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Updated catch-per-unit-effort (CPUE) analysis for tarakihi (*Nemadactylus macropterus*) in TAR 2 (east coast North Island) and CPUE analysis of tarakihi in Pegasus Bay/Cook Strait (mainly TAR 3)

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EXECUTIVE SUMMARY

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This report provides standardised catch-per-unit-effort (CPUE) indices for the TAR 2 (east coast North Island) and Pegasus Bay/Cook Strait (mainly TAR 3) tarakihi fisheries from 1989–90 to 2001–02.

Commercial catch and effort data from CELR (Catch Effort Landing Return) and TCEPR (Trawl Catch Effort Processing Return) forms from 1989–90 to 2001–02 were extracted from the Ministry of Fisheries catch and effort database. The data were intensively groomed to correct errors. CPUE indices were calculated using lognormal generalised linear models, with catch per day as a measure of catch per unit effort. Various models were developed using all vessels involved in the fishery or a set of core vessels (vessels that caught 80% of the tarakihi catch and were involved in the tarakihi fishery for three or more consecutive years).

This study updated an earlier analysis with data from the 2000–01 to 2001–02 fishing years using a similar method. However, this analysis differs from the previous one in that Statistical Area 017 was excluded. A sensitivity analysis was also completed with the inclusion of data from the Bay of Plenty (Statistical Areas 009 & 010). The resulting indices from the TAR 2 bottom trawl fishery all show slight declines from 1989–90 to 1991–92 followed by a moderately large gradual increase until 2001–02.

Standardised CPUE analyses of the Pegasus Bay/Cook Strait fishery were carried out on the bottom trawl fishery and setnet fisheries. The resulting indices for the bottom trawl fishery are variable, but show a gradual increase over the 13 years. The indices derived from the setnet fishery are relatively flat from 1989–90 to 1999–2000, apart from a decline in 1993–94 and a slight increase in the last two years.

The diagnostics from all models indicated a reasonable pattern in the residuals, but the Q-Q plots indicated a deviation from the normal distribution of the residuals at the lower end, suggesting that very small values of catch rate are not well predicted. For the bottom trawl fisheries, standardised CPUE indices were estimated for all vessels combined and for a subset of vessels with a continuous representation in the fishery. In all cases there was little difference in the indices resulting from the two data sets and the variation explained was similar. However, the diagnostics for the core vessels were superior, and it is recommended that core vessel results be used in any modelling.

It was concluded that:

- the standardised CPUE indices from TAR 2 are probably monitoring tarakihi abundance in the area;
- the standardised CPUE indices from the Pegasus Bay/Cook Strait set net fishery may not be monitoring tarakihi abundance in the area and should be treated with caution;
- It is not clear if the standardised CPUE indices from the Pegasus Bay/Cook Strait bottom trawl fishery are monitoring tarakihi abundance in the area, as there is no fishery independent data to validate them, therefore they should be treated with caution.

1. INTRODUCTION

Tarakihi is an important inshore commercial species caught in coastal waters off the North and South Islands, Stewart Island, and the Chatham Islands down to depths of 250 m. The major fishing grounds are west and east Northland (TAR 1), the western Bay of Plenty to Cape Kidnappers (TAR 1 and 2), Cook Strait (TAR 2), Cape Campbell to the Canterbury Bight (TAR 3), and Jackson Head to Cape Foulwind (TAR 7) (Figure 1) (Hanchet & Field 2001). The main fishing method is trawling, typically in depths of 100 to 200 m.

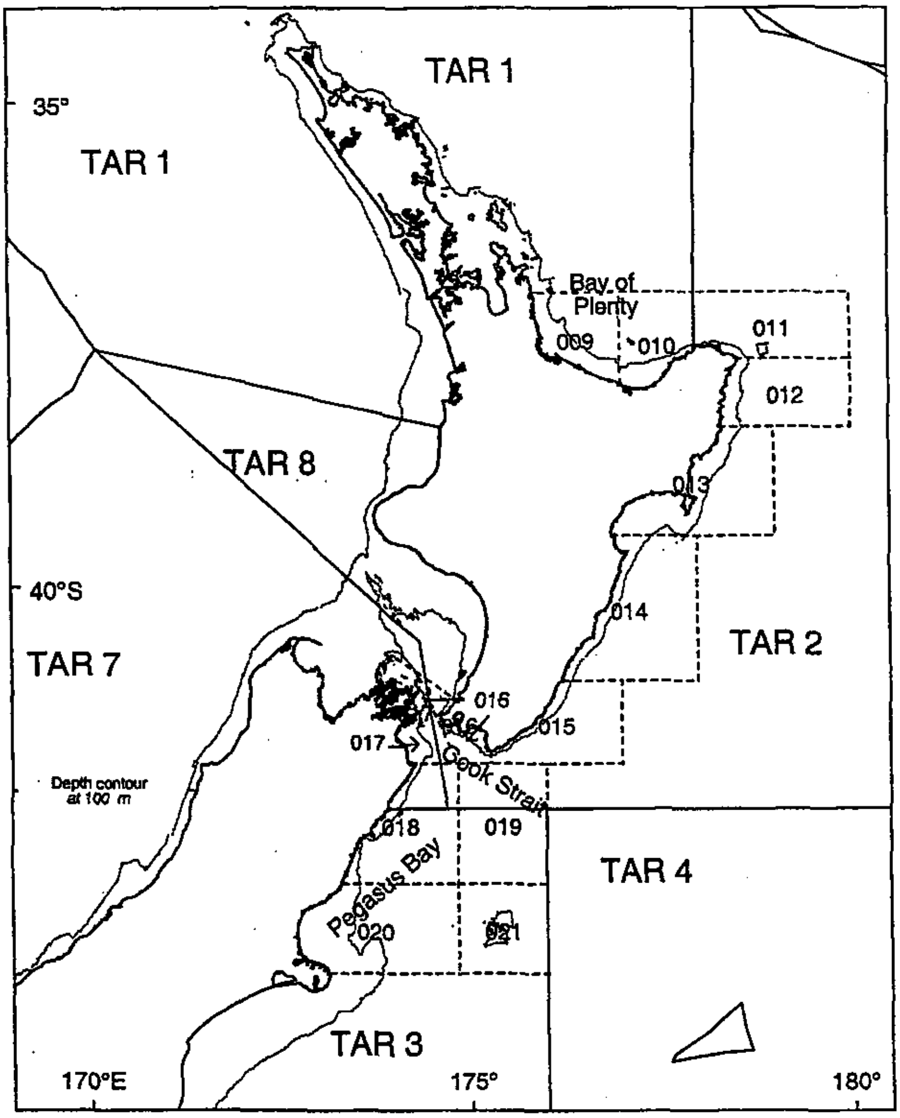

Figure 1: Statistical areas, QMA boundaries, and names of areas used in this report.

The TAR 2 fishery, on the east coast of the North Island between Cape Runaway and Cook Strait, is the largest in New Zealand, and has averaged about 1600 t since 1989–90. Field & Hanchet (2001) carried out a CPUE analysis of TAR 2 for 1989–90 to 1997–98. The analysis was based on a relatively large data set, and a high proportion of the tarakihi used in the analysis was targeted. The model had high explanatory power, reasonable diagnostics, and similar results between the full model and data subsets. There was also agreement between indices and the short time series of trawl survey indices. They concluded that the CPUE indices appeared to be monitoring tarakihi abundance in this area. The first part of the current study was to update the standardised CPUE analysis for TAR 2.

