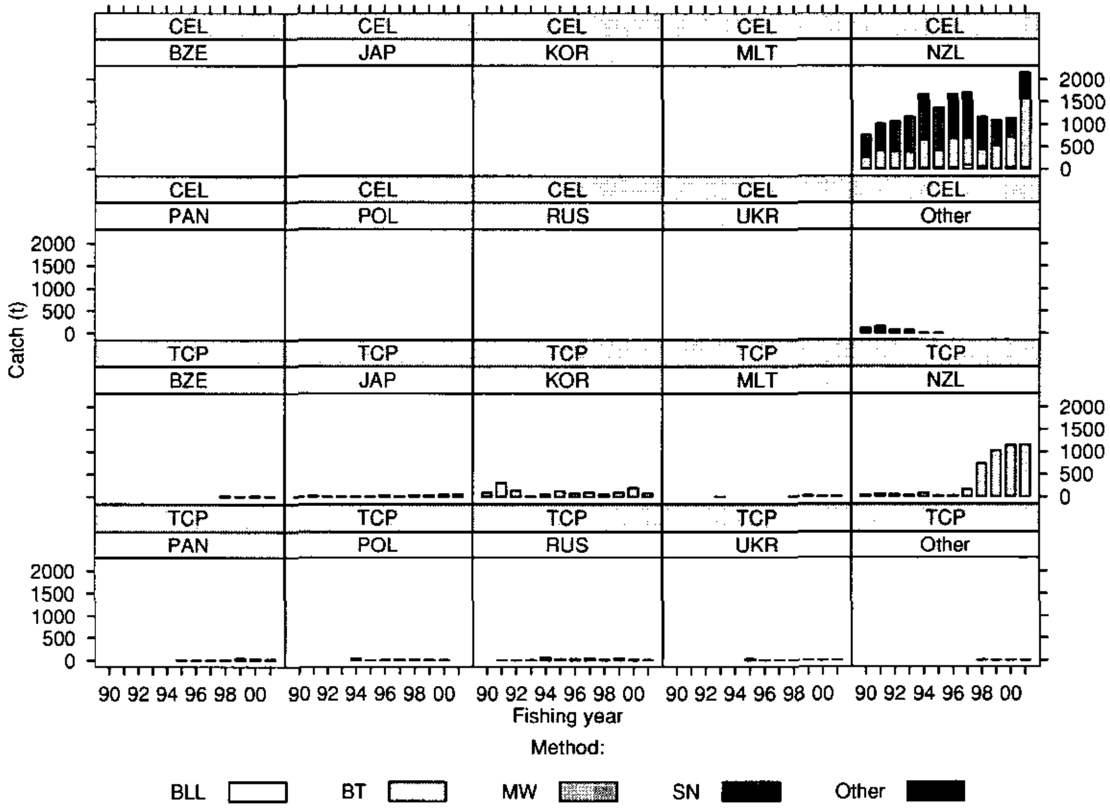

Figure 13: SPD 3 groomed and merged catches by fishing year, catch-effort records form type, vessel flag nationality, and fishing method for the fishing years 1989–90 to 2000–01. Form type, vessel flag nationality, and fishing method codes are defined in Appendix A.

Although SPD 3 includes the western edge of the Chatham Rise, including the Mernoo Bank and other shallow water areas exploited by the Chatham Rise juvenile hoki fishery (e.g., statistical areas 021 and 023), comparatively little of the groomed and merged spiny dogfish catch in SPD 3 was caught in these areas. Spiny dogfish caught by large (over 28 m) bottom trawl vessels targeting hoki appear to be only a minor component of the total spiny dogfish catch in SPD 3 (Figure 11).

The bulk of the catch is caught by bottom trawl and setnet fishing (57% and 40% across all fishing years; Table C3(B)); very little is taken by other methods. The existence of a target setnet fishery in statistical areas 018, 020, 024, and to a lesser extent 022, is noted. Catches in the target fishery have declined since the 1995–96 fishing year when a moratorium on targeting spiny dogfish was issued by the Ministry of Fisheries and catches are now negligible (Figure 11). The target catch accounted for as much as half of the total catch during the early to mid 1990s, but had shrunk to 6% of the total catch during the 2000–01 fishing year (Table C4(B)).

Catches taken by small bottom trawl vessels completing CELRs and targeting barracouta, flatfish, and red cod are a minor but important component of the catch (Figure 11). The CELR bottom trawl catch is greatest in statistical area 022. Of the four principal setnet statistical areas (018, 020, 022, and 024), the setnet catch is lowest in 022 (Figure 12). Furthermore, catches by large trawl vessels completing TCEPRs are low in every statistical area other than 022.

The spiny dogfish catch in SPD 3 is thus defined by the target setnet fishery, although this is now negligible, by bycatch caught in setnet fisheries targeting other species, and by the inshore mixed-species trawl fishery targeting flatfish and red cod among other species. Large vessels completing TCEPR forms and targeting barracouta and hoki, and to lesser extent red cod and squid species, are a minor but important part of the catch. Foreign-flagged chartered fishing vessels are relatively unimportant.

3.3.2 SPD 4

The groomed and merged catch in SPD 4 is summarised in Figures 14–17. There is some evidence of seasonality in the catch, with most of the catch taken during the winter months June to September across the fishing years (52%; Table C1(C)). Catches by month are variable, however the July to September catch appears reasonably consistent over the fishing years compared with catches in other months. The July to September catch is negligible before the 1995–96 fishing year, however.

There is also much variation in the catch by statistical area, although most of the catch appears to have been caught in those statistical areas corresponding to the middle of the Chatham Rise, statistical areas 401 to 404 and 407 to 410 (75% of the total catch across the fishing years; Table C2(B)). The catch around the Chatham Islands, statistical areas 049 to 052, accounts for most of the remainder (25% of the total catch across the fishing years; Table C2(B)). All other statistical areas account for less than 1% of the total catch.

Most of the catch is taken in the target ling bottom longline fishery, although dogfish caught by large trawl vessels completing TCEPRs and targeting barracouta, hake, and especially hoki are a minor but important and growing component of the catch (Figure 15). Nevertheless, bottom longline fishing accounts for roughly 65% of the total catch across the fishing years (Table C3(C)), of which virtually all is caught when targeting ling (Figure 15). Although the bottom longline catch appears to be concentrated in statistical areas 404 and 410 and spread more thinly over the remaining statistical areas in SPD 4 (e.g., 049, 050, 401, 402, etc.), the bottom trawl catch appears reasonably evenly distributed over most statistical areas in SPD 4 (Figure 16).

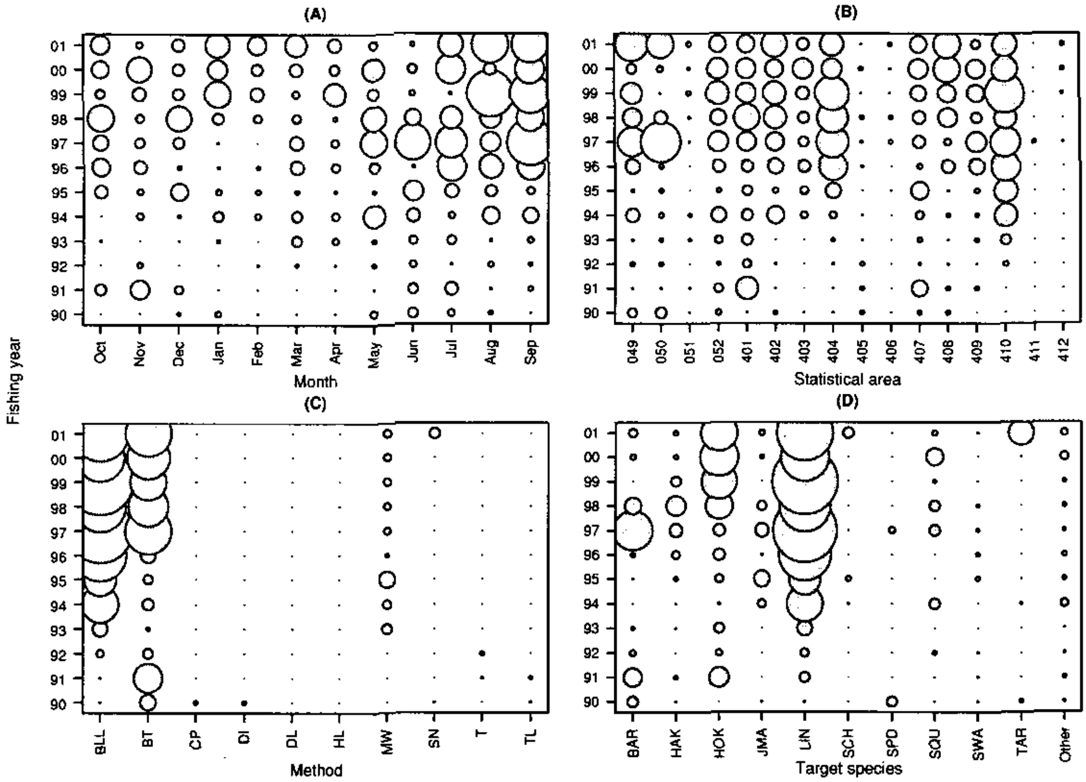

Figure 14: SPD 4 groomed and merged catches (A) by month and fishing year, (B) by statistical area and fishing year, (C) by method and fishing year, and (D) by target species and fishing year. Circle areas are proportional to the amount of catch in each factor level and fishing year combination and are equivalent from plot to plot. The value in catch of a circle 1 cm in diameter is 1000 t. Method and target species codes are defined in Appendix A.

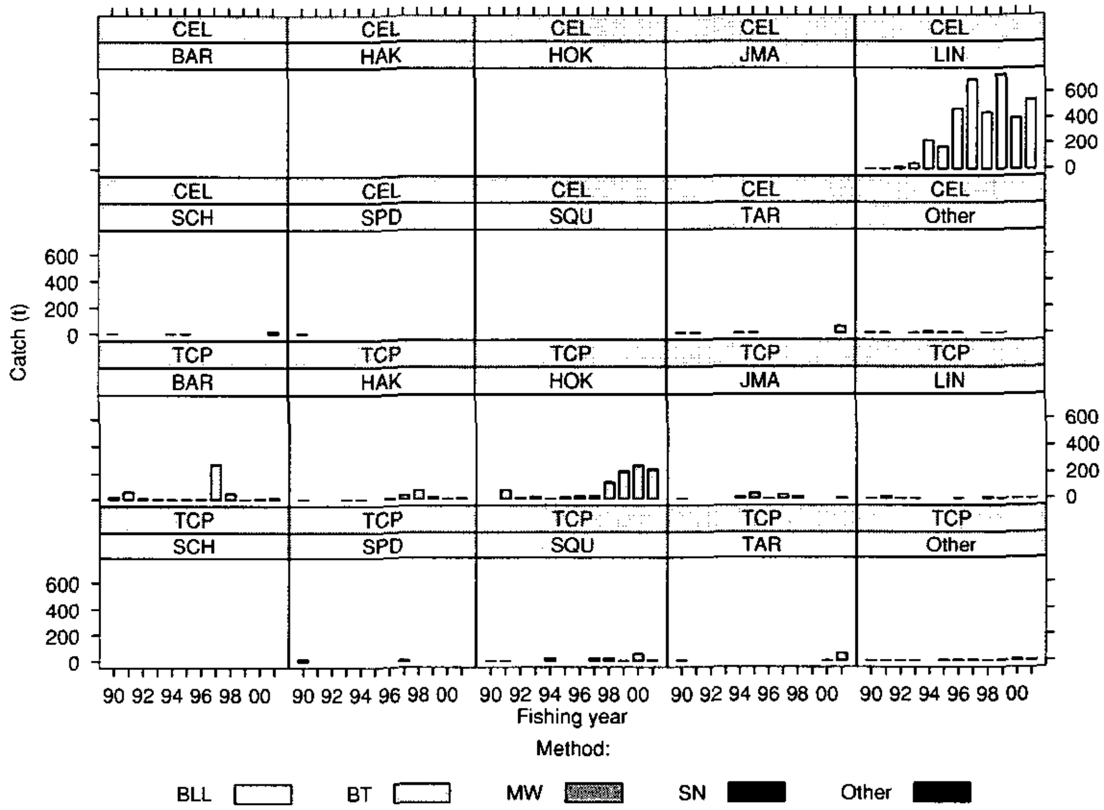

Figure 15: SPD 4 groomed and merged catches by fishing year, catch-effort records form type, target species, and fishing method for the fishing years 1989–90 to 2000–01. Form type, fishing method, and target species codes are defined in Appendix A.

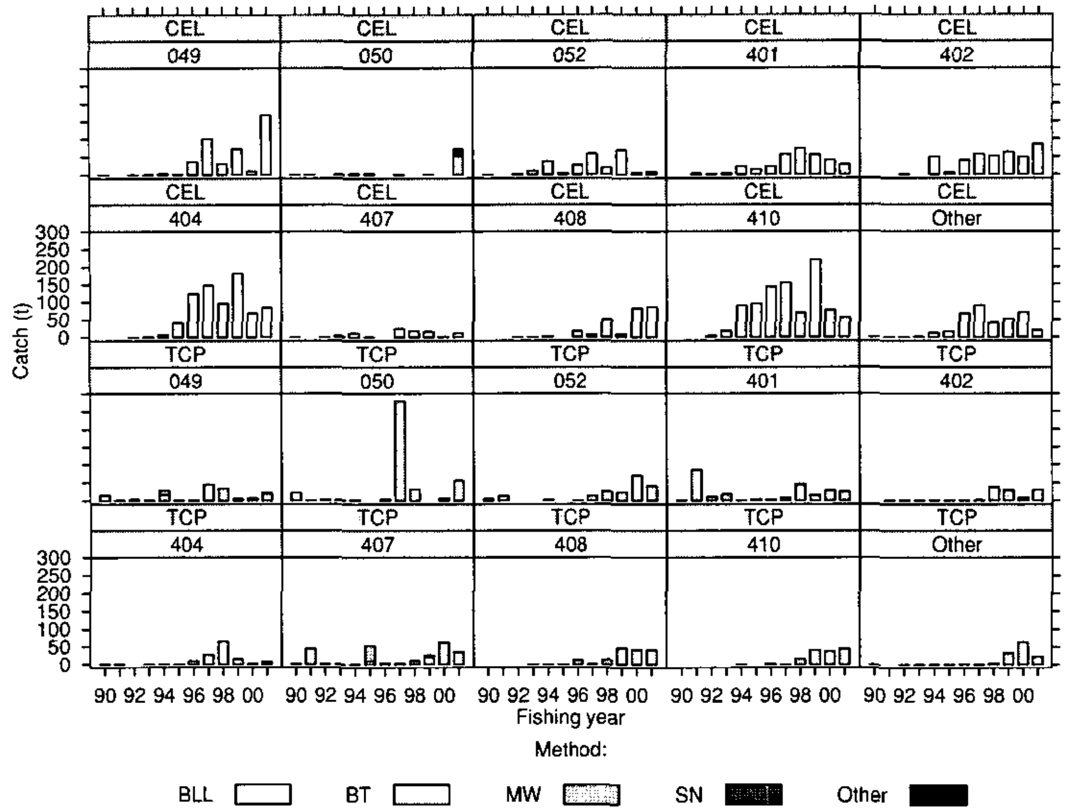

Figure 16: SPD 4 groomed and merged catches by fishing year, catch-effort records form type, statistical area, and fishing method for the fishing years 1989–90 to 2000–01. Form type and fishing method codes are defined in Appendix A.

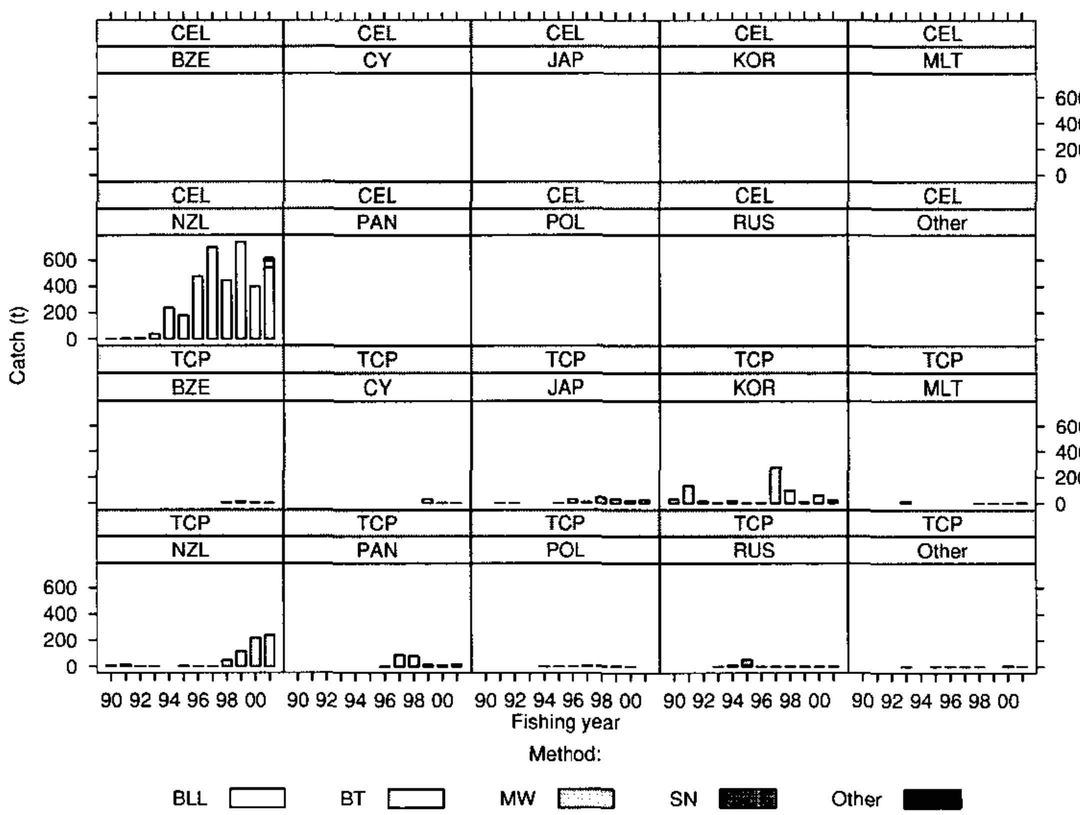

Figure 17: SPD 4 groomed and merged catches by fishing year, catch-effort records form type, vessel flag nationality, and fishing method for the fishing years 1989–90 to 2000–01. Form type, vessel flag nationality, and fishing method codes are defined in Appendix A.

Foreign-flagged charter vessels, especially Korean-flagged vessels, are an important part of the large trawl-vessel catch (Figure 17). Korean vessels account for roughly 12% of the total catch across all methods and fishing years (Table C5(C)).The dogfish catch in the hoki trawl fisheries jumped during the 1997–98 fishing year compared with previous fishing years and remained at the increased catch level throughout the late 1990s (Figure 15). The bottom trawl catch accounts for roughly 32% of the total catch across all groups within the data and fishing years (Table C3(C)).

The spiny dogfish catch in SPD 4 is thus defined by bycatch caught in the target ling bottom longline fishery. Catches taken as bycatch by large domestic and foreign-flagged chartered trawl vessels completing TCEPRs and targeting a range of species, including barracouta, hake, and hoki, are a minor but important component of the catch.

3.3.3 SPD 5

The groomed and merged catch in SPD 5 is summarised in Figures 18–21. There is evidence of seasonality in the catch, with most of the catch taken during the summer months of December to March (65%; Table C1(D)). Catches by month across the fishing years appear highly variable, however (Figure 18). Nearly all of the catch is taken from statistical areas on the southeast of the Stewart-Snares shelf, namely 025, 027, 028, 030, and 504 (96%; Table C2(C)). Nearly half of the catch is caught in statistical area 028 (44%; Table C2(C)), most by large bottom or midwater trawlers (Figure 20). Very little of the catch is caught in statistical areas off the southwest of the South Island, either inshore or offshore.

Bottom and midwater trawlers account for most of the catch across the fishing years (52% and 33% respectively; Table C3(D)). Fishing effort targeting squid and jack mackerels accounts for most of the catch by target species (40% and 15% respectively; Table C4(D)). Large bottom or midwater trawl vessels completing TCEPRs and targeting squid and jack mackerels are the largest contributors to the catch by method and target species (Figure 19). Foreign-flagged charter vessels, especially Korean-flagged vessels, account for more than two-thirds of the catch across the fishing years (68%; Table C5; see also Figure 21). In no other QMA are foreign-flagged vessels as important a component of the catch. Minor elements include the catch by domestic setnet vessels targeting school shark, the catch caught by domestic bottom longline vessels targeting ling, and the catch caught by small domestic trawl vessels targeting flatfish species and giant stargazer (Figures 19–21), although these are far less important than the catch by large foreign-flagged trawl vessels.

The spiny dogfish catch in SPD 5 is thus defined by the catch of large foreign-flagged charter vessels completing TCEPRs and targeting squid and jack mackerel species. In no other QMA is the catch by foreign-flagged vessels as important. The catch by large domestic vessels is negligible compared with large foreign vessels, but catches caught by small domestic vessels completing CELRs and participating in the inshore trawl fishery targeting flatfish and giant stargazer and in the target school shark setnet fishery are minor components of the catch.

3.3.4 SPD 6

The groomed and merged catch in SPD 6 is summarised in Figures 22–25. There is some evidence of seasonality in the data, with catches during the spring and summer months (November to February) accounting for about 62% of the total catch over the fishing years in the time series (Table C1(E)). However, the monthly catches vary greatly across the time series, and the November and January totals have been inflated by very large catches during November 1995 (the 1995–96 fishing year) and January 1998 (the 1997–98 fishing year).

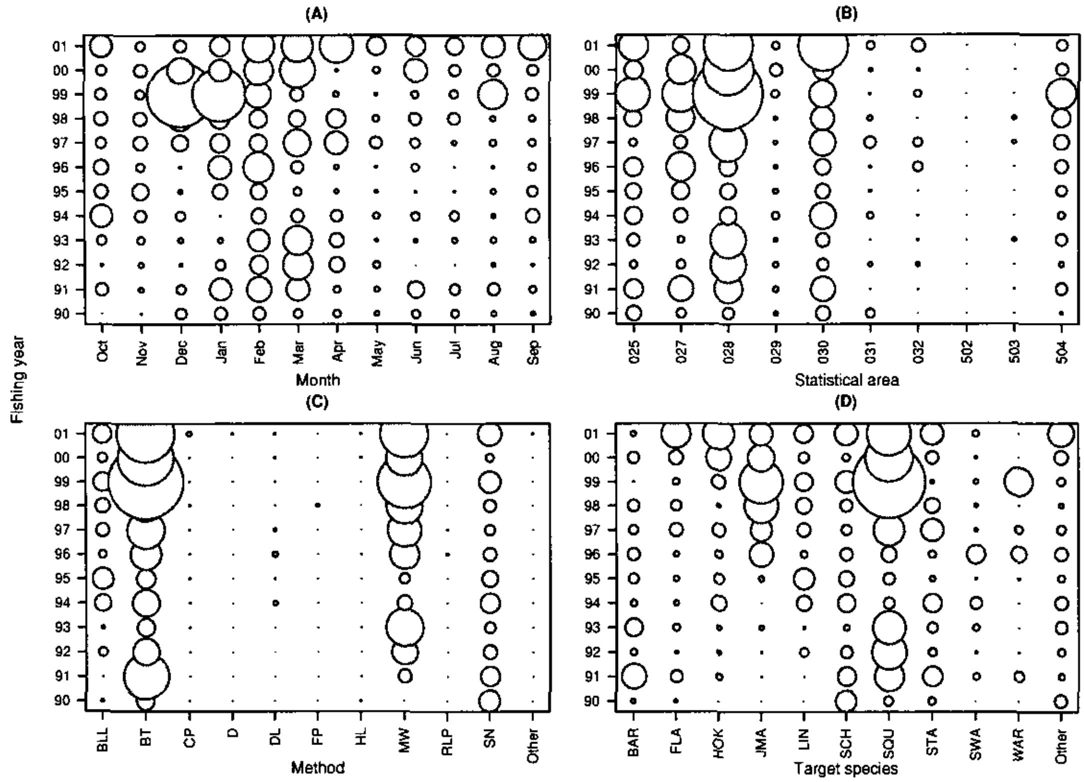

Figure 18: SPD 5 groomed and merged catches (A) by month and fishing year, (B) by statistical area and fishing year, (C) by method and fishing year, and (D) by target species and fishing year. Circle areas are proportional to the amount of catch in each factor level and fishing year combination and are equivalent from plot to plot. The value in catch of a circle 1 cm in diameter is 500 t. Method and target species codes are defined in Appendix A.

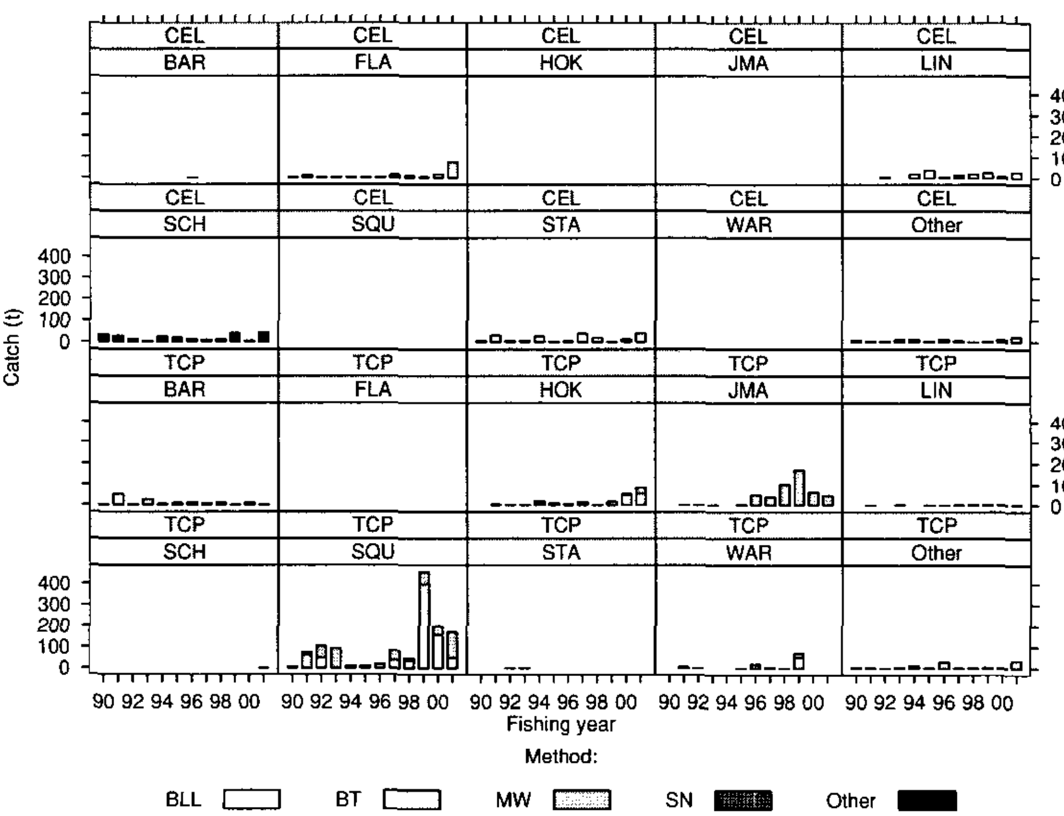

Figure 19: SPD 5 groomed and merged catches by fishing year, catch-effort records form type, target species, and fishing method for the fishing years 1989–90 to 2000–01. Form type, fishing method, and target species codes are defined in Appendix A.

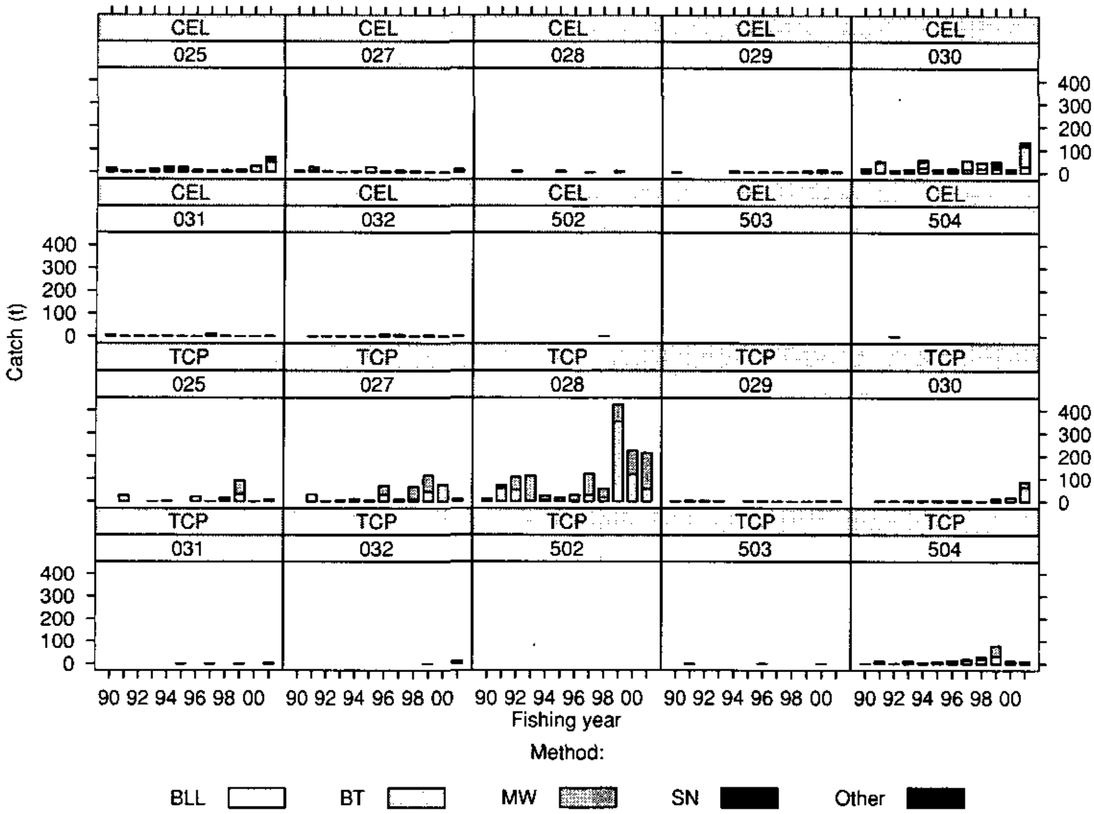

Figure 20: SPD 5 groomed and merged catches by fishing year, catch-effort records form type, statistical area, and fishing method for the fishing years 1989–90 to 2000–01. Form type and fishing method codes are defined in Appendix A.

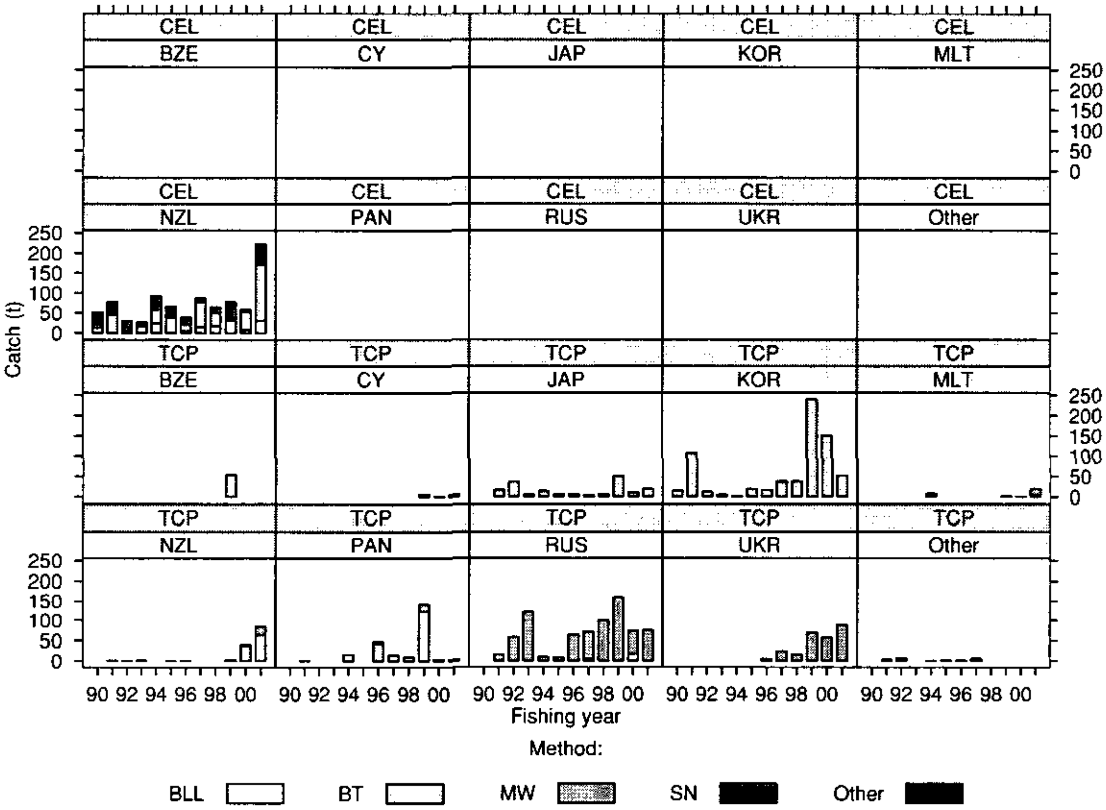

Figure 21: SPD 5 groomed and merged catches by fishing year, catch-effort records form type, vessel flag nationality, and fishing method for the fishing years 1989–90 to 2000–01. Form type, vessel flag nationality, and fishing method codes are defined in Appendix A.

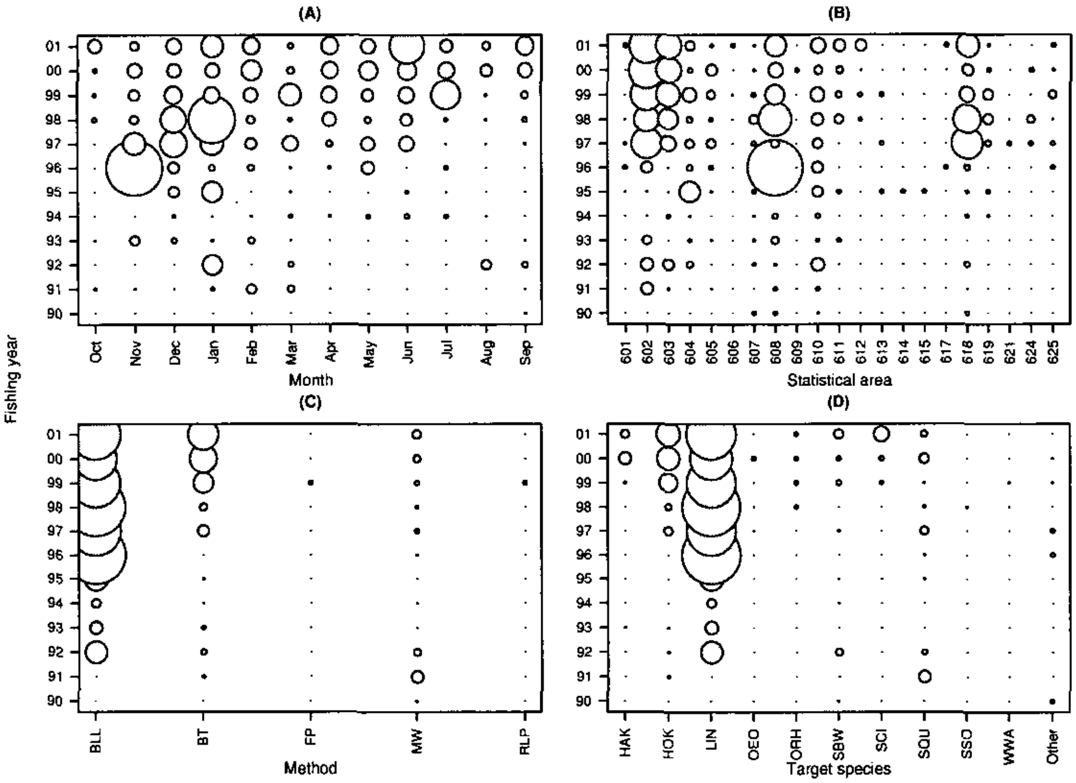

Figure 22: SPD 6 groomed and merged catches (A) by month and fishing year, (B) by statistical area and fishing year, (C) by method and fishing year, and (D) by target species and fishing year. Circle areas are proportional to the amount of catch in each factor level and fishing year combination and are equivalent from plot to plot. The value in catch of a circle 1 cm in diameter is 250 t. Method and target species codes are defined in Appendix A.

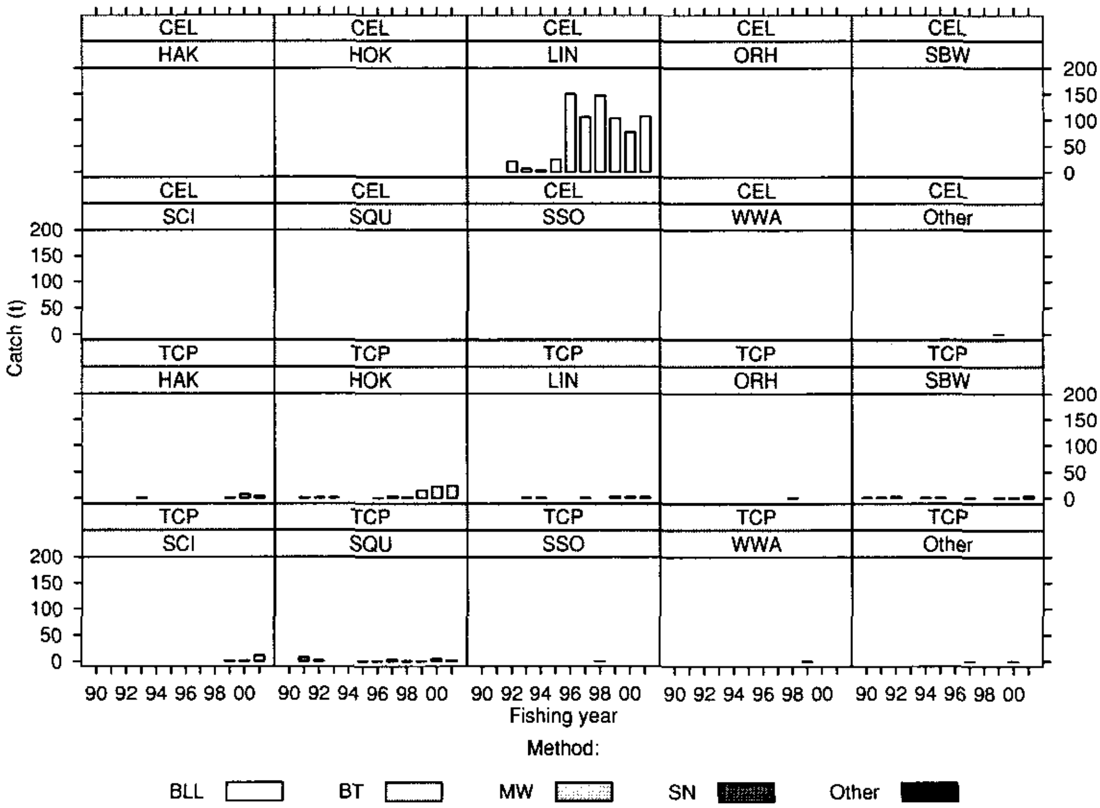

Figure 23: SPD 6 groomed and merged catches by fishing year, catch-effort records form type, target species, and fishing method for the fishing years 1989–90 to 2000–01. Form type, fishing method, and target species codes are defined in Appendix A.

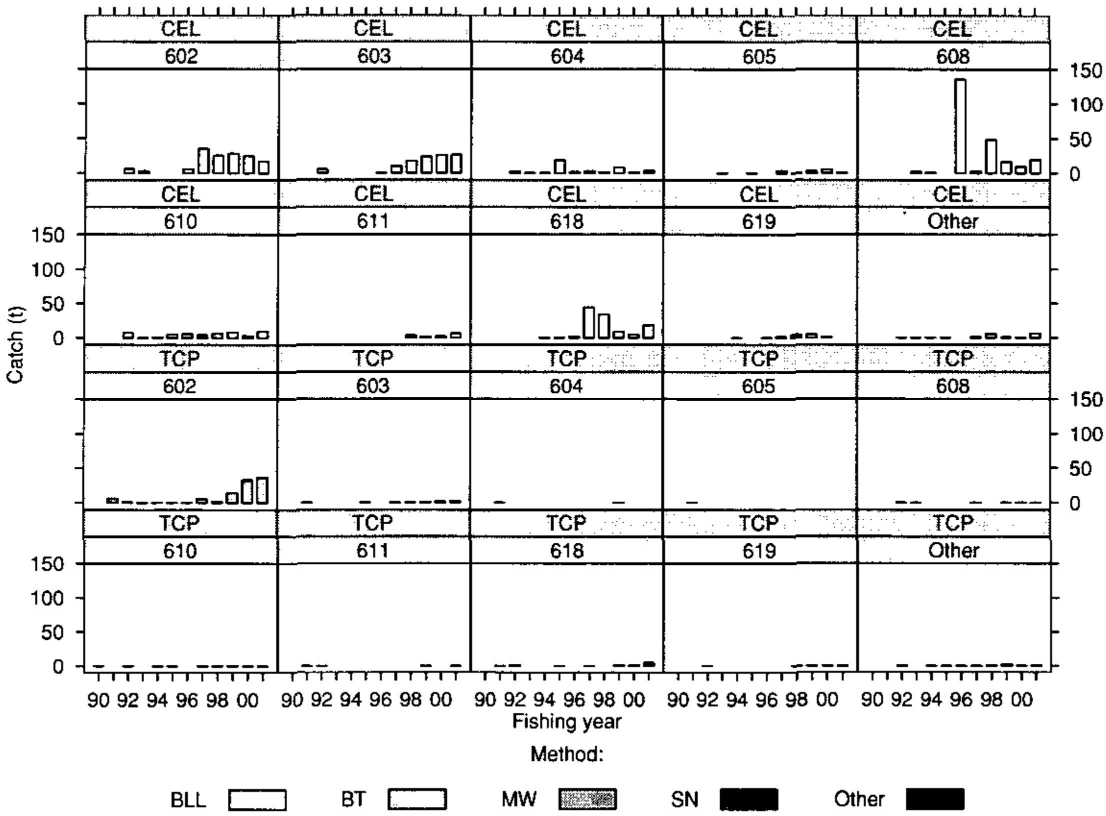

Figure 24: SPD 6 groomed and merged catches by fishing year, catch-effort records form type, statistical area, and fishing method for the fishing years 1989–90 to 2000–01. Form type and fishing method codes are defined in Appendix A.

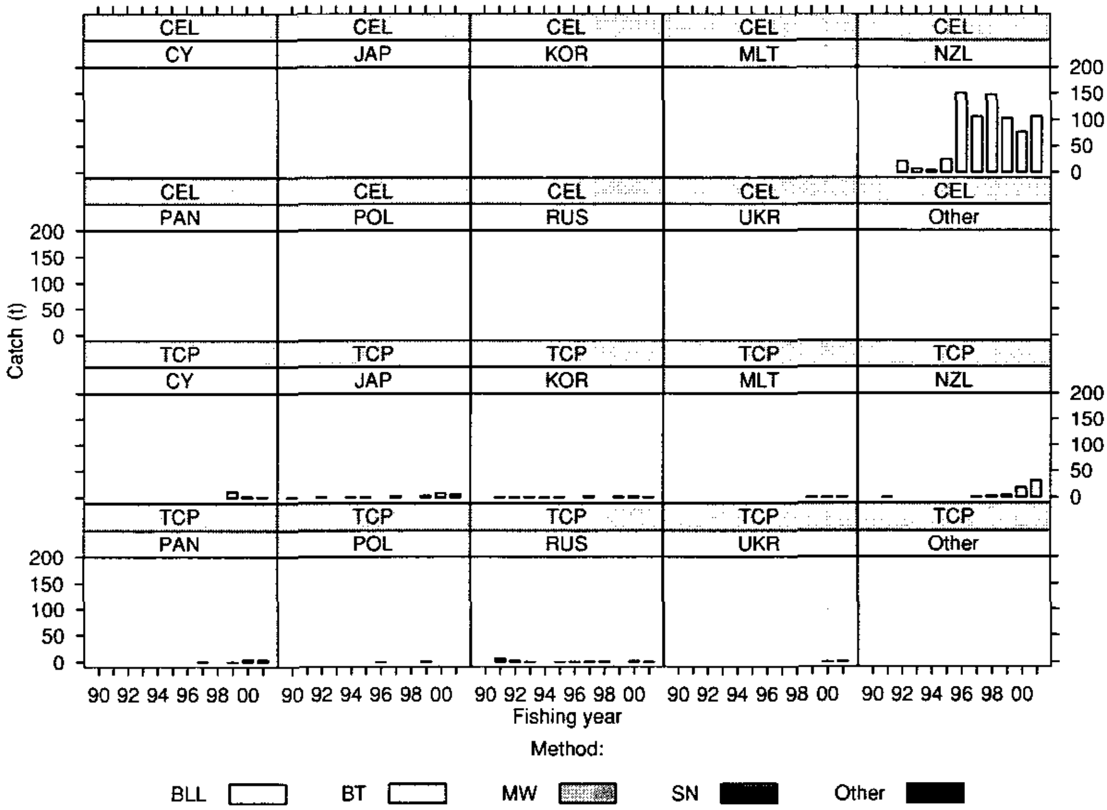

Figure 25: SPD 6 groomed and merged catches by fishing year, catch-effort records form type, vessel flag nationality, and fishing method for the fishing years 1989–90 to 2000–01. Form type, vessel flag nationality, and fishing method codes are defined in Appendix A.

More obvious patterns are apparent in the distribution of catch by statistical area by fishing year (Figure 22, panel B). Eighty-eight percent of the catch was caught in statistical areas 602, 603, 608, 610, and 618 over the fishing years in the time series (28%, 13%, 27%, 6%, 14% of the total catch respectively; Table C2(D)). These areas contain either a sub-Antarctic island group or some portion of the sub-Antarctic plateau (continental shelf). Unsurprisingly, comparatively little of the catch was caught in those statistical areas containing extensive deep water. The catches in statistical areas 602, 603, 608, 610, and 618 also appear reasonably consistent over time, at least from the 1994–95 fishing year and on.

The spiny dogfish catch in SPD 6 is driven by bycatch in the target ling bottom longline fishery (Figure 23). Comparatively little is caught by other methods (14%; Table C3(E)), although bycatch by large trawl vessels completing TCEPRs and targeting hake and hoki with bottom trawl gear is a very minor component of the catch (Figure 23). Most of the bottom trawl catch is taken in statistical area 602 (Figure 24); there are few other clear spatial trends in the bottom trawl catch data. Foreign-flagged chartered vessels are relatively unimportant, accounting for only about 8% of the total catch over the fishing years. The bottom longline fleet is dominated by New Zealand vessels (Figure 25).

3.3.5 SPD 7

The groomed and merged catch in SPD 7 is summarised in Figures 26–29. There is very strong evidence of seasonality in the catch in SPD 7 with 65% of the total catch caught during the winter months of June, July, and August (Table C1(F)). Catches during these three months have remained consistently high over the course of the time series. Groomed unmerged landings in SPD 7 have risen from 326 t during the 1989–90 fishing year to 1321 t during 2000–01, peaking at 1752 t during 1998–99, and averaging 1140 t per year over the time series.

Catches have been recorded from all statistical areas, but most (80%; Table C2(E)) of the catch was caught in statistical areas 017 and 018 in Cook Strait (16% and 5% respectively; Table C2(E)), 034 and 035 off the west coast of the South Island (38% and 12%; Table C2(E)), and 038 in Tasman and Golden Bays (21%; Table C2(E)). While catches in statistical areas 017, 018, 034, and 035 have remained consistently high over the time series, the catch in 038 has declined significantly over time, from as much as 77% of the total annual catch during the early 1990s, to less than 10% per annum during the mid to late 1990s (Table C2(E)). The decline of the catch in 038 is due to the demise of a target fishery in Tasman and Golden Bays (discussed below).

Virtually all of the catch (99%; Table C3(F)) was taken by three methods: bottom and midwater trawling and setnet fishing (42%, 37%, and 20%, respectively; Table C3(F)). The existence of a target fishery in statistical area 038 (Tasman and Golden Bays; see Figures 27 and 28) is noted. The target spiny dogfish catch accounted for as much as 63% of the total annual catch during the early 1990s, but it had declined to about 2% or less per annum during the mid to late 1990s (Table C4(F)). As with the target setnet fishery off the east coast of the South Island, this was due to a targeting moratorium issued by the Ministry of Fisheries at the start of the 1995–96 fishing year.

Nearly all of the bottom and midwater trawl catch is taken by large trawlers completing TCEPRs and targeting hoki (Figure 27). Given the distributions of the dogfish catch by month and by statistical area, we associate the dogfish catch by trawl vessels targeting hoki with bycatch caught in the spawning hoki fisheries off the west coast of the South Island (statistical areas 034 and 035) and in Cook Strait (017 and 018). Vessels over 43 m in length are not permitted to fish in Cook Strait. Most of the dogfish catch by bottom trawlers in statistical areas 017 and 018 is by smaller vessels completing CELRs (Figure 28). We speculate that dogfish caught in the spawning hoki fisheries are preying on schooling hoki, but this is untested. New Zealand vessels account for nearly two-thirds of the catch over the time series (65%; Table C5), although large foreign-flagged chartered trawl vessels, especially Japanese and Russian-flagged vessels (7% and 12% of the total catch respectively; Table C5), are relatively important (Figure 29).

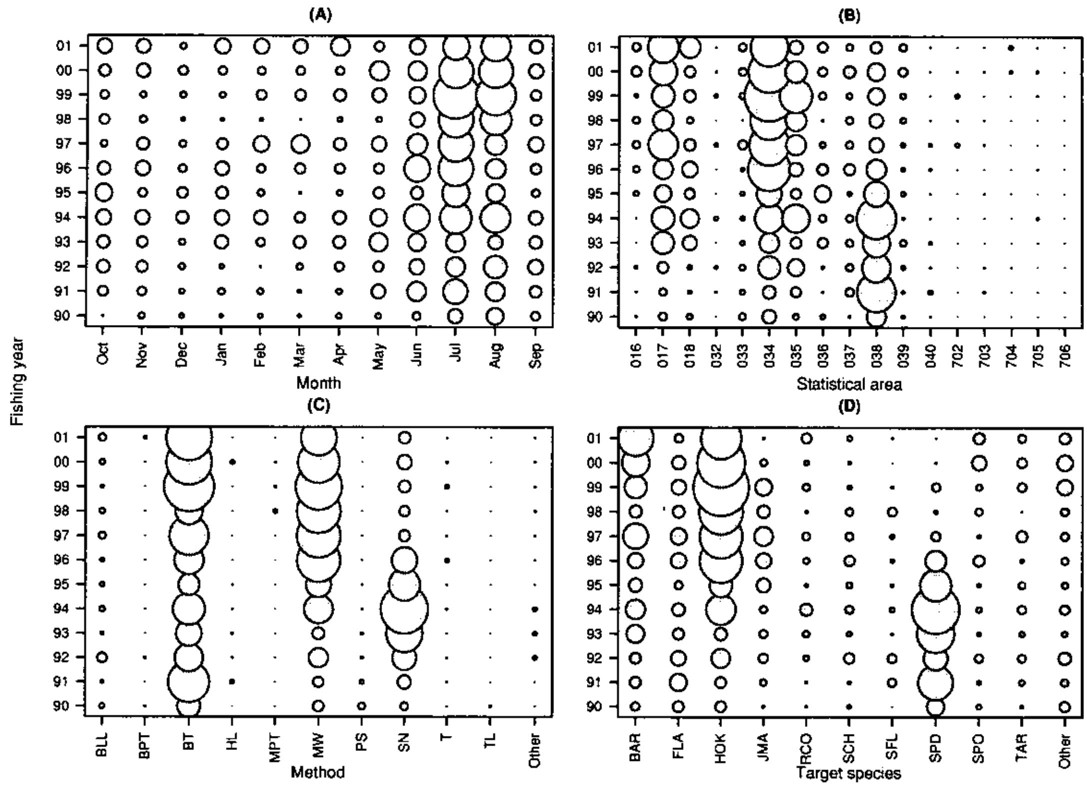

Figure 26: SPD 7 groomed and merged catches (A) by month and fishing year, (B) by statistical area and fishing year, (C) by method and fishing year, and (D) by target species and fishing year. Circle areas are proportional to the amount of catch in each factor level and fishing year combination and are equivalent from plot to plot. The value in catch of a circle 1 cm in diameter is 2000 t. Method and target species codes are defined in Appendix A.

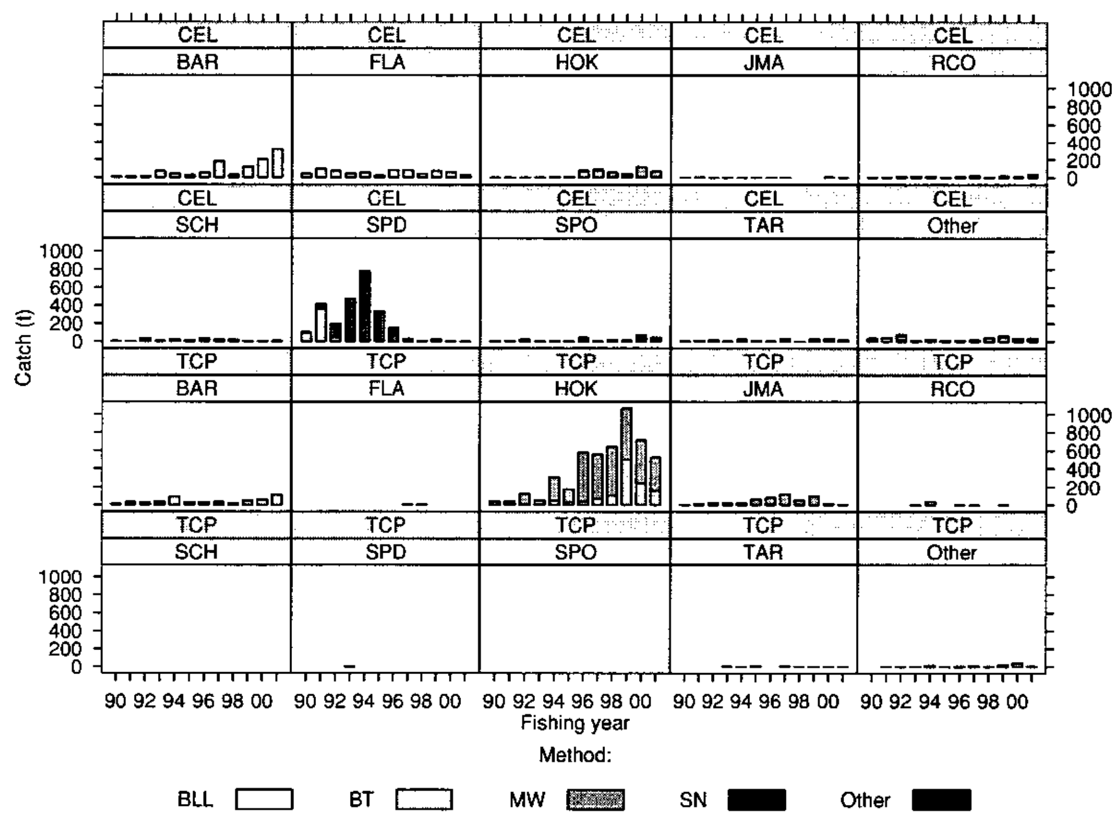

Figure 27: SPD 7 groomed and merged catches by fishing year, catch-effort records form type, target species, and fishing method for the fishing years 1989–90 to 2000–01. Form type, fishing method, and target species codes are defined in Appendix A.

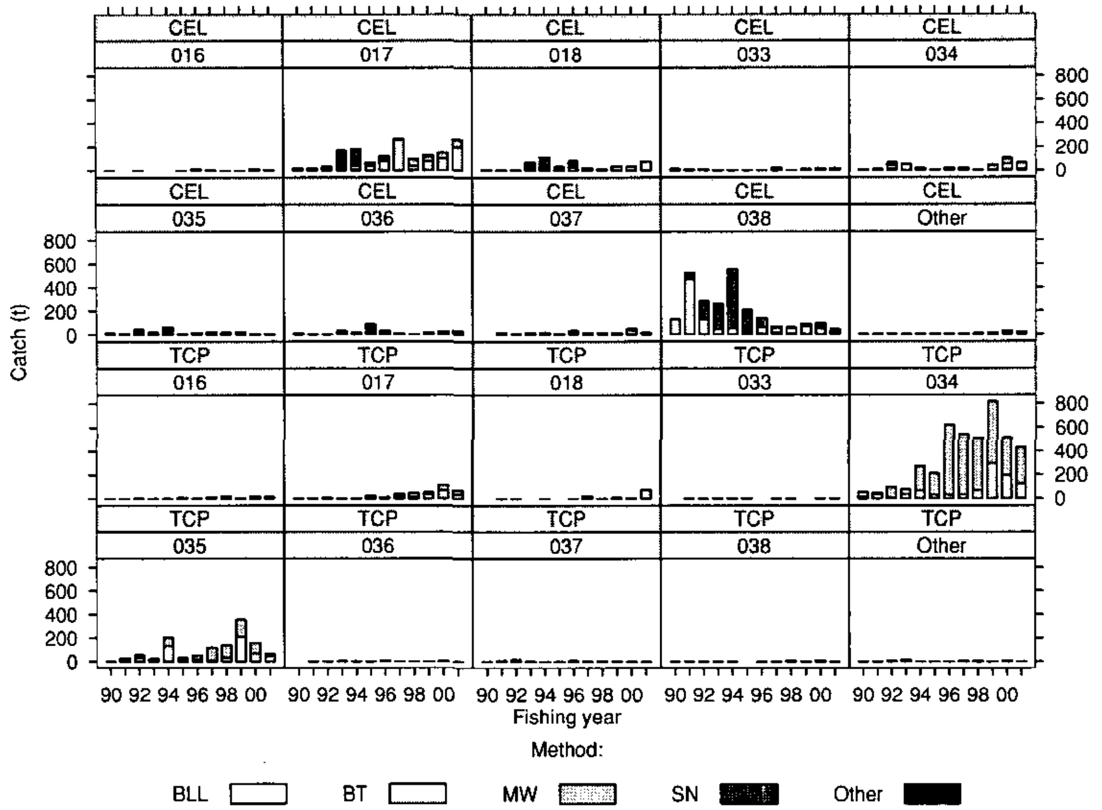

Figure 28: SPD 7 groomed and merged catches by fishing year, catch-effort records form type, statistical area, and fishing method for the fishing years 1989–90 to 2000–01. Form type and fishing method codes are defined in Appendix A.

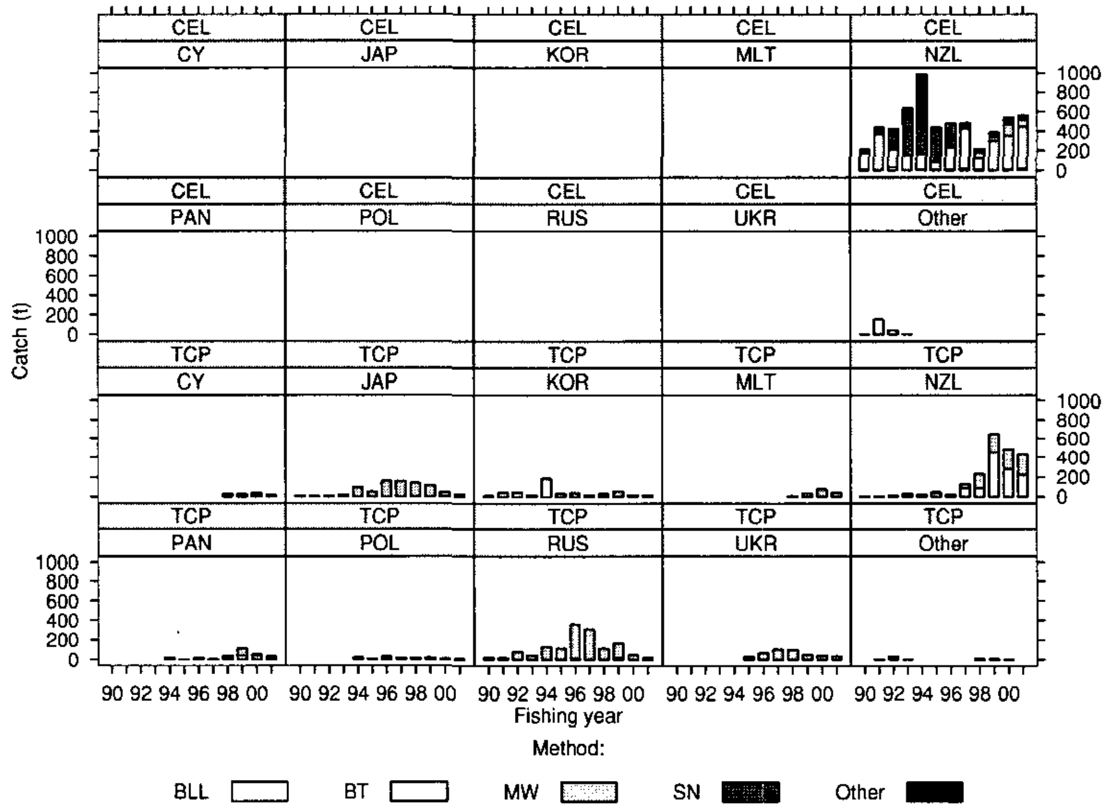

Figure 29: SPD 7 groomed and merged catches by fishing year, catch-effort records form type, vessel flag nationality, and fishing method for the fishing years 1989–90 to 2000–01. Form type, vessel flag nationality, and fishing method codes are defined in Appendix A.

In addition to the target setnet and target hoki trawl bycatch, spiny dogfish caught by small domestic vessels completing CELRs and targeting barracouta, flatfish, red cod, and tarakihi among other species in the mixed-species bottom trawl fishery on the open west coast of the South Island (statistical areas 033–036) form a third but minor component of the catch (Figures 27–29).

The spiny dogfish catch in SPD 7 is thus defined by catches in the spawning hoki trawl fisheries off the west coast of the South Island (statistical areas 034 and 035) and in Cook Strait (statistical areas 017 and 018). The existence of a target setnet fishery in Tasman and Golden Bays (statistical area 038) is noted; however, as with the target setnet fishery off the east coast of the South Island, this has largely disappeared following a targeting moratorium issued by the Ministry of Fisheries during the 1995–96 fishing year. Catches taken by the small domestic vessels completing CELRs participating in the inshore mixed-species trawl fishery off the west coast of the South Island targeting barracouta, flatfish, red cod, and tarakihi are a minor component of the catch.

3.4 On market preferences for northern and southern spiny dogfish and whether fishers can differentiate between the two species

As noted above, the ranges of spiny dogfish (*Squalus acanthias*) and its congeneric, northern spiny dogfish (*S. mitsukurii*), overlap around the west coast of the North Island and the Chatham Islands. Doubtless, the zone of overlap extends throughout areas of suitable habitat in middle latitudes of the central New Zealand EEZ beyond these areas. A quantitative investigation of associations between northern and southern spiny dogfish was outside the scope of this study, but given that some concern exists within the Ministry of Fisheries on misidentification of the two species, we have informally investigated relative market preferences for northern and southern spiny dogfish and whether commercial fishers or fish processors are able to differentiate between the two species. We summarise our findings below. Note that a quantitative market research survey was also outside the scope of this study, therefore the representativeness of our findings is unknown.

3.4.1 The perceived value of both species

Both spiny dogfish and northern spiny dogfish are sold commercially on the New Zealand domestic market, principally as fish and chips. Sales of spiny dogfish greatly exceed sales of northern spiny dogfish, although this may be due to lack of supply rather than market resistance. Developing export markets exist for spiny dogfish, principally in Australia (fish and chips) and Europe (fillets); there are no known existing export markets for northern spiny dogfish, although this may also be due to lack of supply rather than market resistance.

There is some variation between processors over whether either, both, or neither species will be traded. Those fish processors exporting spiny dogfish commented that those factors sought by their markets (principally, the very white, milky flesh of spiny dogfish compared with northern spiny dogfish) make northern spiny dogfish (pinker flesh) less attractive to the market, less easy to sell, and hence not worth trading. The current port price offered for spiny dogfish (\$0.60 kg^{-1}) by one fish processor we interviewed exceeds those offered by the same operator for barracouta (\$0.15 kg^{-1}), hake and red cod (\$0.40 kg^{-1} each).

Spiny dogfish value is strongly affected by fish size and hence by fish sex. As female spiny dogfish tend to be much larger on average than males after maturity, existing domestic and export markets for this species are based primarily on the sale of female fish. One fish processor trading spiny dogfish commented that fillets cut from most male fish fail to make the lowest weight grades specified in his markets.

3.4.2 Species identification

Commercial fishers and fish processors appear currently able to differentiate between the two species. As well as different scientific names (reflecting their status as different biological species), both species have different common names in common use (e.g., *S. acanthias* = "spiny dogfish", "spiky dogfish", "spurdog", etc.; *S. mitsukurii* = "northern spiny dogfish", "northern spiky dogfish", "greeneye", etc.). One fish processor commented that, in his opinion, the morphological differences separating spiny dogfish and northern spiny dogfish were roughly equivalent in magnitude to those separating rig (*Mustelus lenticulatus*) and school shark (*Galeorhinus australis*).

The present ability of fishers to differentiate the species may be due to awareness raised following release of the proposal to enter spiny dogfish into the QMS. Nevertheless, an unknown amount of misidentification may have occurred in the past. Production and circulation of educational materials highlighting the differences between the two species among commercial fishers and fish processors may be useful to prevent misidentification in the future.

3.5 Fisheries characterisations summary and conclusions

Spiny dogfish are caught throughout the New Zealand EEZ, both inshore and offshore, and by foreign and domestic vessels in all QMAs, although the bulk of the catch is from southern waters (94% in SPD 3, 4, 5, 6, and 7 over all fishing years; Table 7(B)) by the domestic fleet (78% by New Zealand vessels over all QMAs and fishing years; Table C5(A)). Catches from the northern QMAs (SPD 1, 9, and 10) are likely to include an unknown number of misreported catches of the congeneric, northern spiny dogfish (*S. mitsukurii*). A quantitative analysis of associations between the two species is beyond the scope of this paper. The total reported catch has increased steadily throughout the fishing years in the time series.

The existence of at least two target fisheries for spiny dogfish is noted. These are an inshore setnet target fishery in SPD 3 off the east coast of the South Island (statistical areas 018, 020, 022, and 024), and an inshore setnet target fishery in SPD 7 in Tasman and Golden Bays off the South Island (statistical area 038). Historically, these fisheries have accounted for a large proportion of the total reported catch (up to 48% over all QMAs and fishing years; Table C4(A)), but catches have declined rapidly since 1995–96 and are now negligible.

The composition of the catch varies markedly by QMA. The spiny dogfish catch in each of the major southern QMAs, SPD 3–7, may be characterised by a single or a small set of fisheries which dominate the catch.

- The catch in SPD 3 is dominated by spiny dogfish caught in the target setnet fishery, although the spiny dogfish catch in the inshore mixed-species trawl fishery targeting barracouta, flatfish, and red cod is also important.

- The catch in SPD 4 is dominated by spiny dogfish caught in the target ling bottom longline fishery, although the spiny dogfish catch in bottom trawl fisheries targeting other species on the Chatham Rise also contribute to a small extent.

- The catch in SPD 5 is dominated by spiny dogfish caught in bottom and midwater trawl fisheries for jack mackerel and squid species by large (i.e., over 28 m) foreign charter vessels. In no other QMA do foreign vessels contribute to the catch as greatly.

- The catch in SPD 6 is dominated by spiny dogfish caught in the target ling bottom longline fishery on the continental shelf around the sub-Antarctic Islands.

- The catch in SPD 7 is dominated by spiny dogfish caught in the bottom and midwater trawl fisheries for spawning hoki off the west coast of the South Island (statistical areas 034 and 035) and in Cook Strait (statistical areas 017 and 018) and the target setnet fishery in Tasman and Golden Bays (statistical area 038). Surprisingly, the inshore mixed-species trawl fishery off the west coast of the South Island is a fairly minor component of the catch.

Trends in reporting types between the QMAs reflect the reporting regimes of those fisheries that dominate the catch in each QMA.

Discarded catches, i.e., catches caught but not landed (destination state code = "D" on CELR and CLR landing records), are an important component of the total catch; i.e., the total removals from the stocks. Discarded catches increased rapidly throughout the 1990s, from about 10–20% of the total catch in the early 1990s to about 60% of the total catch throughout the late 1990s and beyond. The discarding rate appears reasonably stable over the last few fishing years in the time series, however. We suggest that rather than reflecting an actual increase in the amount of discarded catch, this reflects a change in reporting practices, with fishers more accurately recording discarded catches of spiny dogfish than in the past. A quantitative analysis of discarding rates and estimation of total removals from the stocks is an important topic of future research for spiny dogfish in New Zealand waters.

4. CATCH-PER-UNIT-EFFORT ANALYSES

4.1 Exploring the catch and effort data

Data summaries and distribution plots of selected catch and effort variables in the model datasets are presented in Appendix D. The plots reveal some level of dynamism in some datasets, suggesting that fishing patterns have changed over time in these fisheries.

4.1.1 Model 1: target setnet fishing in SPD 3

Distributions of *total catch*, *vessel experience*, *vessel length*, *month*, *statistical area*, *total amount of net set*, *total fishing duration*, and *median net mesh width* per effort stratum in the model 1 core vessel dataset are plotted by fishing year in Figure D1. These reveal a declining trend in *total catch*, a downwards shift in *fishing duration*, and an upwards shift in *vessel length* per effort stratum. The distributions of *total amount of net set* per effort stratum appear reasonably consistent over time, although the upper extreme is trending down. The changes in the *vessel length*, *fishing duration*, and *total amount of net set* distributions roughly coincide with the demise of the target fishery during the 1995–96 fishing year. There are comparatively many effort strata in the dataset (Table D1).

4.1.2 Model 2: all setnet fishing in SPD 3

Distributions of *total catch*, *vessel experience*, *vessel length*, *month*, *statistical area*, *target species*, *total amount of net set*, *total fishing duration*, and *median net mesh width* per effort stratum in the model 2 core vessel dataset are plotted by fishing year in Figure D2. All distributions, other than *vessel experience*, are fairly consistent over time. There is an increasing trend in *vessel experience* per effort stratum over the time series, although new vessels appear to have entered the fishery during every year up to and including the 1998–99 fishing year. The *median net mesh width* distributions are roughly bimodal, with modes centred over the 125 mm (ca. 5 inch) and 175 mm (ca. 7 inch) mesh sizes, suggesting some differentiation within the gear used in the fishery; regulated mesh size limits, 125 mm or 5 inch mesh nets are typically used to target small to medium-sized bony fish species, 175 mm or 7 inch mesh nets are typically used to target sharks and large bony fish species. Although *median net mesh width* was not offered to the model, this may have been indexed to some extent by offering *target species*. There are also comparatively many effort strata in the dataset (Table D2).

4.1.3 Model 3: bottom-trawl fishing in SPD 3

Distributions of *total catch*, *vessel experience*, *vessel length*, *month*, *statistical area*, *target species*, *total fishing duration*, *median wing spread*, *median headline height*, and *total number of trawl shots* per effort stratum in the model 3 core vessel dataset are plotted by fishing year in Figure D3.The *statistical area*, *month*, and *vessel length* distributions are reasonably stable across the time series. Although there is an increasing trend in *vessel experience* per effort stratum over the time series, new vessels have entered the fishery every year up until the 1996–97 fishing year. Most effort strata are associated with vessels less than 20 m in length, although vessels as large as 80 m are active in the fishery, with presumably radically different catching power. This may have been accounted for by offering *vessel key* to the model. Although polymodal, reflecting fleet composition, the distributions of *median wing spread* and *median headline height* per stratum are static across the time series. The *fishing duration* and *number of trawl shots* distributions are also reasonably consistent, although there is some variation in the upper extremes in both sets of distributions with values peaking during the 1995–96 fishing year. There are comparatively many effort strata in the dataset (Table D3).

4.1.4 Models 4 and 5: bottom-trawl fishing on the Chatham Rise (SPD 3 & 4)

Distributions of *total catch, vessel experience, vessel length, month, statistical area, target species, total fishing duration, median wing spread, median headline height,* and *total number of trawl shots* per effort stratum in the model 4 and 5 core vessel datasets are plotted by fishing year in Figures D4–D5, respectively. Both figures suggest a much greater level of dynamism in the data than in either models 1, 2, or 3, which is probably due to the fewer effort strata available. There are roughly one-third the effort strata in the model 5 dataset compared with the model 3 dataset, and fewer still in the model 4 dataset. The distributions of *month, statistical area, target species,* and *number of trawl shots* per effort stratum in the model 4 dataset are highly variable, although the distributions of *vessel length, median wing spread,* and *median headline height* appear comparatively stable. There is evidence of consolidation in the *target species, median wing spread,* and *median headline height* distributions in the model 5 dataset during the 1995–96 fishing year and beyond, which roughly coincides in time with the growth of the juvenile hoki fishery on the western Chatham Rise. There are comparatively few effort strata in either dataset (Tables D4–D5, respectively).

4.1.5 Model 6: bottom-longline fishing on the Chatham Rise (SPD 3 & 4)

Distributions of *total catch, vessel experience, vessel length, month, statistical area, target species, total number of hooks set, total fishing duration,* and *total number of lines set* per effort stratum in the model 6 core vessel dataset are plotted by fishing year in Figure D6. The data are more consistent over time compared with models 4 and 5, although some trends are still apparent. There is an increasing trend in *total catch* while *total number of hooks set* remains reasonably stable, suggesting a nominal increase in catch-per-unit-effort. Distributions of the other effort variables are reasonably static. The *vessel experience* and *vessel length* distributions suggest that the composition of the fleet has changed significantly over time, with new vessels entering the fishery during every fishing year up to and including the 1998–99 fishing year, and the most experienced vessels appearing to leave the fishery during the 1999–2000 fishing year. Most of the effort has clearly gone into the target ling bottom longline fishery over time, although some effort has been spent targeting other species during the mid 1990s (1993–94 to 1997–98 fishing years). Although there are comparatively few effort strata in the dataset in the early years of the time series, the number of effort strata per fishing year roughly doubles in later years of the time series (Table D6).

4.1.6 Model 7: bottom-trawl fishing in SPD 5

Distributions of *total catch, vessel experience, vessel length, month, statistical area, target species, total fishing duration, median wing spread, median headline height,* and *total number of trawl shots* per effort stratum in the model 7 core vessel dataset are plotted by fishing year in Figure D7. *Vessel experience* per effort stratum increases consistently over the time series, although new vessels have entered the fishery during every fishing year other than the 1997–98 and 1999–2000 to 2000–01 fishing years. There appear to be two distinct groups of vessels in the *vessel length* distributions, a mode of small vessels at about 20 m and a group of much larger vessels between about 60–80 m in length and over. The mode of smaller vessels represents vessels active in the inshore mixed-species trawl fishery whereas the larger vessels are foreign charter vessels active in the jack mackerel and squid target fisheries. Although the medians of the *median wing spread* and *median headline height* per effort stratum distributions have remained reasonably consistent over the time series, these appear to be dropping during the 1999–2000 fishing year and beyond. There are relatively large numbers of effort strata in the dataset (Table D7).

4.1.7 Model 8: bottom-longline fishing in SPD 6

Distributions of *total catch, vessel experience, vessel length, month, statistical area, target species, total number of hooks set, total fishing duration,* and *total number of lines set* per effort stratum in the model 8 core vessel dataset are plotted by fishing year in Figure D8. The *vessel experience* and *vessel length* distributions suggest that the fleet composition has changed somewhat over time. There is an increasing trend in *vessel experience* per effort stratum over the time series, although new vessels entered the fishery during the 1994–95 to 1996–97 and 1998–99 fishing years. During the 1999–2000 fishing year and beyond, the more experienced vessels appear to have left the fishery. This is consistent with trends noted in the model 6 dataset. The distribution of effort by *month* and *statistical area* is variable. All effort was spent in the target ling fishery. The *total number of hooks set, total fishing duration,* and *total number of lines set* distributions appear to have stabilised during the 1995–96 fishing year and beyond. There are comparatively few effort strata in the dataset over all fishing years, however (Table D8).

4.1.8 Models 9 and 10: bottom-trawl fishing in SPD 7

Distributions of *total catch, vessel experience, vessel length, month, statistical area, target species, total fishing duration, median wing spread, median headline height,* and *total number of trawl shots* per effort stratum in the model 9 and 10 core vessel datasets are plotted by fishing year in Figures D9–D10, respectively. The model 9 and 10 distributions are very similar, although this is unsurprising given that all of the data in the model 9 dataset are contained within the model 10 dataset (the model 9 data make up 4504 of 4676 effort strata within the model 10 dataset; Table D9 and Table D10). The distributions of *vessel length, month, statistical area,* and *target species* per effort stratum are stable over time. Large vessels (over 28 m long) account for a small but consistent number of effort strata. There is an increasing trend in *vessel experience* per effort stratum over the time series, suggesting an ageing fleet, although new vessels entered the fishery during the 1989–90 to 1996–97 fishing years. The *fishing duration* and *total number of trawl shots* distributions are reasonably stable, although maximum values appear to be increasing over the time series. The *median wing spread* and *median headline height* distributions appear stable but polymodal, reflecting the size composition of the fleet.

4.2 Model selection

The final models selected are given in Table 12. The models explained between 21.8% (model 1) and 55% (model 4) of the variation in their respective datasets. Diagnostic residual plots are presented for each model in Appendix D. Expected log catch rates for each significant predictor variable in each model holding all other significant predictor variables fixed at median values are also presented in Appendix D.

The diagnostic residual plots do not provide strong evidence of a failure to meet the regression assumptions of constant variance and normality of errors in natural log space, although all models generally fail to adequately explain very large and very small values more than two quantiles above the mean log catch rate in their respective datasets.

Between three and seven significant predictors were selected across all the models fitted, including *fishing year. Vessel key* and *month* were found to be significant predictors in all models fitted, typically added during the second or third step of the model selection process. The *month* effect suggests that the apparent seasonality in the catch in most QMAs is probably real; spiny dogfish log catch rates appear significantly affected by the time of the year. Expected log catch rates increased during the winter months in models 1, 2, and 3, peaking during March–April, declining thereafter, and peaking once again during August–September. Expected log catch rates were lowest during the late spring and early summer months of November and December. Similar trends were noted in the other models, although these were weaker in models 6 and 8.

The *vessel key* effect suggests that individual fishing practices significantly affect log catch rates. However, *vessel key* was used as a catch-all index of all the variation associated with the fishing patterns and characteristics of individual vessels such as length, power plant, and flag nationality, and is hence confounded by these factors. Refitting the models with separate terms for these factors (e.g., vessel experience, engine power, vessel length, vessel flag nationality) in the future may help to identify those vessel characteristics that significantly affect spiny dogfish catch rates. Restriction of the data to core vessel subsets reduced the degrees of freedom in each model, allowing the model-fitting algorithm to converge. Less restrictive core vessel definitions in models 3, 9, and 10 meant that the model-fitting algorithm failed to converge.

The effort variables, such as *effort number*, *fishing duration*, and *target species* were typically added relatively late in the model selection process. *Statistical area* was offered to all models, but selected as a significant predictor only in models 4–8.

Table 12: Variables selected in order of selection for all CPUE models fitted. Descriptions of the models fitted are given in Table 4. The variables offered to each model are given in Table 5.

	Model 1		Model 2		Model 3	
Order	Variable	R^2	Variable	R^2	Variable	R^2
1	*Fishing year*	0.038	*Fishing year*	0.016	*Fishing year*	0.013
2	*Vessel key*	0.176	*Vessel key*	0.325	*Vessel key*	0.180
3	*Month*	0.218	*Target species*	0.361	*Month*	0.246
4	–	–	*Month*	0.393	*Target species*	0.271
5	–	–	–	–	*Fishing duration*	0.285
6	–	–	–	–	–	–
7	–	–	–	–	–	–

	Model 4		Model 5		Model 6	
Order	Variable	R^2	Variable	R^2	Variable	R^2
1	*Fishing year*	0.144	*Fishing year*	0.069	*Fishing year*	0.174
2	*Target species*	0.328	*Vessel key*	0.216	*Statistical area*	0.234
3	*Vessel key*	0.412	*Target species*	0.289	*Effort number*	0.287
4	*Statistical area*	0.469	*Month*	0.329	*Vessel key*	0.312
5	*Month*	0.510	*Statistical area*	0.353	*Target species*	0.334
6	*Fishing duration*	0.524	–	–	*Month*	0.350
7	*Effort number*	0.555	–	–	–	–

	Model 7		Model 8		Model 9	
Order	Variable	R^2	Variable	R^2	Variable	R^2
1	*Fishing year*	0.058	*Fishing year*	0.122	*Fishing year*	0.013
2	*Vessel key*	0.283	*Statistical area*	0.392	*Vessel key*	0.180
3	*Month*	0.333	*Vessel key*	0.426	*Month*	0.246
4	*Target species*	0.370	*Month*	0.456	*Target species*	0.271
5	*Fishing duration*	0.391	*Effort number*	0.484	*Fishing duration*	0.285
6	*Statistical area*	0.406	*Fishing duration*	0.503	–	–
7	–	–	–	–	–	–

	Model 10	
Order	Variable	R^2
1	*Fishing year*	0.013
2	*Vessel key*	0.180
3	*Month*	0.246
4	*Target species*	0.271
5	*Fishing duration*	0.285
6	–	–
7	–	–

4.3 Trends in model year effects

Canonical year effects were extracted from each of the final fitted models (Table 13). The nominal (unstandardised) and standardised CPUE series are compared in Figures 30–39. The standardisations have tended to flatten out between year variation in the nominal indices, which is a typical result in these kinds of studies. Precision is variable between models, reflecting the amount of data available in each dataset. The relatively data-poor bottom-trawl series for the Chatham Rise are noticeably less precise than the bottom longline index, in particular during the early years of the series. The following trends were noted in the year effects.

Of all the models fitted, only the setnet indices for the east coast of the South Island (SPD 3; models 1 and 2; Figures 30–31, respectively) show any evidence of a decline. In contrast, the east coast South Island trawl index is reasonably stable showing no evidence of a trend either upwards or downwards (SPD 3; model 3; Figure 32). The trawl model also smoothes out a very large jump in the nominal trawl CPUE during the 1997–98 fishing year and beyond. The indices for all three models are relatively precise, reflecting the large amounts of data in each of the corresponding datasets. Models 2 and 3 explain rather more variation in their datasets (39.3% and 28.5%; Table 13) than model 1 (21.8%; Table 13), however. The lack of a trend in the model 3 year effects compared with models 1 and 2 may be evidence of hyperstability *sensu* Hilborn & Walters (1992) in this model.

The Korean and all-vessel bottom trawl models for the Chatham Rise (SPD 3 and 4; models 4 and 5; Figures 33–34, respectively) are very erratic over the early years, the 1989–90 to 1994–95 fishing years, of the time series. The between-year variation in the early years is implausible, and reflects the relatively few data in the datasets during these years. In contrast, the bottom longline model index (SPD 3 and 4; model 6; Figure 35) shows a steady increase over the course of the time series and explains a comparatively large amount of the variation in the data (35.2%; Table 13). Due to a lack of data, the bottom longline model does not span the entire time series, covering only the 1991–92 to 2000–01 fishing years. Precision in the bottom trawl models could be improved by truncating the corresponding datasets in a similar fashion (i.e., by removing data in the 1989–90 and 1991–92 fishing years and refitting the models), but we have not done so. The bottom trawl indices appear to be increasing over the latter half of the time series.

The bottom-trawl indices for the Stewart-Snares shelf also display little evidence of a consistent trend. (SPD 5; model 7; Figure 36). The indices are fairly precise, although there is some degree of between-year variation in the year effects. The confidence intervals around the indices tend not to overlap, suggesting that these differences are significant. The model explains a moderately large amount of variation in the data (40.6%; Table 13).

The bottom longline index for the sub-Antarctic also displays little evidence of a consistent trend (SPD 6; model 8; Figure 37). The index appears to have declined markedly from the 1992–93 fishing year to the 1993–94 fishing year, but this is probably due to the few data available for the 1992–93 fishing year (9 effort strata for the 1991–92 fishing year out of 208 effort strata overall for core vessels; Table D8, Appendix D). Given that the confidence intervals around the 1992–93 and 1993–94 year effects overlap, we suggest that this decline is implausible and the 1992–93 index should be ignored. Nevertheless, the model does explain a relatively large amount of the variation in the data (50.3%: Table 13) and the indices are relatively precise in the second year of the series (the 1992–93 fishing year) and beyond.

The bottom trawl index calculated for the west coast of the South Island and for the west coast of the North and South Islands combined also show no evidence of a trend (SPD 7 and 8 combined; models 9 and 10; Figures 38–39, respectively). Both indices explain moderate amounts of variation in their datasets (29.4% and 29.5% respectively; Table 13) with very similar year effects between the series. The similarity in the year effects between the series is hardly surprising given that all of the data in model 9 are included in the model 10 dataset.

Table 13: Relative year effects and 95% confidence intervals (in parentheses) for all CPUE models fitted. Descriptions of the models fitted are given in Table 4. The variables offered to each model are given in Table 5.

Fishing year	Model 1		Model 2		Model 3	
1989–90	1.228	(1.100–1.370)	1.188	(1.116–1.263)	0.846	(0.774–0.925)
1990–91	1.178	(1.069–1.299)	1.025	(0.975–1.078)	0.882	(0.828–0.940)
1991–92	1.034	(0.943–1.134)	1.171	(1.120–1.225)	0.933	(0.880–0.988)
1992–93	1.211	(1.113–1.319)	1.063	(1.017–1.110)	1.057	(0.997–1.120)
1993–94	0.850	(0.782–0.924)	0.970	(0.929–1.013)	1.113	(1.056–1.174)
1994–95	0.873	(0.789–0.966)	1.061	(1.012–1.112)	0.876	(0.829–0.926)
1995–96	0.866	(0.787–0.954)	1.088	(1.040–1.138)	0.985	(0.935–1.038)
1996–97	1.063	(0.950–1.189)	1.245	(1.186–1.308)	1.354	(1.284–1.428)
1997–98	1.197	(1.053–1.361)	1.159	(1.094–1.229)	0.989	(0.926–1.055)
1998–99	0.767	(0.648–0.909)	0.819	(0.772–0.868)	1.105	(1.043–1.169)
1999–00	1.050	(0.869–1.268)	0.698	(0.655–0.745)	0.802	(0.758–0.850)
2000–01	0.837	(0.661–1.062)	0.714	(0.670–0.762)	1.192	(1.128–1.261)

Fishing year	Model 4		Model 5		Model 6	
1989–90	0.306	(0.187–0.501)	0.296	(0.188–0.464)	–	–
1990–91	3.756	(1.589–8.880)	2.333	(1.056–5.157)	–	–
1991–92	2.738	(1.550–4.835)	2.478	(1.449–4.236)	0.095	(0.061–0.147)
1992–93	1.462	(0.616–3.468)	1.489	(0.716–3.094)	0.406	(0.271–0.609)
1993–94	5.419	(1.899–15.461)	5.598	(2.286–13.708)	0.537	(0.398–0.724)
1994–95	0.756	(0.399–1.433)	0.656	(0.441–0.976)	0.853	(0.612–1.188)
1995–96	0.307	(0.197–0.477)	0.462	(0.342–0.624)	1.188	(0.883–1.598)
1996–97	0.740	(0.496–1.104)	0.538	(0.398–0.726)	2.046	(1.521–2.752)
1997–98	0.500	(0.327–0.763)	0.766	(0.601–0.976)	2.424	(1.815–3.237)
1998–99	0.478	(0.302–0.756)	0.618	(0.487–0.784)	2.074	(1.514–2.842)
1999–00	1.261	(0.845–1.880)	1.398	(1.098–1.781)	2.192	(1.419–3.388)
2000–01	0.777	(0.510–1.184)	0.652	(0.513–0.830)	2.117	(1.430–3.133)

Fishing year	Model 7		Model 8		Model 9	
1989–90	0.990	(0.512–1.915)	–	–	1.123	(0.899–1.403)
1990–91	0.517	(0.373–0.718)	–	–	1.909	(1.566–2.326)
1991–92	0.730	(0.502–1.061)	2.734	(1.275–5.861)	0.911	(0.796–1.043)
1992–93	0.624	(0.472–0.825)	0.673	(0.346–1.311)	0.799	(0.697–0.915)
1993–94	1.959	(1.498–2.561)	0.460	(0.224–0.944)	0.991	(0.863–1.137)
1994–95	0.717	(0.529–0.973)	0.892	(0.375–2.123)	0.448	(0.389–0.515)
1995–96	1.576	(1.080–2.301)	0.518	(0.289–0.926)	1.086	(0.958–1.232)
1996–97	0.496	(0.399–0.616)	1.832	(1.205–2.785)	0.876	(0.780–0.984)
1997–98	0.891	(0.687–1.155)	1.414	(0.975–2.052)	1.097	(0.951–1.265)
1998–99	1.117	(0.876–1.423)	1.070	(0.671–1.707)	1.355	(1.185–1.549)
1999–00	2.381	(1.931–2.937)	0.835	(0.457–1.525)	1.066	(0.942–1.206)
2000–01	1.647	(1.395–1.944)	1.106	(0.608–2.010)	0.959	(0.847–1.086)

Fishing year	Model 10	
1989–90	1.104	(0.885–1.377)
1990–91	1.633	(1.345–1.982)
1991–92	0.918	(0.803–1.049)
1992–93	0.806	(0.705–0.921)
1993–94	0.985	(0.863–1.124)
1994–95	0.476	(0.415–0.546)
1995–96	1.041	(0.919–1.178)
1996–97	0.909	(0.811–1.019)
1997–98	1.164	(1.013–1.338)
1998–99	1.403	(1.228–1.602)
1999–00	1.081	(0.957–1.222)
2000–01	0.959	(0.848–1.084)

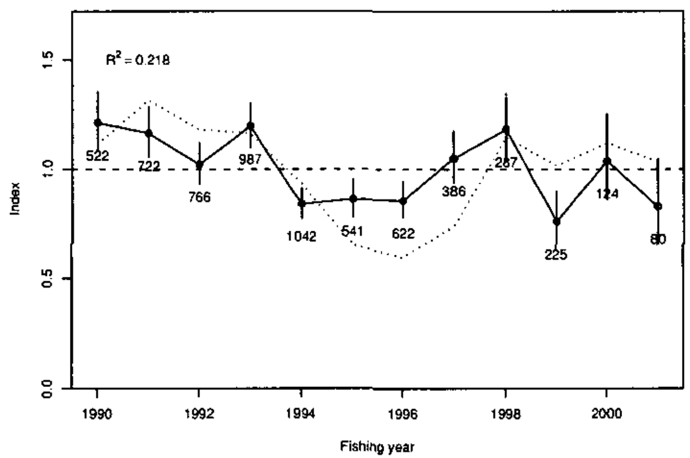

Figure 30: Relative indices for target setnet catches by core vessels in SPD 3 for the 1989–90to 2000–01 fishing years (model 1; solid line). The nominal CPUE series is overlaid (dotted line). Both series are scaled to have mean = 1. The R^2 value for the standardised series and the numbers of effort strata per fishing year are noted. The error bars are 95% confidence intervals about the year effects.