Hanchet & Field (2001) also identified a major fishing ground for tarakihi between Pegasus Bay and Cook Strait, which currently has no monitoring tool. A trawl survey of this area was carried out in autumn 1987 using *James Cook* (Annala et al. 1990). The survey obtained a considerable amount of biological information and caught spawning tarakihi throughout much of the area, but was not developed into a time series for monitoring abundance. Field & Hanchet (2001) carried out CPUE analyses for each of the major Fishstocks, but the Pegasus Bay/Cook Strait region encompasses parts of TAR 2, TAR 3, and TAR 7, and was not treated separately in their analysis. They recommended that a new analysis be carried out specifically for this fishery, which is the second largest tarakihi fishery in New Zealand. The second objective in this study was to derive a CPUE index specific to the Pegasus Bay/Cook Strait area (denoted as Pegasus Bay/Cook Strait fishery for the remainder of this report), which could be used to monitor this fishery on an ongoing basis.

This report fulfils objectives 1 and 2 of the Ministry of Fisheries research contract TAR2002/01 to (1) update the TAR 2 standardised CPUE analyses in 2003 by the inclusion of data up to the end of the 2001–02 fishing year, and (2) develop an index of relative abundance for the Pegasus Bay/Cook Strait area fishery.

2. METHODS

2.1 The data and variables available for analysis

The data comprised commercial catch and effort data, where tarakihi was caught and/or targeted in TAR 1, 2, 3, and 7 from the 1989–90 to the 2001–02 fishing years. The data were extracted from the Ministry of Fisheries catch and effort database in March 2003.

Both Trawl Catch Processing Returns (TCEPR) and Catch Effort Landing Returns (CELR) records are included. Only 18% of the estimated catch for TAR 2 and 9% of the estimated catch for Pegasus Bay/Cook Strait catch were listed on TCEPR records, resulting in insufficient records to allow an analysis of the TCEPR data by themselves. To make the TCEPR and CELR records comparable, the TCEPR catch data were summed over trawls for a given vessel for each day, and the mean was calculated for variables such as *wingspread* and *headline height*. This produced a single record that had the total catch, total hours spent fishing (as calculated by subtracting the start time from the end time for each trawl in the TCEPR form), and the number of trawls per vessel per day.

Table 1 describes the variables available (including those derived) and their description from the combined TCEPR and CELR records. *Target species* was a categorical variable based on five main target fisheries where tarakihi were an important catch in the TAR 2 fishery., The categories were tarakihi, snapper, hoki, gemfish, barracouta, and other. For the Pegasus Bay/Cook Strait fishery, the categories were tarakihi, barracouta, flatfish, hoki, red cod, warehou, and other.

Statistical area was categorised by statistical area, but Statistical Areas 201–205 in TAR 2 were combined into an "other" category as the catch and effort from these areas were minimal. Pegasus Bay/Cook Strait fishery consisted of Statistical Areas 017–021 for the descriptive analysis, but Statistical Areas 019 & 021 were removed in the CPUE analysis, because there was almost no catch.

Table 1: Description of variables used in the descriptive and CPUE analyses. (*, derived variables).

Variable	Type	Description
Year	Categorical	Fishing year (October–September the following year)
Vessel	Categorical	Unique vessel identification number
Length	Continuous	Vessel length (m)
Power	Continuous	Vessel power (kw)
Tonnage	Continuous	Vessel tonnage (t)
Headline	*Continuous*	*Net headline height (m)*
Wingspread	Continuous	Net wingspread (m)
Net length	Continuous	Length of net (m) for the setnet fishery
Start date	Continuous	Date at the start of fishing
Fishing method	Categorical	Method fishing
Target species	Categorical	Species of fish targeted
Statistical area	Categorical	Statistical area where fishing occurred
Total catch	Continuous	Estimated catch in tonnes of target and bycatch species
Tarakihi catch	Continuous	Estimated catch in tonnes of tarakihi for days fishing
*Tow duration**	Continuous	Duration (h) of all tows for the day
*Fishing day**	Continuous	Number of days since the start of the fishing year
*Month**	Continuous	Month of the year
*SOI**	Continuous	Southern oscillation index
*Vessel experience**	Continuous	Number of years the vessel has been operating in the fishery
*CPUE**	Continuous	Catch-per-unit-effort (catch per day)

2.2 Data checking and validation

Catch and effort data often contain many errors, most in the form of missing values, invalid codes, or implausible values. Data for all areas were checked for such errors before the analysis. Individual tow records were checked to see if the tows occurred within the area boundaries within the defined period. Tow records outside the defined boundaries or time period were deleted.

All the variables for each record were checked for valid codes and values, and all variables were range checked. Variables with invalid codes or out of range values were visually compared with records from the same vessel on or around the time and date of the tow in question. Obvious transcription errors and recording errors were corrected if possible. If no correction could be applied and the data were still considered highly improbable or had an invalid code, then the values were set to missing.

For the CPUE analysis, a number of records that were included in the descriptive analysis were removed if, for example, there were missing values for the variables listed in Table 1. This resulted in the removal of 7% of the records from the TAR 2 data set and 3% from the Pegasus Bay/Cook Strait data set.

2.3 Description of the fishery

General aspects of the TAR 2 and Pegasus Bay/Cook Strait fisheries were investigated to ensure the pattern of catch and effort were similar to those in previous years. Such changes, if any, may affect the analysis and interpretation of resulting CPUE indices from the catch effort data. These included catch and catch rates (catch per day) by statistical area, fishing method, target species, and season.

As fishers record only the top five species caught on TCEPR and CELR records, the estimated catch was compared with the reported landings for each Fishstock. For the Pegasus Bay/Cook Strait fishery this was not easy, as reported landings are recorded in QMAs 2, 3, 7, and 8, not by statistical area. An estimate of the reported landings from the Pegasus Bay/Cook Strait fishery was determined by matching trip numbers of the landing records to the TCEPR/CELR records where any tow was recorded in Statistical Areas 017–021. This method should be able to take account of any tarakihi catch not recorded on the TCEPR/CELR records. However, this method could not determine the proportion of catch from tows that recorded catch from the Pegasus Bay/Cook Strait fishery and other areas outside the fishery on the same trip.

2.4 Calculation of standardised CPUE

Estimates of relative year effects were obtained from a stepwise multiple regression method, where the data were modelled using a lognormal model (Vignaux 1994) with zero tows removed as only 3% of all vessel-days targeting tarakihi had a zero catch for TAR 2 and 2.5% for Pegasus Bay/Cook Strait.

A forward stepwise multiple regression-fitting algorithm was employed (Chambers & Hastie 1991, Venables & Ripley 1994) to determine the selected variables. The algorithm generates a final regression model iteratively. The reduction in residual deviance (denoted r^2) is calculated for each single term addition to the base model. The term that results in the greatest reduction in the residual deviance is added to the base model, where the change is more than 0.5%. The algorithm then repeats this process, updating the base model, until no more terms can be added.

Year was treated as a categorical value so that the regression coefficients of each year can vary independently. The relative year effects calculated from the regression coefficients represent the change in CPUE over time, all other effects having been taken into account. *Year* was standardised to the year with the most records. This reduces the standard error for all other years.

The stepwise algorithm also considered first order interaction terms. At each step, all first order interactions between variables selected up to that point were evaluated. As the primary interest in the model is an estimate of relative year effects, possible interactions with *year* were not evaluated. Also, to reduce model complexity, interactions with *vessel* were not considered apart from *vessel/statistical area* interactions.

Alternative stopping rules to the 0.5% change in residual deviance were briefly investigated, but are not reported here. More conservative stopping rules tended to result in models with fewer terms (first order interaction terms were not included), but little change in the estimated relative year effects were found.