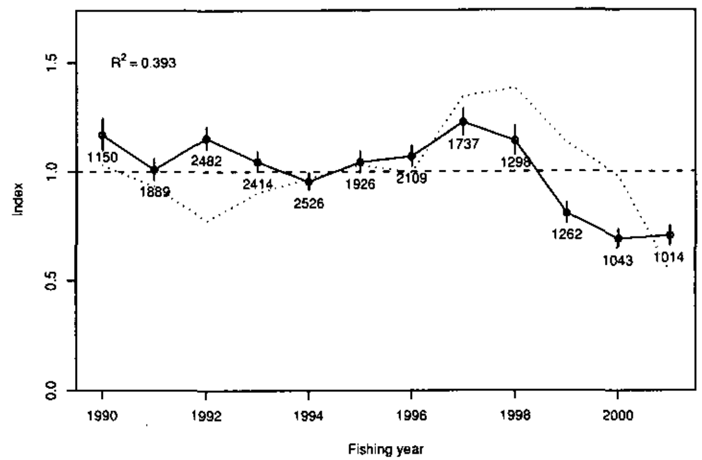

Figure 31: Relative indices for all setnet catches by core vessels in SPD 3 for the 1989–90to 2000–01 fishing years (model 2; solid line). The nominal CPUE series is overlaid (dotted line). Both series are scaled to have mean = 1. The R^2 value for the standardised series and the numbers of effort strata per fishing year are noted. The error bars are 95% confidence intervals about the year effects.

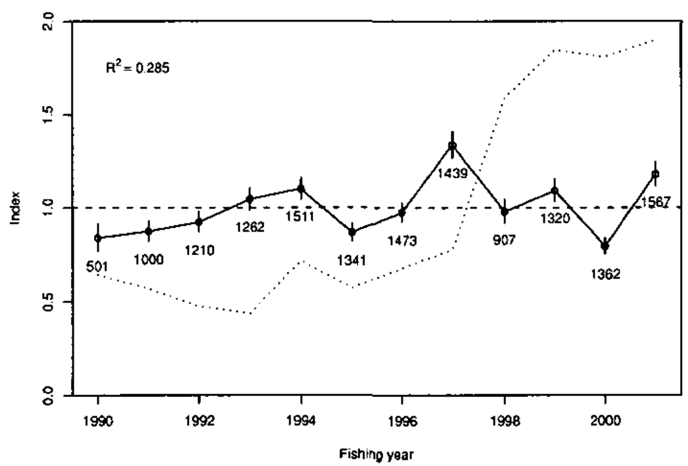

Figure 32: Relative indices for all bottom trawl catches by core vessels in SPD 3 for the 1989–90to 2000–01 fishing years (model 3; solid line). The nominal CPUE series is overlaid (dotted line). Both series are scaled to have mean = 1. The R^2 value for the standardised series and the numbers of effort strata per fishing year are noted. The error bars are 95% confidence intervals about the year effects.

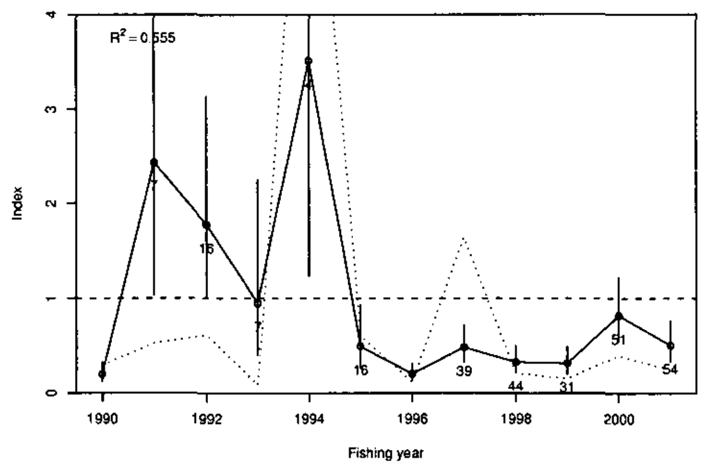

Figure 33: Relative indices for all bottom trawl catches by core Korean vessels on the Chatham Rise (SPD 3 and 4) for the 1989–90to 2000–01 fishing years (model 4; solid line). The nominal CPUE series is overlaid (dotted line). Both series are scaled to have mean = 1. The R^2 value for the standardised series and the numbers of effort strata per fishing year are noted. The error bars are 95% confidence intervals about the year effects.

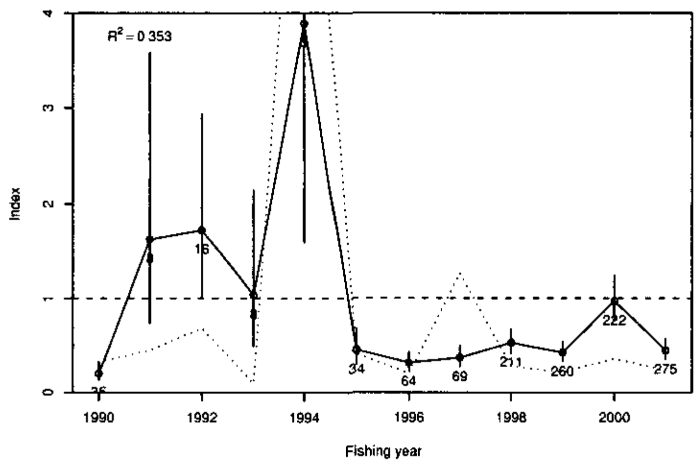

Figure 34: Relative indices for all bottom trawl catches by all core vessels on the Chatham Rise (SPD 3 and 4) for the 1989–90to 2000–01 fishing years (model 5; solid line). The nominal CPUE series is overlaid (dotted line). Both series are scaled to have mean = 1. The R^2 value for the standardised series and the numbers of effort strata per fishing year are noted. The error bars are 95% confidence intervals about the year effects.

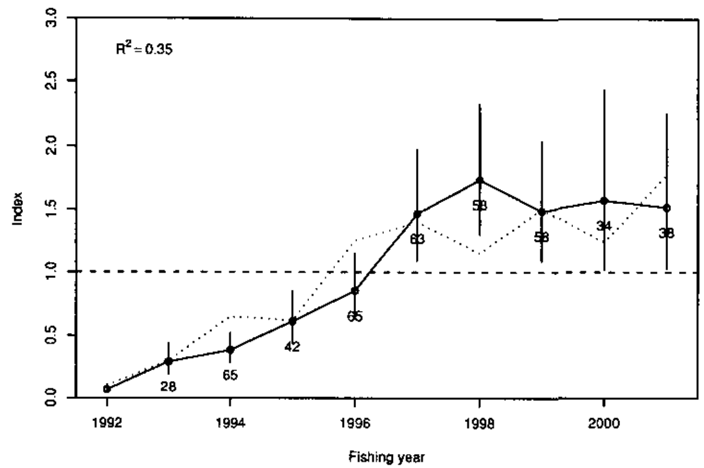

Figure 35: Relative indices for all bottom longline catches by core vessels on the Chatham Rise (SPD 3 and 4) for the 1989–90to 2000–01 fishing years (model 6; solid line). The nominal CPUE series is overlaid (dotted line). Both series are scaled to have mean = 1. The R^2 value for the standardised series and the numbers of effort strata per fishing year are noted. The error bars are 95% confidence intervals about the year effects.

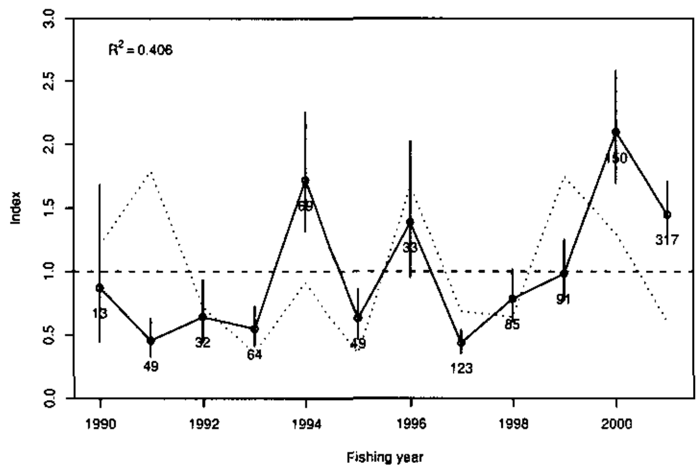

Figure 36: Relative indices for all bottom trawl catches by core vessels in SPD 5 for the 1989–90to 2000–01 fishing years (model 7; solid line). The nominal CPUE series is overlaid (dotted line). Both series are scaled to have mean = 1. The R^2 value for the standardised series and the numbers of effort strata per fishing year are noted. The error bars are 95% confidence intervals about the year effects.

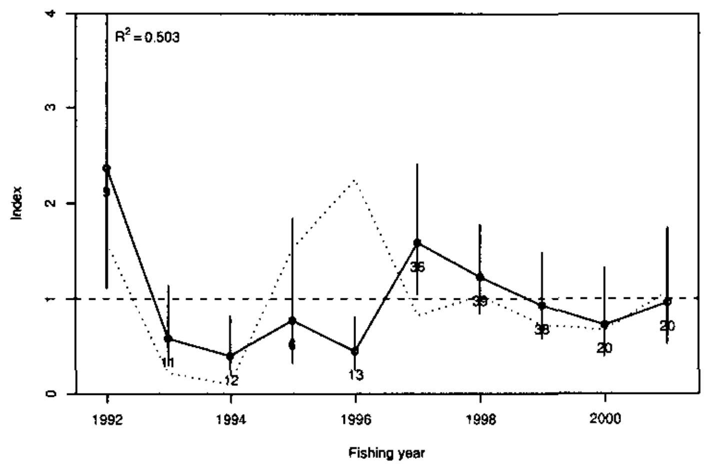

Figure 37: Relative indices for all bottom longline catches by core vessels in SPD 6 for the 1992-93 to 2000–01 fishing years (model 8; solid line). The nominal CPUE series is overlaid (dotted line). Both series are scaled to have mean = 1. The R^2 value for the standardised series and the numbers of effort strata per fishing year are noted. The error bars are 95% confidence intervals about the year effects.

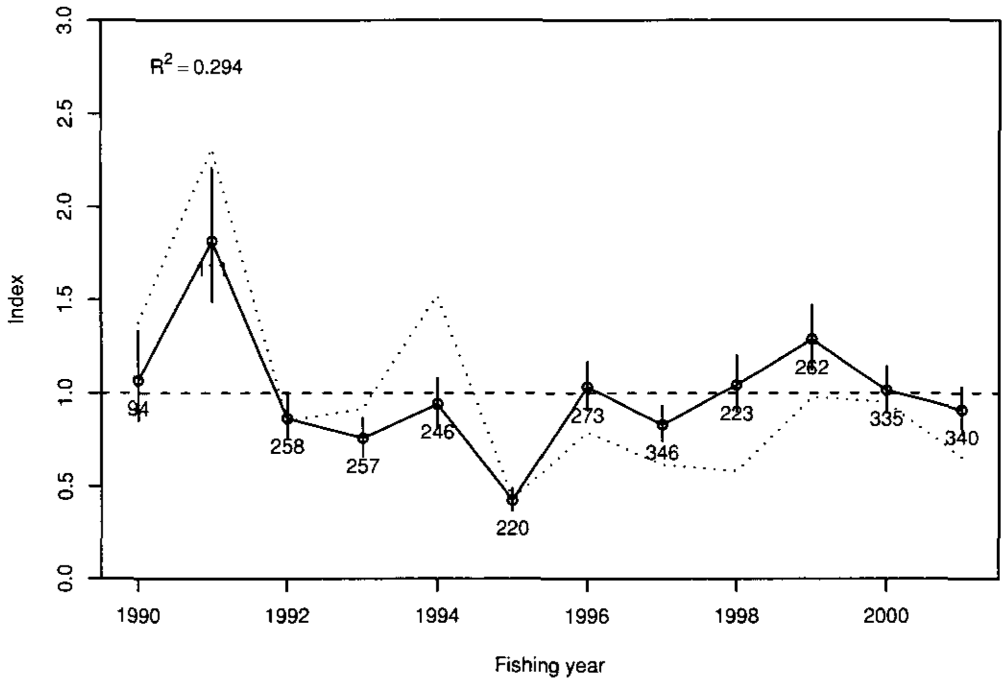

Figure 38: Relative indices for all bottom trawl catches by core vessels in SPD 7 for the 1989–90to 2000–01 fishing years (solid line). The nominal CPUE series, the natural logarithm of kilogram's caught per hour fished per year, is overlaid (dashed line). Both series are scaled to have mean = 1. The R^2 value for the standardised series and the numbers of effort strata per fishing year are noted. The error bars are 95% confidence intervals about the year effects.

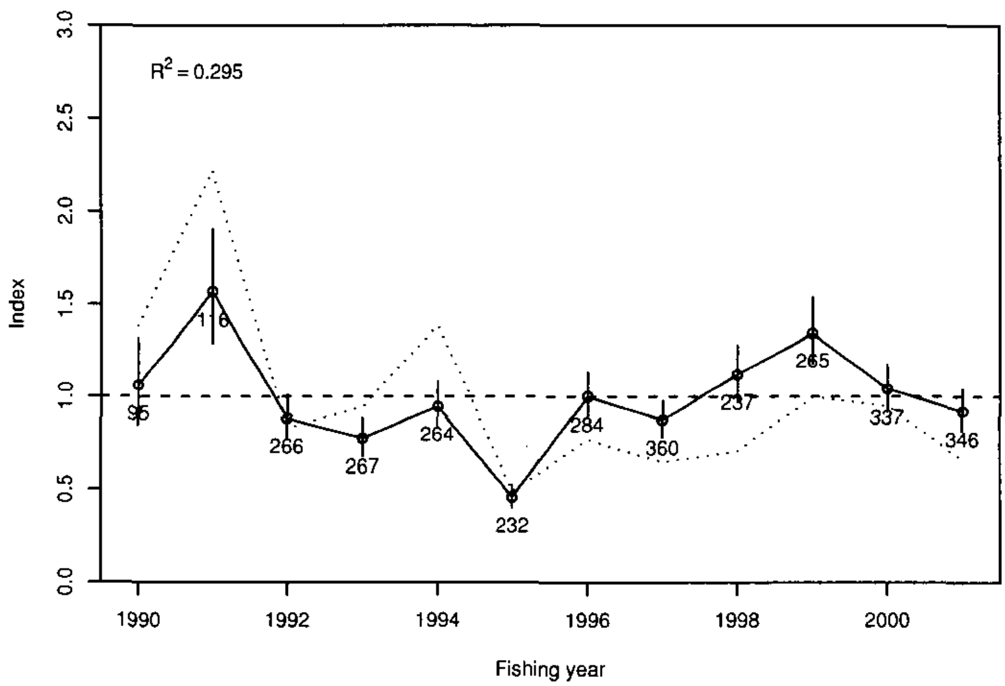

Figure 39: Relative indices for all bottom trawl catches by core vessels in SPD 7 and 8 for the 1989–90to 2000–01 fishing years (solid line). The nominal CPUE series, the natural logarithm of kilogram's caught per hour fished per year, is overlaid (dashed line). Both series are scaled to have mean = 1. The R^2 value for the standardised series and the numbers of effort strata per fishing year are noted. The error bars are 95% confidence intervals about the year effects.

4.4 Catch-per-unit-effort analyses summary and conclusions

Walker et al. (1999) found two consistent catch and effort series that they modelled, namely the target setnet series off the east coast of the South Island and the Korean bottom-trawl series on the Chatham Rise, although they were unable to relate trends in standardised CPUE to the relative abundance of the stocks. We have recomputed both of these models, but using data structured in an entirely different manner and a different definition of catch-per-unit-effort for the Korean bottom trawl index, and thus our results and theirs are not strictly comparable. Nevertheless, for those years where our results and theirs overlap, namely the 1989–90 to 1996–97 fishing years, trends in our results and theirs are similar. Unfortunately, they did not present sufficient numerical output from their models to permit us to directly compare their results and ours (e.g., on the same plots).

Walker et al. (1999) appear to have used low levels of discarded catch to motive their selection of catch and effort data sets to fit models to. We have ignored the level of discarded catch in each of the datasets we have modelled. We have assumed that the sum of the groomed undiscarded and undiscarded landings is the best estimate of total removals from the stocks currently available and thus the most appropriate "catch" to model, although the trends in discarding rates noted in Section 3 may have confounded trends in the year effects identified above. We suggest that the effect of trends in discarding rates on the CPUE indices and any bias imparted should be evaluated once a quantitative analysis of discarding rates and estimation of total removals from the stocks has been carried out.

We were unable to offer the catch of other species as predictors to our models. The Ministry of Fisheries Reporting Group refused to supply us with the catch-effort and landings data for species other than spiny dogfish, hence we were unable to allocate landings of these species to the effort strata in the merged dataset and thus to offer them to our models or to investigate associations between spiny dogfish and other species in the catch. Such associations may be significant predictors of CPUE; e.g., Langley (2001) found that the catches of red cod were a significant predictor of elephantfish CPUE in the east coast South Island fishery. Future spiny dogfish CPUE modelling may wish to consider offering the catches of other species commonly associated with spiny dogfish, e.g., elephantfish, rig, and school shark in the setnet fisheries off the east coast of the South Island, to the models fitted.

The relative lack of data in some datasets and inconsistency in the catch-effort distributions for others noted in Section 4.1 explains some of the between-year variation in the year effects in models 4 and 5. Little can be done to refine those models where few data are available, such as models 4, 5, and 8; however, the predictive power of other models, such as models 2, 3, 9, and 10 could be further enhanced by placing further restrictions on the datasets before fitting the models. By restricting the model datasets to the most important groups within the data, e.g., small vessels active in the inshore mixed species fishery in model 3 omitting large vessels, or by offering predictor variables that might better reflect the structure within the data, e.g., a "form type" variable indexing vessel size and catching power in model 3, the predictive power of the models (i.e., the R^2 value) may be increased. We suggest that future catch-per-unit-effort modelling consider placing such restrictions and offering such predictor variables to the models; nonetheless, we suggest that the models presented above are a useful first attempt at developing sound catch-per-unit-effort models for spiny dogfish in New Zealand waters.

In Section 7 below we compare the CPUE models fitted with the commercial size composition data reviewed in Section 5 and the trawl survey relative biomass estimates and survey catch size composition data collated in Section 6 to identify methods that may allow the status of the stocks to be monitored. We review what data are required to refine the CPUE models, notably a rigorous analysis of discards and estimation of total removals from the stocks, in Section 8.

5. LENGTH COMPOSITION OF THE COMMERCIAL CATCH

Phillips (2004) presented an analysis of observer-collected spiny dogfish length-frequency data, including an analysis of the representativeness of observer coverage and a comparison of his results with those from selected trawl surveys. Here we summarise his results and conclusions to compare the compositions of the trawl survey and the commercial catches.

5.1 Data

A total of 54 444 spiny dogfish were measured by scientific observers from 1996–97 to 2001–02 (Table 14). Eighty-four percent of all measurements were made in QMAs 3, 5, and 7. The locations of observed tows where spiny dogfish were measured are plotted in Figure 40. Phillips (2004) found that there appear to be four main areas where spiny dogfish were measured, which he refers to as "fisheries". These are the Chatham Rise, sub-Antarctic, the west coast South Island, and the west coast of the North Island. As most of the length-frequency data collected from the west coast of the North Island were from the 1997–98 fishing year (98.9%; see Table 15), he did not consider the west coast North Island data further in his analysis.

5.2 Summary of Phillips's (2004) results

Phillips's (2004) estimated scaled length-frequency distributions for the Chatham Rise, sub-Antarctic, and west coast South Island fisheries are plotted in Figures 41–43. Mean-weighted coefficients of variation for each distribution, calculated using a bootstrapping routine, are given in Table 16. Note that in New Zealand, spiny dogfish are measured to the nearest centimetre below total length from the tip of the snout to the tip of the caudal fin. See Sutton (2002) for a description of the sampling protocol.

The lengths of male fish in the Chatham Rise fishery range from 45 to 100 cm in total length and appear unimodally distributed, with a single mode peaking at 65 cm. Female fish tend to be larger on average than males, and range from 45 to 105 cm in total length. Female lengths appear to be bimodally distributed, with two modes peaking at about 55 cm and about 85 cm in total length.

Male fish in the sub-Antarctic fishery range from about 45 to 90 cm in total length and also appear unimodally distributed, with a single mode peaking at about 65–68 cm. Female fish also appear to be larger on average than males, ranging from about 50 cm to over 100 cm in total length, with two modes appearing to peak at about 55–60 cm at about 85 cm.

Male fish in the west coast South Island fishery range from about 50 to about 80 cm in total length, although smaller fish (under 40 cm) were sampled during the 1997–98 fishing year, and are also unimodally distributed with a single mode peaking at about 65 cm. Female fish are larger, ranging from 50 to over 100 cm in total length. Female fish lengths in the west coast South Island fishery have more unimodal distributions than in the other fisheries, with a single mode appearing to peak between 75 and 85 cm, depending on the fishing year.

There are some length classes in all three fisheries that account for a very high proportion of the catch in a given fishing year and fishery relative to other length classes in the catch (e.g., 75 cm male fish in the 1997–98 fishing year distribution from the Chatham Rise fishery). Phillips (2004) stated that this is because fish in these length classes were recorded from tows where very few fish were measured by an observer yet a high catch was recorded, and so each fish received a high weighting when all the length data were scaled up to the catch; these length classes also have very high c.v.s.

The mean-weighted c.v.s for each distribution are generally high, ranging from 27 to 65% for all fish in the Chatham Rise fishery, from 25 to 68% for all fish in the sub-Antarctic fishery, and from 24 to 53% for all fish in the west coast South Island fishery. The mean-weighted c.v.s for each sex within each fishery are worse (higher) than for all fish combined, reflecting the partitioning of the data required to compute separate length-frequency distributions by sex.

Table 14: Numbers of spiny dogfish measured by Ministry of Fisheries scientific observers by QMA and fishing year for the fishing years 1996–97 to 2000–01 (Phillips 2004).

	QMA										
Fishing year	1	2	3	4	5	6	7	8	9	10	Total
1996–97	–	–	471	–	1 753	42	2 681	–	–	–	4 947
1997–98	3	100	2 364	561	3 111	445	1 736	1 149	1 031	–	10 500
1998–99	–	318	3 372	533	3 468	149	2 887	–	–	–	10 727
1999–00	–	777	2 465	998	3 380	605	4 558	–	–	–	12 783
2000–01	–	800	3 574	612	6 861	697	2 943	–	–	–	15 487
Total	3	1 995	12 246	2704	18 573	1938	14 805	1149	1031	0	54 444

Table 15: Numbers of spiny dogfish measured by Ministry of Fisheries scientific observers by proposed fishery and fishing year for the fishing years 1996–97 to 2001–02 (Phillips 2004).

	Fishery					
Fishery year	Chatham Rise	Sub-Antarctic	West coast N.I.	West coast S.I.	Other	Total
1996–97	471	1 795	–	2 681	–	4 947
1997–98	2 853	3 628	1 386	1 499	1 134	10 500
1998–99	3 688	3 776	–	2 832	431	10 727
1999–00	3 197	4 251	16	4 475	844	12 783
2000–01	3 715	8 029	–	2 512	1 231	15 487
Total	16 220	25 789	1 402	14 949	3 640	54 444

Table 16: Mean–weighted coefficients of variation (%) by fishing year for the estimated scaled length–frequency distributions calculated for the Chatham Rise, Sub–Antarctic, and West Coast South Island fisheries. M, males; F, females; Comb., all fish combined (Phillips 2004).

	Chatham Rise			Sub-Antarctic			West coast South Island		
Fishing year	M	F	Comb.	M	F	Comb.	M	F	Comb.
1996–97	54	79	51	61	80	68	70	57	52
1997–98	76	67	65	33	63	33	86	52	53
1998–99	32	32	27	38	64	43	43	36	31
1999–00	43	48	38	25	54	26	35	24	24
2000–01	57	44	39	28	34	25	49	32	31

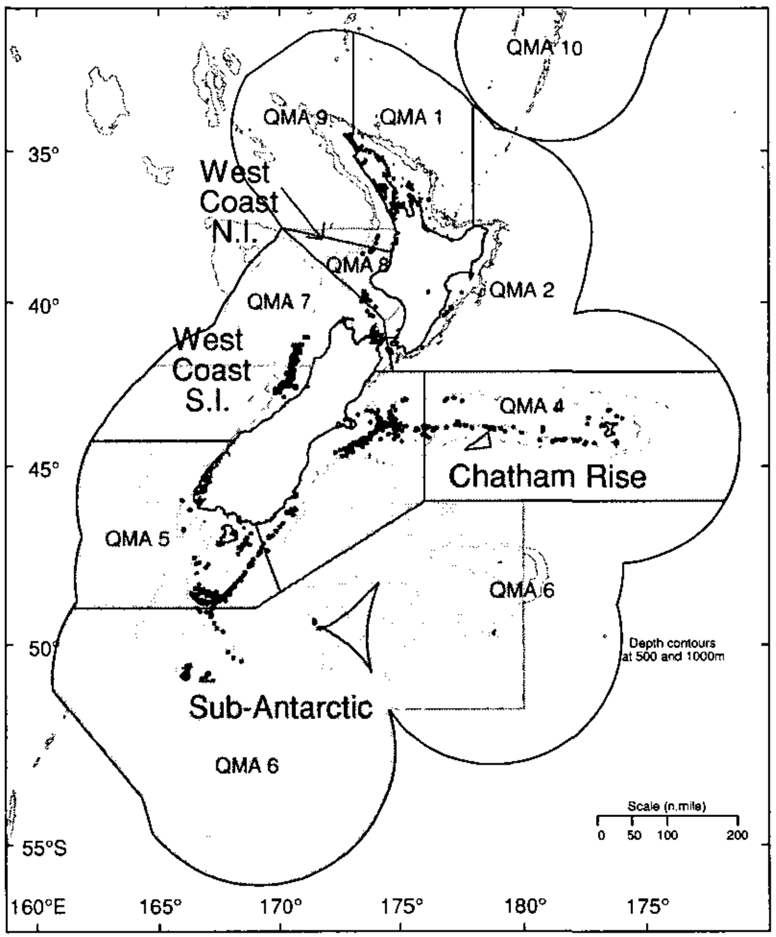

Figure 40: Location of QMAs, proposed fisheries, and location of tows where length frequency samples of spiny dogfish were collected by observers from 1996–97 to 2001–02 (Phillips 2004). Note, commercially sensitive positions are not plotted. *The shading represents the domain of each the four proposed "fisheries".*

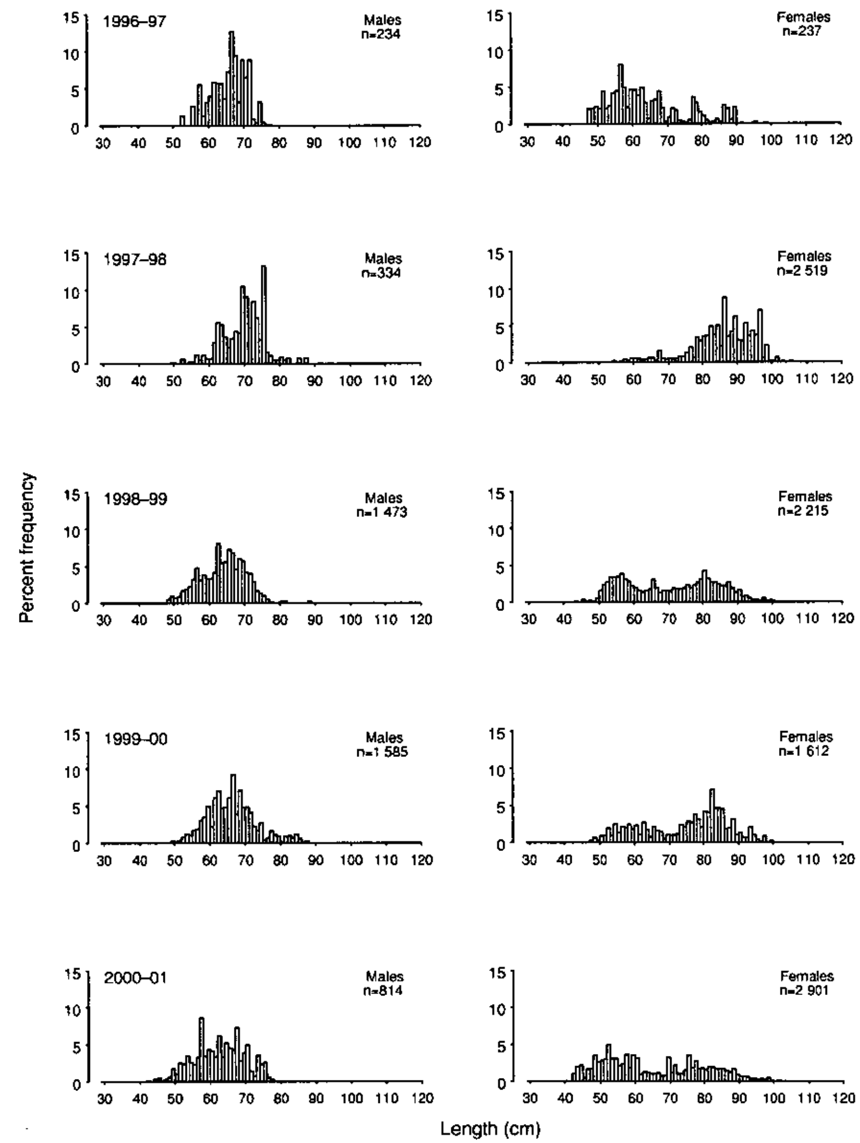

Figure 41: Scaled length-frequency distributions for male and female spiny dogfish sampled by observers from the Chatham Rise fishery (Phillips 2004). The numbers of fish measured are noted on each panel.

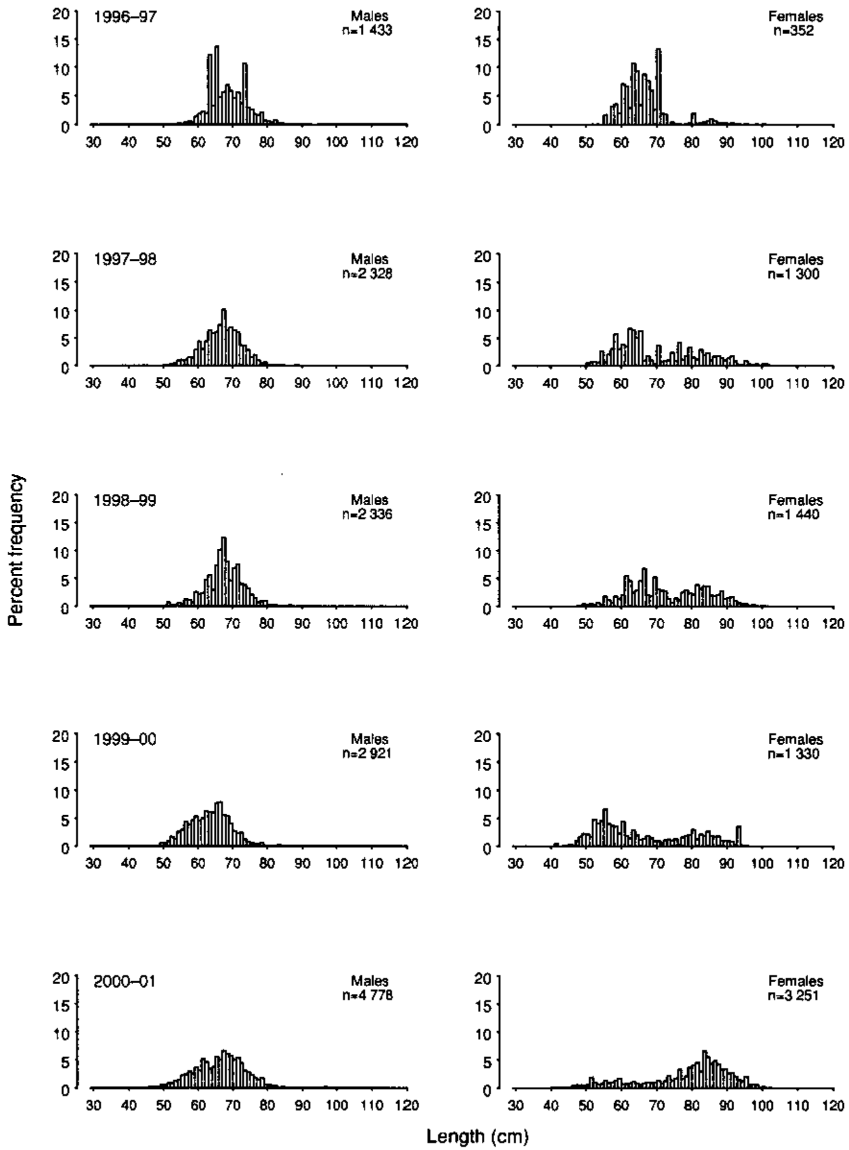

Figure 42: Scaled length-frequency distributions for male and female spiny dogfish sampled by the observers from the Sub-Antarctic fishery (Phillips 2004). The numbers of fish measured are noted on each panel.

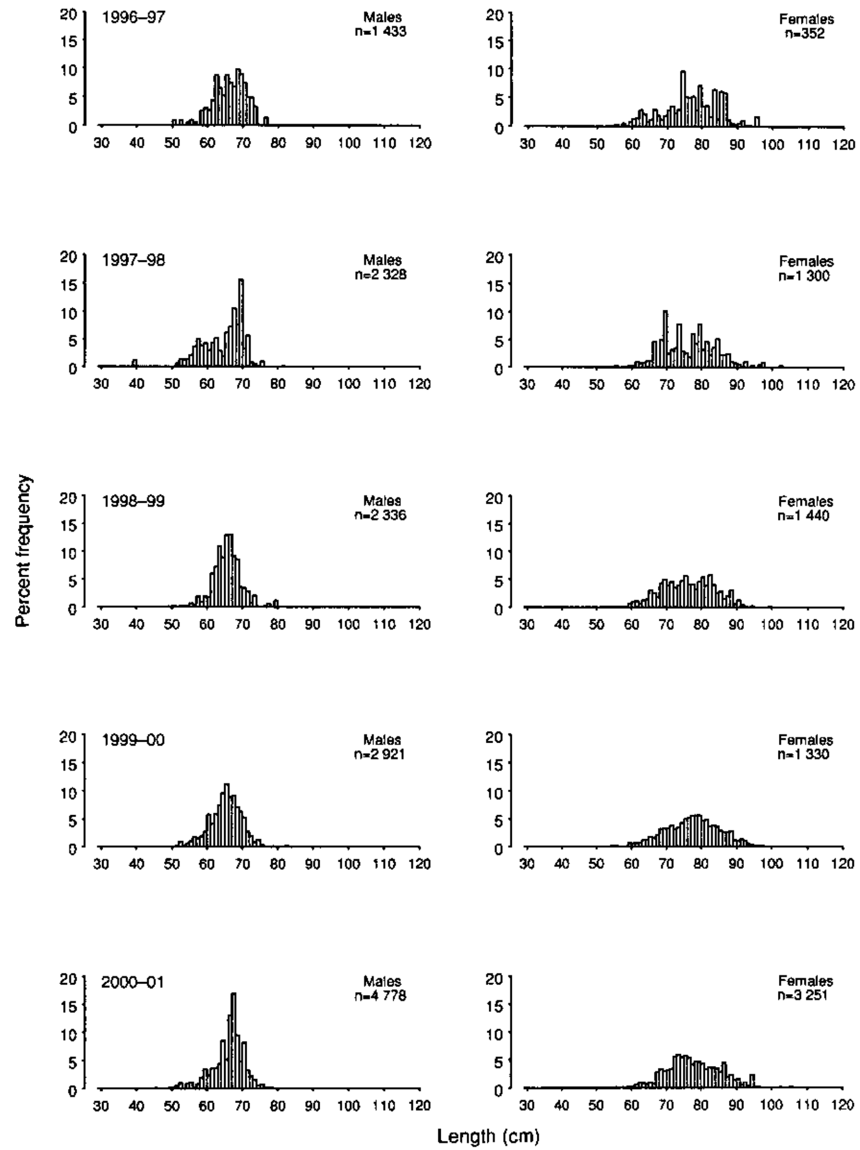

Figure 43: Scaled length-frequency distributions for male and female spiny dogfish sampled by the observers from the west coast South Island fishery (Phillips 2004). The numbers of fish measured are noted on each panel.

5.3 Summary of Phillips's (2004) conclusions

The number of fish measured in the three fisheries varied between 4947 and 14 256 fish per fishing year. There was a general increase in the number of fish measured in the second and subsequent years of the sampling programme, but Phillips (2004) found that the number of observed tows was not proportional to the total number of commercial tows over the same years. Many of the observed tows appear to be clumped in time, area, and depth and are generally not representative of the full depth and area range of the fisheries. Although there has been some improvement in coverage in the last two years in the series, the distribution of observer coverage needs to be improved, with more observed tows in the shallower and deeper parts of the fisheries, which are not adequately sampled at present.

The scaled length-frequency distributions are fairly similar, covering similar length ranges in each fishery. In all three fisheries, female fish tend to be larger than males. Female fish lengths in the Chatham Rise and sub-Antarctic fisheries appear to be bimodally distributed, whereas female fish lengths in the west coast South Island fishery and male fish lengths in all three fisheries appear to be more unimodally distributed. Given the longevity of spiny dogfish, it is unlikely that the modes in the female length distributions correspond to differential year-class success.

Phillips (2004) found proportionally more female than male fish in the Chatham Rise and west coast South Island fisheries, while he found the reverse in the sub-Antarctic fishery. He notes that sampled trawl vessels in the Chatham Rise and west coast South Island fisheries were fishing as deep as 800 m, but sampled trawl vessels in the sub-Antarctic fishery generally fished no deeper than about 400 m. This may have produced a sex bias in the sub-Antarctic catch.

Walker et al. (1999) noted in their review of the trawl survey data that female fish tend to be found in deeper waters, and that males tend to out number females during autumn and winter, when most of the sub-Antarctic catch was caught. Walker et al. (1999) also noted that shifts in sex ratios may also be related to fishing practices, as fishers tend to prefer the larger and more valuable female fish and may adjust their fishing practices to maximise their catches of these fish. We suggest that this is unlikely given that there is no history of directed fishing for spiny dogfish in the sub-Antarctic, and suggest that the difference in sex ratios between the fisheries is more likely to be due to the depth and seasonal distribution of fishing effort in the sub-Antarctic.

Phillips (2004) found that the length-frequency distributions he calculated for the three fisheries were roughly similar to selected trawl surveys carried out in each area, although female fish in the Chatham Rise fishery and both male and female fish in the sub-Antarctic fishery tend to be smaller than fish sampled in trawl surveys of these areas. He also found that certain length-classes are very highly represented in the length-frequency distributions and suggested that this may be an artefact of the scaling algorithm employed. He noted that this occurred when few fish were measured from tows where large catches were recorded and suggested in future either removing these fish from the analysis or adding a weighting function to the scaling algorithm so that the contribution of fish from tows where large catches are recorded but few fish are measured are down-weighted.

The mean-weighted c.v.s calculated were high for all fisheries, ranging from about 25% to over 65% for both sexes combined for all three fisheries across the fishing years. Phillips (2004) suggested that is probably due to insufficient observer coverage, noting that there is no evidence of a stratified sampling design within the length-frequency data, and that the tree-based regressions thus ensured that the data were appropriately post-stratified before scaling and should continue to be used. He suggested that other predictor variables, such as vessel characteristics (e.g., length, processing type, etc.), should be investigated in future.

6. TRAWL SURVEY RELATIVE BIOMASS ESTIMATES AND SCALED LENGTH-FREQUENCY DISTRIBUTIONS

The trawl survey data provide a potentially important fishery-independent means of monitoring stock abundance. Walker et al. (1999) used a novel approach to analysing data from the research trawl survey database. They combined data from all vessels, years, and areas, and standardised them using regression techniques (GLMs) to obtain year effects. However, we believe that their results may have been biased because of the unbalanced nature of the data available. For example, the earlier surveys were carried out using FV *Shinkai Maru*, GRV *W.J. Scott*, and GRV *James Cook*, which have little temporal overlap with the more recent surveys using RV *Kaharoa* and RV *Tangaroa*. Furthermore, within each time period there was little overlap in areas and/or depths between the various vessels. Conclusions regarding changes in annual and seasonal abundance were therefore quite possibly confounded with vessel effects. We believe that the different time series are more powerful when kept separate and used as indices of abundance for the QMA they cover.

Relative abundance indices from early research trawl surveys were summarised for each area by Hanchet & Ingerson (1997). There have also been several recent reviews of the *Kaharoa* and *Tangaroa* trawl survey time series (e.g., Stevenson & Hanchet 2000b, O'Driscoll & Bagley 2001). Most have presented spiny dogfish biomass estimates (see Figure 44) and scaled length frequency distributions (see Figures 45–50). However, because spiny dogfish is not one of the target species few reports have made recommendations on the suitability of the surveys for monitoring its abundance. Here we review the time series, update biomass estimates and length frequency distributions, and make recommendations on the suitability of the surveys for monitoring spiny dogfish abundance.

6.1 Cape Runaway to Cook Strait (SPD 2)

Between 1993 and 1996, a series of four autumn *Kaharoa* trawl surveys covering depths of 20–400 m, and using a 100 mm codend, was carried out between Cape Runaway and Turakirae Head (Stevenson & Hanchet 2000a). Biomass estimates of spiny dogfish from the trawl surveys were imprecise and erratic (see Table 6), and did not appear to be monitoring abundance.

6.2 East coast South Island (mainly SPD 3)

From 1991 to 1996, a series of five winter *Kaharoa* trawl surveys covering depths of 30–400 m, and using an 80 mm codend, was carried out between Pegasus Bay and Shag Point (Beentjes & Stevenson 2000). Total biomass estimates had low to moderate c.v.s (10–25%) see (Table 6). Estimates were stable from 1991 to 1994 but increased three-fold in 1996. The size distribution shows that the survey caught mainly adult male dogfish (Figure 45). The large increase in 1996 arose from a large increase in immature fish of both sexes and mature males.

From 1996–97 to 2000–01 a series of five summer *Kaharoa* trawl surveys covering depths of 10–400 m, and using a 40 mm codend, was carried out from Pegasus Bay to Shag Point (Beentjes & Stevenson 2001)Total biomass estimates had moderate to high c.v.s (mainly 25–35%) and varied two-fold during the series (see Table 6). The size distribution shows that most spiny dogfish caught in the surveys were immature fish of both sexes (Figure 46). The biomass estimates for spiny dogfish showed a strong inverse relationship with sea surface temperature (SST).

Although the summer series covered the same general area and depth range as the winter series, the size structure of the population was very different between the two surveys. This is even true for 1996 when the two surveys were carried out in the same year. This difference reflects a change in the seasonal availability of the fish. Neither the summer nor the winter trawl surveys appear to be monitoring a consistent part of the population of spiny dogfish in Canterbury Bight/Pegasus Bay. The high between-year variability in biomass estimates and size structure – in particular for the winter

1996 and summer 1999–2000 surveys – are indicative of changes in catchability between years. We therefore conclude that neither trawl survey series was adequately monitoring spiny dogfish abundance.

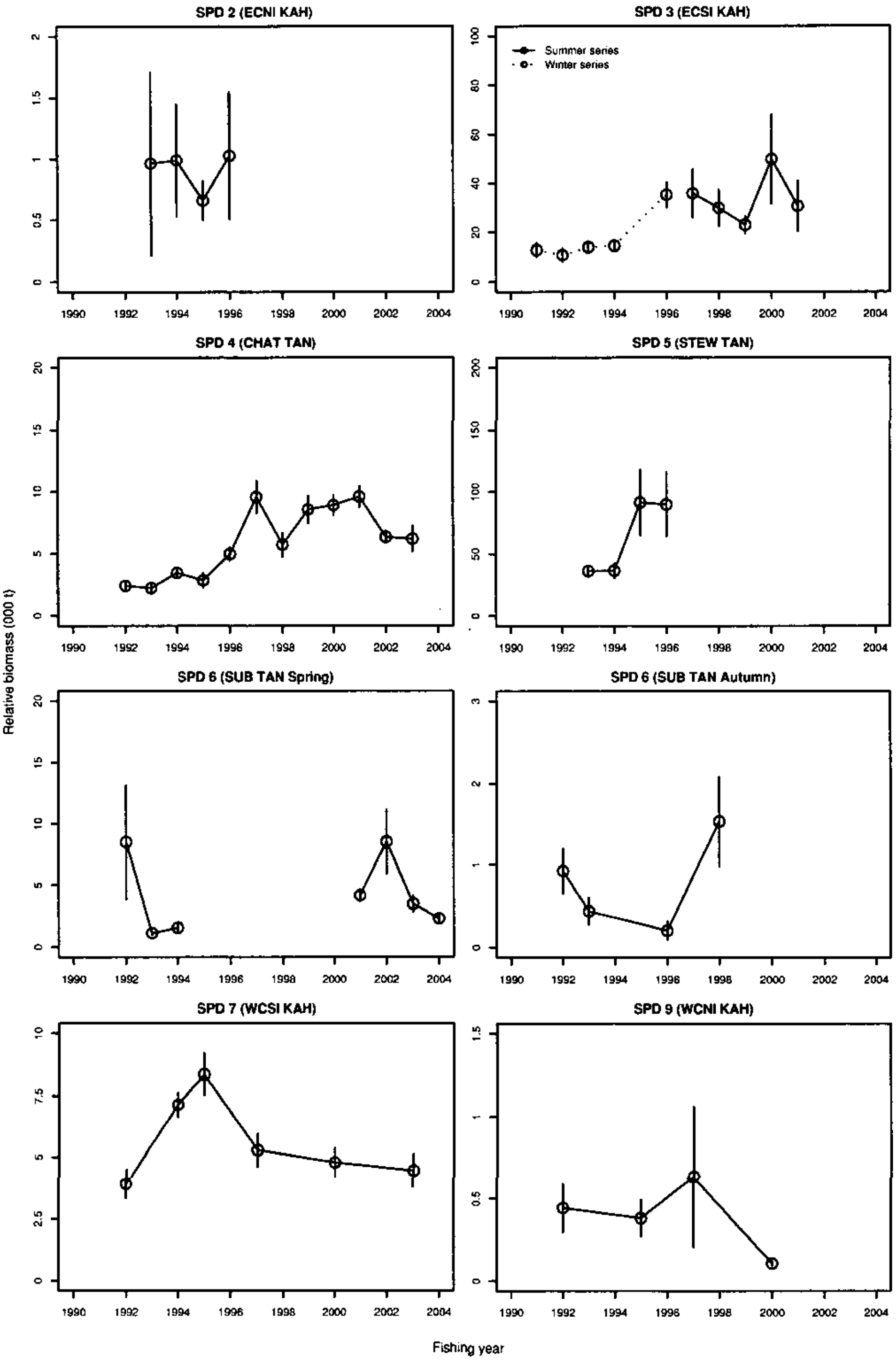

Figure 44: Trawl survey relative biomass estimates for spiny dogfish by fishing year for SPD 1–9. Survey area and research vessel are noted: ECNI, east coast North Island; CHAT, Chatham Rise; STEW, Stewart-Snares shelf; SUB, sub-Antarctic islands; WCSI, west coast South Island; WCNI, west coast North Island; KAH, RV *Kaharoa*; TAN, RV *Tangaroa*. Note the transition from a winter to a summer survey in the RV *Kaharoa* ECSI survey series (SPD 3; right panel top row). The spring and autumn sub-Antarctic surveys (SPD 6; left and right panels second row from bottom) have been plotted separately due to the very large differences between the biomass estimates produced in each series (see Table 6).

6.3 Chatham Rise (SPD 4 and eastern SPD 3)

Between 1991 and 2003, an annual time series of summer *Tangaroa* trawl surveys covering depths of 200–800 m, and using a 60 mm codend, was carried out on the Chatham Rise (Livingston et al. 2002, 2004). Biomass estimates of spiny dogfish have shown a significant (three-fold) increase over this period (see Table 6). During the course of the series, catch rates of spiny dogfish increased, and they have been caught deeper and further east (Livingston et al. 2002). The coefficients of variation for all surveys have been low to moderate (8–21%). Scaled length frequencies suggest the surveys are sampling mainly the larger females as shown by the very skewed 5:1 sex ratio (Figure 47). We conclude that the surveys are monitoring the subadult and adult female population on the Chatham Rise.

6.4 Stewart-Snares shelf (SPD 5)

Between 1993 and 1996, an annual time series of summer *Tangaroa* trawl surveys covering depths of 30–600 m, and using a 60 mm codend, was carried out on the Stewart-Snares shelf (Hurst & Bagley 1997). Biomass estimates of spiny dogfish were stable for the first two surveys, and then showed a significant (three-fold) increase over the next two surveys (see Table 6). The coefficients of variation for all surveys have been moderate to high (13–29%). Scaled length frequencies suggest the surveys sampled adult males, subadult females, and adult females. The large increase from 1993–94 to 1995–96 was a result of a large increase in adult males – the numbers of females remained relatively stable (Figure 48). The surveys may have been adequate for monitoring the female population, but because of changes in catchability do not appear to have been monitoring the male part of the population.

6.5 Southland and Sub-Antarctic (SPD 5 and 6)

Between 1991 and 2003, a time series of seven summer *Tangaroa* trawl surveys covering depths of 300–800 m, and using a 60 mm codend, was carried out on the Southland and Sub-Antarctic (e.g., O'Driscoll & Bagley 2001, O'Driscoll & Bagley 2004). The survey area covers all of SPD 6 but only the deeper part of SPD 5. The highest catch rates are typically found in the shallower strata in the north and west of the survey area – in particular on Puysegur Bank and Snares shelf. Although coefficients of variation for most surveys have been moderately precise (mainly ranging from 15 to 30%), the biomass estimates have been erratic and have varied eight-fold over the course of the surveys (see Table 6). Scaled length frequencies suggest the survey samples adult males, subadult females, and adult females, but the sex ratio is skewed (2:1) towards females (Figure 49). Clearly the survey is sampling only the fringes of the SPD 5 population and is not useful for monitoring this stock. However, the surveys may be useful to detect any broader changes in the distribution and abundance of spiny dogfish in the Sub-Antarctic (as appears to have happened on the Chatham Rise).

6.6 West coast South Island (SPD 7)

Between 1992 and 2003, a time series of six autumn *Kaharoa* trawl surveys covering depths of 20–400 m, and using an 80 mm codend, was carried out in Tasman Bay/Golden Bay and between Cape Farewell and Haast (Stevenson & Hanchet 2000b, Stevenson 2004). Biomass estimates of spiny dogfish in the first four surveys varied two-fold (see Table 6) and it was concluded that the surveys were probably not monitoring abundance (Stevenson & Hanchet 2000b). However, recent estimates have been much more consistent and coefficients of variation for all surveys have been low (7–15%). Scaled length frequencies suggest the survey is catching the full size range of fish in the population (Figure 50). We conclude that the surveys are adequately monitoring the population in this area.

6.7 West coast North Island (SPD 9)

A series of spring surveys on the west coast North Island using *Kaharoa* covering depths of 10–100 m, and using a 40 mm codend, has been carried out since 1986, but the earlier surveys did not go deep enough to fully cover spiny dogfish depths (Morrison et al. 2001). The two most recent surveys, in November 1996 and 1999 (Morrison 1998, Morrison & Parkinson 2001), were extended to 200 m depth to target tarakihi. Biomass estimates of spiny dogfish from the trawl surveys are imprecise and erratic (Table 6), and do not appear to be monitoring abundance.

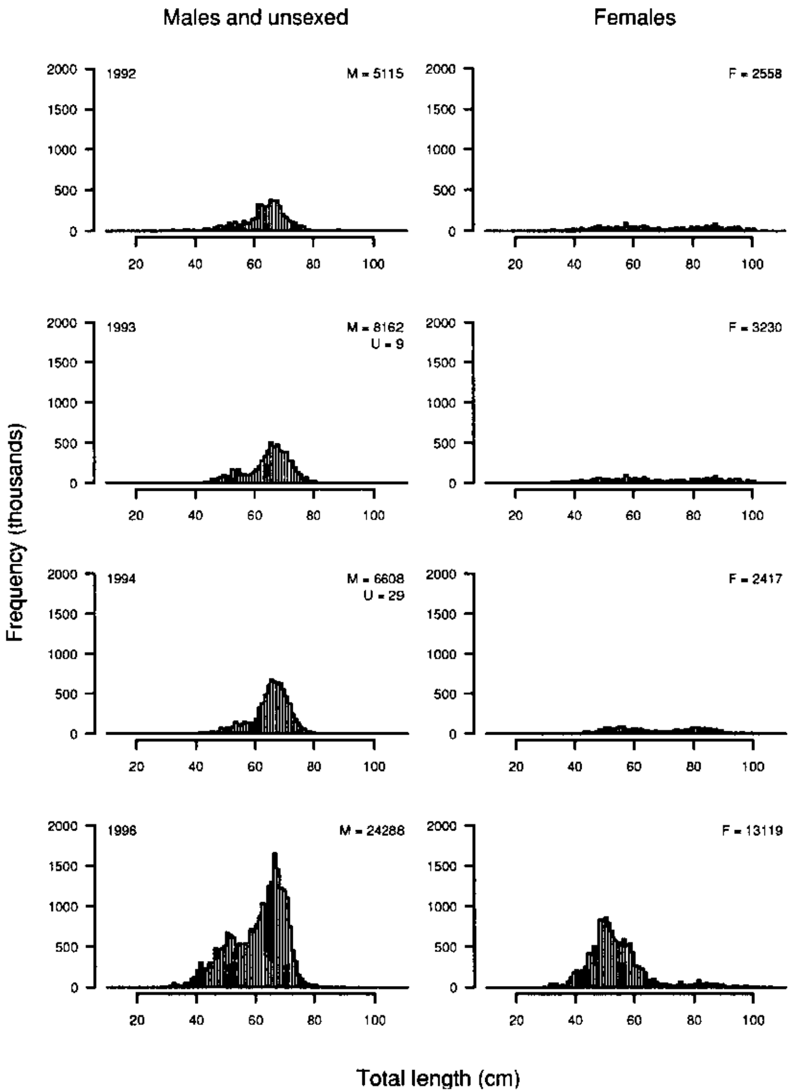

Figure 45: Scaled length-frequency distributions by sex and by survey for winter east coast South Island trawl surveys carried out by RV *Kaharoa* during the calendar years 1996–2001.

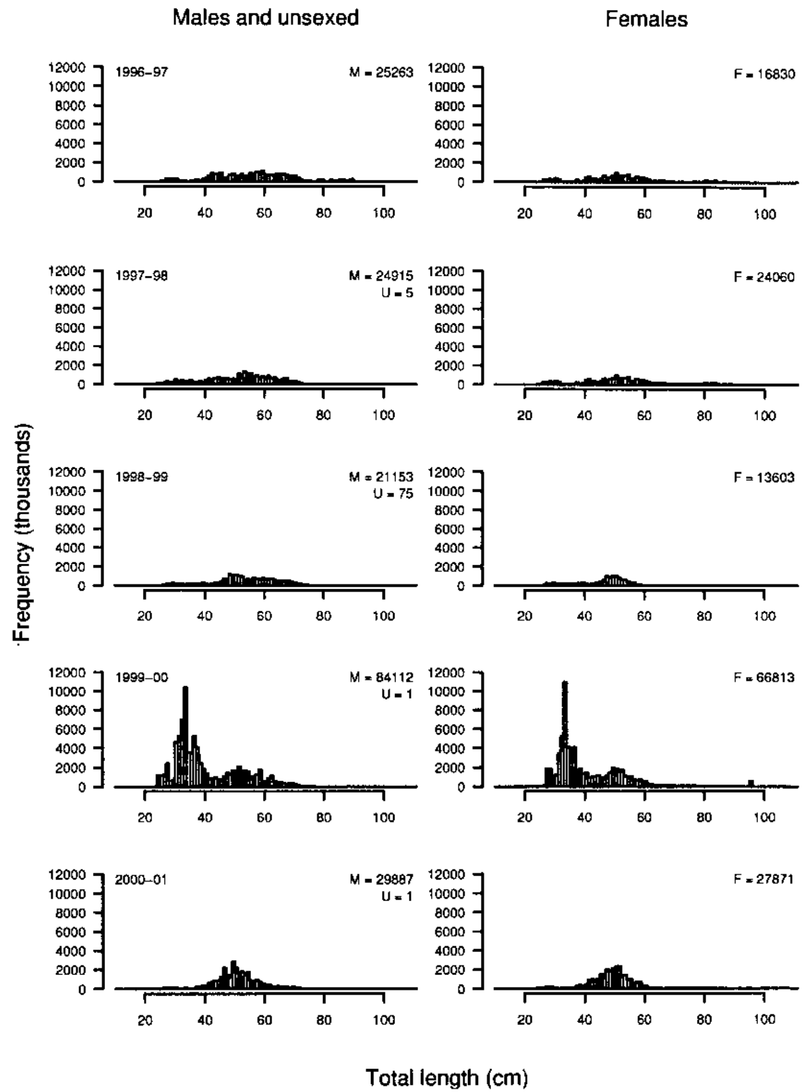

Figure 46: Scaled length-frequency distributions by sex and by survey for summer east coast South Island trawl surveys carried out by RV *Kaharoa* during the calendar years 1996–2001.

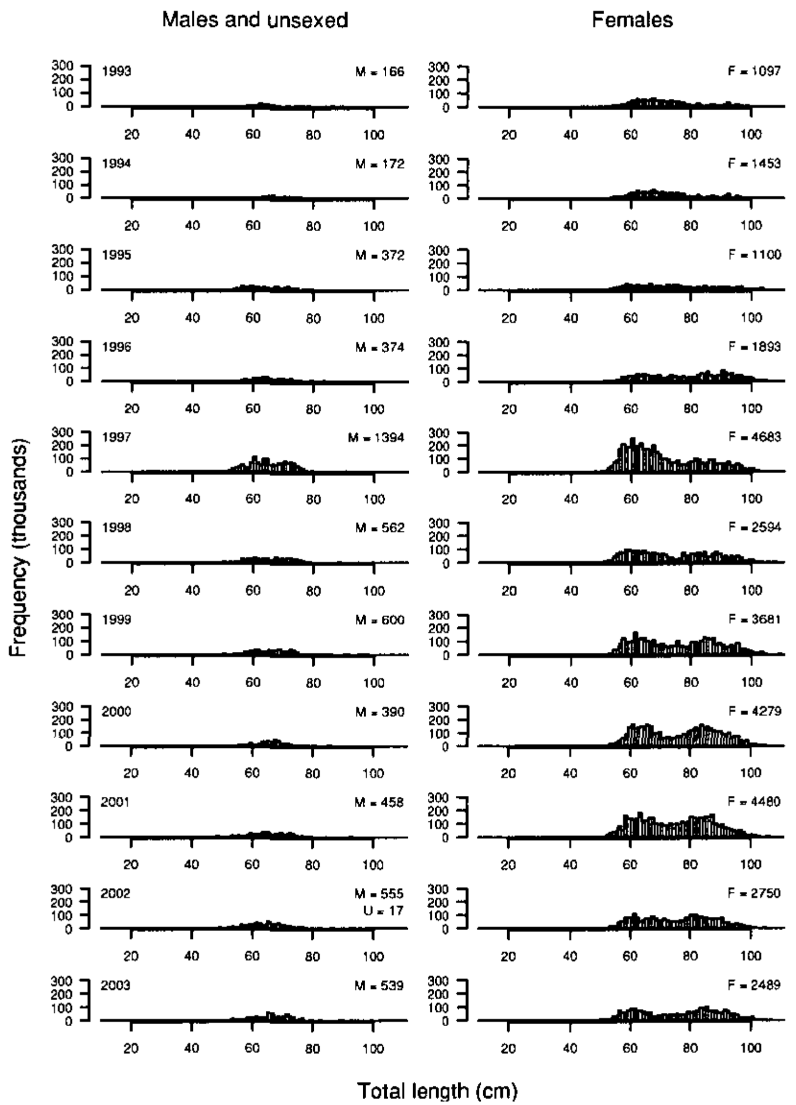

Figure 47: Scaled length-frequency distributions by sex and by survey for Chatham Rise trawl surveys carried out by RV *Tangaroa* during the calendar years 1993–2003.

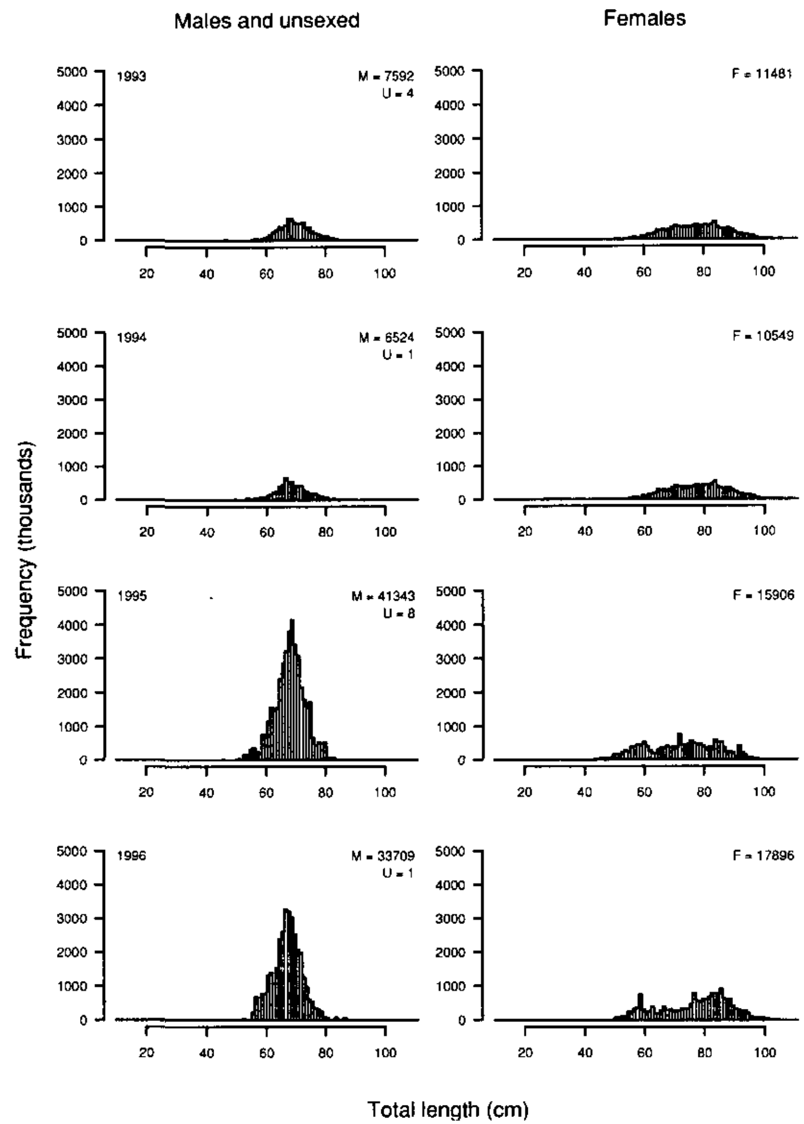

Figure 48: Scaled length-frequency distributions by sex and by survey for Stewart-Snares shelf trawl surveys carried out by RV *Tangaroa* during the calendar years 1993–1996.

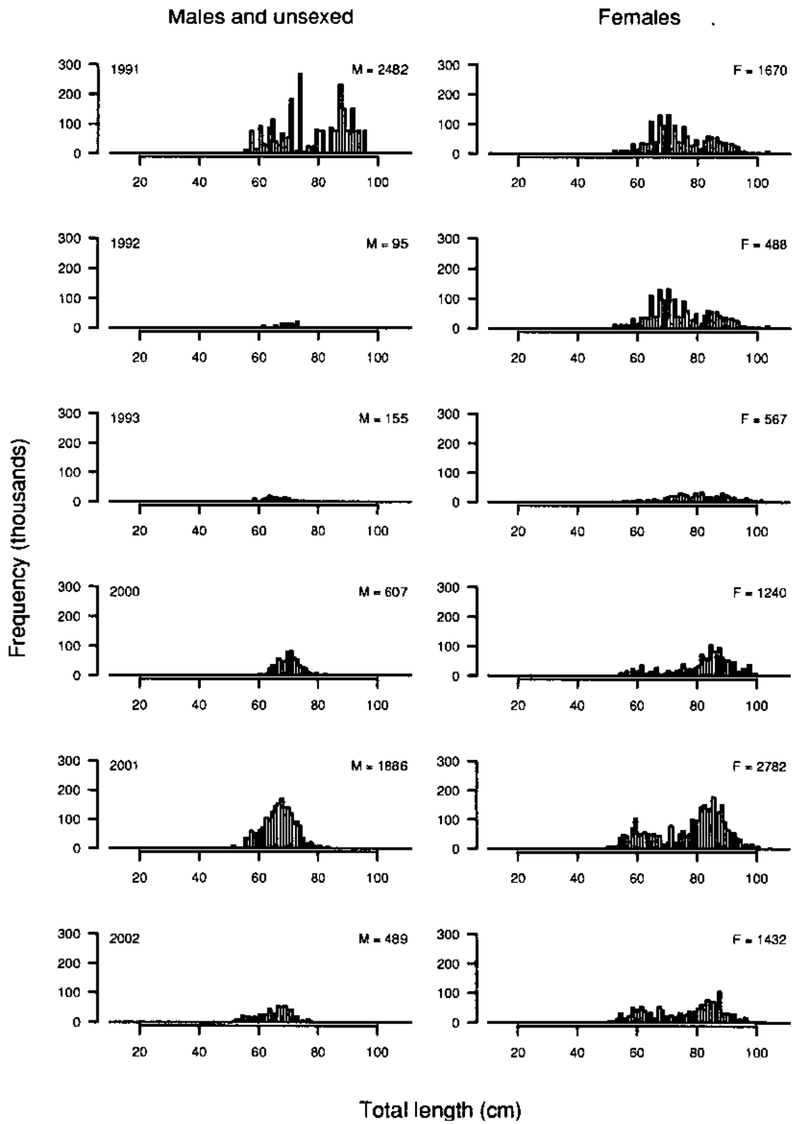

Figure 49: Scaled length-frequency distributions by sex and by survey for sub-Antarctic trawl surveys carried out by RV *Tangaroa* during the calendar years 1991–2002.

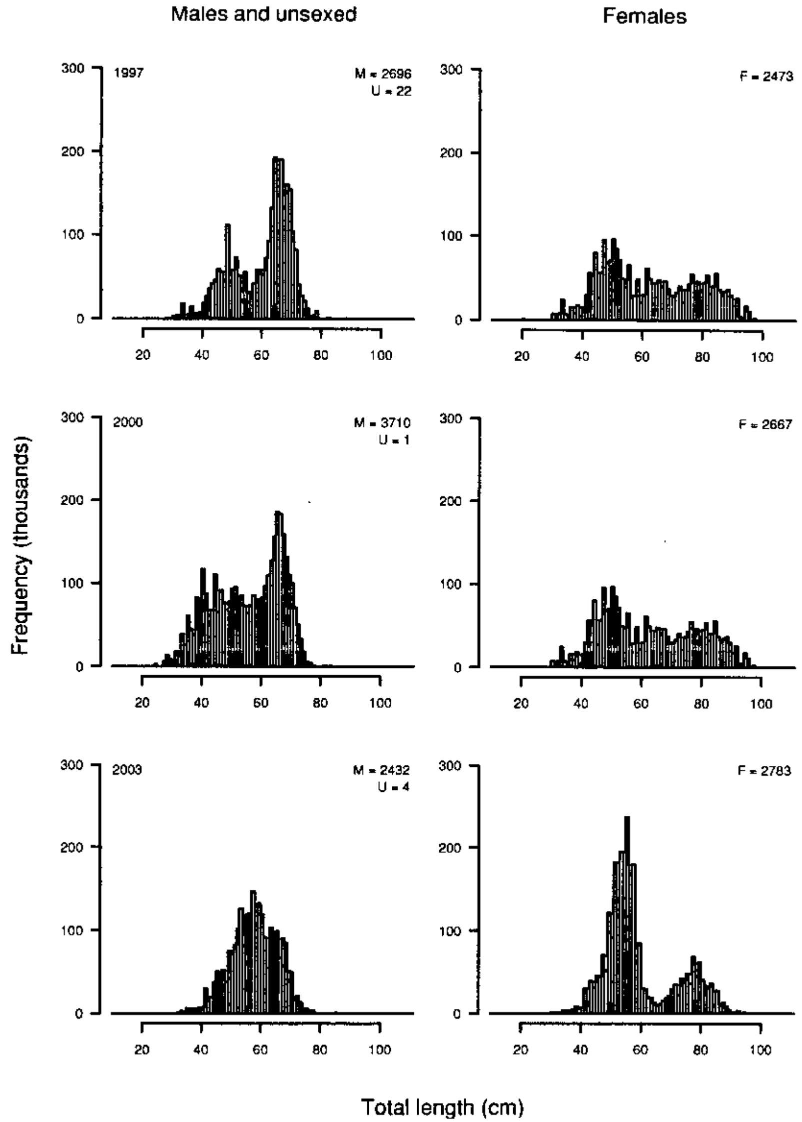

Figure 50: Scaled length-frequency distributions by sex and by survey for west coast South Island trawl surveys carried out by RV *Kaharoa* during the calendar years 1997–2003.

7. RECOMMENDATIONS FOR THE FUTURE MONITORING OF THE STOCKS

Fishstocks can be monitored by a variety of means including following trends in landings, in catch and effort, in CPUE, in biomass estimates and size structure from research surveys, and in the size composition of the commercial catch. For most elasmobranch fisheries, research surveys are rarely carried out and the main form of monitoring is CPUE. However, elasmobranchs are often spatially structured and interpretation of CPUE needs caution – particularly in highly selective setnet and/or longline fisheries (Walker 1998, Punt et al. 2000). In the northwest Atlantic, a series of groundfish surveys have provided an important time series of abundance indices for spiny dogfish, and have been used in monitoring and assessing the stock in that area (Rago et al. 1998). Another important method of monitoring elasmobranchs is the size composition of the population and/or of the catches in the fishery. Overseas studies have shown that the larger mature females are often targeted in preference to other parts of the population (Fahy & Gleeson 1990, Rago et al. 1998, Walker 1998). In the recent collapse of the northeast Atlantic spiny dogfish fishery there was a large reduction in the abundance of larger female dogfish (over 80 cm), which subsequently led to the virtual absence of juvenile dogfish below 55 cm (Rago, pers. comm.).

For each of the major Fishstocks we review the CPUE indices from Section 4 and evaluate their usefulness for monitoring abundance by considering the proportion of the total catch that they represent, the between-year fluctuations, the precision of the indices, and the consistency in trends with the trawl surveys. The size composition data from Section 5 and the trawl survey indices from Section 6 are evaluated using a similar approach.

We have defined the major fisheries as those QMAs or areas where the reported catch of spiny dogfish has been more than 10% of the total since 1990. As noted, between them SPD 3, 4, 5, and 7 account for over 90% of the total catch. The remaining QMAs are mentioned briefly at the end of this section. For our analysis we have focused on areas and fishing grounds rather than strict QMA boundaries, as we believe that these better describe the stocks and fisheries.

7.1 East coast South Island (SPD 3)

The east coast South Island fishery is the largest spiny dogfish fishery, averaging 2700 t per year since 1989–90, and contributing about 45% of the total catch. Although the total SPD 3 catch has increased from 1200 t in 1989–90 to 5300 t in 2002–03, much of this is due to an increase in reported discards, which have risen from under 20% to over 60% during this time. The actual landings have averaged only 1500 t per year. The characterisation identified two main fisheries on the east coast South Island: a setnet fishery that targets a range of elasmobranchs including spiny dogfish, rig (*Mustelus lenticulatus*), school shark (*Galeorhinus galeus*); and a target red cod (*Pseudophycis bachus*) and barracouta (*Thyrsites atun*) bottom trawl fishery operating mainly in the Canterbury Bight. For the analyses we have excluded that portion of SPD 3 which lies on the Chatham Rise.

The inshore trawl survey and various CPUE indices are summarised in Figure 51. As discussed above, trends in biomass in both trawl survey series appear to have been affected by changes in catchability between years and are unreliable. The two CPUE series show contradictory trends with the bottom trawl series increasing by 20–30% and the setnet series declining by a similar amount over the same time period. The effect of the increase in reported discards on both the CPUE time series has not been quantified. However, the main increase in reported catch has come from the bottom trawl fishery, and so it is likely that this CPUE series is unreliable. The setnet fishery has been more stable over the period, and although it has declined slightly over the past 2–3 years, we believe that it would provide a better indication of the stock status.

We therefore recommend that the setnet CPUE be used to monitor abundance in this area. Furthermore, we strongly recommend that data be collected to determine the size composition of the spiny dogfish taken in the setnet fishery. The only existing data (based on a very small sample size) suggest that setnetters target and catch mainly the larger adult females (Hanchet 1986). A decline in this part of the population would be of some concern for the viability of the population. Regular sampling of the size composition of the commercial catch combined with trends in the setnet CPUE should provide a good tool for monitoring the abundance of spiny dogfish in this area. We also recommend that possible reasons for the increase in trawl CPUE be investigated.

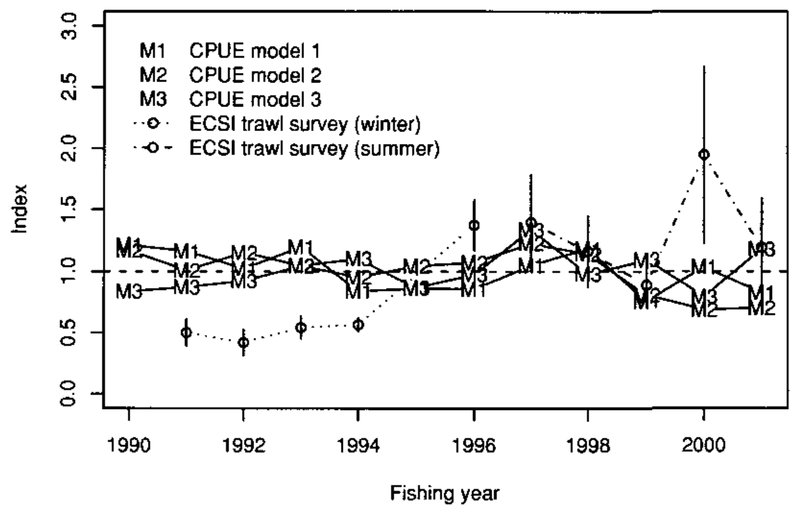

Figure 51: Standardised CPUE series (models 1, 2, and 3) and trawl survey relative biomass indices for SPD 3 for the fishing years 1989–90to 2001. All indices have been scaled to have mean = 1; 95% confidence intervals around the trawl survey indices are provided (error bars).

7.2 Chatham Rise (SPD 4 and eastern SPD 3)

The Chatham Rise fishery is the fourth largest spiny dogfish fishery, averaging 700 t per year since 1989–90, and contributing 10% of the total catch. Although the total SPD 4 catch has increased from 50 t in 1989–90 to 1600 t in 2002–03, much of this is due to reported discards, which have increased from under 5% to over 60% during this time. The annual landings have averaged only 250 t. The characterisation identified two main fisheries on the Chatham Rise: a bottom longline fishery operating mainly around the Chatham Islands that targets ling, and a bottom trawl fishery operating mainly on the western Chatham Rise that targets mainly hoki. For the analyses we have included the eastern portion of SPD 3 which lies on the Chatham Rise.

The hoki and middle depths trawl survey and the bottom longline CPUE indices are summarised in Figure 52. The trawl survey series has shown a steady three-fold increase in spiny dogfish biomass since 1992. The trends in the bottom longline CPUE, CPUE model 6, are remarkably consistent with trends in the trawl survey (Figure 52). The early years of both bottom trawl CPUE series are based on few observations and the indices are probably unreliable, although since 1995, sample sizes have been larger and both sets of indices are more consistent with both the bottom longline CPUE series and the trawl survey series (c.f., Figures 33–34 and Figure 52). The effect of the increase in reported discards on the bottom longline CPUE time series has not been quantified.

The size composition of spiny dogfish on the Chatham Rise appears to be dominated by large adult females (see Figure 47). Both trawl survey and observer length frequencies suggest a highly skewed sex ratio (varying from 2:1 to 10:1) in favour of females. Although segregation by sex and size is not uncommon in elasmobranchs, the occurrence of such a dominance of females is unusual. The mean weighted c.v.s (mean-weighted c.v.s) for the observer data are high (26–66%), and so sampling intensity and frequency would need to be increased for these data to be useful for monitoring purposes.

We recommend that the Chatham Rise trawl survey series be used to monitor abundance in this area. We further recommend that data be collected to determine the size composition of the spiny dogfish taken in the bottom longline fishery. This is important to determine the selectivity of the longline fishery. Sampling intensity and frequency of the size composition of the commercial trawl fishery should be increased to determine any changes in selectivity in the fishery and for comparison with the trawl surveys.

7.3 Stewart-Snares shelf (SPD 5)

The Stewart-Snares shelf fishery is the third largest spiny dogfish fishery contributing 17% of the total catch since 1989–90. Annual reported catches were relatively stable at about 300–400 t until 1997–98, but jumped to 2000 t in 1998–99 and then doubled to almost 4000 t in 2001–02. Reported discards have varied erratically over this time from 20 to 70% and the annual landings have averaged only about 400 t. The characterisation identified one main fishery on the Stewart/Snares shelf: a bottom and midwater summer trawl fishery operating on the Snares shelf that targets arrow squid.

The trawl survey and CPUE indices are summarised in Figure 53. Trends in biomass in the trawl survey series appear to have been affected by changes in catchability between years and are probably unreliable. The CPUE indices are also very erratic showing large increases in 1994 and 1996, and again more recently. The effect of the increase in reported discards on the CPUE time series has not been quantified. In the past two years the number of observations in the CPUE series was much higher, so the increased recent CPUE may simply reflect an increase in reporting rather than stock abundance.

Both trawl survey and observer data suggest that the size composition of spiny dogfish on the Stewart/Snares shelf is dominated by large mature males, and sub-adult and mature females (see Figure 48). Both trawl survey and observer length frequencies suggest a 2:1 sex ratio skewed towards males. However, the mean-weighted c.v.s for the observer data are high (31–68%) and so sampling intensity and frequency would need to be increased for these data to be useful for monitoring.

We recommend a closer examination of the commercial catch and effort data from SPD 5 to determine whether there are any possible biases due to the increased reporting of spiny dogfish. After checking for possible biases, we recommend that the abundance of spiny dogfish in SPD 5 be monitored using the CPUE indices together with the size composition of the commercial catch. Recognising the high mean-weighted c.v.s, we further recommend that the sampling frequency and intensity be increased for spiny dogfish in the arrow squid fishery.

7.4 Sub-Antarctic (SPD 6)

SPD 6 accounts for about 2% of the total catch and has been increasing in importance since the 1994–95 fishing year, peaking at a maximum of about 4% of the total catch across all QMAs during the 1997–98 fishing year. As noted, most of the catch in SPD 6 is bycatch of the target ling bottom longline fishery and no trend in the standardised CPUE index calculated for this catch-effort series is apparent (model 8). The CPUE index is compared with the sub-Antarctic trawl survey indices in Figure 54 and there is agreement between the CPUE index and both the autumn and spring sub-Antarctic trawl survey indices for most years for both survey series. The sub-Antarctic trawl survey data could be reanalysed to include only those survey strata found in SPD 6, but the survey only covers depths greater than 300 m and may miss fish caught by the longline fishery in shallower water. We conclude that no methods are available to monitor the status of the stock.

7.5 West coast South Island (SPD 7)

The west coast South Island fishery is the second largest spiny dogfish fishery, averaging 1200 t per year since 1989–90, and contributing 20% of the total catch. SPD 7 catches increased to a peak of 1750 t in 1998–99, but have since declined to about 1000 t. Discard rates have increased over the course of the fishery and have averaged 80% over the past four years. The annual landings have averaged about 500 t. The characterisation identified two main fisheries: the winter bottom and midwater trawl spawning hoki fishery between Hokitika and Westport, and a target spiny dogfish setnet fishery operating in winter in Tasman and Golden Bays which ceased in 1996. For the analyses we have excluded statistical areas 017 and 018 in Cook Strait.

The trawl survey and CPUE indices are summarised in Figure 55. The WCSI inshore trawl survey series seems to be adequately monitoring the population with consistent biomass estimates and low c.v.s. There is poor agreement between the trawl survey and CPUE series for individual years, but both show essentially no change since 1991–92. The effect of the increase in reported discards on the CPUE time series has not been quantified. The size composition of spiny dogfish in the hoki fishery appears to be dominated by adult males and females with a 2:1 sex ratio skewed towards males (see Figure 43). However, the mean-weighted c.v.s for the observer data are high (24–54%) and so sampling intensity and frequency would need to be increased for these data to be useful for monitoring. In contrast, the trawl survey is monitoring the entire range of sizes in the population, and has a more even sex ratio (see Figure 50).

We recommend that the abundance of spiny dogfish in SPD 7 be monitored using the west coast South Island trawl survey. We also recommend that the size composition of the commercial catch in the hoki fishery be monitored for changes in size composition or sex ratio, and suggest that sampling frequency and intensity be increased for spiny dogfish in the this fishery.

7.6 Other QMAs (SPD 1, 2, 8, and 9)

SPD 1 accounts for about 1% of the total catch by weight, all of which is probably northern spiny dogfish. No methods are available to monitor the status of the stock.

SPD 2 accounts for about 3% of the total catch with discards as a percentage of the total catch or removals from the stock appearing to increase since the 1996–97 fishing year. The trawl survey indices from 1993–96 surveys were imprecise and erratic (Stevenson & Hanchet 2000a) and no methods are available to monitor the status of the stock.

SPD 8 also accounts for about 2% of the total catch. No trend in total landings is apparent and the CPUE analysis based on the bottom-trawl catch-effort series (model 10) was stable. No methods are available to monitor the status of the stock.

SPD 9 accounts for less than 1% of the total catch. The relative biomass estimates from the west coast North Island trawl survey series were also imprecise and erratic (Morrison et al. 2001). No methods are available to monitor the status of the stock.

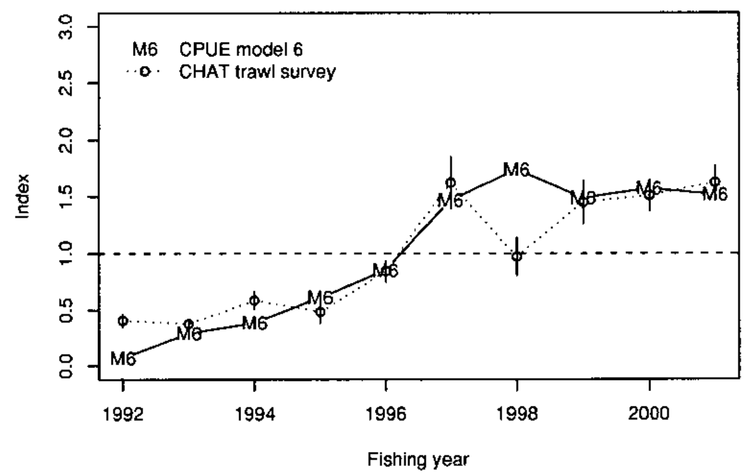

Figure 52: Standardised CPUE series (model 6) and trawl survey relative biomass indices for the Chatham Rise (SPD 3 and 4) for the fishing years 1989–90to 2001. All indices have been scaled to have mean = 1; 95% confidence intervals around the trawl survey indices are provided (error bars).

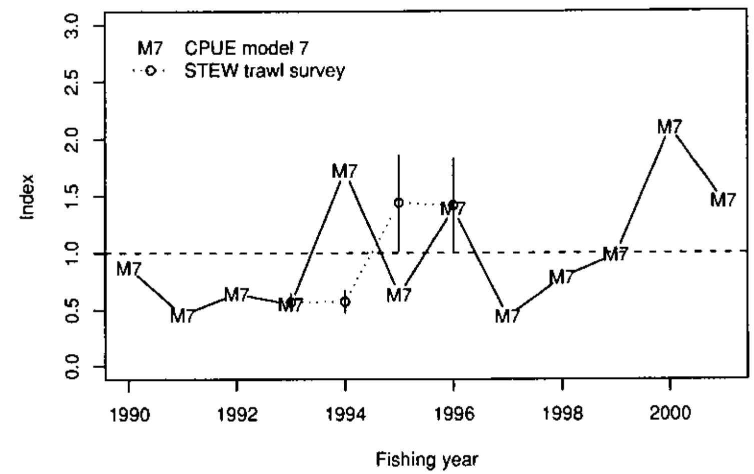

Figure 53: Standardised CPUE series (model 7) and trawl survey relative biomass indices for SPD 5 for the fishing years 1989–90to 2001. All indices have been scaled to have mean = 1; 95% confidence intervals around the trawl survey indices are provided (error bars).

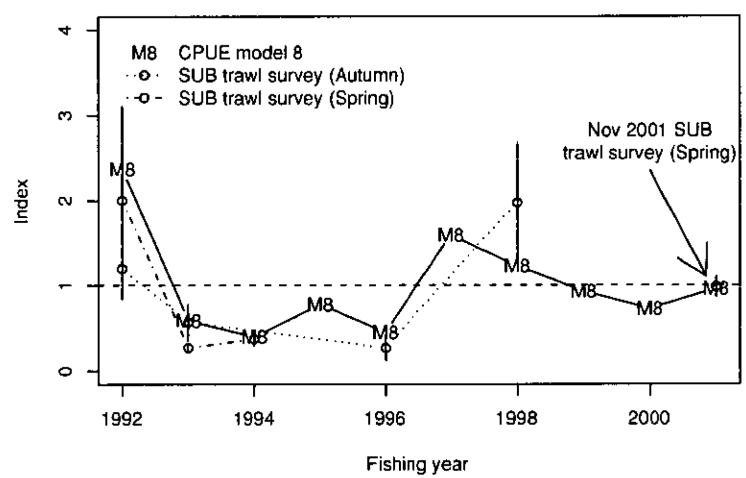

Figure 54 Standardised CPUE series (model 8) and trawl survey relative biomass indices for SPD 6 for the fishing years 1989–90to 2001. All indices have been scaled to have mean = 1; 95% confidence intervals around the trawl survey indices are provided (error bars).

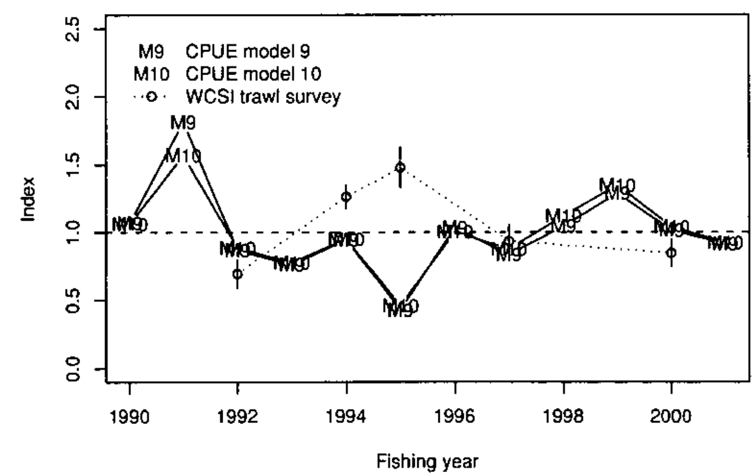

Figure 55: Standardised CPUE series (models 9 and 10) and trawl survey relative biomass indices for SPD 7 for the fishing years 1989–90to 2001. All indices have been scaled to have mean = 1; 95% confidence intervals around the trawl survey indices are provided (error bars).

8. TOWARDS A QUANTITATIVE STOCK ASSESSMENT OF NEW ZEALAND'S SPINY DOGFISH FISHERIES

Walker et al. (1999) carried out the first quantitative stock assessment of New Zealand's spiny dogfish stocks. Their estimates of biomass and yield were very uncertain and they identified a number of reasons for this. Their reasons included the catch history (in particular the high level of under-reporting), the stock structure (movement between areas could be affecting the indices), biological parameters (including gear selectivity and density dependent mortality), and inconsistencies between different abundance indices. In this section we consider these issues and how they should be addressed before a revised quantitative assessment is carried out to estimate the status of the stocks more precisely.

8.1 Stock structure

Stock structure of spiny dogfish is poorly known. No directed research on the stock structure of spiny dogfish has been carried out, and the only data available come from seasonal trawl surveys and fisheries landings. Hanchet (1986) and Hanchet & Ingerson (1997) found evidence for north-south migrations on the east coast South Island and on the west coast South Island. However, the full extent of the migrations is unknown and may also vary between years. While a better understanding of the stock structure would be desirable, it is unlikely that this could be easily achieved without a large scale tagging programme – or similar. A quantitative assessment would need to consider the possibilities of some degree of mixing between areas, however.

8.2 Catch history

For a quantitative assessment of stock status it is essential that a catch history (or in this case an estimate of total removals) of the stock is available. However, historical removals from the various stocks are incomplete and poorly known. Some vessels process and land spiny dogfish, other vessels report only discards, while many vessels show no records of catching spiny dogfish at all despite being in areas likely to catch them. There has also been a strong trend in reporting of discards over time. Walker et al. (1999) made some preliminary estimates of removals based on using a subset of the commercial fleet and by extrapolating observer data. They concluded that there were insufficient data to reliably estimate total discards or total catch on an EEZ-wide basis. More recently there have been several studies looking at fish discards and non-target catch in various target trawl fisheries around New Zealand (e.g., Anderson et al. 2001, Livingston et al. 2003).

Is it possible to estimate a reliable history of removals for spiny dogfish? This requires an estimate of the total catches of spiny dogfish, an estimate of the total discards, and an estimate of the survival rate of the discarded fish. Clearly, spiny dogfish are caught in a variety of fisheries by a variety of methods around the EEZ: catches from inshore vessels are usually reported on CELRs while catches from deepwater vessels are usually reported on TCEPRs. Total catches and more importantly total removals from vessels reporting on TCEPRs would probably be the easiest to estimate precisely. Certain sectors of the commercial fleet (e.g., Korean vessels) clearly report a large proportion of their catch. Also these vessels have observers and so it will be possible to compare catches between data sources for some of the deepwater fisheries – such as those on the Chatham Rise, Stewart-Snares shelf and west coast South Island. Estimating total catches from inshore vessels would be more problematic. However, recently the amount of reported catches and discards has increased considerably from inshore vessels. This increase has been due to improved reporting of discarded fish that stems, at least in part, from a desire to develop a catch history for spiny dogfish in case it was introduced into the QMS. These recent estimates of catch may still underestimate the true total catch – but are probably much closer than existing estimates.

Estimates of mortality rates of the discarded spiny dogfish will also be required. In the northwest Atlantic, a recent study assumed a 75% mortality rate of discards of spiny dogfish from setnetting operations and a 50% mortality rate from trawling operations (Rago et al. 1998). In the absence of other information these values could be used as a starting point.

8.3 Biological parameters

Most of the necessary biological parameters are available for spiny dogfish from earlier studies by Hanchet (1986, 1988) and Hanchet & Ingerson (1997). Data are also available now to estimate fishing selectivity for most of the fisheries, which was identified as an area of uncertainty by Walker et al. (1999) However, further data are required to estimate fishing selectivity in the setnet and bottom longline fisheries (see also Section 7).

8.4 Conclusions

To determine estimates of yield and stock status requires a quantitative stock assessment, which in turn requires a method of monitoring the stock and some contrast in the abundance indices. Of the abundance indices considered in Section 6, only the setnet CPUE indices on the east coast South Island showed any evidence of a decline. In contrast, abundance indices have shown a large increase on the Chatham Rise and have been erratic or shown no trend on the Stewart-Snares shelf and west coast South Island.

Clearly then the only area where there is sufficient contrast in the abundance indices to attempt a stock assessment is QMA3. However, there are currently insufficient data to carry out such an assessment. Firstly, a catch history for this area would need to be developed and secondly, data would need to be collected on the size composition of the setnet catch. It is recommended that these two issues be addressed as soon as possible so that a quantitative stock assessment can be carried out in the short term (i.e., the next 2–3 years).

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 All stocks

We recommend that estimates of historical removals of spiny dogfish in the four major fisheries be developed and that information needs and methods to help improve these estimates in the future be identified. We recommend that the potential effects of bias caused by the increase in reported discards on the CPUE indices in each of the four major fisheries, in particular those derived for the east coast of the South Island and Stewart-Snares shelf fisheries, be investigated. We recommend that the intensity and frequency of MFish SOP catch-sampling of spiny dogfish in each of the four major fisheries be increased.

9.2 East coast South Island (SPD 3)

We recommend that the east coast South Island fishery be monitored using the all-setnet CPUE index (model 2) and that the index be updated every 2–3 fishing years. We recommend that a quantitative stock assessment be carried out, depending on the results of the updated CPUE analysis, once the existing information needs identified in Section 7 have been met. The east coast South Island stock is the only stock where there is any suggestion of a decline in abundance.