Vessel effects were incorporated into the CPUE standardisation to allow for likely differences in fishing power between vessels. Vessels that were not involved in the fishery for consecutive years, or only participated for a couple of years provide little information to the standardisations (Knuckey et al. 1998) and can result in model overfitting (Francis 2001). Therefore a "core vessel" CPUE analysis was carried out using vessels that caught 80% of the total tarakihi catch and were involved in the fishery for at least 3 consecutive years. The number of tows for core vessels for each fishing year for TAR 2 and Pegasus Bay/Cook Strait bottom trawl fisheries and for all vessels for the Pegasus Bay/Cook Strait setnet fishery are given in Appendix A (Figures A1–A4).

Several changes were made to the analysis of Field & Hanchet (2001).

1. Field & Hanchet (2001) used catch-per-hour-per-day as a measure of CPUE. However, catch-per-hour-per-day does not increase linearly with tow duration (Figure 2). There were higher catch rates for short duration tows and lower catch rates for long tows, so the length of the tow in time or distance is not a relevant measure of effort. Instead we used catch per day, and offered the model the number of hours fished and the number of tows completed as explanatory variables.

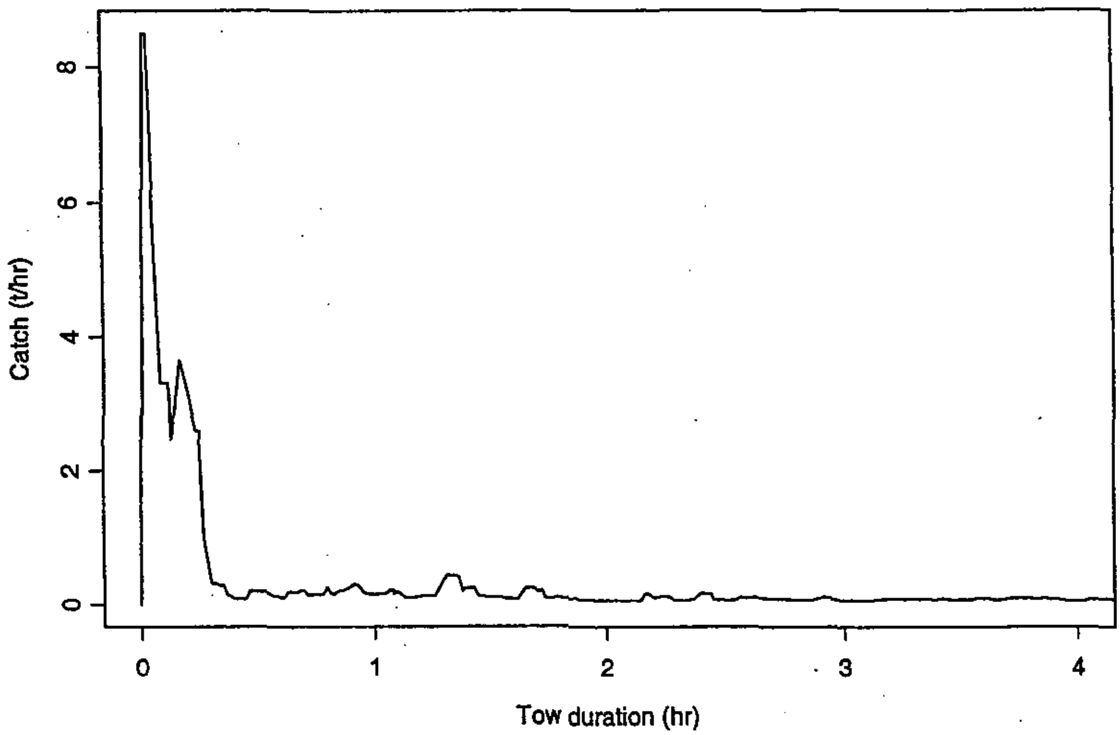

Figure 2: Relationship between tarakihi catch rate (t/h) and duration of the tow. The data have been smoothed using a kernel smoother.

2. Field & Hanchet (2001) included Statistical Area 017 in their CPUE analysis of TAR 2. For the current analysis, Statistical Area 017 was excluded from the TAR 2 analysis, but included in the Pegasus Bay/Cook Strait analysis instead.

3. The main fishery off the east coast North Island appears to be centred on East Cape, with high landings extending from Cape Kidnappers to the Bay of Plenty (Hanchet & Field 2001). Although the Bay of Plenty is part of TAR 1, it appears to be a natural continuation of the main fishing ground from East Cape. A sensitivity analysis of TAR 2 was completed in which data from the Bay of Plenty fishery (Statistical Areas 009 and 010) were included with the TAR 2 data.

In summary, the following indices were estimated and compared.

- TAR 2 fishery
  - lognormal model of catch rates for all vessels
  - lognormal model of catch rates for core vessels

- TAR 2 fishery plus Statistical Areas 009 & 010
  - lognormal model of catch rates for all vessels
  - lognormal model of catch rates for core vessels

- Pegasus Bay/Cook Strait bottom trawl fishery
  - lognormal model of catch rates for all vessels
  - lognormal model of catch rates for core vessels

- Pegasus Bay/Cook Strait bottom setnet fishery
  - lognormal model of catch rates for all vessels

3. RESULTS

3.1 TAR 2 descriptive analysis

The TAR 2 fishery, on the east coast of the North Island between Cape Runaway and Cook Strait, is the largest in New Zealand, and landings have averaged about 1600 t since 1989–90. Estimated catches have fluctuated between 1100 and 1600 t since 1989–90 (Table 2). Eighty-eight percent (range 82–93%) of the estimated catch reported from TCEPR and CELR forms account for the QMR landings. Eighty-two percent of the estimated catch has been recorded on CELR forms, but there has been an increasing amount recorded on TCEPR forms.

Table 2: Annual tarakihi catch (t) reported from the TAR 2 fishery from CELR, TCEPR, and Quota Management Returns (QMR) landings (Annala et al. 2002). The estimated catch from the TCEPRs is also presented as a percentage of the total estimated catch and the estimated catch from both the TCEPR and CELR records are presented as a percentage of the total QMR landings. All values are rounded to the nearest tonne. (Note, the estimated catches from CELR and TCEPR records exclude Statistical Areas 017, 009 & 010.)

	CELR	TCEPR	Total	QMR landings	% TCEPR	% QMR
1989–90	1 150	7	1 157	1 374	1	84
1990–91	1 496	111	1 607	1 729	7	93
1991–92	1 446	89	1 535	1 700	6	90
1992–93	1 433	83	1 516	1 654	5	92
1993–94	1 152	172	1 324	1 594	13	83
1994–95	1 124	222	1 346	1 580	16	85
1995–96	891	448	1 339	1 551	33	86
1996–97	1 008	335	1 343	1 639	25	82
1997–98	1 120	336	1 456	1 678	23	87
1998–99	1 083	365	1 448	1 594	25	91
1999–00	1 258	294	1 552	1 741	19	89
2000–01	1 117	373	1 490	1 658	25	90
2001–02	1 042	520	1 562	1 733	33	90
Total	15 320	3 355	18 675	21 225	18	88

Bottom trawling was the major method used (95% of vessel days for TAR 2 and 75% for Statistical areas 009 & 010) and fluctuated between 1800 and 3000 vessel days per year for TAR 2 with no obvious trend, and 700–1300 vessel days for Statistical Areas 009 & 010, again with no obvious trend (Table 3). Bottom trawling accounted for 99% of the tarakihi catch for TAR 2 and 92% in Statistical Areas 009 & 010 (Table 4). Tarakihi catch has also fluctuated between 1300 and 1600 t for TAR 2 and 300 and 600 t for Statistical Areas 009 & 010, both with no obvious trend. There is no obvious trend in the unstandardised CPUE index for TAR 2, which fluctuated between 0.46 and 0.59 t per vessel-day (Table 5).

Table 3: Summary of effort (vessel-days caught and or targeted tarakihi) in TAR 2 (excluding Statistical Area 017) and for Statistical Areas 009 and 010 by fishing method from 1989–90 to 2001–02. BT, bottom trawl; SN, set net; DS, danish seine; BLL, bottom long line; "OTH" includes all other methods and unknown methods.