9.3 Chatham Rise (SPD 4 and eastern SPD 3)

We recommend that the Chatham Rise fishery be monitored using the Chatham Rise trawl survey and the size composition of the commercial catch. The stock appears to be increasing under current levels of removals and there appear to be no sustainability issues. We recommend that the trawl survey and size composition data be reviewed in the medium term (i.e., after 3–5 years).

9.4 Stewart-Snares shelf (SPD 5)

We recommend the Stewart-Snares shelf fishery be monitored using the bottom-trawl fishery CPUE index, once this has been investigated for bias, and the size composition of the commercial catch. The stock appears to be stable under current levels of removals and there appear to be no sustainability issues. We recommend that the CPUE analysis and size composition data be updated in the short to medium term (i.e., after 2–3 years).

9.5 West coast South Island (SPD 7 excluding statistical areas 017 and 018)

We recommend the west coast South Island fishery be monitored using the west coast South Island trawl survey and the size composition of the commercial catch. The stock appears to be stable under current levels of removals and there appear to be no sustainability issues. We recommend that the trawl survey and size composition data be reviewed in the medium term (i.e., after 3–5 years).

10. ACKNOWLEDGMENTS

We thank Paul Starr for freely sharing his method to merge catch-effort and landings data and his correspondence. We thank Fred Wei for his help with data processing. We thank the scientific staff and crew of RV *Kaharoa* and RV *Tangaroa* and all Ministry of Fisheries scientific observers who have collected spiny dogfish catch and biological data over the years. We thank Michael Beentjes for his review of a draft version of the manuscript.

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Appendix A: Codes used in figures and tables

Fishing method codes

Code	Method	Code	Method
BLL	Bottom longlining	HL	Handlining
BPT	Bottom pair trawling	MPT	Midwater pair trawling
BT	Bottom single trawling	MW	Midwater single trawling
CP	Cod potting	PS	Purse seining
D	Dredging	RLP	Rock lobster potting
DI	Diving	SN	Setnetting
DL	Drop or dahn lining	T	Trolling
DN	Inshore drift netting	TL	Trot lining
FP	Fish trapping	TL	Trot lining

Form type codes

Code	Form type
CEL	*Catch-Effort-Landing-Return.* Used by trawl vessels less than 28 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. See Duckworth (2002).
CLR	*Catch-Landing-Return.* Used by trawl vessels 28 m in overall length or greater to record landings data. Associated catch-effort and processing data are recorded on TCEPRs. See Duckworth (2002).
TCPER	*Trawl-Catch-Effort-Processing-Return.* Used by trawl vessels 28 m in overall length or greater to record catch-effort and processing data. Associated landings data are recorded on TCEPRs are recorded on CLRs. See Duckworth (2002).

Species codes

Code	Common name	Scientific name
ALB	Albacore tuna	*Thunnus alalunga*
BAR	Barracouta	*Thyrsites atun*
BCO	Blue cod	*Parapercis colias*
BNS	Bluenose	*Hyperoglyphe antarctica*
BOE	Black oreo	*Allocyttus niger*
BYX	Alfonsinos	*Beryx splendens, B. decadactylus*
CAR	Carpet shark	*Cephaloscyllium isabellum*
CON	Conger eels	*Conger* spp.
CRA	Red rock lobster	*Jasus edwardsii*
CRB	Crabs	Decapoda
ELE	Elephant fish	*Callorhinchus milii*
ESO	New Zealand sole	*Peltorhamphus novaezeelandiae*
FLA	Flatfishes	*Colistum guntheri, C. nudipinnis, Peltorhamphus novaezelandiae, Rhombosolea flavilatus, R. leporina, R. plebeia, R. retiaria, R. tapirina*
FLO	Flounders	*Rhombosolea flavilatus, R. leporina, R. plebeia, R., retiaria, R. tapirina*
FRO	Frostfish	*Lepidopus caudatus*
GFL	Greenback flounder	*Rhombosolea tapirina*
GSH	Ghost shark	*Hydrolagus novaezealandiae*
GUR	Gurnard	*Chelidonichthys kumu*
HAK	Hake	*Merluccius australis*

Species codes (continued)

Code	Common name	Scientific name
HAP	Hapuku	*Polyprion oxygeneios*
HOK	Hoki	*Macruronus novaezelandiae*
HPB	Hapuku and bass	*Polyprion oxygeneios, P. americanus*
JDO	John dory	*Zeus faber*
JMA	Jack mackerels	*Trachurus declivis, T. novaezelandiae, T. symmetricus murphyi*
LDO	Lookdown dory	*Cyttus traversi*
LEA	Leatherjacket	*Parika scaber*
LIN	Ling	*Genypterus blacodes*
LSO	Lemon sole	*Pelotretis flavilatus*
MOK	Blue moki	*Latridopsis ciliaris*
OEO	Oreos	*Pseudocyttus maculatus, Allocyttus niger, Neocyttus rhomboidalis*
ORH	Orange roughy	*Hoplostethus atlanticus*
OSD	Sharks	Selachii
OYS	Dredge oysters	*Tiostrea chilensis*
RAT	Rattails	Macrouridae
RCO	Red cod	*Pseudophycis bachus*
REC	Red rock crab	*Lotella rhacinus*
RLA	Lance mactra	*Resania lanceolata*
ROC	Rock cod	*Lotella rhacinus*
RSK	Rough skate	*Dipturus nasutus*
SBW	Southern blue whiting	*Micromesistius australis*
SCH	School shark	*Galeorhinus australis*
SCI	Scampi	*Metanephrops challengeri*
SDO	Silver dory	*Cyttus novaezealandiae*
SFL	Sand flounder	*Rhombosolea plebeia*
SKA	Skates	Rajidae, Arhynchobatidae
SKI	Gemfish	*Rexea solandri*
SNA	Snapper	*Pagrus auratus*
SPD	Spiny dogfish	*Squalus acanthias*
SPE	Sea pearches	*Helicolenus* spp.
SPF	Scarlet wrasse	*Pseudolabrus miles*
SPO	Rig	*Mustelus lenticulatus*
SQU	Squids	*Nototodarus gouldi, N. sloanii*
SSK	Smooth skate	*Dipturus innominatus*
SSO	Smooth oreo	*Neocyttus rhomboidalis*
STA	Giant stargazer	*Kathetostoma giganteum*
SUR	Kina	*Evechinus chloroticus*
TAR	Tarakihi	*Nemadactylus macropterus*
TRE	Trevally	*Pseudocaranx dentex*
SWA	Silver warehou	*Seriolella punctata*
WAR	Blue warehou	*Seriolella brama*
WWA	White warehou	*Seriolella caerula*

Vessel flag nationality codes

Code	Vessel flag nationality	Code	Vessel flag nationality
BZE	Belize	NZL	New Zealand
CY	Cyprus	PAN	Panama
JAP	Japan	POL	Poland
KOR	Korea	RUS	Russia
MLT	Malta	UKR	Ukraine

Appendix B: Procedure used to produce the merged catch-effort and landings dataset

Introduction

These notes document the procedure used to produce the merged catch-effort and landings dataset analysed in this study. We assume that the reader is familiar with the nomenclature and structure of the Ministry of Fisheries' catch-effort and landings database *warehou*, in particular the concepts of fishing and landing events. If not, the reader is referred to Duckworth (2002). Database field and table names referred to directly in the text are set in italics (e.g., the *event_key* field in the *fishing_event* table in database *warehou*).

We have adapted the approach given by Starr (2003) for "single species characterisation studies". Where possible, these notes follow his documentation, but our aim is to record our approach. As programming tastes and methods will differ between readers, we leave it to the interested reader as to how best to implement or alter the approach we followed, although we have included descriptions either in the text or in tables of all the algorithms we used. For a more detailed, "cook book" recipe, we refer the interested reader to Starr's (2003) notes. Where we have deviated from his approach in this analysis is noted explicitly.

All data extracted from *warehou* were stored in a Microsoft Access database before merging the data. The merging procedure was implemented using Structured Query Language (SQL) statements within the database and the "R" statistical programming language (R Development Core Team 2003). There are five steps to the approach we followed: defining the data, grooming the vessel data, grooming the landing event records before merging, grooming the fishing event records before merging, and then merging the fishing and landing event records. Each of these will be discussed in turn.

Step 1: defining the data

All landing event records from all commercial fishing trips in New Zealand waters that reported a landing of spiny dogfish between 1 October 1989 and 30 September 2001 and all fishing event records associated with those trips were extracted from *warehou* (MFish catch-effort reports 4986 and 5026; Table B1). Totals of 72 767 landing event records and 389 071 fishing event records were extracted (Table B2). All fishing events associated with those trips in the landing event records extract were needed to carry out the median imputation of values failing the range checks described in Step 3 of these notes and to properly compute the effort strata for each trip. Of 62 226 unique trip keys in the landing event records file, 61 943 unique trip keys were also contained in the fishing event records file. All landing events with trip keys not contained in the fishing event records file were dropped from the analysis. The fields extracted from the database tables are listed in Table B3. Furthermore, a total of 23 237 vessel records containing 1411 unique vessel keys were extracted.

Step 2: grooming the vessel data

The number of vessel records far outnumbered the number of unique vessel keys within the data. This is due to a new vessel record being created within the database each time a vessel is registered as a commercial fishing vessel (the *specification_from* and *specification_to* fields in table *vessel*). Unfortunately, errors in the vessel records mean that the data cannot be reduced to a single record per vessel key using simple grouping queries. Fortunately, most of the errors are either missing data or simple transcription errors. The 23 237 vessel records were reduced to 1411 vessel records, one for each unique vessel key, using the following simple algorithm. The data were grouped by vessel key and the most common non-missing value in each field returned, randomly breaking ties between values. The vessel records could then be related to the fishing and landing event records using the vessel keys recorded in each fishing and landing event record.

Table B1: : Files provided by the Ministry of Fisheries for research project SPD200201 (Ministry of Fisheries Reporting Group data extracts 4986 and 5026). *n*, number of records in each file.

File	*n*	Description
A1	72767	All trips that landed spiny dogfish, 1 October 1989 to 30 September 2001
A2	389071	All fishing events associated with those trips identified in table A1

Table B2: : Counts of numbers of trips for each file in extracts 4986 and 5026. The number of unique trip keys in each file are shown in the diagonal of the matrix. Matching trip keys between files are shown in the diagonals of the matrix.

	A1	A2
A1	62226	61943
A2	61943	61943

Table B3: Fields extracted from database *warehou* by table. See Duckworth (2002) for descriptions of each field and table and database design and structure. Note that "*SPD_catch_weight*" is a generated field containing the estimated catch of spiny dogfish associated with each fishing event record, derived from related records held in table *estimated_subcatch*. The field *catch_weight* contains the total estimated catch (kg) for all species for that fishing event record.

Database table

fishing_event	*landing*	*vessel*
event_key	*event_key*	*vessel_key*
start_datetime	*landing_datetime*	*vessel_reg_type*
end_datetime	*landing_name*	*overall_length*
set_end_datetime	*fishstock_code*	*year_built*
haul_start_datetime	*state_code*	*kilowatts*
primary_method	*destination_type*	*nationality_type*
target_species	*unit_type*	*breadth*
fishing_duration	*unit_num*	*draught*
catch_weight	*unit_weight*	*gross_tonnage*
effort_depth	*conv_factor*	*specification_from*
effort_height	*green_weight*	*specification_to*
effort_num	*green_weight_type*	
effort_width	*processed_weight*	
total_hook_num	*processed_weight_type*	
effort_speed	*vessel_key*	
total_net_length	*dcf_key*	
bottom_depth	*version_seqno*	
start_latitude	*form_type*	
start_longitude	*trip_key*	
end_latitude	*trip_start_datetime*	
end_longitude	*trip_end_datetime*	
distance_travelled		
start_stats_area_code		
vessel_key		
dcf_key		
version_seqno		
form_type		
trip		
SPD_catch_weight		

Step 3: grooming the landing event records before merging

The following procedure was used to groom the landing event records before merging:

Step	Description
3.1	Extract valid destination codes
3.2	Check for out-of-range landings
3.3	Calculate "best date" for landings
3.4	Drop all records where landed greenweight is zero or null
3.5	Collapse the landings data to one record per trip and fishstock

Extracting valid destination codes

The *destination_type* field in each landing event record records the destination of the landed catch. Some destination codes represent terminal events and should be kept while others may be offloaded under another code and should be dropped to avoid double-counting of the catch. The destination codes retained in the analysis are listed in Table B4. This differs from Starr (2003), who suggests that discarded landings of non-ITQ species such as spiny dogfish should be dropped. We suggest that the sum of the discarded and undiscarded valid landings represents the current best estimate of the total removals from the stocks and that discarded landings of non-ITQ species should be retained, although we note that discarded landings of non-ITQ species, such as spiny dogfish, from the early 1990s are certainly under-reported and probably remain so.

Checking for out-of-range landings

A range check on the *green_weight* field in each landing event was applied using a table of verified maximum landed catch totals for spiny dogfish prepared by K. Duckworth (Ministry of Fisheries; Table B5). The data are the 95th and 99th percentiles of verified maximum catch totals by method for fishing event records and for all methods for landing events. Since 1 October 2001, these data have been used as internal range checks within *warehou*. For each landing event record failing the range-check, the total greenweight landed catch for the trip was compared with the total estimated catch for spiny dogfish recorded on the fishing events records for that trip and the amount of time that the vessel had been at sea during the trip (the difference between the *trip_start_datetime* and *trip_end_datetime* fields in each landing event record). Out-of-range values that were likely to have been the result of transcription errors were edited. Landing event records with implausibly high out-of-range values were dropped from the analysis, including all fishing event records and all other landing event records associated with that trip.

Calculating the "best date" for each trip

The landing date, the *landing_datetime* field in each landing event record, was the preferred date for each trip from which the fishing year for each trip was calculated. As Starr (2003) noted, alternative dates such as the trip start or end dates could be used, but we agree that some standardisation is necessary. The algorithm given in Table B6 was used to check that the *landing_datetime*, *trip_start_datetime*, and *trip_end_datetime* values for each trip were internally consistent. Step 3 traps errors where landing date has a lower value than either the trip start or trip end dates. Step 4 traps errors where either the trip start date or trip end date are incorrect relative to each other but not to the landing date. Step 5 traps errors where the trip end date runs into an invalid fishing year at the upper end of the time series. The Ministry of Fisheries appears to use trip end dates to define their extracts,hence landing dates occasionally stray into a non-valid fishing year at the upper end of the time series of data extracted.

Table B4: Destination codes and descriptions for landings in database *warehou* and how those landings were used in the merging procedure: 1, kept; 0, dropped.

Destination code	Description	How used
A	Accidental loss	1
C	Disposed to Crown	1
E	Eaten	1
F	Landed under "approval" from Ministry of Fisheries	1
H	Loss from holding pot	1
L	Landed in New Zealand to licensed fish receiver	1
O	Conveyed outside New Zealand	1
S	Seized by Crown	1
U	Bait used on board	1
W	Sold at wharf	1
D	Discarded (non-ITQ)	1
B	Bait stored for later use	0
P	Holding in marine waters	0
Q	Holding on land	0
R	Retained on board	0
T	Transferred to another vessel	0
NULL	Null record	0

Table B5: 95th and 99th percentiles of verified maximum catch totals for spiny dogfish fishing and landing events provided by K. Duckworth (Ministry of Fisheries).

Event type	Method	95th percentile of validated maximum catch total (kg)	99th percentile of validated maximum catch total (kg)
Fishing events	BLL	7 139	14 279
	BT	25 250	50 500
	CP	125	250
	DL	250	500
	MW	10 100	20 200
	RLP	125	250
	SN	3 817	7 635
Landing events	All	67 765	135 531

Table B6: Algorithm used to calculate the "best date" for each trip in the landing event records file.

Step	Description
1	Calculate for each trip: $$TL_t = (TE_t - TS_t) + 1$$ $$ATL_t = (TE_t - LD_t) + 1 \text{ if } LD_t < TE_t$$ $$TC_f = Q_{0.95}\left(TL_f\right) - Q_{0.90}\left(TL_f\right)$$ where TL_t is the trip length for trip t, TE_t is the trip end date for trip t, TS_t is the trip start date for trip t, ATL_t is an alternative trip length for trip t, LD_t is the landing date for trip t, TC_f is the trip "cut-off" length for form type f, and $Q_{0.90}(TL_f)$ and $Q_{0.95}(TL_f)$ are the 90th and 95th percentiles of the distribution of trip lengths for form type f. Go to step 2.
2	Let $$BD_t = LD_t$$ where BD_t is the "best date" for trip t and go to step 3.
3	Let $$BD_t = TE_t$$ if $LD_t < TS_t$ and go to step 4.
4	Let $$BD_t = TE_t$$ if $TL_t > TC_f$ and $LD_t < TE_t$ and $ATL_t \leq TC_f$ and go to step 5.
5	Let $$BD_t = LVD \text{ if } LD_t < LVD$$ where LVD is the last valid date in the dataset (e.g., 30 September 2001 in this analysis) and stop.

Step 4: grooming the fishing event records before merging

The following procedure was used to groom the fishing event records before merging.

Step	Description
4.1	Check for missing method values in each trip
4.2	Check for missing statistical area values in each trip
4.3	Check for missing target species values in each trip
4.4	Run range checks on effort variables to identify outlier values and use median imputation to correct missing or outlier values
4.5	Collapse the fishing event records to one record per trip, statistical area, method, and target species ensuring that each record contains all relevant effort fields and the estimated catch field.

Grooming method values

The method codes recorded for each trip were groomed for missing values as follows. For those trips containing missing method codes, if only a single method code was used throughout the trip, then the missing values were replaced with the single method code and the trip retained in the analysis. If more than one method code was used, then the trip and all associated records were dropped from the analysis.

Grooming statistical area values

The statistical area values recorded for each trip were groomed for missing values as follows. For those trips with missing statistical area values, the missing values were replaced with the most common statistical area value recorded across all fishing event records associated with that trip. Trips where all statistical area values were missing were dropped from the analysis.

Grooming target species values

The target species values recorded for each trip were groomed for missing values using the same method used to identify and groom missing statistical area values. For those trips with missing target species values, the missing values were replaced with the most common target species value across all fishing event records associated with that trip. Trips where all target species values were missing were dropped from the analysis.

Running range checks to identify outlier values and replacing outliers or missing values using median imputation

Although replacing missing or outlier values with median values may lead to underestimation of the variance for a given variable, this approach uses the data to "fix itself" rather than merely dropping cases containing missing or outlier data, thus maximising the amount of data available for analysis while eliminating missing or implausible values (e.g., see the start and end fishing positions before and after grooming plotted in Figure B1). In this study, method and form-specific range checks were used to identify outlier variables in the effort variables (Table B7), which were then replaced with median values calculated over some subset of the data as follows. Note that not all effort variables are defined for all methods.

Where defined, fishing event start or end latitudes and longitudes failing crude range checks on latitude or longitude were set to null. Missing values or values for a given vessel on a particular fishing day more than one degree different from the median start or finish latitude or longitude for that vessel on that fishing day were replaced with the median start or end latitude or longitude for that vessel on that fishing day.

Where defined, fishing events where *effort_depth* was recorded as greater than *bottom_depth* had these values transposed. Where defined, *effort_depth*, *bottom_depth*, and *effort_speed* were investigated using method and form-specific range checks and missing or outlier values for each vessel on each fishing day replaced with median values for each variable calculated over the subset of fishing events for that vessel and fishing day and the range checks repeated. Missing or outlier values after this process were set to median values calculated over all vessels and all fishing years for that method and form type.

Where defined, *effort_number*, *effort_width*, *effort_height*, *total_hook_num*, and *total_net_length* were investigated using method and form-specific range checks and missing or outlier values for each vessel in each fishing year were replaced with median values for each variable calculated over the subset of fishing events for that vessel and fishing year and the range checks repeated. Missing or outlier values after this process were set to median values calculated over all vessels and fishing years for that method and form type.

Where defined, *fishing_duration* was investigated using method and form-specific range checks and missing or outlier values for each trip replaced with median values calculated over that trip and the range checks repeated. Missing or outlier values after this process were replaced with median values calculated over all trips for that method and form type.

Finally, where defined, values failing method and form-specific range checks for *distance_travelled* were set to null. No attempt was made to correct missing or outlier values. Similarly, spiny dogfish catches failing method and form-specific range checks for catch weight were inspected visually for plausibility based on the value of the other effort variables in that record. Implausible catches were set to null.

Collapsing the fishing event records to a single record per trip, statistical area, method, and target species

Collapsing the groomed set of fishing event records to a single record per trip, statistical area, method, and target species restratifies all fishing events – i.e., all fishing effort regardless of form type – to the same resolution. How effort variables that differed from record to record within each effort stratum were treated during the restratification process is described in Table B8. The groomed fishing and landing event records were merged during the next step and the groomed landed catches for each trip allocated to the effort strata associated with each trip, producing the final groomed and merged catch-effort dataset analysed subsequently.

Table B7: Error range-checks applied to catch-effort variables during data grooming to identify outlier values. BT, bottom trawling; MW, midwater trawling; SN, setnetting; BLL, bottom longlining.

Method	Variable	Range check applied
BT	Total number of shots per day	< 1 or > 10
	Distance	< 0 or > 100 km
	Duration	< 0.25 or > 12 hours (TCPER events only)
		or < 0.25 or > 24 hours (CELR events only)
	Speed	< 2.5 or > 6.5 knots
	Bottom depth	> 1200 m
	Net depth	> 1200 m
	Headline height	> 10 m
	Gear width	< 10 m or > 70 m
	Catch per shot	> 50.500 t
MW	Total number of shots per day	< 1 or > 10
	Distance	< 0 or > 100 km
	Duration	< 0.08 or > 12 hours (TCPER events only)
		or < 0 .08 or > 24 hours (CELR events only)
	Speed	< 2.5 or > 6.5 knots
	Bottom depth	> 1200 m
	Net depth	> 1200 m
	Headline height	< 10 m or > 100 m
	Gear width	< 30 m or > 160 m
	Catch per shot	> 20.200 t
SN	Total length of net set per day	< 100 or > 7500 m
	Mesh size	< 90 or > 250 mm
	Fishing duration	< 3 or > 72 hours
	Catch per day	> 7.635 t
BLL	Total number of lines set per day	< 1 or > 12
	Total number of hooks set per day	< 300 or > 50000
	Fishing duration	< 3 or > 72 hours
	Catch per day	> 14.279 t
Other methods	Total amount of effort per day	< 1 or > 300
All methods	Trip greenweight catch	> 67765 t
	Start or end latitude	< 24° S or > 58° S
	Start or end longitude	< 157° E or < 157° W

Table B8: How effort variables were treated during restratification of the data in step four of the merging procedure: "–", variable values identical for all fishing event records within a stratum and no function applied; "•", variable dropped during restratification.

Effort variable	Function	Effort variable	Function	Effort variable	Function
event_key	•	*effort_height*	Median	*end_longitude*	•
start_datetime	Min	*effort_num*	Sum	*distance_travelled*	Sum
end_datetime	Max	*effort_width*	Median	*start_stats_area_code*	–
set_end_datetime	•	*total_hook_num*	Sum	*vessel_key*	–
haul_start_datetime	•	*effort_speed*	Median	*dcf_key*	•
primary_method	–	*total_net_length*	Sum	*version_seqno*	•
target_species	–	*bottom_depth*	Median	*form_type*	–
fishing_duration	Sum	*start_latitude*	Median	*trip*	–
catch_weight	Sum	*start_longitude*	Median	*SPD_catch_weight*	Sum
effort_depth	Median	*end_latitude*	•		

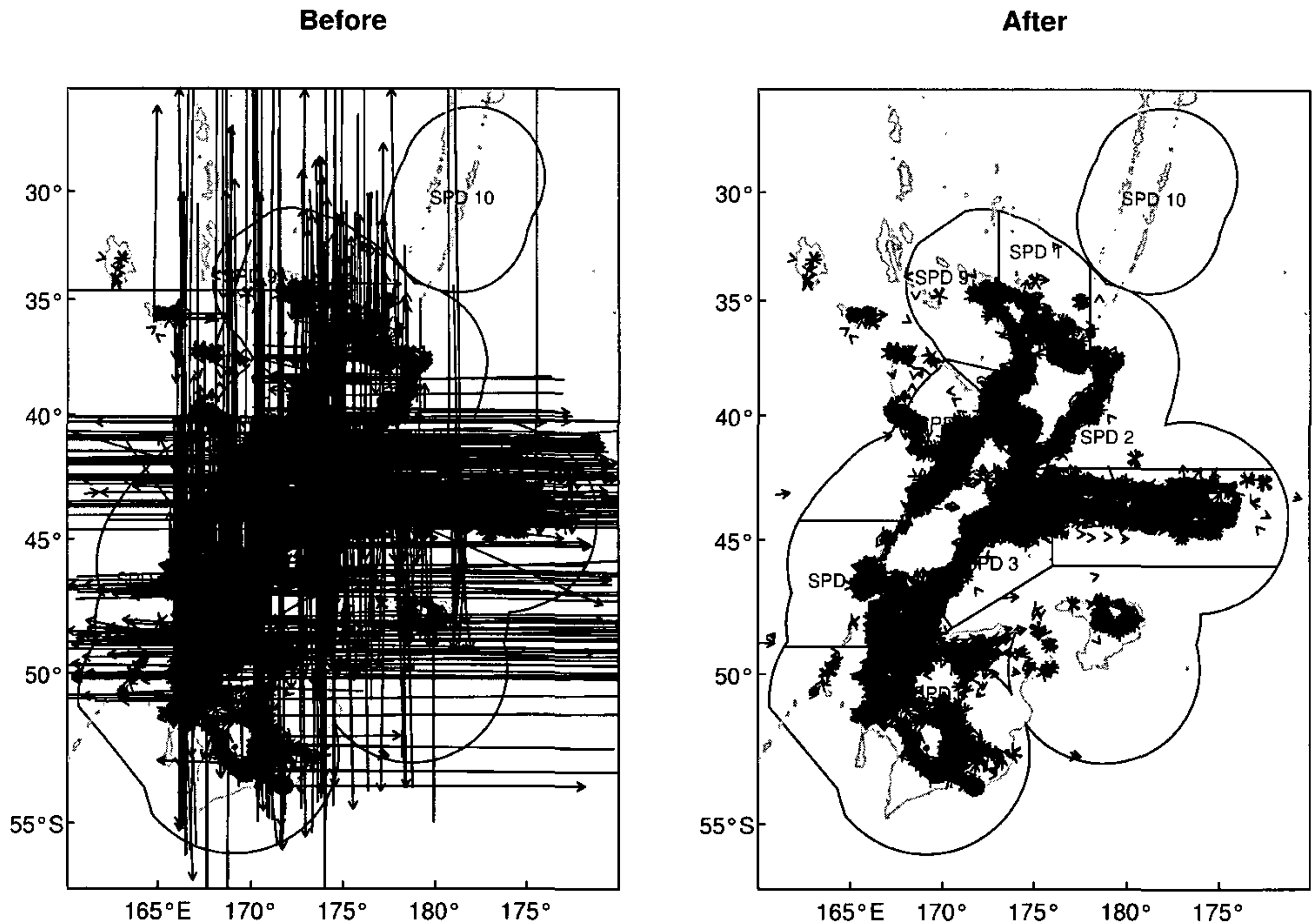

Figure B1: Start and end positions for all fishing events in the raw dataset before and after data grooming. Fishing event direction and distance are indicated by the *arrow-head at the end of a line joining the start and end positions for each fishing event. The very long distances between start and end positions in the first panel* indicate errors in at least one of the *start_longitude*, *start_latitude*, *end_longitude*, or *end_latitude* fields that were eliminated during grooming. Fishing positions in the Southern Alps are noted wryly.

Step 5: merging the landing and fishing event records

The following procedure was used to merge the groomed landing and fishing event records.

Step	Description
5.1	Prepare a pointer file relating the statistical areas in the fishing event records with the fishstocks in the landing event records.
5.2.	Match landings to the fishing event records based on the relationship between statistical areas and fishstocks defined in the pointer file.
5.3	Groom trips containing statistical areas that straddle adjacent fishstocks
5.4	Allocate the landings in each trip to the effort strata associated with each trip

Preparing a pointer file relating statistical areas to fishstocks

The groomed fishing and landing event records are merged using the relationship between statistical areas and fishstocks. Statistical areas are mapped onto fishstocks in a "pointer file". The pointer file prepared for this study is given in Table B9. Pointer files prepared for other studies will need to reflect the fishstock configuration of the species studied. Note that more than one fishstock may be mapped to some statistical areas. Statistical areas that straddle adjacent fishstocks were dealt with in step 5.3.

Matching landings to fishing events

Landings were matched onto fishing events in a two-step process using the pointer file generated in step 5.1. First, the three fishstock fields in the pointer field were matched onto the restratified and groomed fishing event records using the statistical area fields in both tables as an index. The resulting table was then expanded into a long-form result consisting of a single fishstock field per record and all records where fishstock = 0 were dropped, eliminating all non-valid statistical area and fishstock combinations. Second, the resulting table was then matched onto the groomed landing event records using the trip and fishstock fields in both tables as an index. Only those records with a match in the landings table were kept; all other records were dropped

Grooming trips containing statistical areas that straddle adjacent fishstocks

Some statistical areas straddle adjacent fishstocks (Figure 1; Table B9), confounding the relationship between statistical areas and fishstocks. Trips containing straddling statistical areas where landings were recorded from more than one of the adjacent fishstocks were dropped from the analysis. Trips containing straddling fishstocks where landings from only one of the adjacent fishstocks were recorded were retained.

Allocating the total groomed landed catch for each trip

The groomed landed catch for each trip was allocated to the associated effort strata using the following procedure. If estimated catches of spiny dogfish were recorded in the effort strata, then the total groomed landed catch was allocated proportionally to the total estimated catch for each trip. If estimated catches were not recorded, then the landed catch was allocated proportionally to the total fishing effort for the trip. The definitions of total fishing effort used to allocate landings were method-dependent and are given in Table B10. Completion of this step produces the groomed, restratified catch-effort dataset used in the characterisation and catch-per-unit-effort sections of this study.

Table B9: Relationships between statistical area and SPD fishstocks used to merge effort and landed catches. Up to three fishstocks (F1, F2, and F3) were matched to each statistical area (stat. area). A value greater than "0" in F1, F2, or F3 indicates a valid statistical area-fish stock match. A value of "0" indicates an invalid match. Statistical areas 901 to 943 are rock lobster statistical areas and were dropped from the analysis. Statistical area 999 is an error code produced during grooming of the statistical area field.

Stat. area	F1	F2	F3	Stat. area	F1	F2	F3	Stat. area	F1	F2	F3	Stat. area	F1	F2	F3
001	1	0	0	042	9	0	0	501	5	0	0	906	0	0	0
002	1	0	0	043	9	0	0	502	5	0	0	907	0	0	0
003	1	0	0	044	9	0	0	503	5	0	0	908	0	0	0
004	1	0	0	045	9	0	0	504	5	0	0	909	0	0	0
005	1	0	0	046	9	0	0	601	6	0	0	910	0	0	0
006	1	0	0	047	9	0	0	602	6	0	0	911	0	0	0
007	1	0	0	048	9	0	0	603	6	0	0	912	0	0	0
008	1	0	0	049	4	0	0	604	6	0	0	913	0	0	0
009	1	0	0	050	4	0	0	605	6	0	0	914	0	0	0
010	1	0	0	051	4	0	0	606	6	0	0	915	0	0	0
011	2	0	0	052	4	0	0	607	6	0	0	916	0	0	0
012	2	0	0	093	10	0	0	608	6	0	0	917	0	0	0
013	2	0	0	094	10	0	0	609	6	0	0	918	0	0	0
014	2	0	0	101	9	0	0	610	6	0	0	919	0	0	0
015	2	0	0	102	9	0	0	611	6	0	0	920	0	0	0
016	2	7	0	103	9	0	0	612	6	0	0	921	0	0	0
017	2	7	0	104	9	0	0	613	6	0	0	922	0	0	0
018	2	3	7	105	1	0	0	614	6	0	0	923	0	0	0
019	2	3	0	106	1	0	0	615	6	0	0	924	0	0	0
020	3	0	0	107	1	0	0	616	6	0	0	925	0	0	0
021	3	0	0	201	2	0	0	617	6	0	0	926	0	0	0
022	3	0	0	202	2	0	0	618	6	0	0	927	0	0	0
023	3	0	0	203	2	0	0	619	6	0	0	928	0	0	0
024	3	0	0	204	2	0	0	620	6	0	0	929	0	0	0
025	3	5	0	205	2	0	0	621	6	0	0	930	0	0	0
026	3	0	0	206	2	0	0	622	6	0	0	931	0	0	0
027	3	5	0	301	3	0	0	623	6	0	0	932	0	0	0
028	5	0	0	302	3	0	0	624	6	0	0	933	0	0	0
029	5	0	0	303	3	0	0	625	6	0	0	934	0	0	0
030	5	0	0	401	4	0	0	701	7	0	0	935	0	0	0
031	5	0	0	402	4	0	0	702	7	0	0	936	0	0	0
032	5	7	0	403	4	0	0	703	7	0	0	937	0	0	0
033	7	0	0	404	4	0	0	704	7	0	0	938	0	0	0
034	7	0	0	405	4	0	0	705	7	0	0	939	0	0	0
035	7	0	0	406	4	0	0	706	7	0	0	940	0	0	0
036	7	8	0	407	4	0	0	801	8	0	0	941	0	0	0
037	7	8	0	408	4	0	0	901	0	0	0	942	0	0	0
038	7	0	0	409	4	0	0	902	0	0	0	943	0	0	0
039	7	8	0	410	4	0	0	903	0	0	0	999	0	0	0
040	7	8	0	411	4	0	0	904	0	0	0				
041	9	8	0	412	4	0	0	905	0	0	0				

Table B10: Definitions of total fishing effort used when allocating the groomed landed catch for each trip to the associated effort strata. See Table B11 for the algorithm followed.

Method code	Definition of total fishing effort
BT, BPT, MW, D, RLP, CP, EP, FP, FN, H, DI, and SJ	Sum of *effort_number* per stratum
BLL, SLL, DL, TL, HL, T, and PL	Sum of *total_hook_num* per stratum
SN, DN, PS, DS, L, BS, and RN	Sum of *total_net_length* per stratum

Table B11: Algorithm used to allocate the groomed landed catch for each trip to the associated effort strata.

Step	Description
1	Calculate for each trip:

$$C_t = \sum_{i=1}^{n} C_{t,i}$$

$$E_t = \sum_{i=1}^{n} E_{t,i}$$

where $C_{t,i}$ is the estimated catch of spiny dogfish for trip t in effort stratum i, where $E_{t,i}$ is the total amount of effort (see Table B10 for definitions), and i is the total number of effort strata for trip t. Go to step 2.

2 Let

$$L_{t,i} = L_t \frac{C_{t,i}}{C_t} \text{ if } C_t > 0$$

where L_t is the groomed landed catch of spiny dogfish for trip t. Otherwise go to step 3.

3 Let

$$L_{t,i} = L_t \frac{E_{t,i}}{E_t} \text{ if } C_t = 0$$

and stop.

Appendix C: Cross-tabulations of catches in the groomed and merged dataset by interactions between fishing year and other factors

Table C1: Groomed and merged catches by fishing year and month for selected QMAs. The catch for each month for each fishing year and QMA is given as a percentage of the total groomed and merged catch for that fishing year and QMA.

(A) All QMAs

	Month (% of total catch)												Total
Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	catch (t)
1989–90	2	4	5	6	10	8	9	12	8	13	15	7	1 435
1990–91	10	11	6	7	6	6	5	8	10	13	10	8	2 682
1991–92	5	7	5	9	6	11	11	6	9	10	13	8	2 326
1992–93	6	5	7	9	8	12	9	10	9	11	8	7	2 477
1993–94	7	5	4	7	7	5	11	11	11	12	13	6	3 930
1994–95	10	7	6	7	7	7	7	11	7	13	10	8	2 808
1995–96	7	8	3	5	7	8	8	7	9	16	12	10	4 089
1996–97	3	4	3	7	8	11	7	9	10	15	8	12	4 832
1997–98	8	7	7	8	8	5	7	9	7	14	13	9	4 332
1998–99	4	2	8	10	6	10	5	5	5	16	22	9	6 381
1999–00	5	5	4	6	8	11	7	11	7	16	13	9	5 533
2000–01	9	5	4	8	8	8	9	7	8	9	13	13	6 715
Total	6	5	5	8	7	8	8	8	8	14	13	9	47 540

(B) SPD 3

	Month (% of total catch)												Total
Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	catch (t)
1989–90	3	4	5	6	12	10	10	16	6	10	11	7	999
1990–91	12	12	9	8	6	6	7	9	6	7	9	11	1 553
1991–92	4	8	8	14	8	11	8	8	8	7	9	7	1 322
1992–93	6	5	4	8	11	12	10	10	7	9	10	7	1 270
1993–94	8	5	4	9	9	7	19	12	6	6	9	7	1 898
1994–95	8	7	4	7	9	12	11	16	5	4	7	10	1 588
1995–96	7	3	3	5	8	13	15	13	7	5	10	12	1 830
1996–97	4	5	3	13	14	16	12	12	5	5	6	5	2 020
1997–98	7	12	4	8	13	8	11	13	7	3	3	10	2 057
1998–99	8	3	4	9	11	22	8	8	7	4	6	10	2 364
1999–00	5	3	3	8	11	16	12	14	7	8	5	8	2600
2000–01	11	7	5	9	7	8	10	10	10	5	5	11	3 500
Total	7	6	5	9	10	12	11	11	7	6	7	9	23 001

(C) SPD 4

	Month (% of total catch)												Total
Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	catch (t)
1989–90	0	<1	5	13	<1	<1	<1	18	39	18	6	<1	45
1990–91	15	42	8	0	<1	<1	<1	<1	12	19	<1	3	146
1991–92	<1	20	0	0	2	7	1	10	30	2	19	8	26
1992–93	1	0	<1	3	0	29	12	<1	20	23	2	9	58
1993–94	0	3	1	6	2	7	4	31	11	3	18	15	268
1994–95	12	3	22	2	2	<1	<1	1	30	14	10	4	236
1995–96	11	6	1	<1	<1	6	2	4	<1	28	18	24	513
1996–97	4	1	2	<1	0	3	1	12	21	16	6	34	1 074
1997–98	17	2	15	3	2	2	<1	14	6	12	10	17	729
1998–99	1	3	2	12	3	1	9	2	1	<1	38	27	971
1999–00	7	15	3	9	3	4	2	11	2	21	3	20	730
2000–01	6	1	3	11	6	9	3	1	<1	11	24	23	941
Total	7	5	5	6	2	4	3	8	8	13	16	23	5 736

Table C1: (continued)

(D) SPD 5

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total catch (t)
											Month (% of total catch)		
1989–90	0	<1	15	20	21	10	7	3	9	8	4	2	66
1990–91	6	1	3	19	24	21	2	1	11	4	6	2	222
1991–92	<1	1	1	6	20	54	13	3	0	<1	1	<1	142
1992–93	5	3	1	1	26	46	11	1	1	2	2	2	159
1993–94	30	8	5	<1	14	10	8	3	4	5	1	11	140
1994–95	16	23	2	19	22	5	1	1	<1	<1	2	10	101
1995–96	11	3	<1	26	45	7	1	<1	3	<1	<1	3	179
1996–97	4	7	9	13	11	26	18	5	3	1	2	2	245
1997–98	7	7	21	14	12	10	13	2	6	5	1	2	233
1998–99	1	1	45	31	8	2	<1	<1	1	1	9	2	801
1999–00	2	4	15	11	19	28	<1	1	12	3	3	3	393
2000–01	7	1	2	6	15	15	17	5	6	5	8	12	570
Total	6	3	16	16	17	16	7	2	5	3	5	4	3 250

(E) SPD 6

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total catch (t)
											Month (% of total catch)		
1989–90	0	0	0	0	0	0	0	0	0	0	0	100	<1
1990–91	4	1	0	9	58	28	<1	0	0	0	0	<1	7
1991–92	0	<1	0	71	0	5	0	0	0	0	17	6	24
1992–93	1	53	17	3	24	1	0	0	0	0	0	1	7
1993–94	0	0	14	1	3	17	7	23	33	<1	1	<1	3
1994–95	<1	1	21	76	0	<1	0	0	2	<1	0	<1	25
1995–96	0	89	4	1	1	<1	<1	5	<1	<1	0	0	150
1996–97	0	19	28	21	5	9	2	7	9	<1	<1	<1	112
1997–98	1	2	20	64	2	<1	5	1	4	<1	<1	1	150
1998–99	<1	4	11	9	7	17	9	5	9	29	<1	2	122
1999–00	<1	8	7	8	15	2	10	13	14	10	5	8	113
2000–01	5	2	6	14	8	1	8	6	35	4	2	9	152
Total	1	21	12	23	6	4	5	6	11	6	2	3	867

(F) SPD 7

Fishing year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total catch (t)
											Month (% of total catch)		
1989–90	<1	5	3	1	3	1	4	4	8	27	35	10	272
1990–91	5	4	1	2	2	1	2	10	19	30	18	7	682
1991–92	9	7	2	1	<1	2	4	5	13	20	26	11	649
1992–93	7	5	2	8	3	7	7	16	14	16	9	7	761
1993–94	5	5	4	5	4	2	4	7	17	23	20	4	1 466
1994–95	14	4	5	7	2	<1	2	6	7	35	15	3	717
1995–96	5	6	2	6	2	3	3	3	21	35	11	3	1 181
1996–97	1	4	1	3	7	9	4	6	12	34	12	6	1 227
1997–98	4	2	1	<1	<1	<1	1	1	8	45	34	4	949
1998–99	2	1	1	1	2	2	3	4	6	45	32	2	1 635
1999–00	4	5	2	2	2	2	2	9	9	30	28	5	1 369
2000–01	6	6	1	7	6	5	10	3	7	20	24	5	1 213
Total	5	4	2	4	3	3	4	6	12	31	22	5	12 121

Table C2: Catches by fishing year, statistical area, and area for selected QMAs in the groomed and merged dataset. The catch for each fishing year, area, and fishing year is given as a percentage of the total catch for each fishing year and QMA. Catches by fishing year and QMA for all QMAs are given in Table 7.

(A) SPD 3

	Statistical area (% of total catch)													Total
Fishing year	018	019	020	021	022	023	024	025	026	027	301	302	303	catch (t)
1989–90	19	<1	36	<1	24	<1	18	<1	2	<1	0	0	0	1 435
1990–91	19	<1	30	8	29	1	13	<1	1	<1	0	0	0	2 682
1991–92	26	<1	32	<1	22	<1	14	1	3	2	0	<1	0	2 326
1992–93	43	<1	23	<1	15	<1	15	<1	3	<1	0	0	0	2 477
1993–94	23	<1	28	2	24	<1	21	<1	2	<1	0	0	0	3 930
1994–95	25	<1	23	4	26	1	21	<1	1	<1	<1	0	0	2 808
1995–96	24	<1	34	2	16	1	16	<1	6	1	0	0	0	4 089
1996–97	17	<1	32	1	27	1	17	<1	4	<1	<1	<1	0	4 832
1997–98	9	<1	27	3	36	3	22	<1	1	<1	0	<1	0	4 332
1998–99	7	<1	26	1	43	4	17	<1	1	<1	<1	<1	<1	6 381
1999–00	4	<1	26	2	44	6	15	<1	2	1	<1	0	<1	5 533
2000–01	10	<1	17	2	52	4	13	<1	1	<1	0	<1	<1	6 715
Total	17	<1	27	2	33	2	17	<1	2	<1	<1	<1	<1	47 540

(B) SPD 4

Fishing year	049	050	051	052	401	402	403	404	405	406	407	408	409	410	411	412	Total catch (t)
1989–90	32	48	<1	12	1	<1	<1	<1	<1	<1	7	<1	0	0	0	0	45
1990–91	<1	<1	<1	9	59	<1	0	<1	<1	0	31	<1	<1	0	0	0	146
1991–92	12	11	<1	7	45	2	0	2	<1	<1	4	2	<1	15	0	0	26
1992–93	1	4	2	18	35	<1	<1	4	<1	0	7	<1	<1	30	0	<1	58
1993–94	12	2	1	14	8	19	3	3	<1	0	4	1	1	33	0	0	268
1994–95	1	1	0	1	7	2	5	17	0	<1	23	<1	2	40	0	0	236
1995–96	7	1	0	5	5	8	5	26	<1	<1	1	6	8	28	0	0	513
1996–97	14	26	<1	7	6	6	2	16	<1	<1	3	1	7	14	<1	<1	1 074
1997–98	9	4	<1	6	16	12	3	22	<1	<1	4	9	3	12	0	<1	729
1998–99	8	<1	<1	9	7	9	3	20	<1	<1	4	6	5	27	0	<1	971
1999–00	2	1	<1	10	9	8	10	10	<1	<1	9	17	8	16	0	<1	730
2000–01	20	14	<1	5	6	12	3	10	<1	<1	5	13	1	11	0	<1	941
Total	10	8	<1	7	10	9	4	15	<1	<1	6	7	5	19	<1	<1	5 736

(C) SPD 5

Fishing year	025	027	028	029	030	031	032	502	503	504	Total catch (t)
1989–90	29	12	18	3	28	11	0	0	0	1	66
1990–91	14	25	32	1	24	<1	<1	0	<1	5	222
1991–92	3	5	79	2	8	1	1	0	0	2	142
1992–93	8	3	71	1	10	<1	<1	0	<1	7	159
1993–94	18	12	18	3	43	3	<1	0	0	3	140
1994–95	21	26	21	2	19	1	<1	0	0	10	101
1995–96	17	41	16	1	13	<1	5	0	<1	8	179
1996–97	2	6	50	1	24	5	3	0	<1	8	245
1997–98	11	30	24	1	21	1	<1	<1	<1	13	233
1998–99	13	14	54	1	8	<1	1	0	0	10	801
1999–00	8	19	57	4	9	<1	<1	0	<1	3	393
2000–01	13	4	37	1	39	1	3	0	0	2	570
Total	12	15	44	1	19	1	1	<1	<1	6	3 250

Table C2: (continued)

(D) SPD 6

Fishing year	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	617	618	619	621	624	625	Total catch (t)
1989–90	0	0	0	0	0	0	<1	<1	0	100	0	0	0	0	0	0	<1	0	0	0	0	<1
1990–91	0	95	3	<1	1	0	0	<1	0	<1	<1	0	0	0	0	0	<1	0	0	0	0	7
1991–92	0	29	22	8	0	0	2	1	0	32	<1	0	0	0	0	0	6	<1	0	0	0	24
1992–93	0	47	0	6	1	0	5	34	0	7	<1	0	0	0	0	0	0	0	0	0	0	7
1993–94	0	1	<1	3	0	0	4	37	0	29	0	0	0	0	0	0	18	7	0	0	0	3
1994–95	<1	<1	<1	76	1	0	<1	<1	0	21	<1	0	<1	<1	<1	0	2	<1	0	0	0	25
1995–96	<1	4	<1	1	<1	<1	<1	90	0	4	0	0	0	0	0	<1	1	<1	0	0	<1	150
1996–97	<1	37	9	3	3	0	1	2	0	4	0	0	<1	0	0	0	39	1	<1	<1	<1	112
1997–98	<1	18	12	1	<1	0	2	32	0	4	2	<1	<1	<1	0	0	23	3	0	2	<1	150
1998–99	0	35	20	7	2	<1	1	13	0	7	1	<1	<1	0	0	0	8	4	0	<1	2	122
1999–00	0	51	25	1	5	0	<1	8	<1	3	2	<1	0	0	0	0	5	1	0	<1	<1	113
2000–01	<1	36	19	2	<1	<1	<1	13	0	6	4	4	0	0	0	<1	15	<1	0	<1	<1	152
Total	<1	28	13	5	2	<1	1	27	<1	6	2	1	<1	<1	<1	<1	14	1	<1	<1	<1	867

(E) SPD 7

Fishing year	016	017	018	032	033	034	035	036	037	038	039	040	702	703	704	705	706	Total catch (t)
1989–90	<1	8	4	0	6	24	4	3	1	48	1	<1	0	<1	0	0	0	272
1990–91	<1	3	1	<1	1	9	5	<1	4	77	<1	<1	0	<1	0	<1	0	682
1991–92	<1	6	1	<1	2	26	15	<1	3	44	1	<1	0	<1	<1	0	0	649
1992–93	<1	22	10	0	1	18	6	5	2	35	2	<1	0	<1	<1	<1	0	761
1993–94	<1	13	8	<1	<1	20	18	1	1	38	<1	<1	0	<1	<1	<1	0	1 466
1994–95	1	13	5	0	1	30	5	13	1	29	1	<1	0	<1	0	0	<1	717
1995–96	1	11	7	0	<1	54	6	4	4	12	<1	<1	0	<1	0	<1	0	1 181
1996–97	2	25	4	<1	2	46	11	1	1	6	<1	<1	<1	<1	0	<1	0	1 227
1997–98	2	16	2	0	<1	54	16	<1	2	7	1	<1	<1	<1	<1	<1	0	949
1998–99	<1	11	3	<1	1	53	23	1	1	6	1	<1	<1	<1	0	<1	0	1 635
1999–00	3	19	3	<1	2	45	12	2	4	8	2	<1	<1	<1	<1	<1	0	1 369
2000–01	2	28	13	<1	2	41	5	3	1	4	2	<1	0	<1	<1	<1	0	1 213
Total	1	16	5	<1	1	38	12	2	2	21	1	<1	<1	<1	<1	<1	<1	12 121

Table C3: Groomed and merged catches by fishing year and top ten methods by weight for selected QMAs. The catch for each target species for each fishing year and QMA is given as a percentage of the total groomed and merged catch for that fishing year and QMA. Note that only five unique gear method codes are present in the SPD 6 subset of the groomed and merged dataset.

(A) All QMAs

	Method (% of total catch)											Total
Fishing year	BLL	BPT	BT	CP	DL	MW	PS	SN	T	TL	Other	catch (t
1989–90	2	<1	47	<1	<1	3	1	46	<1	<1	<1	1 435
1990–91	1	0	63	<1	<1	2	1	32	<1	<1	<1	2 682
1991–92	4	<1	40	<1	<1	12	<1	44	<1	<1	<1	2 326
1992–93	3	<1	33	<1	<1	8	<1	55	<1	<1	<1	2 477
1993–94	8	<1	32	<1	<1	11	<1	48	<1	<1	<1	3 930
1994–95	11	0	26	<1	<1	13	<1	50	<1	<1	<1	2 808
1995–96	17	<1	30	<1	<1	21	<1	32	<1	<1	<1	4 089
1996–97	19	0	40	<1	<1	18	<1	22	<1	<1	<1	4 832
1997–98	16	0	44	<1	<1	22	<1	19	<1	<1	<1	4 332
1998–99	14	0	52	<1	<1	23	<1	11	<1	<1	<1	6 381
1999–00	10	<1	62	<1	<1	18	<1	9	<1	<1	<1	5 533
2000–01	11	<1	64	<1	<1	14	<1	11	<1	<1	<1	6 715
Total	11	<1	47	<1	<1	16	<1	26	<1	<1	<1	47 540

(B) SPD 3

	Method (% of total catch)											Total
Fishing year	BLL	BT	CP	DL	DN	HL	MW	PS	RLP	SN	Other	catch (t)
1989–90	<1	42	<1	<1	<1	<1	0	<1	0	57	<1	999
1990–91	1	51	<1	<1	0	<1	<1	2	0	47	<1	1 553
1991–92	<1	43	<1	<1	<1	<1	<1	<1	<1	57	<1	1 322
1992–93	1	32	<1	<1	0	<1	1	1	0	66	<1	1 270
1993–94	1	40	<1	<1	0	0	6	<1	<1	53	<1	1 898
1994–95	2	34	<1	<1	<1	<1	4	<1	0	60	<1	1 588
1995–96	2	43	<1	<1	0	<1	2	1	<1	53	<1	1 830
1996–97	4	42	<1	<1	0	0	3	1	<1	50	<1	2 020
1997–98	2	60	<1	<1	0	0	2	<1	<1	35	<1	2 057
1998–99	<1	73	<1	<1	0	0	2	<1	0	24	0	2 364
1999–00	2	82	<1	<1	0	0	1	<1	<1	16	0	2 600
2000–01	1	81	<1	<1	0	<1	1	<1	0	17	<1	3 500
Total	1	57	<1	<1	<1	<1	2	<1	<1	40	<1	23 001

(C) SPD 4

	Method (% of total catch)											Total
Fishing year	BLL	BT	CP	DI	DL	HL	MW	SN	T	TL	Other	catch (t)
1989–90	1	97	<1	<1	<1	<1	0	1	0	1	0	45
1990–91	<1	98	0	0	0	0	0	0	<1	1	0	146
1991–92	35	65	0	0	0	0	0	0	<1	0	0	26
1992–93	67	4	0	0	<1	0	29	0	0	0	0	58
1993–94	87	8	0	0	0	0	5	<1	0	0	0	268
1994–95	75	6	0	0	0	0	19	0	0	0	0	236
1995–96	92	7	0	0	0	0	<1	0	0	0	0	513
1996–97	65	34	0	0	0	0	1	0	0	0	0	1 074
1997–98	61	38	0	0	0	0	1	0	0	0	0	729
1998–99	76	23	0	0	0	0	1	0	0	0	0	971
1999–00	55	44	0	0	0	0	1	0	0	0	0	730
2000–01	58	39	0	0	0	0	1	2	0	0	0	941
Total	65	32	<1	<1	<1	<1	2	<1	<1	<1	<1	5 736

Table C3: (continued)

(D) SPD 5

Fishing year	Method (% of total catch) BLL	BT	CP	D	DL	FP	HL	MW	RLP	SN	Other	Total catch (t)
1989–90	1	40	<1	0	0	0	<1	0	0	58	0	66
1990–91	<1	79	<1	0	<1	0	<1	7	0	14	<1	222
1991–92	5	43	<1	0	0	0	<1	41	0	11	<1	142
1992–93	1	16	<1	0	<1	0	<1	76	0	6	0	159
1993–94	17	45	<1	0	1	0	0	13	0	23	<1	140
1994–95	38	30	<1	0	<1	0	0	9	0	22	0	101
1995–96	3	45	<1	0	1	0	<1	42	<1	8	0	179
1996–97	6	49	<1	0	<1	0	0	41	<1	4	0	245
1997–98	8	36	<1	0	<1	<1	0	50	0	6	0	233
1998–99	4	60	<1	<1	<1	0	0	31	0	5	0	801
1999–00	2	67	<1	0	<1	0	<1	29	0	1	<1	393
2000–01	5	50	<1	<1	<1	0	<1	35	0	9	<1	570
Total	6	52	<1	<1	<1	<1	<1	33	<1	9	<1	3 250

(E) SPD 6

Fishing year	Method (% of total catch BLL	BT	FP	MW	RLP	Total catch (t)
1989–90	0	0	0	100	0	<1
1990–91	0	6	0	94	0	7
1991–92	85	6	0	10	0	24
1992–93	91	9	0	<1	0	7
1993–94	98	1	0	1	0	3
1994–95	99	1	0	<1	0	25
1995–96	100	<1	0	<1	0	150
1996–97	94	5	0	1	0	112
1997–98	98	2	0	<1	0	150
1998–99	84	15	<1	1	<1	122
1999–00	68	30	0	2	0	113
2000–01	70	27	0	2	0	152
Total	86	12	<1	2	<1	867

(F) SPD 7

Fishing year	Method (% of total catch) BLL	BPT	BT	HL	MPT	MW	PS	SN	T	TL	Other	Total catch (t)
1989–90	4	<1	66	0	0	15	6	8	<1	1	<1	272
1990–91	<1	0	84	<1	0	5	1	9	<1	0	<1	682
1991–92	5	<1	42	<1	0	20	<1	33	<1	0	<1	649
1992–93	<1	0	29	<1	0	7	<1	63	<1	0	<1	761
1993–94	1	0	24	<1	0	19	<1	56	<1	0	<1	1 466
1994–95	1	0	21	<1	0	30	<1	49	<1	0	<1	717
1995–96	<1	0	25	0	0	54	<1	20	<1	0	<1	1 181
1996–97	1	0	42	<1	0	53	<1	3	<1	0	<1	1 227
1997–98	1	0	26	0	<1	69	0	4	<1	0	<1	949
1998–99	<1	0	52	0	<1	45	0	3	<1	0	<1	1 635
1999–00	1	<1	51	<1	<1	43	0	5	<1	0	<1	1 369
2000–01	2	<1	58	0	0	36	0	4	<1	0	<1	1 213
Total	1	<1	42	<1	<1	37	<1	20	<1	<1	<1	12 121

Table C4: Groomed and merged catches by fishing year and top ten target species by weight for selected QMAs. The catch for each target species for each fishing year and QMA is given as a percentage of the total groomed and merged catch for that fishing year and QMA.

(A) All QMAs

	Target species (% of total catch)											Total
Fishing year	BAR	FLA	HOK	JMA	LIN	RCO	SCH	SPD	SPO	SQU	Other	catch (t
1989–90	5	7	3	1	1	7	5	48	2	4	18	1 435
1990–91	11	8	7	3	2	8	2	38	2	7	12	2 682
1991–92	6	5	6	5	5	13	4	30	6	7	14	2 326
1992–93	6	4	3	7	3	10	2	45	4	4	12	2 477
1993–94	4	4	11	1	7	11	5	37	3	4	13	3 930
1994–95	4	3	10	6	13	10	10	27	8	2	8	2 808
1995–96	3	6	21	4	18	9	7	14	5	2	12	4 089
1996–97	11	7	17	4	20	8	3	6	3	4	16	4 832
1997–98	10	4	27	4	17	12	6	5	3	2	8	4 332
1998–99	15	3	33	5	15	3	5	3	1	9	9	6 381
1999–00	15	3	33	2	10	10	2	2	2	11	11	5 533
2000–01	21	4	22	1	11	14	2	3	4	9	10	6 715
Total	11	4	20	3	12	9	4	15	3	6	11	47 540

(B) SPD 3

	Target species (% of total catch)											Total
Fishing year	BAR	FLA	HOK	LIN	RCO	SCH	SPD	SPO	SQU	TAR	Other	catch (t)
1989–90	2	6	<1	1	10	1	54	2	4	11	9	999
1990–91	9	6	4	3	13	1	38	3	7	4	13	1 553
1991–92	7	2	<1	3	22	1	37	8	4	6	10	1 322
1992–93	1	4	<1	2	18	2	50	6	<1	7	9	1 270
1993–94	2	4	3	2	19	6	35	5	7	10	7	1 898
1994–95	2	3	2	8	17	14	27	11	3	3	9	1 588
1995–96	2	9	3	6	19	13	21	7	2	4	15	1 830
1996–97	3	11	2	8	19	5	12	7	5	4	25	2 020
1997–98	16	5	10	5	25	12	11	5	2	1	7	2 057
1998–99	34	5	13	1	7	12	6	1	6	4	12	2 364
1999–00	22	3	15	2	21	3	4	1	13	1	14	2 600
2000–01	26	4	8	2	26	1	6	6	11	1	9	3 500
Total	13	5	6	4	19	6	20	5	6	4	12	23 001

(C) SPD 4

	Target species (% of total catch)											Total
Fishing year	BAR	HAK	HOK	JMA	LIN	SCH	SPD	SQU	SWA	TAR	Other	catch (t)
1989–90	47	<1	0	1	1	<1	42	<1	1	6	2	45
1990–91	40	<1	46	0	12	0	0	<1	<1	<1	1	146
1991–92	23	0	27	0	45	0	0	<1	2	0	3	26
1992–93	3	<1	29	0	67	0	0	0	0	0	<1	58
1993–94	<1	<1	<1	4	83	<1	0	7	0	<1	4	268
1994–95	<1	<1	5	18	72	2	0	0	1	<1	1	236
1995–96	1	2	4	<1	92	0	0	0	<1	0	1	513
1996–97	25	3	2	3	65	0	1	2	<1	0	<1	1 074
1997–98	6	9	17	2	62	0	0	3	<1	0	<1	729
1998–99	<1	2	22	0	76	0	0	<1	<1	0	<1	971
1999–00	1	<1	35	<1	55	0	0	7	0	<1	2	730
2000–01	1	<1	25	1	58	2	0	1	<1	12	1	941
Total	7	2	17	2	66	<1	<1	2	<1	2	1	5 736

Table C4: (continued)

(D) SPD 5

	Target species (% of total catch)											Total
Fishing year	BAR	FLA	HOK	JMA	LIN	SCH	SQU	STA	SWA	WAR	Other	catch (t)
1989–90	3	1	0	0	0	57	11	7	0	0	21	66
1990–91	24	6	2	<1	<1	13	34	15	2	4	1	222
1991–92	3	1	1	<1	4	9	74	4	<1	<1	3	142
1992–93	17	3	1	1	<1	2	59	5	2	0	8	159
1993–94	3	2	14	0	14	20	8	20	9	0	11	140
1994–95	9	3	9	3	38	20	12	2	<1	<1	4	101
1995–96	7	1	3	28	2	8	11	3	17	11	8	179
1996–97	3	6	6	17	6	4	35	17	<1	2	3	245
1997–98	5	4	1	44	10	6	21	9	1	<1	1	233
1998–99	<1	1	2	21	4	5	57	<1	<1	9	1	801
1999–00	3	5	14	16	3	1	51	3	<1	0	4	393
2000–01	<1	13	15	8	5	8	30	8	1	0	10	570
Total	5	5	7	15	5	8	40	6	2	3	5	3 250

(E) SPD 6

	Target species (% of total catch)											Total
Fishing year	HAK	HOK	LIN	OEO	ORH	SBW	SCI	SQU	SSO	WWA	Other	catch (t)
1989–90	0	0	0	0	0	100	0	0	0	0	<1	<1
1990–91	0	5	0	0	0	<1	0	95	0	0	0	7
1991–92	0	1	85	0	0	9	0	5	0	0	0	24
1992–93	1	1	98	0	0	0	0	0	0	0	0	7
1993–94	0	0	99	0	0	1	0	0	0	0	0	3
1994–95	0	0	99	0	0	<1	0	<1	0	0	0	25
1995–96	0	<1	100	0	0	0	0	<1	0	0	<1	150
1996–97	0	3	94	<1	0	<1	0	3	0	0	<1	112
1997–98	0	1	98	0	<1	0	0	<1	<1	0	0	150
1998–99	<1	12	86	0	<1	1	<1	<1	0	<1	<1	122
1999–00	6	20	69	<1	<1	1	1	4	0	0	<1	113
2000–01	2	16	71	0	<1	3	7	1	0	0	0	152
Total	1	8	87	<1	<1	1	1	2	<1	<1	<1	867

(F) SPD 7

	Target species (% of total catch)											Total
Fishing year	BAR	FLA	HOK	JMA	RCO	SCH	SFL	SPD	SPO	TAR	Other	catch (t)
1989–90	9	16	16	1	<1	2	0	38	3	1	14	272
1990–91	6	15	6	2	<1	<1	4	61	1	2	3	682
1991–92	6	12	20	5	2	6	4	30	4	3	8	649
1992–93	15	6	7	3	2	1	<1	63	1	1	1	761
1993–94	9	4	22	1	4	2	1	53	1	2	2	1 466
1994–95	8	3	26	9	<1	2	<1	47	1	2	2	717
1995–96	7	7	56	7	1	3	<1	13	4	<1	1	1 181
1996–97	18	7	54	10	2	2	<1	2	<1	3	2	1 227
1997–98	5	5	74	6	<1	2	3	<1	2	<1	2	949
1998–99	11	5	68	6	1	<1	<1	2	1	2	5	1 635
1999–00	19	5	61	1	1	<1	0	<1	5	2	6	1 369
2000–01	36	2	49	<1	3	1	<1	<1	4	2	4	1 213
Total	14	6	44	4	2	2	1	21	2	2	4	12 121

Table C5: Groomed and merged catches by fishing year and vessel flag nationality for selected QMAs. The catch for each flag nationality for each fishing year and QMA is given as a percentage of the total groomed and merged catch for that fishing year and QMA. Unsp, vessel flag nationality unspecified.

(A) All QMAs

	Vessel flag nationality (% of total catch)												Total
Fishing year	BZE	CY	JAP	KOR	MLT	NOR	NZL	PAN	POL	RUS	UKR	Unsp	catch (t)
1989–90	0	0	1	11	0	0	78	0	0	2	0	8	1 435
1990–91	0	0	2	22	0	<1	63	<1	0	2	0	12	2 682
1991–92	0	0	2	9	0	0	72	0	0	10	0	7	2 326
1992–93	0	0	7	2	1	0	81	0	0	7	0	3	2 477
1993–94	0	0	3	7	<1	0	82	1	2	6	0	<1	3 930
1994–95	0	0	2	6	0	0	81	1	<1	7	2	<1	2 808
1995–96	0	0	6	3	0	0	76	2	1	11	2	0	4 089
1996–97	0	0	4	9	0	0	73	2	1	9	3	0	4 832
1997–98	1	1	5	5	<1	<1	75	3	1	5	3	0	4 332
1998–99	1	1	4	6	1	0	73	5	1	6	2	0	6 381
1999–00	<1	1	2	8	2	0	80	2	<1	3	2	0	5 533
2000–01	<1	<1	2	3	1	0	89	1	<1	2	2	0	6 715
Total	<1	<1	3	7	1	<1	78	2	1	6	2	1	47 540

(B) SPD 3

	Vessel flag nationality (% of total catch)												Total
Fishing year	BZE	CY	JAP	KOR	MLT	NOR	NZL	PAN	POL	RUS	UKR	Unsp	catch (t)
1989–90	0	0	<1	9	0	0	79	0	0	0	0	11	999
1990–91	0	0	1	20	0	0	69	0	0	<1	0	10	1 553
1991–92	0	0	<1	10	0	0	84	0	0	<1	0	6	1 322
1992–93	0	0	<1	<1	<1	0	94	0	0	1	0	5	1 270
1993–94	0	0	<1	3	0	0	91	0	2	4	0	<1	1 898
1994–95	0	0	<1	8	0	0	87	1	<1	2	2	<1	1 588
1995–96	0	0	2	4	0	0	92	<1	<1	2	<1	0	1 830
1996–97	0	0	<1	5	0	0	92	<1	1	2	<1	0	2 020
1997–98	1	0	2	3	<1	<1	92	1	1	1	<1	0	2 057
1998–99	<1	<1	2	4	1	0	89	2	<1	2	<1	0	2 364
1999–00	<1	<1	2	7	1	0	87	2	<1	1	<1	0	2 600
2000–01	<1	<1	2	2	<1	0	95	1	0	<1	<1	0	3 500
Total	<1	<1	1	6	<1	<1	89	1	<1	1	<1	2	23 001

(C) SPD 4

	Vessel flag nationality (% of total catch)												Total
Fishing year	BZE	CY	JAP	KOR	MLT	NOR	NZL	PAN	POL	RUS	UKR	Unsp	catch (t)
1989–90	0	0	0	75	0	0	25	0	0	0	0	0	45
1990–91	0	0	<1	89	0	0	11	0	0	0	0	0	146
1991–92	0	0	<1	62	0	0	38	0	0	0	0	0	26
1992–93	0	0	0	4	29	0	67	0	0	<1	0	<1	58
1993–94	0	0	0	7	0	0	88	0	<1	4	0	0	268
1994–95	0	0	<1	<1	0	0	76	0	<1	23	<1	0	236
1995–96	0	0	6	1	0	0	92	<1	<1	<1	<1	0	513
1996–97	0	0	1	25	0	0	65	8	1	<1	<1	0	1 074
1997–98	1	0	6	13	<1	<1	68	11	1	<1	<1	0	729
1998–99	2	4	4	1	<1	0	88	2	<1	<1	0	0	971
1999–00	1	<1	3	8	<1	0	85	2	<1	<1	1	0	730
2000–01	<1	<1	3	3	1	0	91	2	0	<1	<1	0	941
Total	<1	1	3	12	<1	<1	78	4	<1	1	<1	<1	5 736

Table C5: (continued)

(D) SPD 5

	Vessel flag nationality (% of total catch)												Total
Fishing year	BZE	CY	JAP	KOR	MLT	NOR	NZL	PAN	POL	RUS	UKR	Unsp	catch (t)
1989–90	0	0	0	21	0	0	79	0	0	0	0	0	66
1990–91	0	0	7	48	0	2	36	<1	0	7	0	0	222
1991–92	0	0	26	8	0	0	21	0	0	41	0	5	142
1992–93	0	0	3	3	0	0	18	0	0	76	0	0	159
1993–94	0	0	10	<1	5	0	66	11	<1	7	0	0	140
1994–95	0	0	5	18	0	0	66	0	1	9	0	0	101
1995–96	0	0	3	9	0	0	22	26	1	36	3	0	179
1996–97	0	0	1	15	0	0	36	6	2	29	10	0	245
1997–98	0	0	2	16	0	0	28	4	0	42	7	0	233
1998–99	7	1	6	30	<1	0	10	18	0	20	9	0	801
1999–00	0	<1	2	38	<1	0	25	1	0	19	15	0	393
2000–01	0	1	3	9	3	0	54	1	0	13	15	0	570
Total	2	<1	5	21	1	<1	32	7	<1	23	8	<1	3 250

(E) SPD 6

	Vessel flag nationality (% of total catch)												Total
Fishing year	BZE	CY	JAP	KOR	MLT	NOR	NZL	PAN	POL	RUS	UKR	Unsp	catch (t)
1989–90	0	0	100	0	0	0	0	0	0	0	0	0	<1
1990–91	0	0	0	2	0	0	5	0	0	94	0	0	7
1991–92	0	0	5	1	0	0	85	0	0	10	0	0	24
1992–93	0	0	0	9	0	0	91	0	0	<1	0	0	7
1993–94	0	0	1	1	0	0	98	0	0	0	0	0	3
1994–95	0	0	<1	<1	0	0	99	0	0	<1	0	0	25
1995–96	0	0	0	0	0	0	100	0	<1	<1	0	0	150
1996–97	0	0	2	2	0	0	94	1	0	1	0	0	112
1997–98	0	0	0	0	0	0	100	0	0	<1	0	0	150
1998–99	0	9	2	1	<1	0	87	<1	<1	0	0	0	122
1999–00	0	2	7	2	<1	0	84	4	0	1	<1	0	113
2000–01	0	<1	4	<1	1	0	91	3	0	<1	1	0	152
Total	<1	2	2	1	<1	<1	92	1	<1	1	<1	<1	867

(F) SPD 7

	Vessel flag nationality (% of total catch)												Total
Fishing year	BZE	CY	JAP	KOR	MLT	NOR	NZL	PAN	POL	RUS	UKR	Unsp	catch (t)
1989–90	0	0	5	5	0	0	80	0	0	10	0	<1	272
1990–91	0	0	1	6	0	1	65	0	0	3	0	23	682
1991–92	0	0	2	7	0	0	67	0	0	12	0	12	649
1992–93	0	0	3	2	0	0	88	0	0	6	0	<1	761
1993–94	0	0	6	13	0	0	69	1	2	9	0	0	1 466
1994–95	0	0	7	4	0	0	68	<1	1	16	4	0	717
1995–96	0	0	13	3	0	0	43	2	3	30	6	0	1 181
1996–97	0	0	13	2	0	0	50	<1	2	26	8	0	1 227
1997–98	<1	3	14	3	1	1	48	4	2	12	10	0	949
1998–99	1	2	7	3	2	0	64	7	1	10	3	0	1 635
1999–00	<1	3	3	1	6	0	75	4	1	4	3	0	1 369
2000–01	0	2	2	1	3	0	82	3	1	2	3	0	1 213
Total	<1	1	7	4	1	<1	65	2	1	12	4	2	12 121

Appendix D: Data summaries, and distribution and diagnostic plots for all CPUE models

D.1 Target setnet fishing in SPD 3 (CPUE model 1)

Table D1: Number of vessels, total catch, total number of days fishing, total number of effort strata, median net set per stratum, median catch per stratum, and median catch per 1000 m net set per stratum for all target setnet effort strata in SPD 3 (statistical areas 018, 020, 021, 022, 023, 024, 025, and 026) in the groomed and merged dataset. Summaries are provided separately for all vessels in the dataset and for core vessels (vessels active in the fishery for more than three years).

All vessels

	Fishing year												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	27	30	23	24	23	24	18	18	11	9	6	9	81
Total catch (t)	491	562	480	626	666	367	328	206	204	127	64	199	4 320
Total number of days fishing	761	1 109	878	1 069	1 186	875	784	447	310	234	137	291	8 081
Total number of effort strata	678	1 024	825	1 048	1 174	860	750	440	299	227	136	213	7 674
Median net set per stratum (m)	1 200	1 000	1 000	1 200	1 200	2 000	2 000	1 500	1 500	1 500	1 000	2 000	1 200
Median catch per stratum (kg)	324.0	159.0	216.0	267.0	234.0	238.5	213.0	199.8	361.0	325.0	344.5	610.0	245.0
Median catch per 1000 m net set per stratum (kg.1000 m^{-1})	296.2	197.8	237.1	270.7	185.9	159.5	180.0	169.1	264.6	278.0	344.5	318.5	217.8

Core vessels

	Fishing year												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	14	17	17	14	20	17	10	13	8	7	4	3	27
Total catch (t)	356	445	471	556	562	249	257	194	195	125	61	52	3 523
Total number of days fishing	588	762	819	1 005	1 054	549	645	393	297	232	125	80	6 549
Total number of effort strata	522	722	766	987	1 042	541	622	386	287	225	124	80	6 304
Median net set per stratum (m)	1 000	1 000	1 000	1 000	1 200	2 000	2 000	2 000	1 500	1 500	1 000	1 500	1 200
Median catch per stratum (kg)	324.0	202.5	229.5	258.0	210.0	234.0	204.5	215.1	361.0	325.0	352.5	466.5	245.0
Median catch per 1000 m net set \per stratum (kg.1000 m^{-1})	315.9	240.2	236.9	260.5	192.2	150.0	146.6	137.2	263.9	278.0	369.9	323.0	220.8

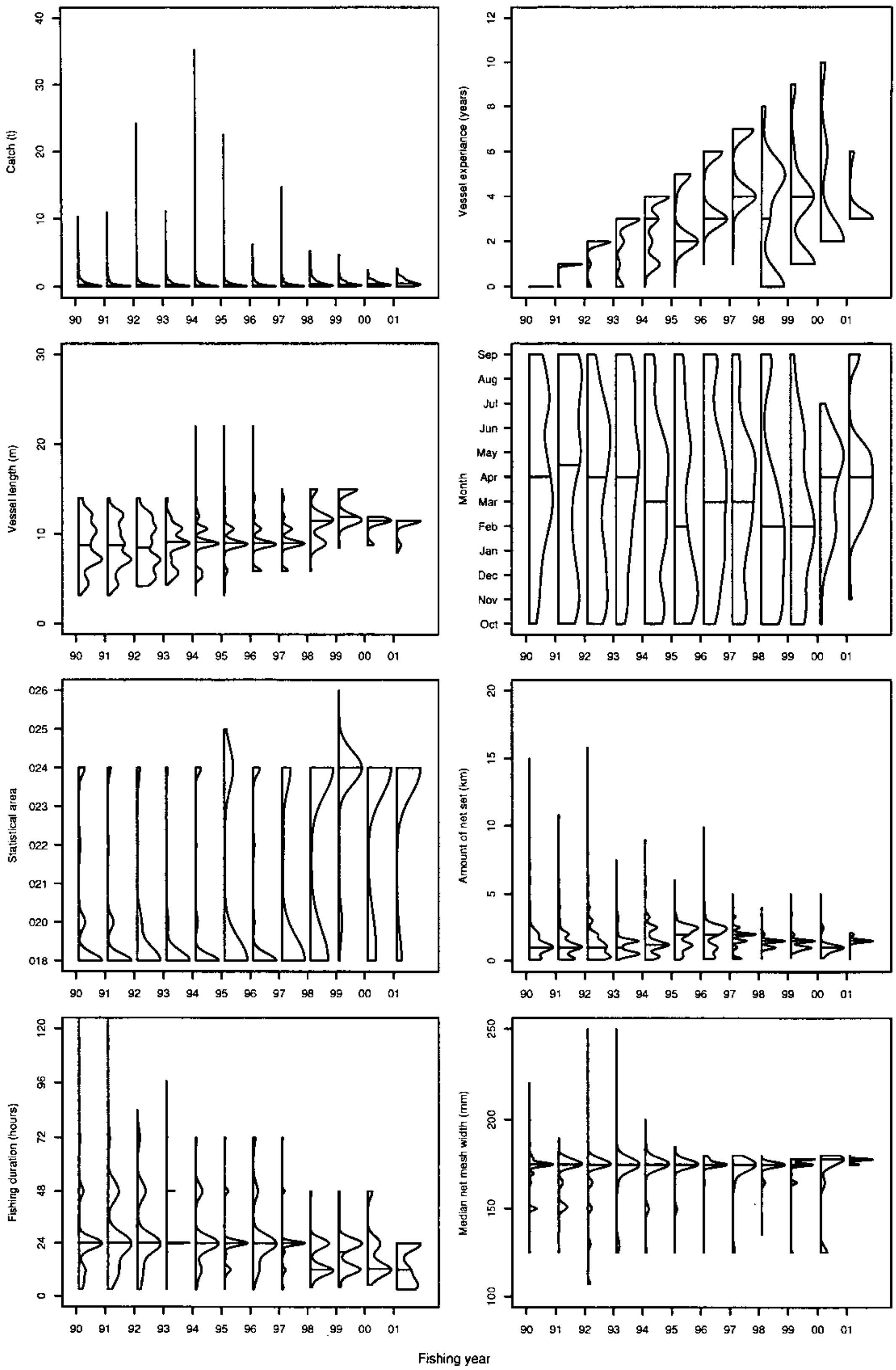

Figure D1: Distribution plots of relative frequency for all non-zero target setnet effort strata for core vessels in SPD 3 for *catch, vessel experience, vessel length, month, statistical area, total amount of net set, fishing duration,* and *median net mesh width.* Approximate frequencies are plotted by fishing year for the fishing years 1989–90 to 2000–01. The horizontal line in each distribution indicates the position of the median.

D.2 All setnet fishing in SPD 3 (CPUE model 2)

Table D2: Number of vessels, total catch, total number of days fishing, total number of effort strata, median net set per stratum, median catch per stratum, and median catch per 1000 m net set per stratum for all setnet effort strata in SPD 3 (statistical areas 018, 020, 021, 022, 023, 024, 025, and 026) in the groomed and merged dataset. Summaries are provided separately for all vessels in the dataset and for core vessels (vessels active in the fishery for more than three years).

All vessels

												Fishing year	
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	45	49	47	48	46	46	39	41	26	19	28	28	127
Total catch (t)	574	724	747	843	1 004	948	964	1 006	730	567	404	590	9 101
Total number of days fishing	1 517	2 452	2 687	2 569	2 734	2 370	2 429	1 928	1 455	1 372	1 166	1 459	24 138
Total number of effort strata	1 414	2 280	2 584	2 519	2 680	2 264	2 233	1 801	1 326	1 262	1 103	1 303	22 769
Median net set per stratum (m)	1 200	1 200	1 500	1 500	1 400	1 500	1 800	1 500	1 500	1 500	1 500	2 000	1 500
Median catch per stratum (kg)	112.0	79.0	90.0	101.0	111.0	129.0	137.0	145.2	152.0	113.4	83.7	97.0	109.0
Median catch per 1000 m net set per stratum ($kg.1000\ m^{-1}$)	115.0	83.0	75.9	98.0	93.6	93.5	96.0	111.0	121.5	80.3	67.5	63.5	90.9

Core vessels

												Fishing year	
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	29	36	40	37	38	35	35	31	23	19	23	21	62
Total catch (t)	422	589	730	757	895	831	916	993	717	567	396	257	8 068
Total number of days fishing	1 234	1 987	2 584	2 456	2 577	2 025	2 297	1 863	1 425	1 372	1 106	1 085	22 011
Total number of effort strata	1 150	1 889	2 482	2 414	2 526	1 926	2 109	1 737	1 298	1 262	1 043	1 014	20 850
Median net set per stratum (m)	1 200	1 200	1 500	1 400	1 400	1 500	1 800	1 500	1 500	1 500	1 500	1 800	1 500
Median catch per stratum (kg)	99.5	77.0	89.5	98.0	100.0	108.9	126.0	148.5	153.9	113.4	83.7	70.9	102.6
Median catch per 1000 m net set per stratum ($kg.1000\ m^{-1}$)	110.0	80.0	74.6	93.6	90.0	81.8	86.4	104.1	120.9	80.3	67.5	45.4	85.0

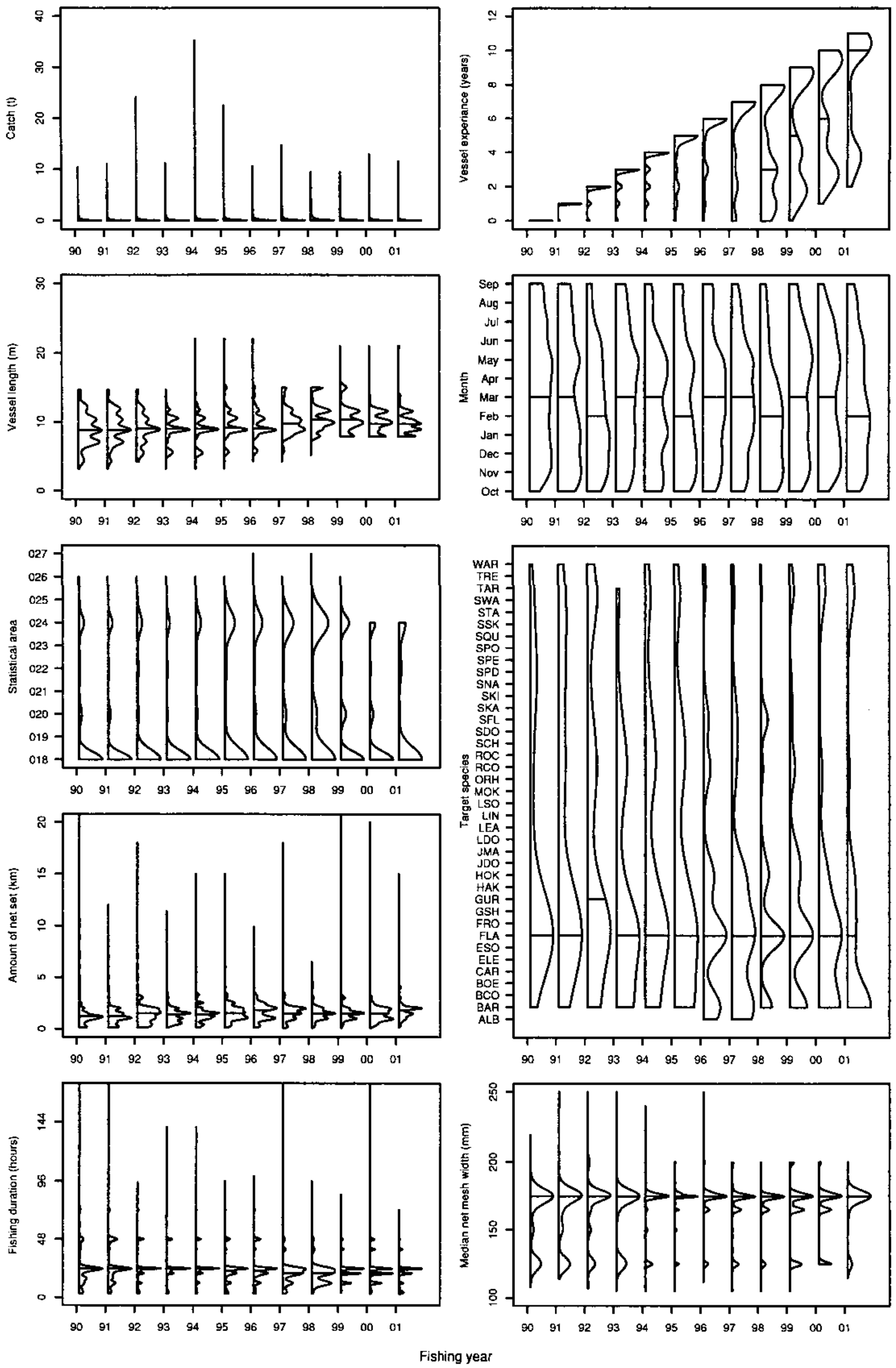

Figure D2: Distribution plots of relative frequency for all non-zero setnet effort strata for core vessels (all target species) in SPD 3 for *catch, vessel experience, vessel length, month, statistical area, total amount of net set, target species, fishing duration,* and *median net mesh width.* Approximate frequencies are plotted by fishing year for the fishing years 1989–90 to 2000–01. The horizontal line in each distribution indicates the position of the median.

D.3 Bottom-trawl fishing in SPD 3 (CPUE model 3)

Table D3: Number of vessels, total catch, total number tows, total number of effort strata, median fishing duration, median catch per stratum, and median catch per hour fished per stratum for all bottom-trawl effort strata in SPD 3 (statistical areas 018, 020, 021, 022, and 024) in the groomed and merged dataset. Summaries are provided separately for all vessels in the dataset and for core vessels (vessels active in the fishery for more than five years).

All vessels

											Fishing year		
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	70	93	84	77	90	84	89	105	96	93	86	94	283
Total catch (t)	394	650	504	384	719	490	660	792	1 173	1 637	1 935	2 776	12 114
Total number of tows	2 748	4 223	5 487	4 249	4 820	4 056	4 939	5 313	5 276	5 906	6 869	9 195	63 082
Total number of effort strata	848	1 399	1 644	1 480	1 679	1 494	1 603	1 658	1 073	1 529	1 689	2 091	18 187
Median fishing duration per stratum (h)	9.9	9.8	10.2	10.0	9.0	10.0	9.0	10.0	10.5	10.0	10.0	12.0	10.0
Median catch per stratum (kg)	98.0	68.0	63.0	70.0	81.0	57.0	60.0	94.5	76.0	75.6	72.9	132.5	75.6
Median catch per hour fished per stratum ($kg.h^{-1}$)	8.2	7.0	6.0	6.2	8.2	5.7	7.4	9.7	6.8	8.4	7.6	11.5	7.7

Core vessels

											Fishing year		
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	30	47	47	50	60	59	65	69	59	57	50	51	84
Total catch (t)	198	318	398	336	646	454	584	703	978	1 417	1 594	2 127	9 752
Total number of tows	1 465	2 589	3 794	3 501	4 391	3 654	4 361	4 522	3 204	4 231	4 715	5 955	46 382
Total number of effort strata	501	1 000	1 210	1 262	1 511	1 341	1 473	1 439	907	1 320	1 362	1 567	14 893
Median fishing duration per stratum (h)	10.0	10.0	12.0	10.0	10.0	10.0	9.0	10.0	10.0	9.8	10.0	11.2	10.0
Median catch per stratum (kg)	96.0	64.0	70.0	73.0	89.0	58.0	62.6	99.9	68.0	73.3	65.6	126.9	75.6
Median catch per hour fished per stratum ($kg.h^{-1}$)	7.4	6.9	6.0	6.7	8.6	5.8	6.9	9.1	6.6	8.7	7.2	12.0	7.5

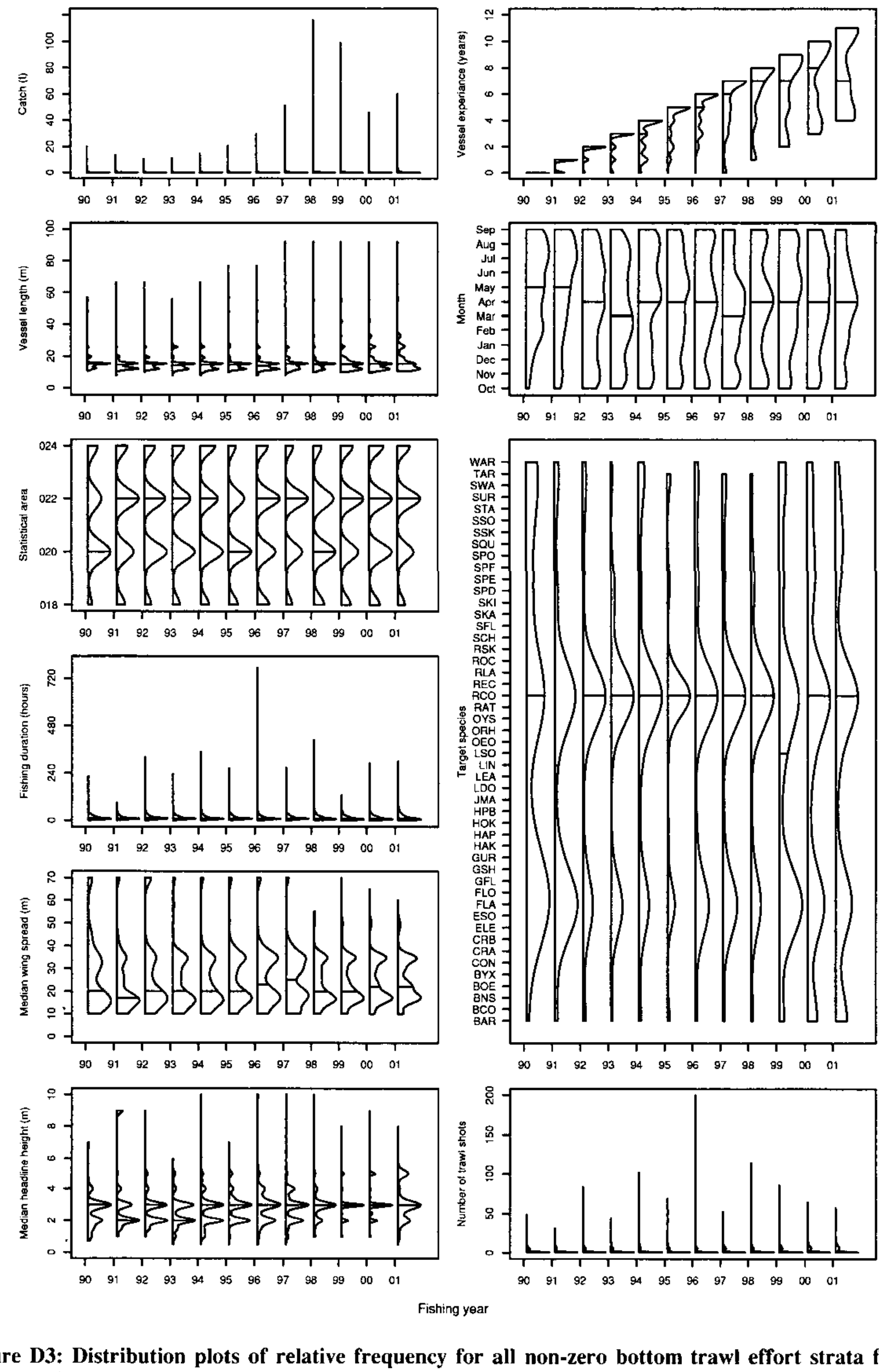

Figure D3: Distribution plots of relative frequency for all non-zero bottom trawl effort strata for core vessels in SPD 3 for *catch, vessel experience, vessel length, month, statistical area, fishing duration, target species, median wing spread, median headline height,* and *total number of trawl shots.* Approximate frequencies are plotted by fishing year for the fishing years 1989–90 to 2000–01. The horizontal line in each distribution indicates the position of the median.

D.4 Bottom-trawl fishing by Korean vessels on the Chatham Rise (SPD 3 and 4; CPUE model 4)

Table D4: Number of vessels, total catch, total number of tows, total number of effort strata, median fishing duration per stratum, median catch per stratum, and median catch per hour fished per stratum for all bottom-trawl effort strata for Korean vessels on the Chatham Rise (SPD 3 & 4: statistical areas 019, 021, 023, 049, 050, 051, 052, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, and 412) in the groomed and merged dataset. Summaries are provided separately for all vessels in the dataset and for core vessels (vessels active in the fishery for more than three years).