	TAR2					Statistical Areas 009 & 010				
Fishing year	BT	SN	DS	BLL	OTH	BT	SN	DS	BLL	OTH
1989–90	1 873	89	0	0	0	666	190	0	0	14
1990–91	2 541	95	0	0	1	1 111	235	0	0	4
1991–92	2 972	127	0	0	3	1 276	451	0	0	1
1992–93	2 714	148	0	0	3	1 192	718	0	0	6
1993–94	2 588	181	0	0	4	1 090	500	0	0	4
1994–95	2 671	135	0	10	12	1 124	389	8	0	3
1995–96	2 433	122	17	15	48	894	341	24	15	5
1996–97	2 676	124	14	17	10	968	419	30	8	0
1997–98	2 480	85	6	15	6	848	216	53	0	7
1998–99	2 624	42	9	20	7	960	129	57	10	4
1999–00	2 464	52	17	19	10	723	58	47	4	1
2000–01	2 572	97	48	29	6	908	32	19	24	5
2001–02	2 640	89	18	26	12	1 032	31	76	7	21
Total	33 248	1 386	129	151	122	12 792	3 709	314	68	75
% of total	95	4	<1	<1	<1	75	22	2	<1	<1

Table 4: Summary of estimated catches (t) from TCEPR and CELR records in TAR 2 (excluding Statistical Area 017) and for Statistical Areas 009 and 010 by fishing method from 1989–90 to 2001–02. BT, bottom trawl; SN, set net; DS, danish seine; BLL, bottom long line; OTH, all other and unknown methods. All catches have been rounded to the nearest tonne; 0, catches less than 500 kg; – no catch.

	TAR 2					Statistical areas 009 & 010				
Fishing year	BT	SN	DS	BLL	OTH	BT	SN	DS	BLL	OTH
1989–90	1 153	5	–	–	–	225	10	–	–	0
1990–91	1 605	3	–	–	0	449	18	–	–	0
1991–92	1 529	7	–	–	0	428	59	–	–	0
1992–93	1 506	11	–	–	0	486	92	–	–	1
1993–94	1 303	20	–	–	1	525	73	–	–	0
1994–95	1 337	7	–	1	0	440	59	0	–	0
1995–96	1 296	8	8	1	26	421	28	6	0	0
1996–97	1 332	8	2	0	0	406	34	2	0	1
1997–98	1 448	5	2	0	0	433	14	10	–	0
1998–99	1 443	1	4	0	0	399	10	17	0	1
1999–00	1 537	1	9	0	3	297	3	18	0	0
2000–01	1 455	3	24	1	5	498	1	7	0	0
2001–02	1 547	4	9	0	1	609	1	12	0	0
Total	18 491	83	58	3	36	5 616	402	72	1	3
% of total	99	<1	<1	<1	<1	92	7	1	0	0

Table 5: Comparison of unstandardised CPUE (catch (t) per vessel day) of tarakihi by fishing method in TAR 2 (includes statistical areas 009 and 010 and excluding Statistical Area 017) from 1989–90 to 2001–02. –, no catch.

Fishing year	Bottom Trawl	Set net	Danish seine	Bottom long-line	Other
1989–90	0.54	0.05	–	–	0.54
1990–91	0.56	0.06	–	–	0.56
1991–92	0.46	0.11	–	–	0.46
1992–93	0.51	0.12	–	–	0.51
1993–94	0.50	0.14	–	–	0.50
1994–95	0.47	0.13	0.03	0.09	0.47
1995–96	0.52	0.08	0.34	0.06	0.52
1996–97	0.48	0.08	0.11	0.02	0.48
1997–98	0.57	0.07	0.21	0.02	0.57
1998–99	0.51	0.06	0.32	0.02	0.51
1999–00	0.58	0.04	0.42	0.02	0.58
2000–01	0.56	0.03	0.47	0.03	0.56
2001–02	0.59	0.04	0.22	0.02	0.59

Catches of tarakihi for the bottom trawl fishery by statistical area are given in Table 6. About 60% of the tarakihi catch came from Statistical Areas 011–014, between Cape Runaway and Cape

Kidnappers. Substantial catches were also taken from Bay of Plenty (Areas 009 & 010) and Cape Kidnappers to Cook Strait (Areas 014–016).

Unstandardised CPUE indices appeared stable in the main statistical areas apart from a moderate increase in Areas 009, 010, 014, and 015 in the last 2–3 years (Table 7).

Table 6: Summary of estimated catch (t) of tarakihi for the bottom trawl fishery by statistical areas in TAR 2 (plus Statistical areas 009 and 010 and excluding Statistical Area 017) from 1989–90 to 2001–02. All catches have been rounded to the nearest tonne; 0, catch less than 500 kg; –, no catch.

	Statistical Area													
Fishing year	009	010	011	012	013	014	015	016	201	202	203	204	205	Total
1989–90	95	130	175	280	386	106	106	99	–	–	–	–	–	1 377
1990–91	200	249	236	484	560	124	117	82	1	–	–	0	0	2 053
1991–92	180	247	299	274	570	172	43	171	–	0	–	0	–	1 956
1992–93	238	248	290	418	461	198	42	96	–	–	–	–	–	1 991
1993–94	195	330	314	355	327	187	36	84	–	–	–	0	–	1 828
1994–95	208	231	252	468	318	174	31	94	0	–	–	–	–	1 776
1995–96	192	229	271	455	269	153	43	105	0	–	–	0	–	1 717
1996–97	201	205	222	383	468	145	41	71	–	–	–	1	–	1 737
1997–98	283	150	237	490	446	140	74	58	1	0	–	1	–	1 880
1998–99	216	182	284	269	581	176	63	71	0	–	0	–	–	1 842
1999–00	158	139	242	419	562	192	47	72	0	–	0	3	–	1 834
2000–01	238	259	208	350	554	198	63	82	–	–	–	0	0	1 952
2001–02	353	256	204	362	647	179	74	81	–	–	–	0	–	2 156
% of total	11	12	13	21	26	9	3	5	0	0	0	0	0	

Table 7: Comparison of unstandardised CPUE (catch (t) per vessel day) of tarakihi for the bottom trawl fishery by statistical area for successful vessel-days that targeted tarakihi from 1989–90 to 2001–02; –, no catch.

	Statistical Area													
Fishing year	009	010	011	012	013	014	015	016	201	202	203	204	205	Total
1989–90	0.47	0.68	1.20	1.00	0.80	0.48	0.86	0.48	–	–	–	–	–	0.47
1990–91	0.54	0.69	1.00	1.20	0.78	0.49	0.62	0.38	0.60	–	–	0.26	–	0.54
1991–92	0.34	0.68	0.94	0.97	0.65	0.50	0.47	0.55	–	0.15	–	–	–	0.34
1992–93	0.55	0.65	1.30	1.30	0.73	0.45	0.57	0.45	–	–	–	–	–	0.55
1993–94	0.48	0.81	1.10	1.10	0.57	0.39	0.42	0.37	–	–	–	0.12	–	0.48
1994–95	0.45	0.65	0.96	1.00	0.62	0.37	0.37	0.36	–	–	–	–	–	0.45
1995–96	0.57	0.79	0.94	1.10	0.60	0.47	0.50	0.45	0.09	–	–	–	–	0.57
1996–97	0.47	0.89	1.20	1.10	0.67	0.38	0.80	0.24	–	–	–	1.00	–	0.47
1997–98	0.65	0.77	1.10	1.30	0.77	0.46	0.71	0.27	0.30	–	–	0.20	–	0.65
1998–99	0.45	0.79	1.30	0.86	0.74	0.50	0.72	0.30	0.20	–	–	–	–	0.45
1999–00	0.43	0.71	1.50	1.20	0.73	0.63	1.10	0.24	–	–	–	0.54	–	0.43
2000–01	0.75	1.10	1.40	0.95	0.67	0.54	1.10	0.37	–	–	–	–	–	0.75
2001–02	0.78	1.10	1.30	0.96	0.84	0.75	0.97	0.45	–	–	–	–	–	0.78

Catches of tarakihi in the bottom trawl fishery are given by main target species in Table 8. About 80% of the catch since 1989–90 has been taken from tows targeting tarakihi for TAR 2 and 78% for

Statistical Areas 009 & 010. Tows targeting gemfish accounted for another 5% of the tarakihi catch and tows targeting hoki and barracouta accounted for a further 2.5%.

Table 8: Summary of estimated catch (t) of tarakihi for the bottom trawl fishery by target species in TAR 2 (excluding Statistical Area 017) and Statistical areas 009 and 010 from 1989–90 to 2001–02. All catches were rounded to the nearest tonne; 0, catches less than 500 kg; –, indicates no catch. Also presented is the percentage of total tarakihi catch when tarakihi is the target species.

							TAR 2
	Tarakihi	Snapper	Hoki	Gemfish	Barracouta	Other	% tarakihi
1989–90	1 057	3	9	27	23	26	92
1990–91	1 462	3	5	37	27	42	91
1991–92	1 289	1	6	73	19	70	84
1992–93	1 251	13	7	88	30	74	83
1993–94	1 059	23	40	44	54	74	81
1994–95	1 128	14	31	62	18	62	84
1995–96	1 001	21	54	112	27	63	77
1996–97	951	12	72	97	46	67	72
1997–98	1 098	16	99	91	22	52	76
1998–99	1 209	23	15	55	28	62	84
1999–00	1 183	16	20	102	35	74	77
2000–01	1 098	18	14	57	28	96	75
2001–02	1 200	14	13	69	15	90	78
						Statistical Areas 009 & 010	
1989–90	155	44	–	15	3	52	69
1990–91	373	31	–	31	9	34	83
1991–92	330	32	2	42	12	38	77
1992–93	406	20	10	24	10	31	84
1993–94	464	23	3	15	4	33	88
1994–95	365	15	11	14	19	26	83
1995–96	341	38	9	20	4	46	81
1996–97	328	14	24	22	3	22	81
1997–98	318	21	43	11	13	42	73
1998–99	311	18	25	7	12	43	78
1999–00	239	11	11	10	3	30	81
2000–01	350	17	7	5	18	114	70
2001–02	453	40	2	11	18	115	74

Vessel and fishing characteristics for bottom trawl vessels between 1989–90 and 2001–02 are presented in Figure 3. Vessel length decreased from a mean of about 17.5 m to less than 14 m. Vessel power has remained reasonably consistent.

The recorded *headline height* increased from a mean of about 4 m in 1989–90 to 9 m in 1998–99 and has remained constant at about 9 m since. The mean *wingspread* remained relatively constant at about 20 m, but there is some variability. This could be because of errors in recording wingspread, (i.e., recording the distance between the doors). A small proportion of tows was also made using midwater trawls over the last four years.

Recoded mean *tow duration* decreased slightly over the last 10 years from 9 h to 7.5 h. The recorded mean *number of tows* per day was relatively constant at two from 1989–90 to 2000–01, but dropped sharply to just over 1 in 2001–02.

The mean recorded catch per day has remained constant at about 500 kg over the last 13 years.

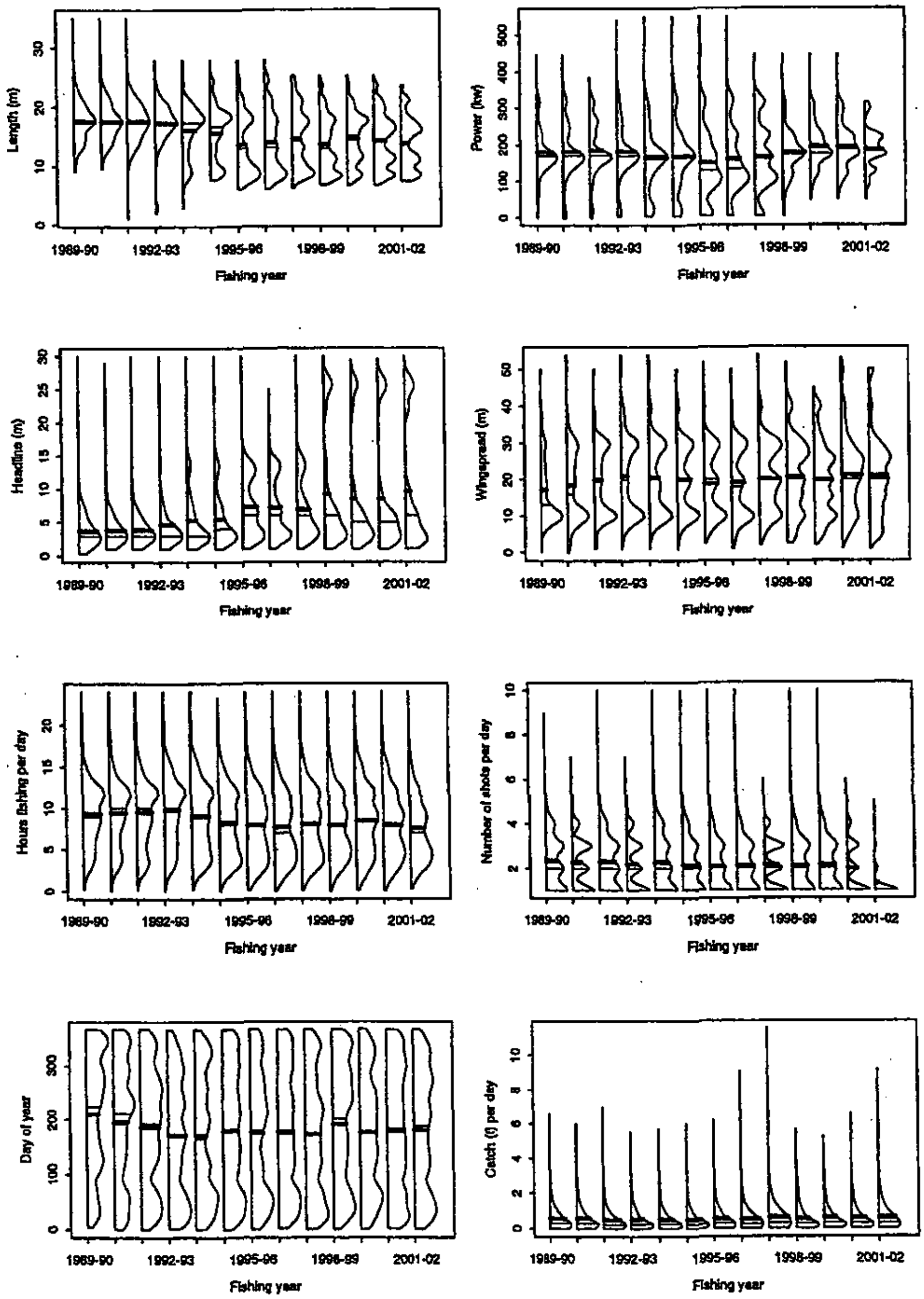

Figure 3: Distribution plots of vessel and fishing characteristics for all bottom trawl vessels in TAR 2 and Statistical Areas 009 & 010. Thick horizontal bars indicate the mean and thin horizontal lines indicate the median.