All vessels

	Fishing year												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	5	8	5	4	2	3	8	12	10	5	7	7	20
Total catch (t)	37	233	20	3	20	33	15	285	100	16	83	42	886
Total number of tows	237	433	78	62	10	93	185	366	408	141	388	259	2 660
Total number of effort strata	41	42	22	7	4	16	33	56	67	31	51	54	424
Median fishing duration per stratum (h)	14.0	33.8	9.8	10.0	5.1	26.8	25.0	12.8	15.0	13.4	23.4	14.9	16.4
Median catch per stratum (kg)	340.0	2 749.0	402.3	240.0	1 702.0	981.4	227.3	929.2	449.9	171.0	429.3	229.2	373.7
Median catch per hour fished per stratum ($kg.h^{-1}$)	18.3	41.9	34.0	17.0	315.9	39.5	14.3	73.2	23.6	8.5	14.7	17.1	21.2

Core vessels

	Fishing year												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	3	4	4	4	2	3	7	8	8	5	7	7	11
Total catch (t)	35	4	16	3	20	33	11	240	27	16	83	42	529
Total number of tows	211	15	48	62	10	93	163	289	207	141	388	259	1 886
Total number of effort strata	34	7	16	7	4	16	29	39	44	31	51	54	332
Median fishing duration per stratum (h)	13.0	6.2	9.2	10.0	5.1	26.8	26.7	12.3	13.9	13.4	23.4	14.9	14.9
Median catch per stratum (kg)	347.8	39.9	337.5	240.0	1 702.0	981.4	145.5	941.7	199.2	171.0	429.3	229.2	313.5
Median catch per hour fished per stratum ($kg.h^{-1}$)	18.3	5.5	36.7	17.0	315.9	39.5	4.8	63.0	12.8	8.5	14.7	17.1	17.4

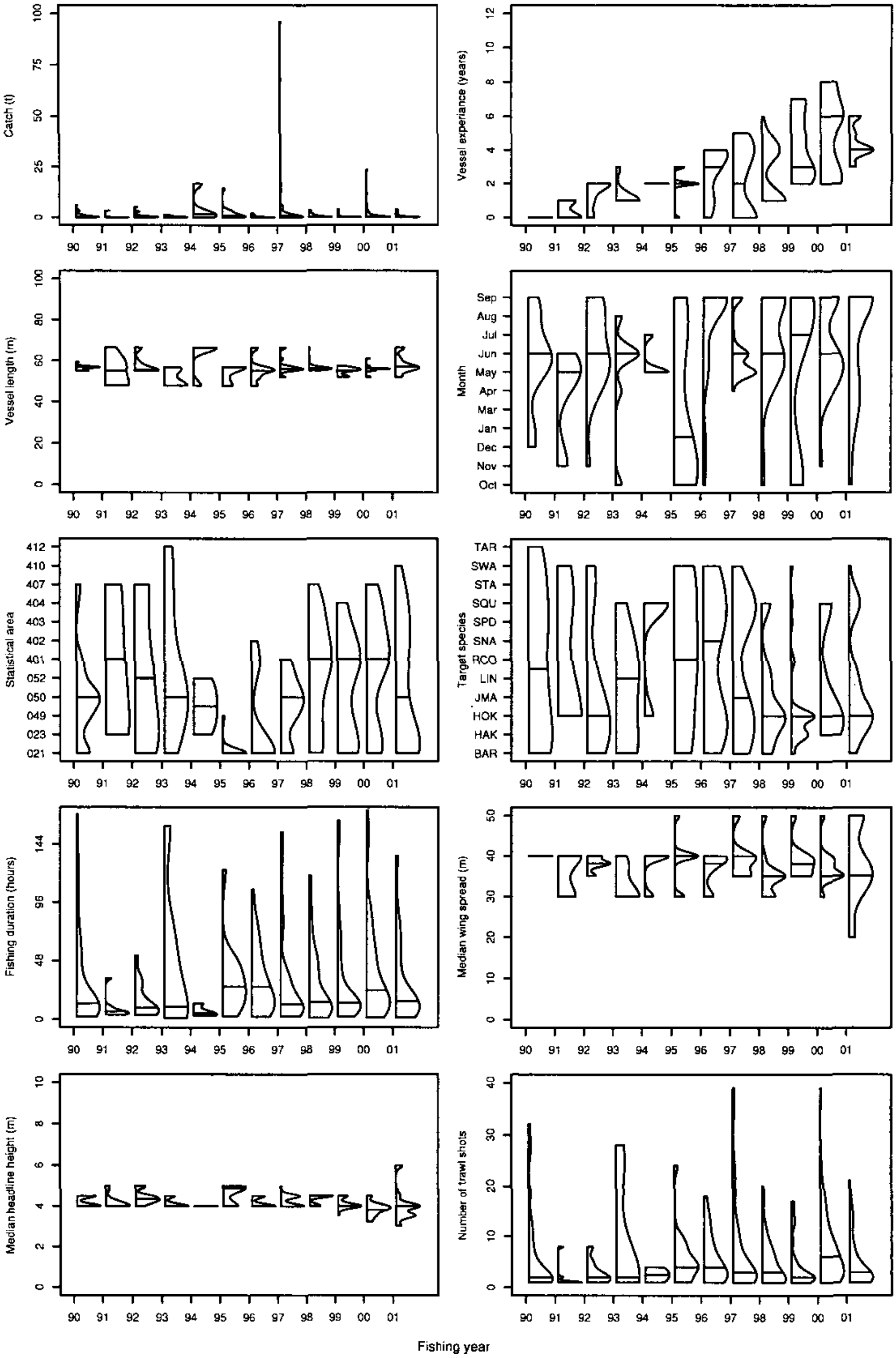

Figure D4: Distribution plots of relative frequency for all non-zero bottom trawl effort strata for core Korean vessels on the Chatham Rise (SPD 3 & 4) for *catch, vessel experience, vessel length, month, statistical area, target species, fishing duration, median wing spread, median headline height,* and total *number of trawl shots*. Approximate frequencies are plotted by fishing year for the fishing years 1989–90 to 2000–01. The horizontal line in each distribution indicates the position of the median.

D.5 Bottom-trawl fishing by all vessels on the Chatham Rise (SPD 3 and 4; CPUE model 5)

Table D5: Number of vessels, total catch, total number of tows, total number of effort strata, median fishing duration per stratum, median catch per stratum, and median catch per hour fished per stratum for all bottom-trawl effort strata for all vessels on the Chatham Rise (SPD 3 & 4: statistical areas 019, 021, 023, 049, 050, 051, 052, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, and 412) in the groomed and merged dataset. Summaries are provided separately for all vessels in the dataset and for core vessels (vessels active in the fishery for more than three years).

All vessels

	Fishing year												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	12	17	12	10	8	14	22	24	37	34	28	44	116
Total catch (t)	48	267	21	5	43	58	68	391	336	342	487	546	2 611
Total number of tows	301	572	292	170	81	310	811	904	2 571	4 224	3 447	4 998	18 681
Total number of effort strata	59	66	38	14	41	53	81	93	250	295	256	413	1 659
Median fishing duration per stratum (h)	10.3	21.5	11.2	21.2	8.0	13.1	16.0	15.5	19.4	24.0	33.6	23.0	20.5
Median catch per stratum (kg)	300.0	252.1	204.0	183.1	464.0	146.0	257.5	511.1	187.2	198.0	549.7	334.3	305.6
Median catch per hour fished per stratum (kg.h^{-1})	15.0	18.3	17.6	10.7	50.9	11.5	11.3	31.9	9.5	8.3	14.6	13.2	12.5

Core vessels

	Fishing year												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	4	5	4	5	3	9	12	17	28	26	21	24	36
Total catch (t)	35	4	16	3	20	42	56	341	258	322	449	370	1 915
Total number of tows	212	25	48	63	11	237	610	634	2 238	3 840	3 029	3 654	14 601
Total number of effort strata	35	8	16	8	5	34	64	69	211	260	222	275	1 207
Median fishing duration per stratum (h)	15.2	6.4	9.2	8.2	3.7	17.1	21.1	16.1	18.6	27.4	37.4	31.2	25.0
Median catch per stratum (kg)	340.0	37.9	337.5	183.1	1 528.7	128.8	168.0	585.0	155.2	199.0	734.6	291.7	302.5
Median catch per hour fished per stratum (kg.h^{-1})	18.3	5.4	36.7	17.9	148.1	9.9	6.3	24.5	7.9	8.4	16.9	11.0	12.1

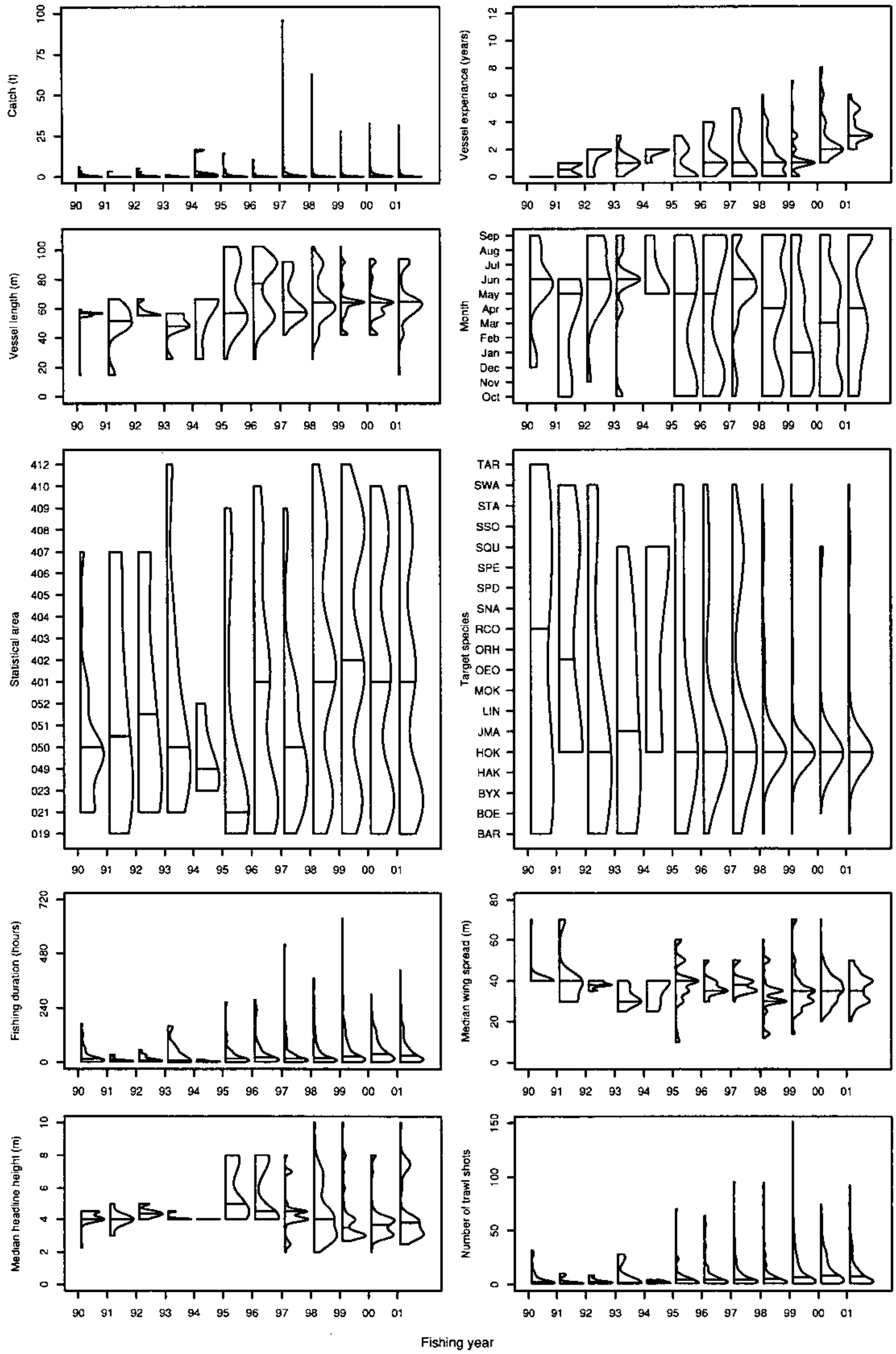

Figure D5: Distribution plots of relative frequency for all non-zero bottom trawl effort strata for all core vessels (all nationalities) on the Chatham Rise (SPD 3 & 4) for *catch, vessel experience, vessel length, month, statistical area, target species, fishing duration, median wing spread, median headline height,* and *total number of trawl shots.* Approximate frequencies are plotted by fishing year for the fishing years 1989–90 to 2000–01. The horizontal line in each distribution indicates the position of the median.

D.6 Bottom-longline fishing on the Chatham Rise (SPD 3 and 4; CPUE model 6)

Table D6: Number of vessels, total catch, total number of hooks set, total number of effort strata, median number of hooks set per stratum, median catch per stratum, and median catch per 1000 hooks set per stratum for all bottom-longline effort strata for all vessels on the Chatham Rise (SPD 3 & 4: statistical areas 019, 021, 023, 049, 050, 051, 052, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, and 412) in the groomed and merged dataset. Summaries are provided separately for all vessels in the dataset and for core vessels (vessels active in the fishery for more than three years).

All vessels

										Fishing year	
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	4	4	5	7	8	9	8	8	5	5	21
Total catch (t)	9	40	235	197	489	720	486	737	429	572	3 914
Total number of hooks set	1 614 780	2 324 320	6 362 640	5 599 504	6 815 901	9 074 186	7 479 339	8 644 193	6 268 362	5 686 129	59 869 354
Total number of effort strata	23	29	70	44	71	65	60	60	35	39	496
Median hooks set per stratum (hooks)	22 400	33 600	34 200	70 500	24 000	84 800	67 400	98 400	100 800	100 768	60 180.5
Median catch per stratum (kg)	80.8	620.0	960.6	1 721.9	2 100.0	4 082.0	4 377.0	5 823.0	7 354.3	6 254.7	2 329.3
Median catch per thousand hooks set per stratum (kg.1000 hooks^{-1})	4.9	16.0	21.8	23.8	64.1	66.8	60.5	67.3	54.2	84.0	45.0

Core vessels

										Fishing year	
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	3	3	4	6	7	7	6	7	4	4	10
Total catch (t)	9	40	234	197	439	719	486	737	429	572	3 861
Total number of hooks set	1 614 030	2 322 820	6 355 820	5 597 604	6 199 701	9 034 266	7 457 439	8 635 193	6 111 162	5 669 729	58 997 764
Total number of effort strata	22	28	65	42	65	63	58	58	34	38	473
Median hooks set per stratum (hooks)	23 200	36 900	43 200	86 300	24 000	85 300	69 350	110 800	94 200	104 386	63 600
Median catch per stratum (kg)	90.4	655.4	1 069.7	1 955.6	2 100.0	5 083.7	4 863.6	6 361.6	7 776.9	6 331.3	2 663.8
Median catch per thousand hooks set per stratum (kg.1000 hooks^{-1})	4.9	16.8	23.2	22.0	55.9	67.3	·61.6	70.1	57.0	86.6	45.6

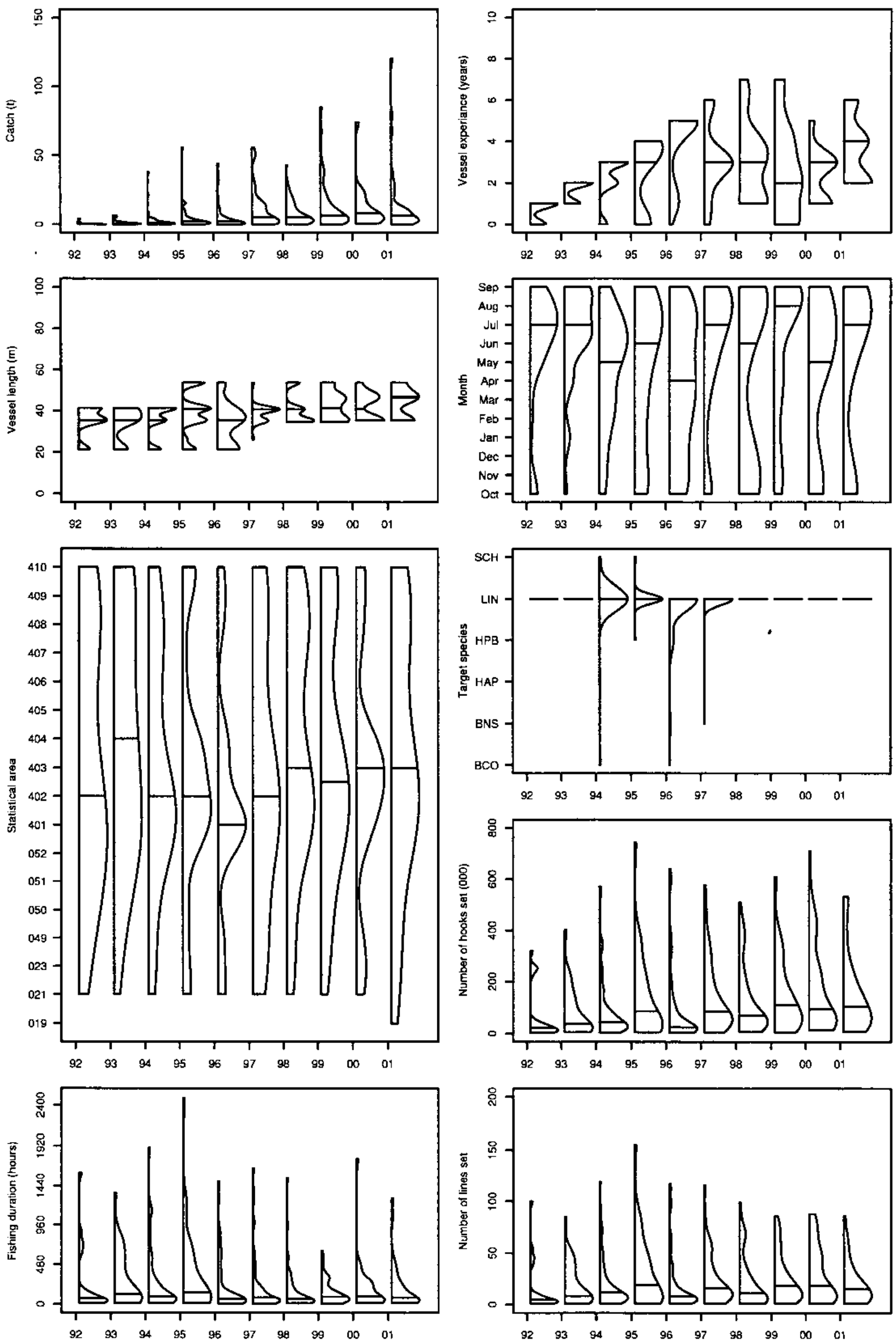

Figure D6: Distribution plots of relative frequency for all non-zero bottom longline effort strata for all core vessels on the Chatham Rise (SPD 3 & 4) for *catch, vessel experience, vessel length, month, statistical area, target species, total number of hooks set, fishing duration,* and *total number of lines set.* Approximate frequencies are plotted by fishing year for the fishing years 1989–90 to 2000–01. The horizontal line in each distribution indicates the position of the median.

D.7 Bottom-trawl fishing in SPD 5 (CPUE model 7)

Table D7: Number of vessels, total catch, total number of tows, total number of effort strata, median fishing duration per stratum, median catch per stratum, and median catch per hour fished per stratum for all bottom-trawl effort strata for all vessels in SPD 5 in the groomed and merged dataset. Summaries are provided separately for all vessels in the dataset and for core vessels (vessels active in the fishery for more than three years).

All vessels

											Fishing year		
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	9	21	13	19	20	19	14	22	14	26	29	43	102
Total catch (t)	27	175	61	26	62	30	80	120	84	478	265	284	1 693
Total number of tows	119	1 281	392	522	591	717	297	1 170	798	1 428	1 251	3 095	11 661
Total number of effort strata	24	103	40	75	80	60	39	134	90	113	171	400	1 329
Median fishing duration per stratum (h)	15.1	26.6	18.2	13.5	12.1	19.7	12.0	15.7	17.7	19.0	13.0	16.6	16.5
Median catch per stratum (kg)	488.0	244.0	285.9	160.1	241.0	144.0	555.6	116.8	189.1	235.0	302.3	262.3	235.0
Median catch per hour fished per stratum ($kg.h^{-1}$)	36.5	12.1	16.6	9.6	19.9	6.4	29.1	4.9	6.4	12.7	18.8	17.1	15.0

Core vessels

											Fishing year		
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	5	9	7	15	14	14	10	17	12	17	21	22	33
Total catch (t)	14	102	32	24	56	28	77	109	84	336	209	185	1 255
Total number of tows	65	385	323	461	436	550	275	1 066	770	1 140	991	2 266	8 728
Total number of effort strata	13	49	32	64	69	49	33	123	85	91	150	317	1 075
Median fishing duration per stratum (h)	14.9	21.0	17.7	11.8	7.5	18.5	16.1	15.5	18.0	18.6	12.0	16.4	15.5
Median catch per stratum (kg)	414.0	210.0	285.9	167.0	247.0	156.0	653.7	104.5	190.0	210.0	306.2	242.0	223.5
Median catch per hour fished per stratum ($kg.h^{-1}$)	35.2	19.6	18.7	10.1	22.2	7.9	46.3	4.1	6.3	8.5	21.7	16.3	15.2

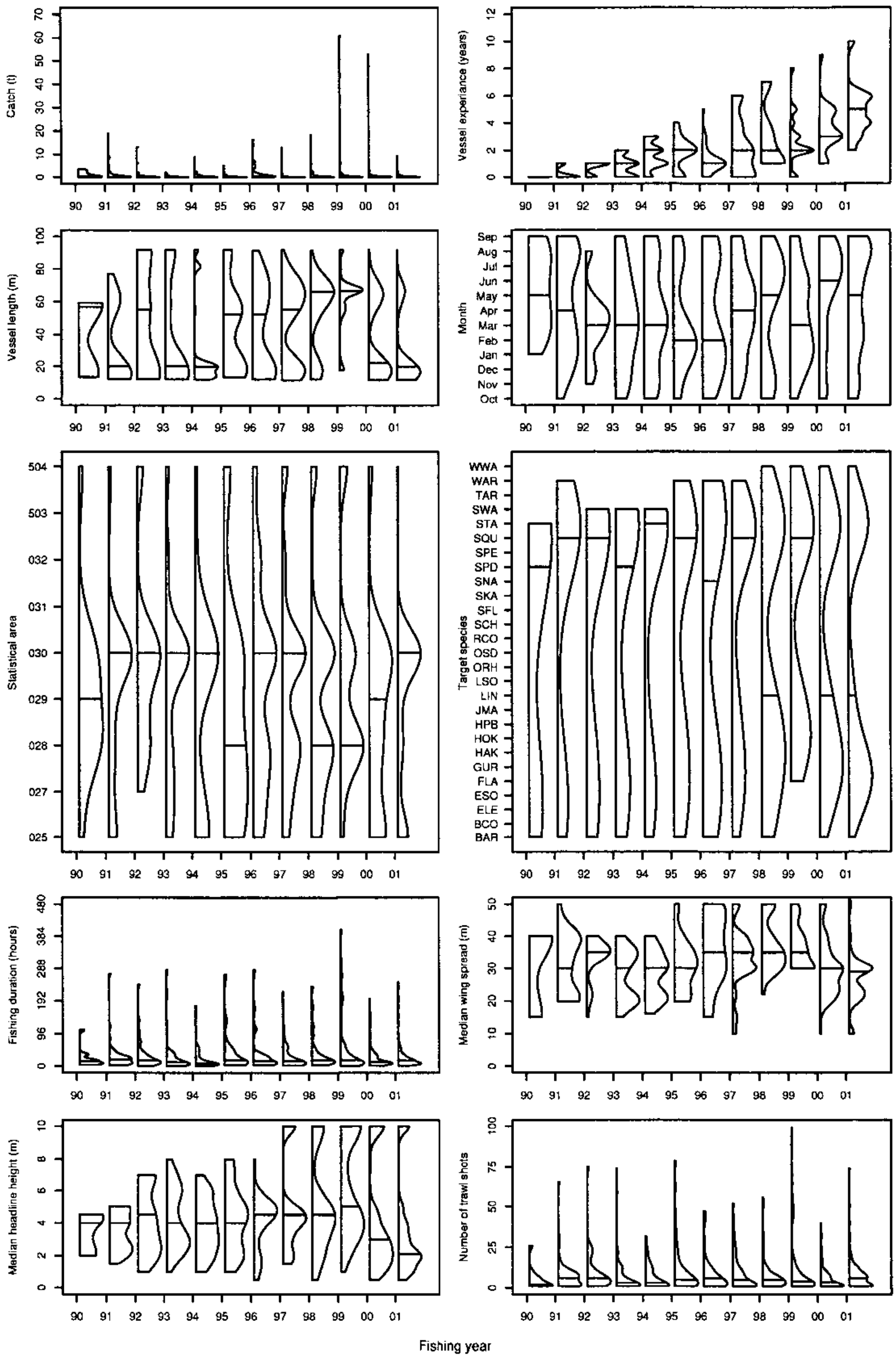

Figure D7: Distribution plots of relative frequency for all non-zero bottom trawl effort strata for all core vessels in SPD 5 for *catch, vessel experience, vessel length, month, statistical area, target species, fishing duration, median wing spread, median headline height,* and *total number of trawl shots.* Approximate frequencies are plotted by fishing year for the fishing years 1989–90 to 2000–01. The horizontal line in each distribution indicates the position of the median.

D.8 Bottom-longline fishing in SPD 6 (CPUE model 8)

Table D8: Number of vessels, total catch, total number of hooks set, total number of effort strata, median number of hooks set per stratum, median catch per stratum, and median catch per 1000 hooks set per stratum for all bottom-longline effort strata for all vessels in SPD 6 in the groomed and merged dataset. Summaries are provided separately for all vessels in the dataset and for core vessels (vessels active in the fishery for more than three years).

All vessels

	Fishing year										
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	2	2	1	3	4	5	5	5	4	3	7
Total catch (t)	21	7	3	25	150	106	147	103	77	107	745
Total number of hooks set	747 600	1 768 240	2 032 120	921 300	3 808 061	7 341 859	8 163 403	10 052 742	6 933 205	5 689 331	47 457 862
Total number of effort strata	9	11	12	6	13	36	39	45	28	20	219
Median hooks set per stratum (hooks)	51 200	163 200	99 260	150 650	292 500	116 499	144 000	107 200	162 496	209 503	139 200
Median catch per stratum (kg)	1 426.4	258.2	88.6	262.9	1 080.0	1 009.9	743.1	870.6	1 694.6	3 524.7	1 010.0
Median catch per thousand hooks set per stratum (kg.1000 hooks^{-1})	14.7	1.4	1.2	2.9	2.4	6.6	6.8	7.4	7.2	19.7	6.8

Core vessels

	Fishing year										
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	2	2	1	3	4	5	5	4	3	3	6
Total catch (t)	21	7	3	25	150	106	147	101	66	107	732
Total number of hooks set	747 600	1 768 240	2 032 120	921 300	3 808 061	7 341 859	8 163 403	7 951 055	5 624 805	5 689 331	44 047 774
Total number of effort strata	9	11	12	6	13	36	39	38	20	20	204
Median hooks set per stratum (hooks)	51 200	163 200	99 260	150 650	292 500	116 499	144 000	108 800	187 863	209 503	142 400
Median catch per stratum (kg)	1 426.4	258.2	88.6	262.9	1 080.0	1 009.9	743.1	1 266.2	2 044.3	3 524.7	1 072.9
Median catch per thousand hooks set per stratum (kg.1000 hooks^{-1})	14.7	1.4	1.2	2.9	2.4	6.6	6.8	8.3	9.4	19.7	7.1

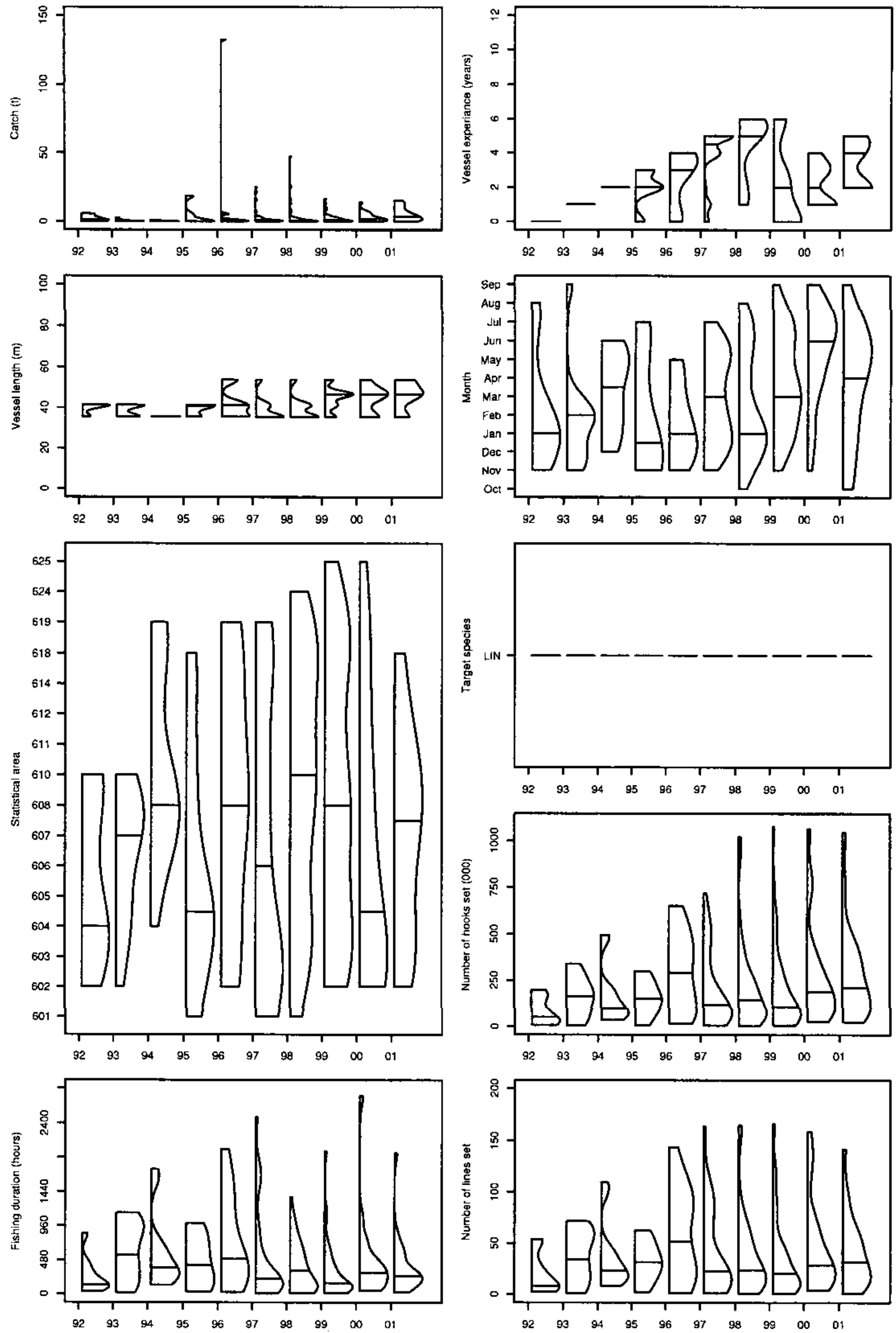

Figure D8: Distribution plots of relative frequency for all non-zero bottom longline effort strata for all core vessels in SPD 6 for *catch, vessel experience, vessel length, month, statistical area, target species, total number of hooks set, fishing duration,* and *total number of lines set.* Approximate frequencies are plotted by fishing year for the fishing years 1989–90 to 2000–01. The horizontal line in each distribution indicates the position of the median.

D.9 Bottom-trawl fishing in SPD 7 (CPUE model 9)

Table D9: Number of vessels, total catch, total number of tows, total number of effort strata, median fishing duration per stratum, median catch per stratum, and median catch per hour fished per stratum for all bottom-trawl effort strata for all vessels in SPD 7 (excluding statistical areas 016, 017, and 018) in the groomed and merged dataset. Summaries are provided separately for all vessels in the dataset and for core vessels (vessels active in the fishery for more than five years).

All vessels

	Fishing year												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	40	48	68	61	63	56	65	72	69	68	65	68	231
Total catch (t)	170	560	253	193	299	84	171	178	183	688	482	316	3 578
Total number of tows	1 518	2 393	3 157	2 357	2 073	2 203	3 144	3 559	2 711	3 677	4 618	4 238	35 648
Total number of effort strata	192	329	460	372	339	334	394	468	299	382	469	466	4 504
Median fishing duration per stratum (h)	18.2	16.0	16.0	18.0	15.0	12.0	15.0	17.5	18.0	21.2	24.0	26.0	18.0
Median catch per stratum (kg)	247.5	358.0	90.0	76.9	86.0	47.5	79.7	115.2	100.0	210.0	195.0	163.7	124.0
Median catch per hour fished per stratum (kg.h^{-1})	14.7	27.9	5.0	5.3	5.5	4.0	5.6	7.1	5.7	10.9	8.4	7.0	7.1

Core vessels

	Fishing year												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	17	17	32	32	38	36	38	42	40	37	38	32	60
Total catch (t)	85	151	114	133	196	42	106	119	88	165	251	182	1 632
Total number of tows	730	861	1 562	1 663	1 473	1 257	2 004	2 685	1 914	2 211	3 233	2 663	22 256
Total number of effort strata	94	111	258	257	246	220	273	346	223	262	335	340	2 965
Median fishing duration per stratum (h)	16.8	17.8	15.0	18.0	15.2	12.0	12.0	16.9	16.5	18.3	24.0	23.4	17.0
Median catch per stratum (kg)	187.5	303.3	73.0	77.1	87.4	39.0	81.0	111.4	95.2	146.6	195.7	150.0	108.5
Median catch per hour fished per stratum (kg.h^{-1})	12.1	13.9	3.8	5.3	6.8	3.7	6.3	6.2	5.6	8.6	7.5	7.9	6.2

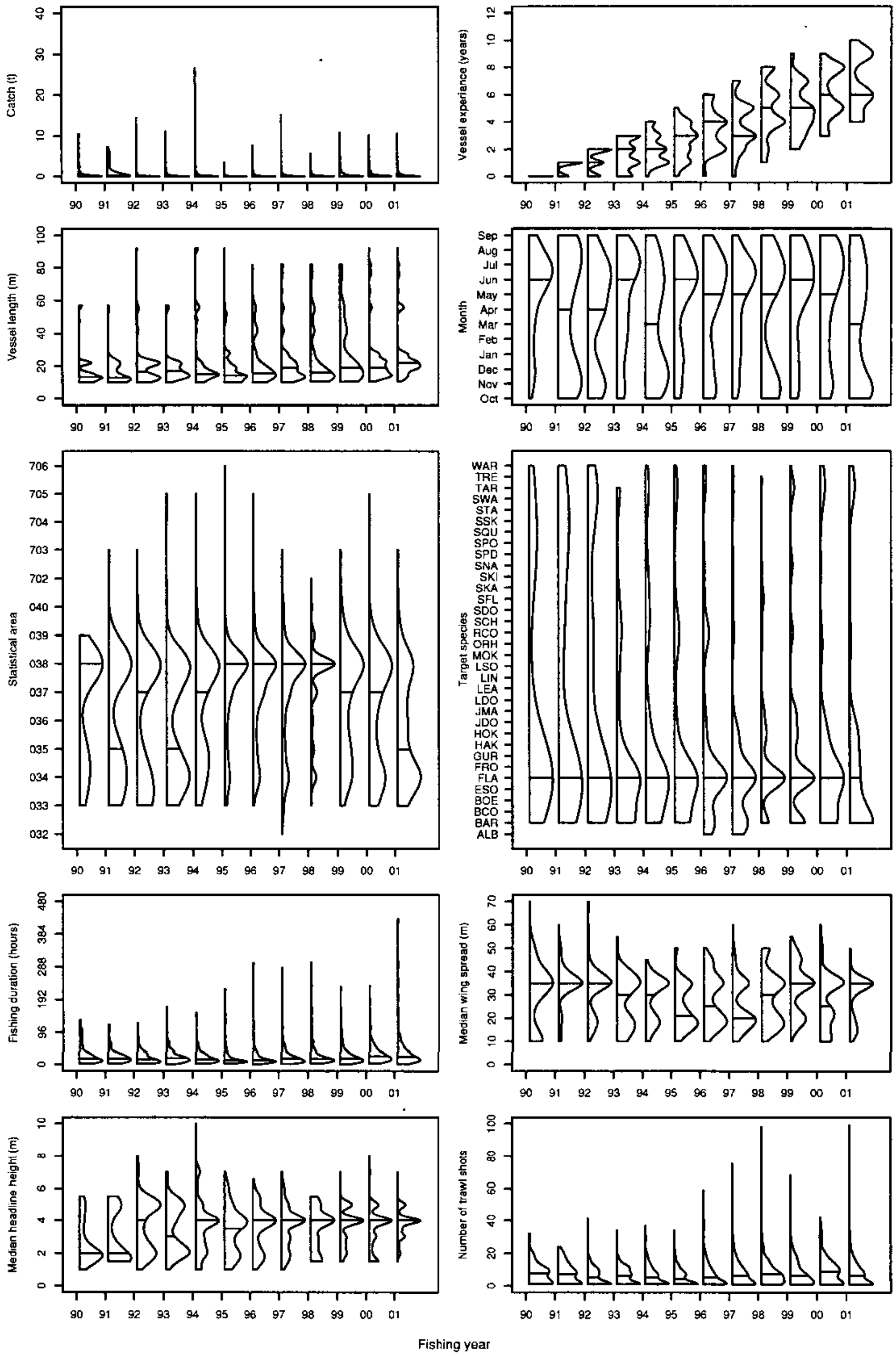

Figure D9: Distribution plots of relative frequency for all non-zero bottom trawl effort strata for all core vessels in SPD 7 for *catch, vessel experience, vessel length, month, statistical area, target species, fishing duration, median wing spread, median headline height,* and *total number of trawl shots.* Approximate frequencies are plotted by fishing year for the fishing years 1989–90 to 2000–01. The horizontal line in each distribution indicates the position of the median.

D.10 Bottom-trawl fishing in SPD 7 and 8 (CPUE model 10)

Table D10: Number of vessels, total catch, total number of tows, total number of effort strata, median fishing duration per stratum, median catch per stratum, and median catch per hour fished per stratum for all bottom-trawl effort strata for all vessels in SPD 7 & 8 (excluding statistical areas 016, 017, and 018) in the groomed and merged dataset. Summaries are provided separately for all vessels in the dataset and for core vessels (vessels active in the fishery for more than five years).

All vessels

	Fishing year												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	40	51	74	65	67	57	66	76	71	70	67	77	246
Total catch (t)	171	561	258	344	358	93	182	188	207	693	484	337	3 875
Total number of tows	1 519	2 511	3 304	2 718	2 366	2 258	3 254	3 627	2 821	3 698	4 667	4 74	37 118
Total number of effort strata	193	336	470	389	366	347	412	483	317	388	477	498	4 676
Median fishing duration per stratum (h)	18.0	16.2	16.0	18.0	15.0	12.0	14.8	17.0	18.0	21.0	24.0	24.0	18.0
Median catch per stratum (kg)	249.0	336.8	90.0	81.0	89.0	51.3	71.3	117.9	105.3	210.0	193.5	159.9	124.7
Median catch per hour fished per stratum ($kg.h^{-1}$)	14.7	26.9	5.0	5.7	5.6	4.4	5.4	7.2	6.7	10.9	8.3	7.0	7.2

Core vessels

	Fishing year												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total
Number of vessels	17	18	34	35	40	36	38	45	42	37	39	33	62
Total catch (t)	85	151	118	152	213	51	106	128	112	170	251	185	1 724
Total number of tows	731	895	1 654	1 802	1 700	1 311	2 054	2 752	2 022	2 228	3 235	2 674	23 058
Total number of effort strata	95	116	266	267	264	232	284	360	237	265	337	346	3 069
Median fishing duration per stratum (h)	16.0	17.7	15.0	18.0	15.5	12.0	12.0	16.6	18.0	18.7	24.0	23.0	17.0
Median catch per stratum (kg)	192.0	273.0	76.4	86.0	94.1	46.0	71.3	111.4	102.6	159.3	195.0	150.0	110.7
Median catch per hour fished per stratum ($kg.h^{-1}$)	12.5	11.4	3.8	5.3	7.0	4.0	5.7	6.4	5.9	8.9	7.5	7.8	6.3

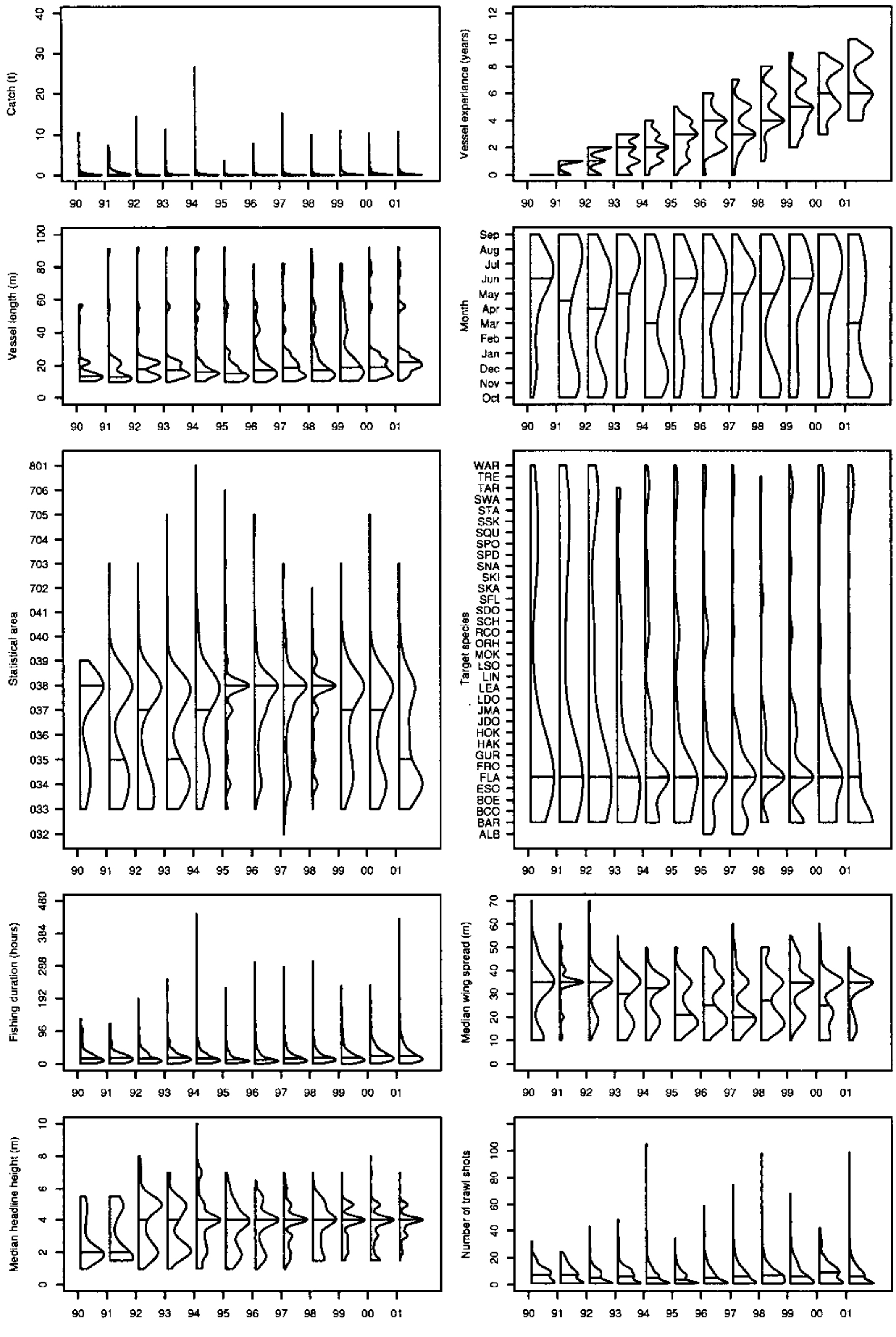

Figure D10: Distribution plots of relative frequency for all non-zero bottom trawl effort strata for all core vessels in SPD 7 & 8 for *catch, vessel experience, vessel length, month, statistical area, target species, fishing duration, median wing spread, median headline height,* and *total number of trawl shots.* Approximate frequencies are plotted by fishing year for the fishing years 1989–90 to 2000–01. The horizontal line in each distribution indicates the position of the median.

D.11 Diagnostic residual plots for the fit of CPUE model 1

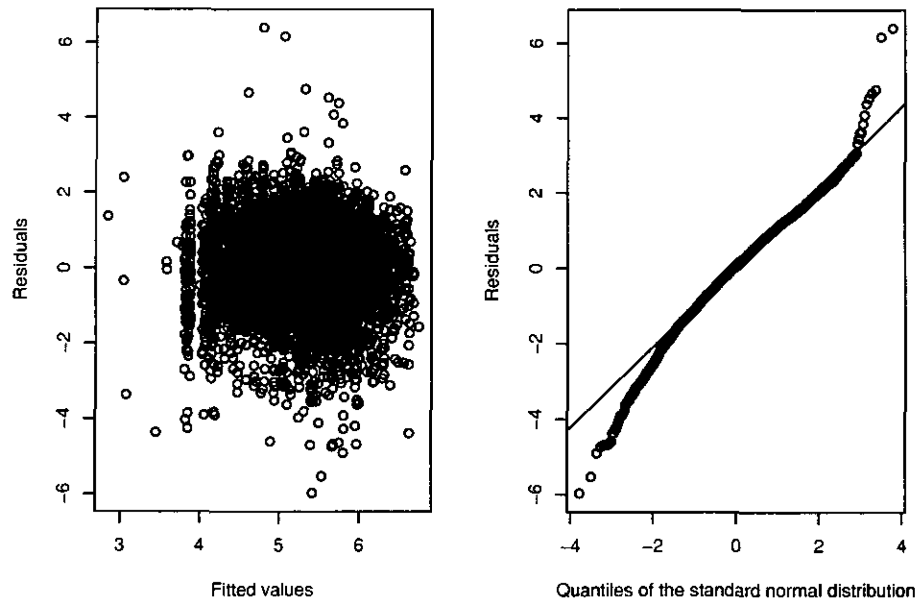

Figure D11: Distributions of fitted values against residuals and normalised residuals against standardised residuals for the model fitted to target setnet, groomed, merged, and allocated catches by core vessels in SPD 3 for the 1989–90to 2000–01 fishing years.