3.2 TAR 2 CPUE analysis

A total of 179 vessels fished in TAR 2 from 1989–90 to 2001–02 and caught 17 558 t of tarakihi (Table 9). This resulted in about 30 435 records used in the analysis for all vessels data set. Restricting the data to core vessels resulted in a 29% reduction in records to 21 588 records and a 17% reduction in tarakihi catch to 14 566 t (30 unique vessels).

When Statistical Areas 009 & 010 were included in the all vessels data set, the number of records increased to 42 605. For core vessels, an extra 7836 records were included, which resulted in 36 vessels catching 19 211 t of tarakihi.

Table 9: Summary of data used in the final standardised CPUE analysis for TAR 2 by vessel selection, and statistical area. Records, the number of accepted records; Catch, estimated catch (t) from accepted records; Vessel, number of unique vessels from accepted records. The total in the Vessel column indicates the number of unique vessel contributing to the accepted records for all years combined. The totals in the catch columns may not add up to those presented in Section 3.1, as these are accepted records. See methods for explanation.

	Excludes Statistical Areas 009 & 010					
	All vessels			Core vessels		
	Records	Catch	Vessels	Records	Catch	Vessels
1989–90	1 795	1 152	57	1 213	922	21
1990–91	2 440	1 604	69	1 724	1 343	23
1991–92	2 902	1 529	68	1 861	1 202	23
1992–93	2 650	1 505	65	1 763	1 261	26
1993–94	2 532	1 303	69	1 645	1 040	24
1994–95	2 578	1 336	74	1 613	1 052	25
1995–96	2 371	1 295	73	1 673	1 071	25
1996–97	2 579	1 325	67	1 785	1 090	23
1997–98	2 382	1 446	61	1 766	1 219	24
1998–99	1 968	1 188	55	1 773	1 149	23
1999–00	1 541	1 024	47	1 529	1 165	19
2000–01	2 110	1 304	52	1 637	1 048	19
2001–02	2 587	1 547	49	1 606	1 004	17
Total	30 435	17 558	179	21 588	14 566	30

	Includes Statistical Areas 009 & 010					
	All vessels			Core vessels		
	Records	Catch	Vessels	Records	Catch	Vessels
1989–90	2 434	1 376	80	1 500	1 051	28
1990–91	3 524	2 053	89	2 204	1 623	29
1991–92	4 077	1 956	96	2 276	1 413	32
1992–93	3 816	1 991	88	2 334	1 576	33
1993–94	3 594	1 827	91	2 385	1 407	33
1994–95	3 659	1 776	88	2 459	1 438	29
1995–96	3 243	1 716	91	2 241	1 374	30
1996–97	3 481	1 728	89	2 171	1 349	28
1997–98	3 205	1 879	82	2 243	1 500	30
1998–99	2 797	1 474	66	2 469	1 560	29
1999–00	2 177	1 250	56	2 062	1 490	24
2000–01	2 989	1 785	64	2 403	1 609	25
2001–02	3 609	2 156	61	2 677	1 821	24
Total	42 605	22 967	200	29 424	19 211	36

The predictor variables selected by the stepwise regression model are given in Table 10. For the core vessels data set, five variables were selected with a total r^2 of about 48%. Six variables and three interaction terms were selected for the all vessels data set with a total r^2 of 46%. With the inclusion of Statistical Areas 009 & 010, there was a slight increase in the r^2 for the core vessels, but there was a slight decrease when using all vessels. For each of the model runs, the variables *duration, target species, statistical area, fishing year,* and either *vessel* (for core vessels data set) or *vessel length* (for the all vessels data set) were selected.

Table 10: Selected variables and the percentage of deviance explained (r^2) from the stepwise multiple regression algorithm for TAR 2 by vessel selection, and statistical area.

Excludes Statistical Areas 009 & 010			
Core vessels		All vessels	
Selected variable	r^2	Selected variable	r^2
Vessel	19.67	*Target species*	22.85
Duration	35.55	*Duration*	33.98
Target species	45.97	*Statistical area*	38.50
Statistical area	47.25	*Vessel length*	41.03
Fishing year	47.85	*Target species:Vessel length*	42.90
		Target species:Statistical area	44.02
		Fishing year	44.90
		Statistical area:Vessel length	45.72
		Experience	46.40

Includes Statistical Areas 009 & 010			
Core vessels		All vessels	
Selected variable	r^2	Selected variable	r^2
Duration	20.62	*Target species*	22.08
Target species	33.38	*Duration*	34.32
Vessel	42.98	*Statistical area*	38.09
Statistical area	44.48	*Vessel length*	38.71
Fishing year	45.37	*Experience*	39.91
Month	46.02	*Target species:Statistical area*	41.11
Month:Statistical area	47.80	*Fishing year*	42.38
Target species:Month	48.32		

The standardised indices are shown in Figure 4 and are listed in Appendix B, (Table B1). All models showed similar trends, with declines from 1989–90 to 1991–92 followed by a gradual increase. The indices for the core vessels, excluding Statistical Areas 009 & 010 appeared flatter, but this is a result of the base year being the 2001–02 fishing year

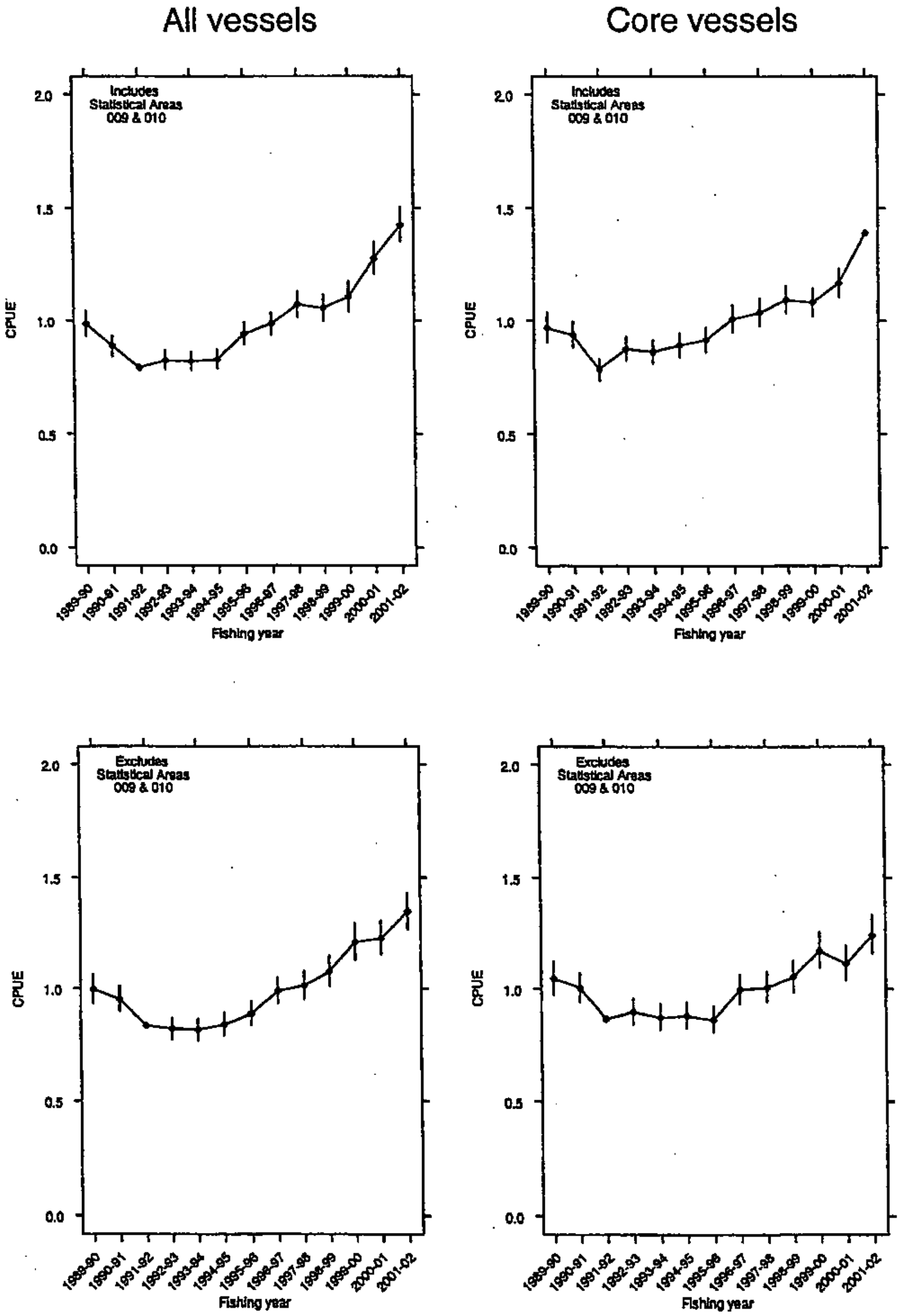

Figure 4: Relative year effects and approximate 95% confidence intervals for TAR 2 by vessel selection and statistical area. Top left, all vessels including Statistical Areas 009 & 010; top right, core vessels including Statistical Areas 009 & 010; bottom left, all vessels excluding Statistical Areas 009 & 010; bottom right, core vessels excluding Statistical Areas 009 & 010.

The effects of the selected variables for the different models are shown in Figures 5–8. The comparison of the *vessel* coefficients suggested that the relative fishing power of the different vessels was broadly similar for the core vessels with expected catch rates ranging between 100 to 450 kg per day (Figures 5 & 7).

For the all vessels data sets, there appear to be high catch rates for smaller vessels (Figure 6), but from Figure 3 there were only a few vessels under 10 m involved in the fishery. These vessels lasted only for 2–3 years. .

All models included a variable that aliases the location of the tow (*statistical area*) and targeted species (*target species*). There were higher catch rates for vessels that targeted tarakihi and fished in Statistical Areas 011 & 012 (Figures 5–8). The tow *duration* was included in all models, and showed higher expected catch rates for longer tow durations (Figures 5–8).

Vessel *experience* was significant for the all vessel models, and as expected there was a higher catch rate with greater experience (Figures 6 and 8).

The diagnostics indicate a reasonable pattern in the residuals, but the Q-Q plots indicate a deviation from the normal distribution of the residuals at the lower end, suggesting that very small values of catch rate are not well predicted (Appendix B, Figures B2–B5). This suggests that the models can be improved, and there may be violations of model assumptions.

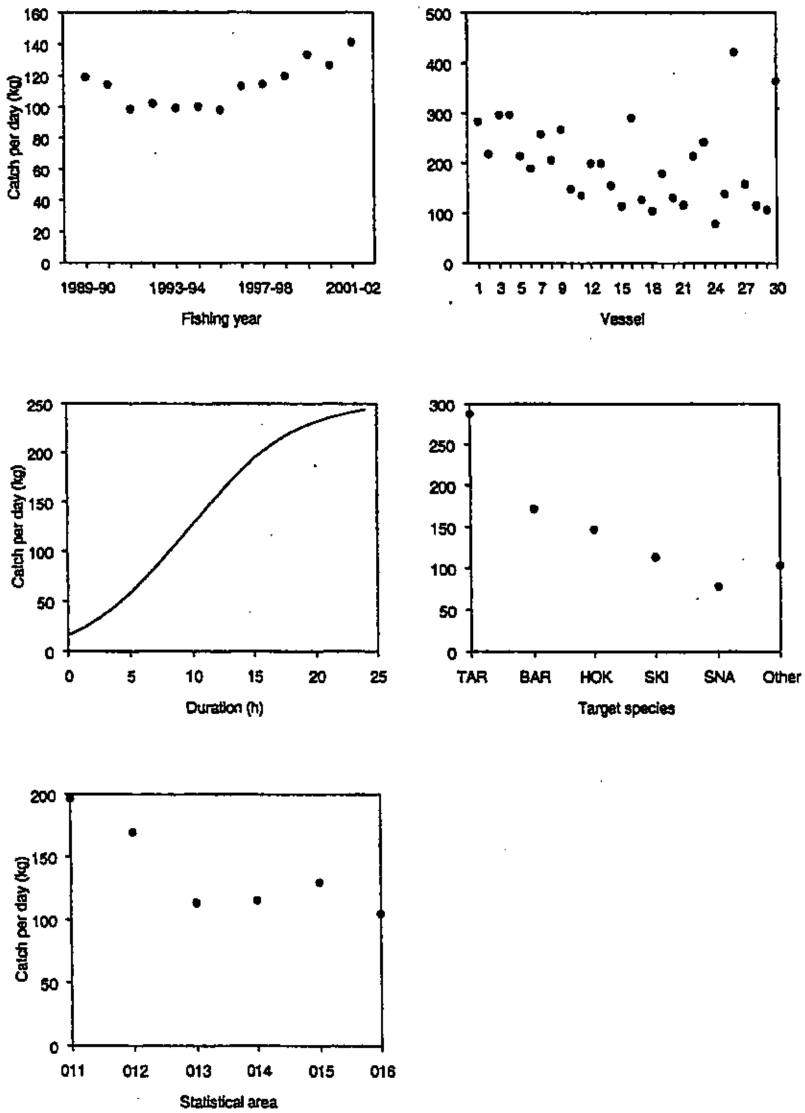

Figure 5: Expected catch rates (kg per day) for median values of fixed parameters for the TAR 2 fishery, core vessels.