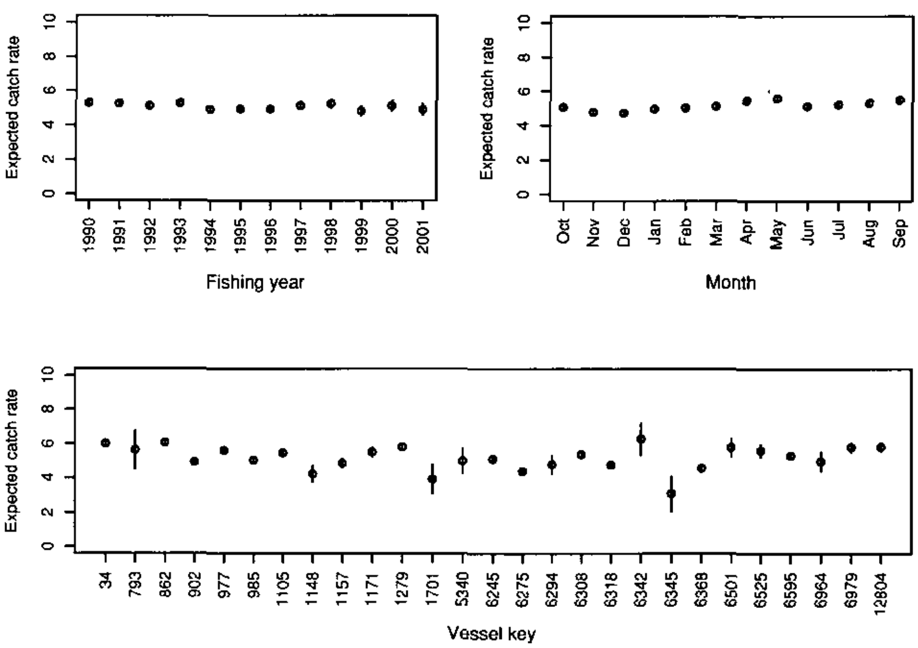

Figure D12: Expected catch rates, the natural logarithm of kilogram's caught per 1000 m net set, for median values of fixed parameters in the model fitted to target setnet, groomed, merged, and allocated catches by core vessels in SPD 3 for the 1989–90 to 2000–01 fishing years. The width of the error bars is equal to two standard errors about the expected catch rates.

D.12 Diagnostic residual plots for the fit of CPUE model 2

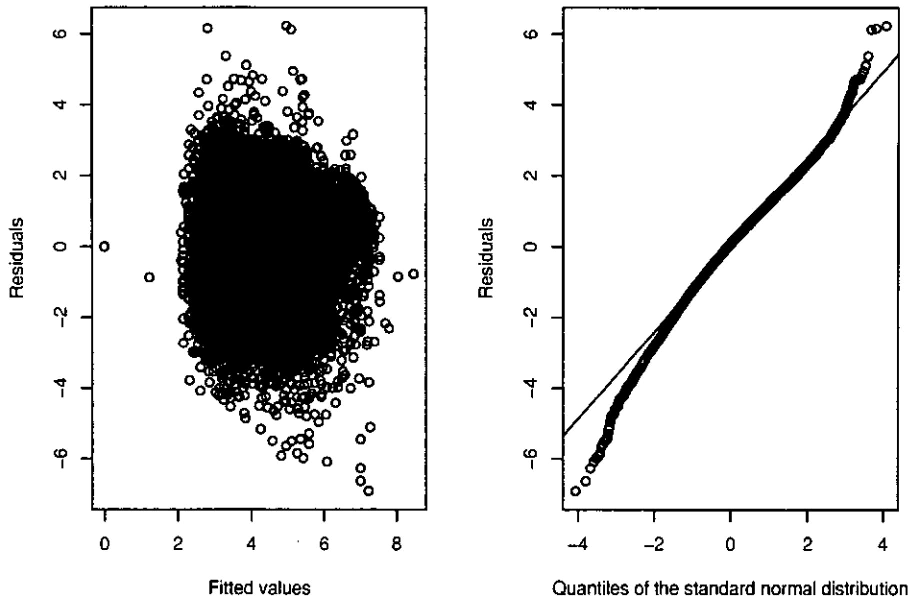

Figure D13: Distributions of fitted values against residuals and normalised residuals against standardised residuals for the model fitted to all setnet, groomed, merged, and allocated catches by core vessels in SPD 3 for the 1989–90to 2000–01 fishing years.

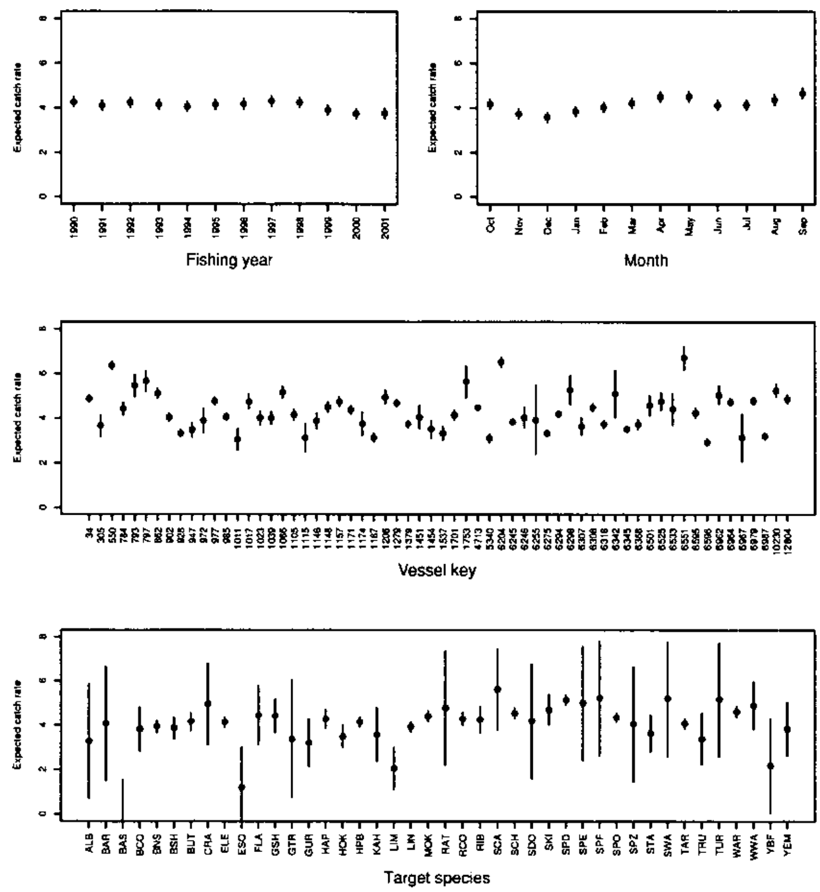

Figure D14: Expected catch rates, the natural logarithm of kilogram's caught per 1000 m net set, for median values of fixed parameters in the model fitted to all setnet, groomed, merged, and allocated catches by core vessels in SPD 3 for the 1989–90to 2000–01 fishing years. The width of the error bars is equal to two standard errors about the expected catch rates.

D.13 Diagnostic residual plots for the fit of CPUE model 3

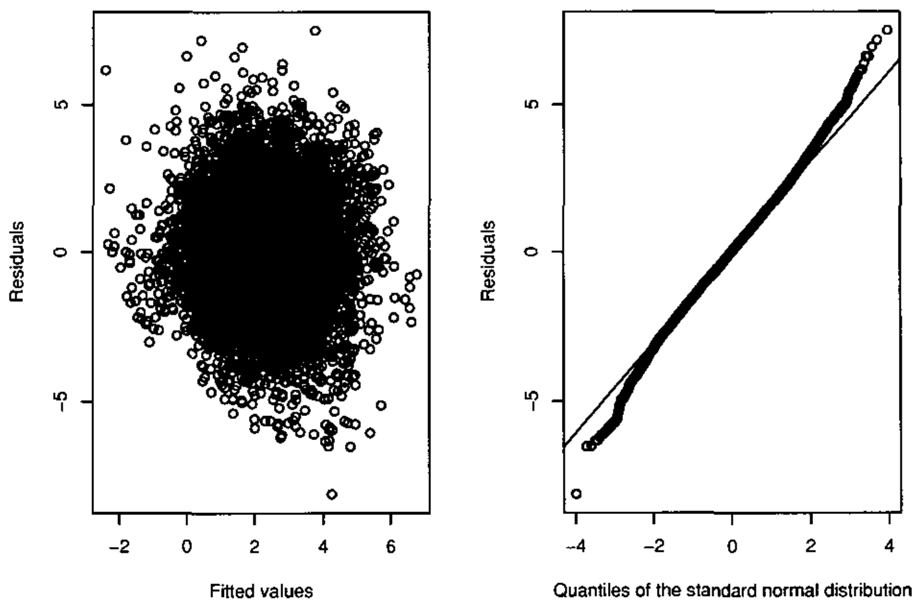

Figure D15: Distributions of fitted values against residuals and normalised residuals against standardised residuals for the model fitted to all bottom trawl, groomed, merged, and allocated catches by core vessels in SPD 3 for the 1989–90to 2000–01 fishing years.

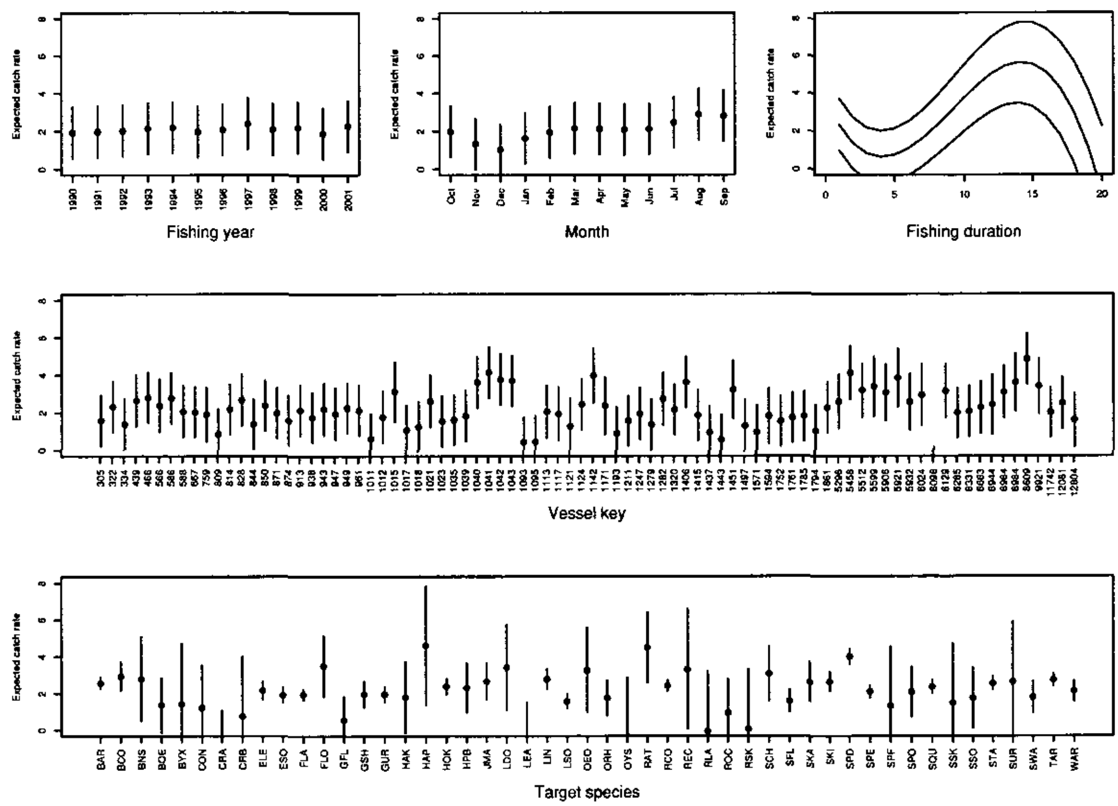

Figure D16: Expected catch rates, the natural logarithm of kilogram's caught per hour fished, for median values of fixed parameters in the model fitted to all bottom trawl, groomed, merged, and allocated catches by core vessels in SPD 3 for the 1989–90to 2000–01 fishing years. The width of the error bars is equal to two standard errors about the expected catch rates.

D.14 Diagnostic residual plots for the fit of CPUE model 4

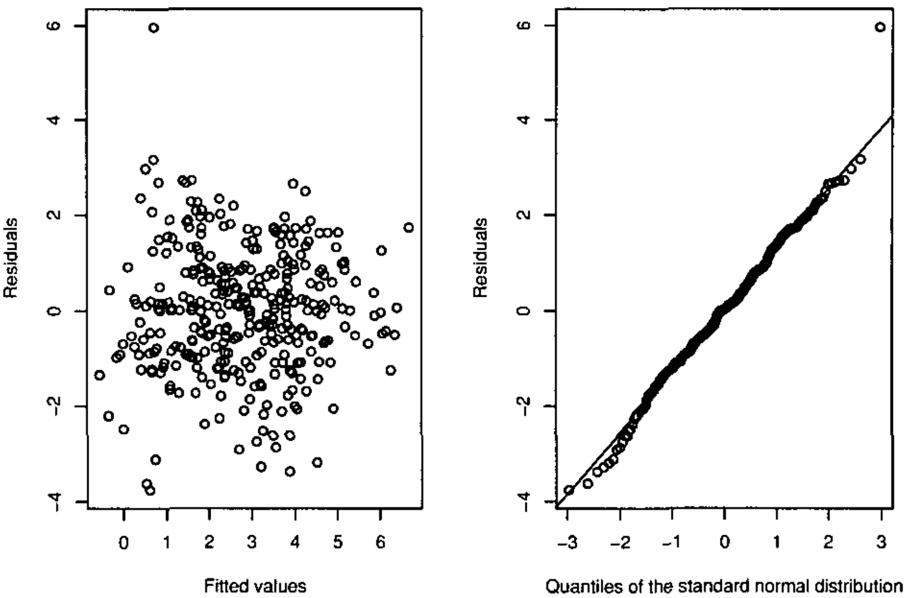

Figure D17: Distributions of fitted values against residuals and normalised residuals against standardised residuals for the model fitted to bottom trawl, groomed, merged, and allocated catches by core Korean vessels on the Chatham Rise (SPD 3 and 4) for the 1989–90to 2000–01 fishing years.

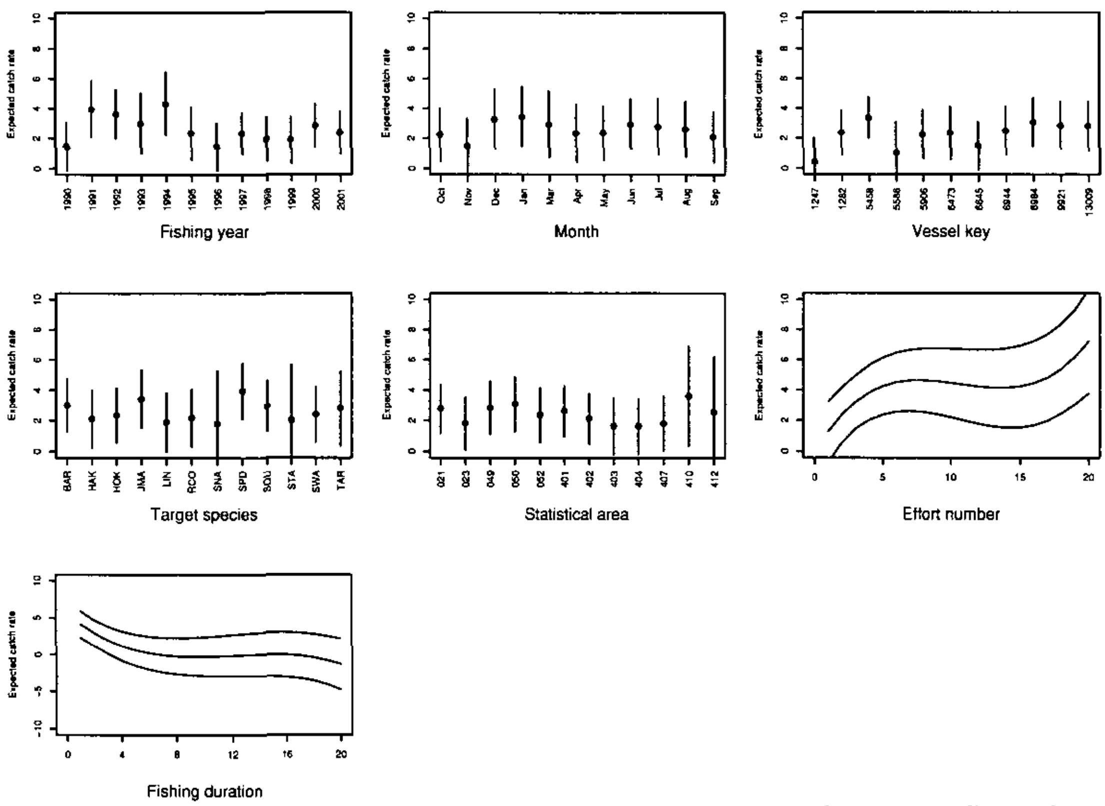

Figure D18: Expected catch rates, the natural logarithm of kilogram's caught per hour fished, for median values of fixed parameters in the model fitted to all bottom trawl, groomed, merged, and allocated catches by core Korean vessels on the Chatham Rise (SPD 3 and 4) for the 1989–90to 2000–01 fishing years. The width of the error bars is equal to two standard errors about the expected catch rates.

D.15 Diagnostic residual plots for the fit of CPUE model 5

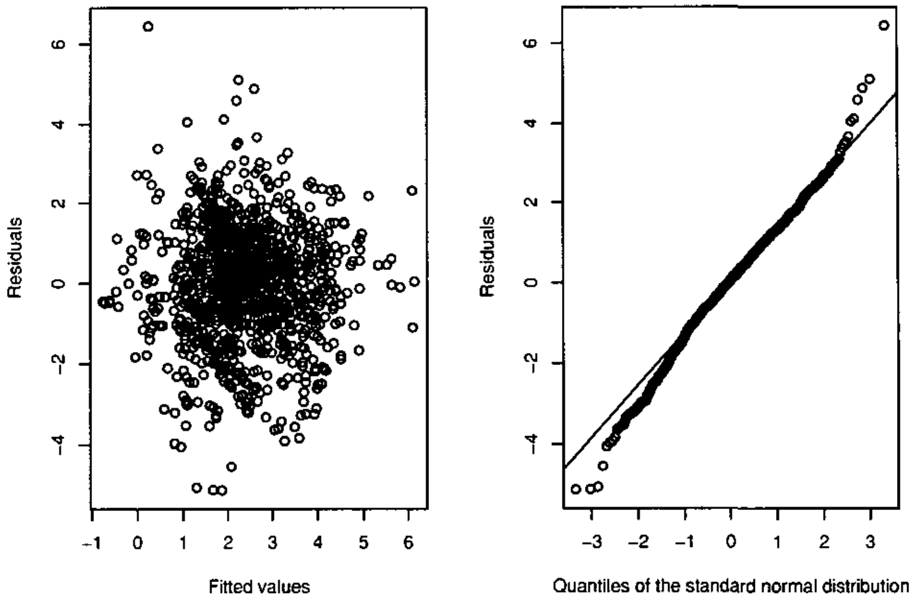

Figure D19: Distributions of fitted values against residuals and normalised residuals against standardised residuals for the model fitted to all bottom trawl, groomed, merged, and allocated catches by all core vessels on the Chatham Rise (SPD 3 and 4) for the 1989–90to 2000–01 fishing years.

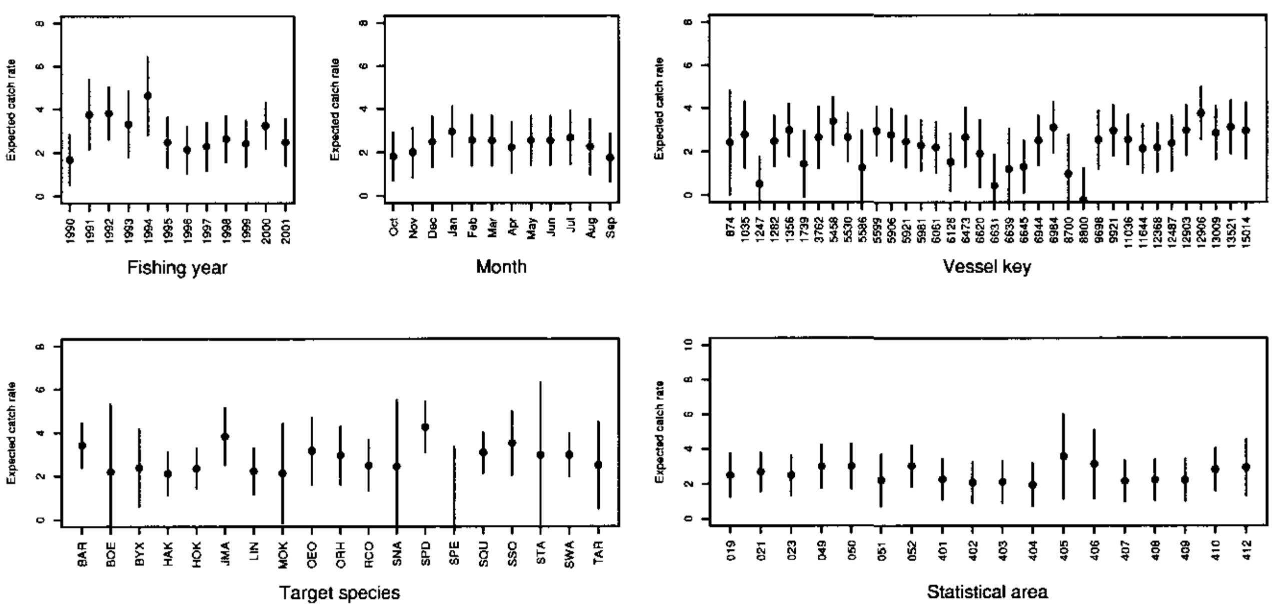

Figure D20: Expected catch rates, the natural logarithm of kilogram's caught per hour fished, for median values of fixed parameters in the model fitted to all bottom trawl, groomed, merged, and allocated catches by core vessels on the Chatham Rise (SPD 3 and 4) for the 1989–90to 2000–01 fishing years. The width of the error bars is equal to two standard errors about the expected catch rates.

D.16 Diagnostic residual plots for the fit of CPUE model 6

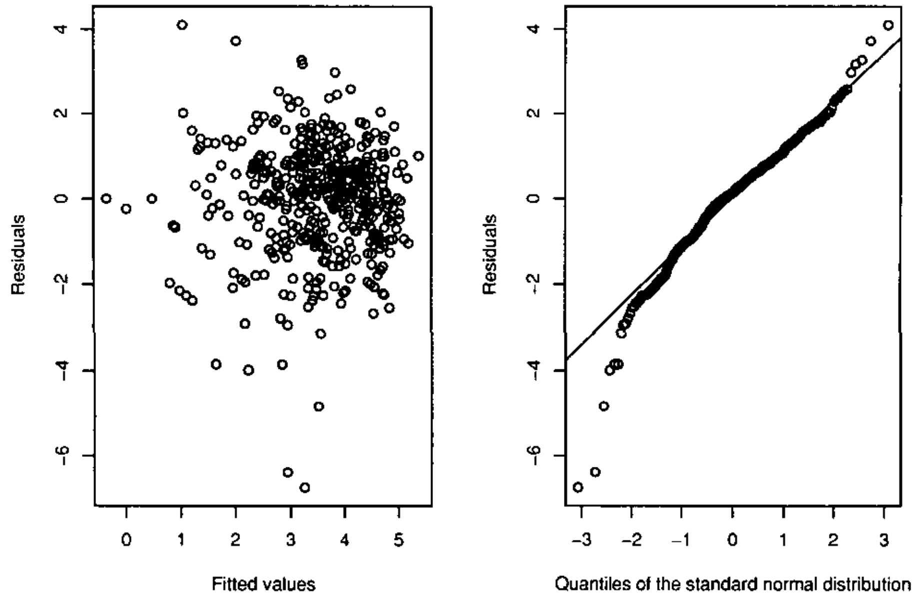

Figure D21: Distributions of fitted values against residuals and normalised residuals against standardised residuals for the model fitted to all bottom longline, groomed, merged, and allocated catches by core vessels on the Chatham Rise (SPD 3 and 4) for the 1989–90to 2000–01 fishing years.

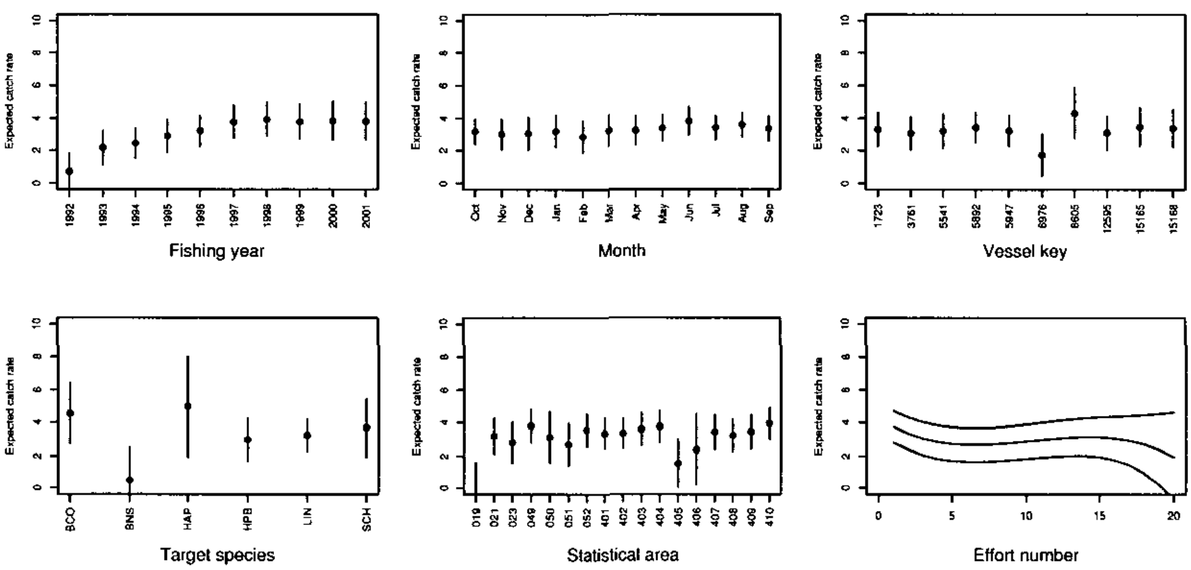

Figure D22: Expected catch rates, the natural logarithm of kilogram's caught per 1000 hooks set, for median values of fixed parameters in the model fitted to all bottom longline, groomed, merged, and allocated catches by core vessels on the Chatham Rise (SPD 3 and 4) for the 1989–90to 2000–01 fishing years. The width of the error bars is equal to two standard errors about the expected catch rates.

D.17 Diagnostic residual plots for the fit of CPUE model 7

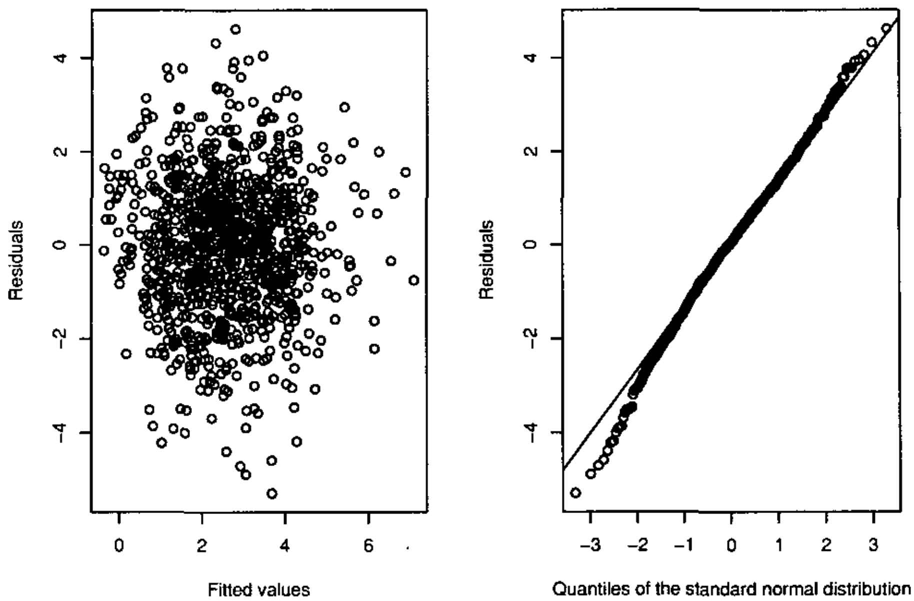

Figure D23: Distributions of fitted values against residuals and normalised residuals against standardised residuals for the model fitted to all bottom trawl, groomed, merged, and allocated catches by core vessels in SPD 5 for the 1989–90to 2000–01 fishing years.

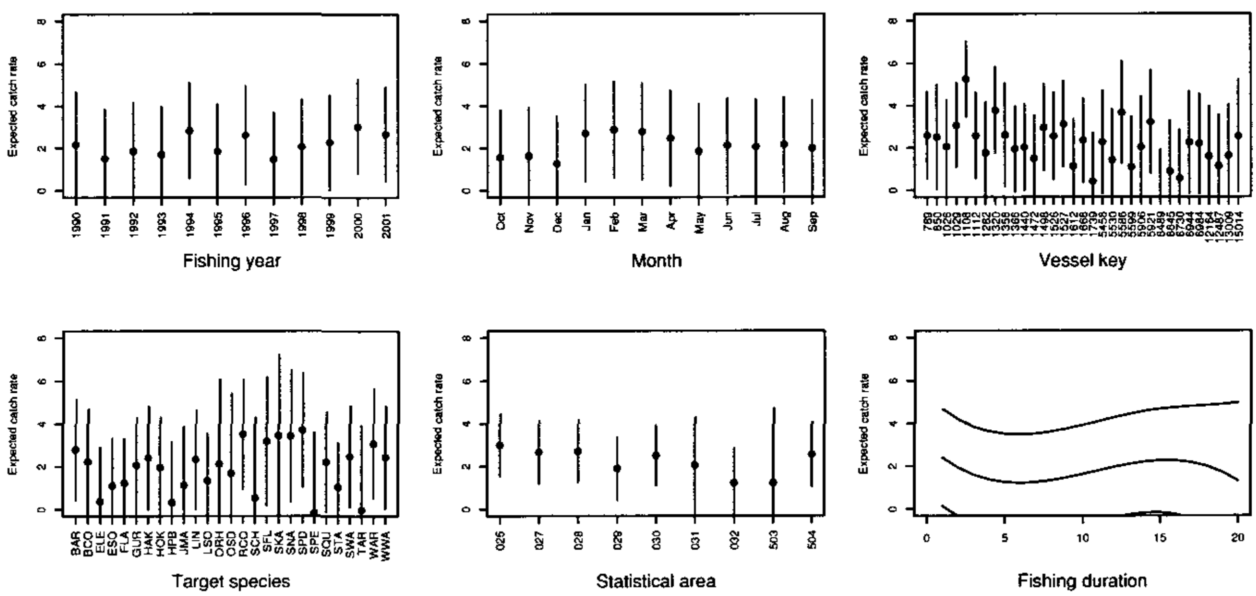

Figure D24: Expected catch rates, the natural logarithm of kilogram's caught per hour fished, for median values of fixed parameters in the model fitted to all bottom trawl, groomed, merged, and allocated catches by core vessels in SPD 5 for the 1989–90to 2000–01 fishing years. The width of the error bars is equal to two standard errors about the expected catch rates.

D.18 Diagnostic residual plots for the fit of CPUE model 8

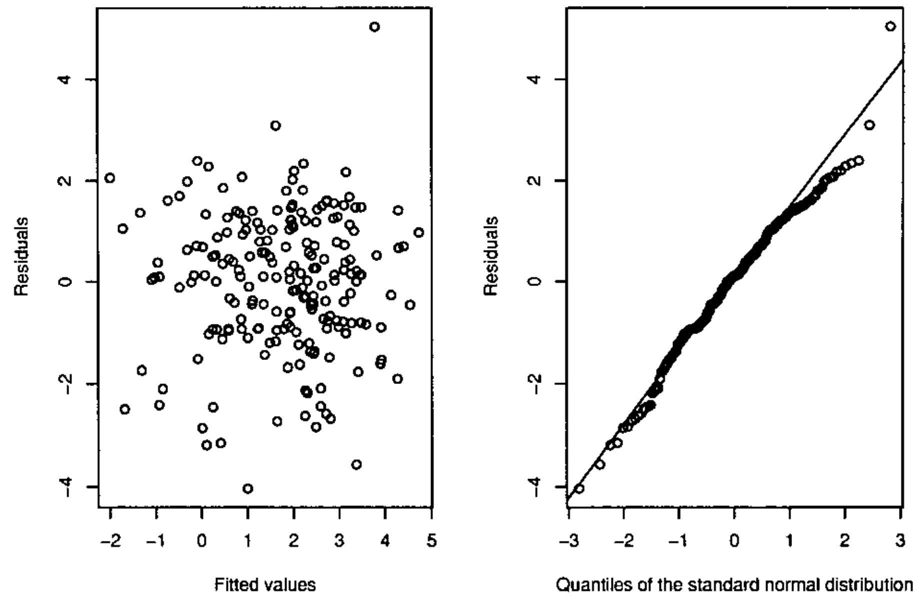

Figure D25: Distributions of fitted values against residuals and normalised residuals against standardised residuals for the model fitted to all bottom longline, groomed, merged, and allocated catches by core vessels in SPD 6 for the 1992-93 to 2000–01 fishing years.

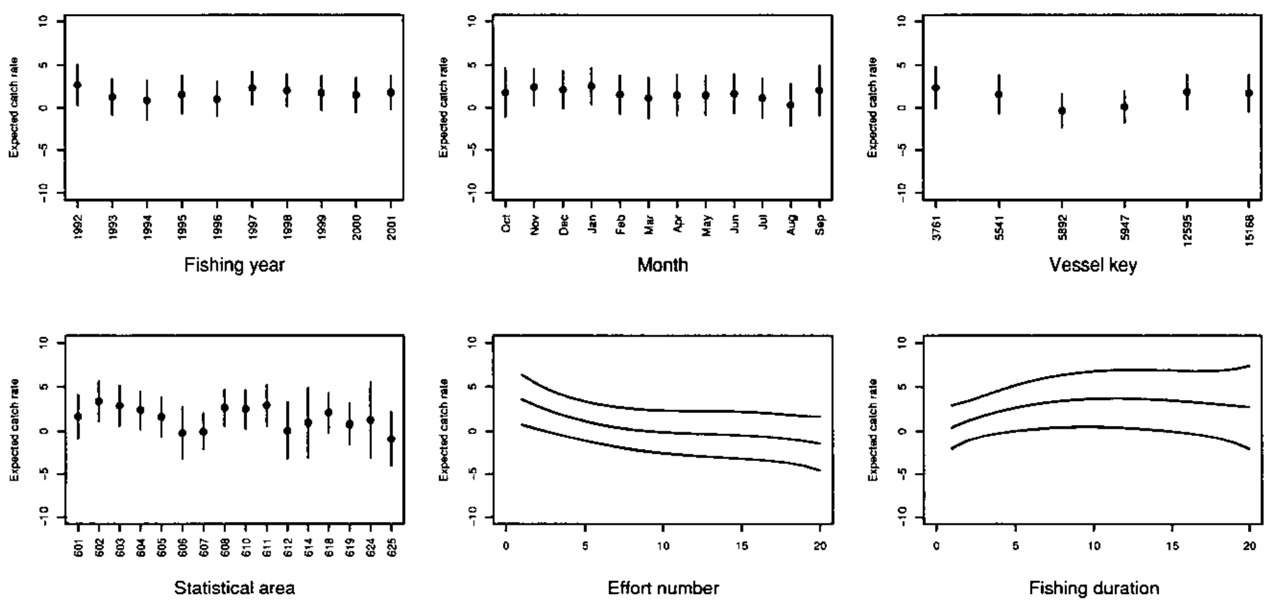

Figure D26: Expected catch rates, the natural logarithm of kilogram's caught per 1000 hooks set, for median values of fixed parameters in the model fitted to all bottom longline, groomed, merged, and allocated catches by core vessels in SPD 6 for the 1992-93 to 2000–01 fishing years. The width of the error bars is equal to two standard errors about the expected catch rates.

D.19 Diagnostic residual plots for the fit of CPUE model 9

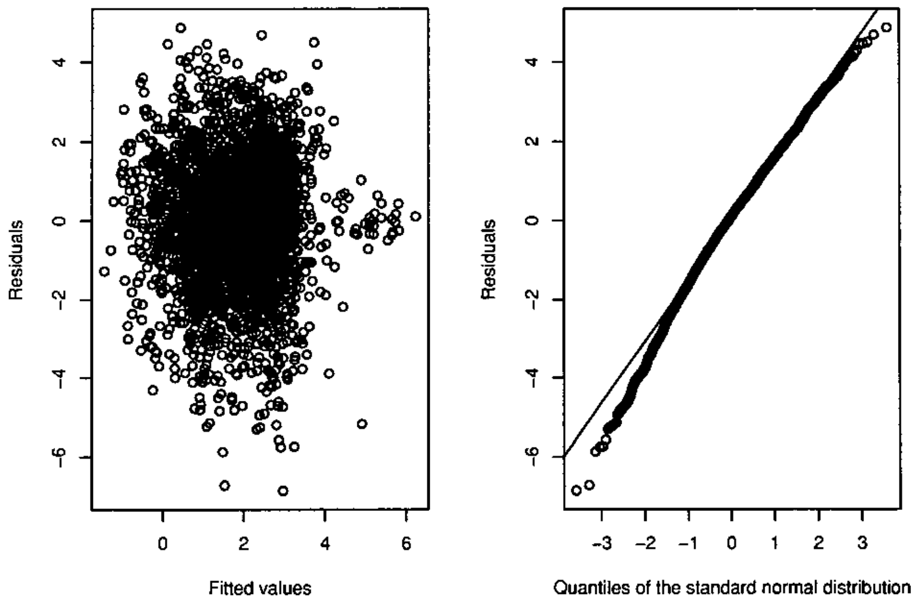

Figure D27: Distributions of fitted values against residuals and normalised residuals against standardised residuals for the model fitted to all bottom trawl, groomed, merged, and allocated catches by core vessels in SPD 7 for the 1989–90to 2000–01 fishing years.

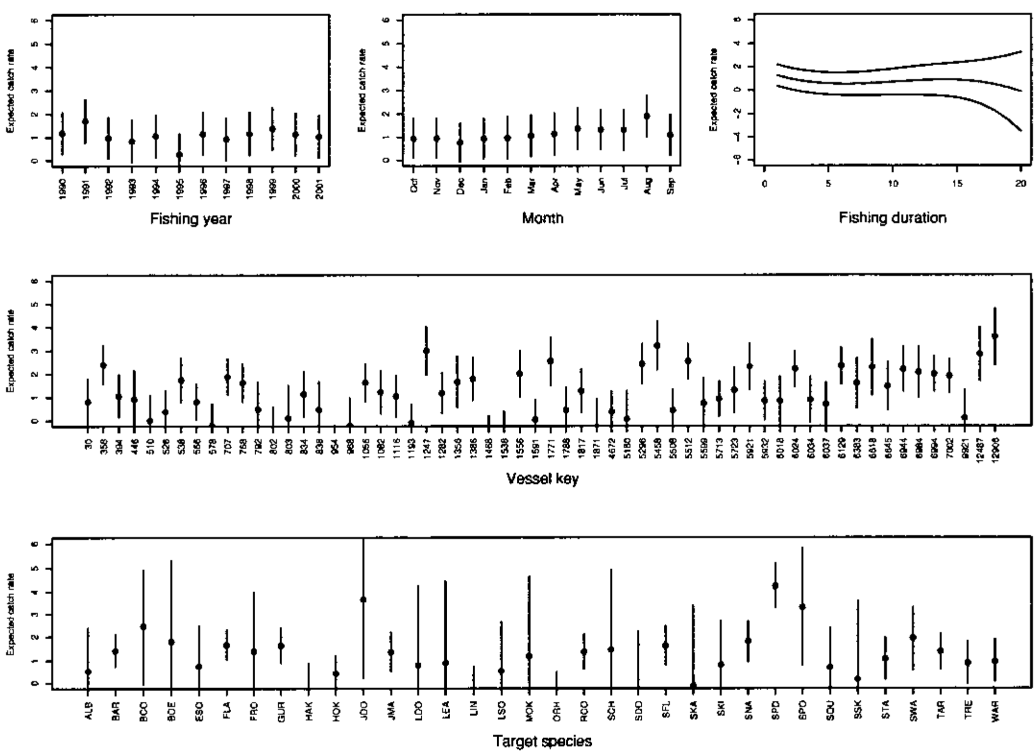

Figure D28: Expected catch rates, the natural logarithm of kilogram's caught per hour fished, for median values of fixed parameters in the model fitted to all bottom trawl, groomed, merged, and allocated catches by core vessels in SPD 7 for the 1989–90to 2000–01 fishing years. The width of the error bars is equal to two standard errors about the expected catch rates.

D.20 Diagnostic residual plots for the fit of CPUE model 10

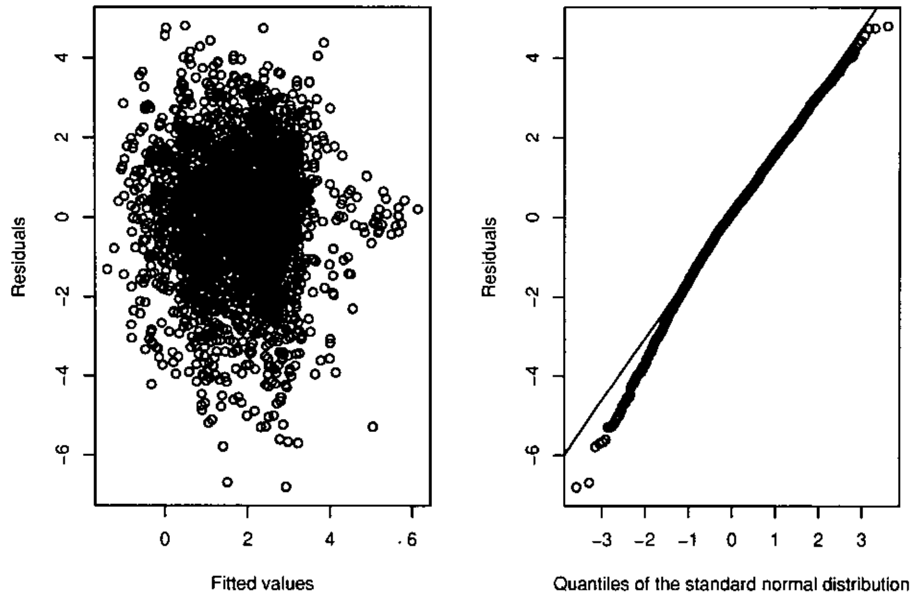

Figure D29: Distributions of fitted values against residuals and normalised residuals against standardised residuals for the model fitted to all bottom trawl, groomed, merged, and allocated catches by core vessels in SPD 7 and 8 for the 1989–90to 2000–01 fishing years.

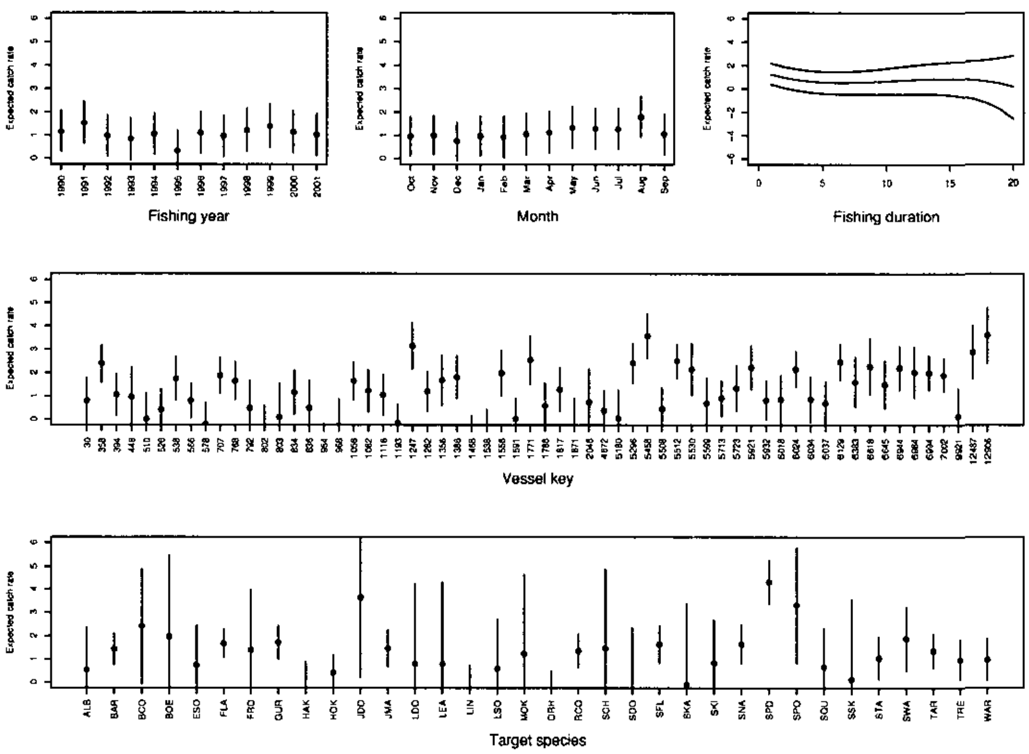

Figure D30: Expected catch rates, the natural logarithm of kilogram's caught per hour fished, for median values of fixed parameters in the model fitted to all bottom trawl, groomed, merged, and allocated catches by core vessels in SPD 7 and 8 for the 1989–90to 2000–01 fishing years. The width of the error bars is equal to two standard errors about the expected catch rates.