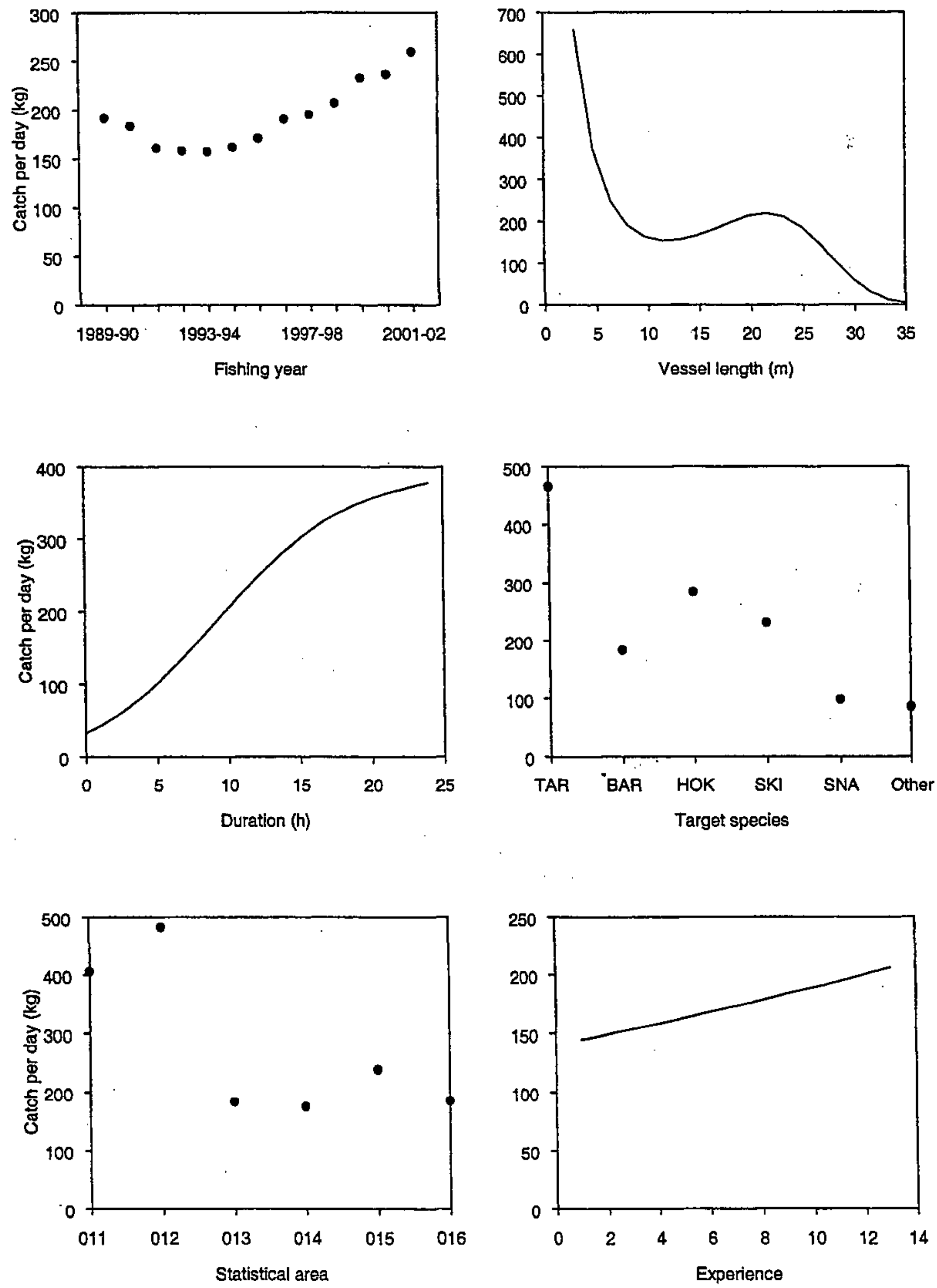

Figure 6: Expected catch rates (kg per day) for median values of fixed parameters for the TAR 2 fishery, all vessels.

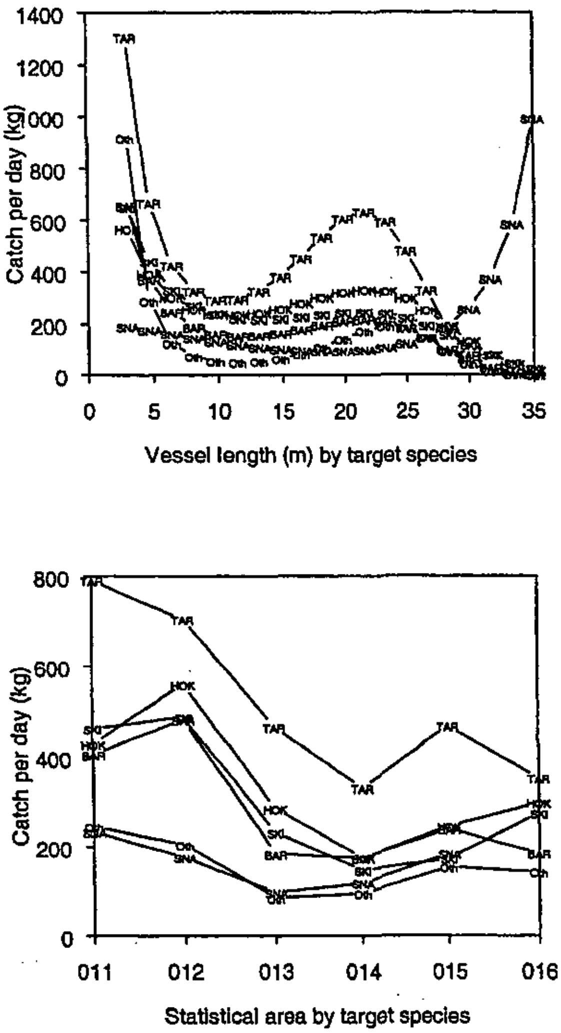

Figure 6: ***Continued.***

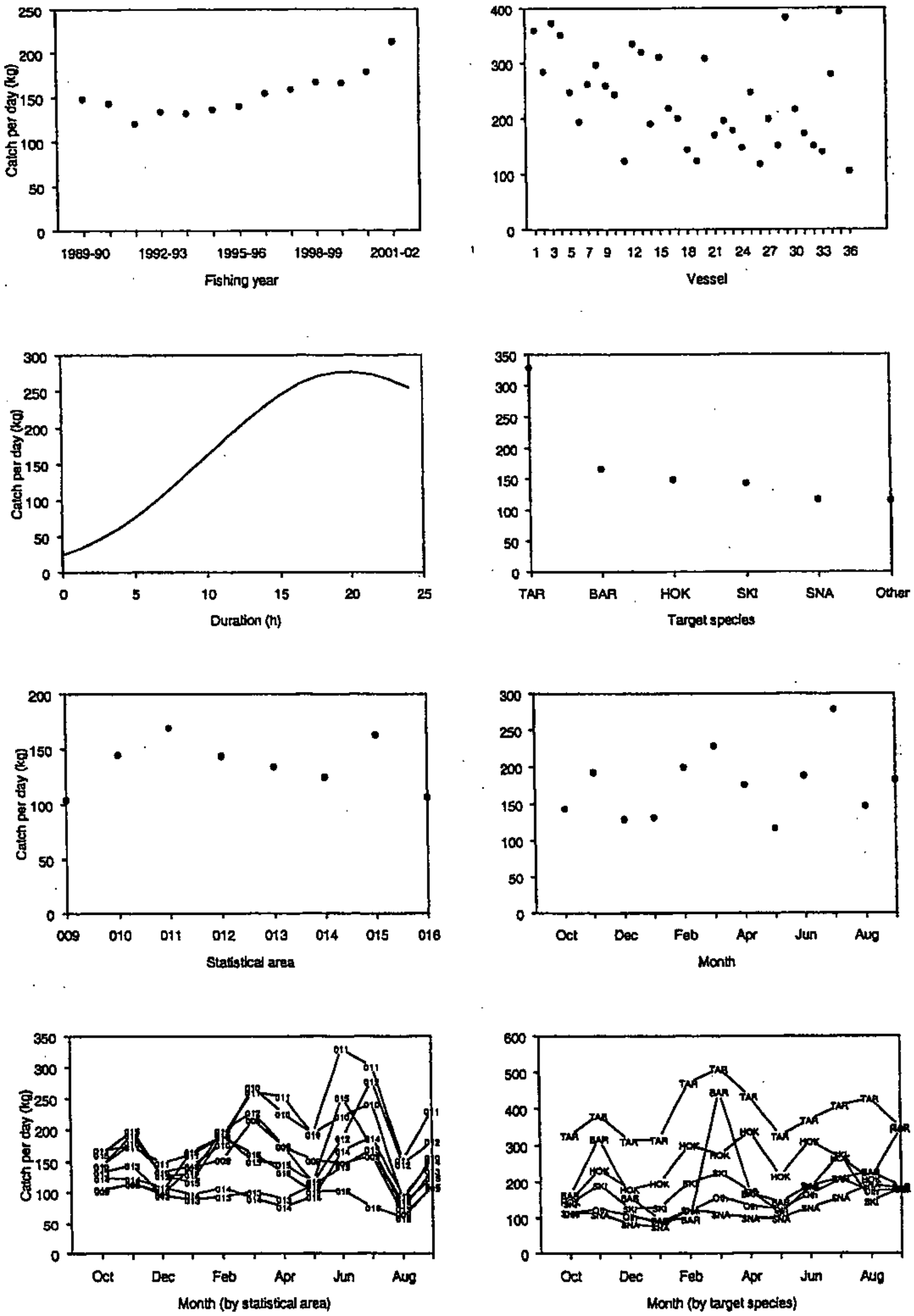

Figure 7: Expected catch rates (kg per day) for median values of fixed parameters for the TAR 2 and Statistical Areas 009 & 010 fishery, core vessels.

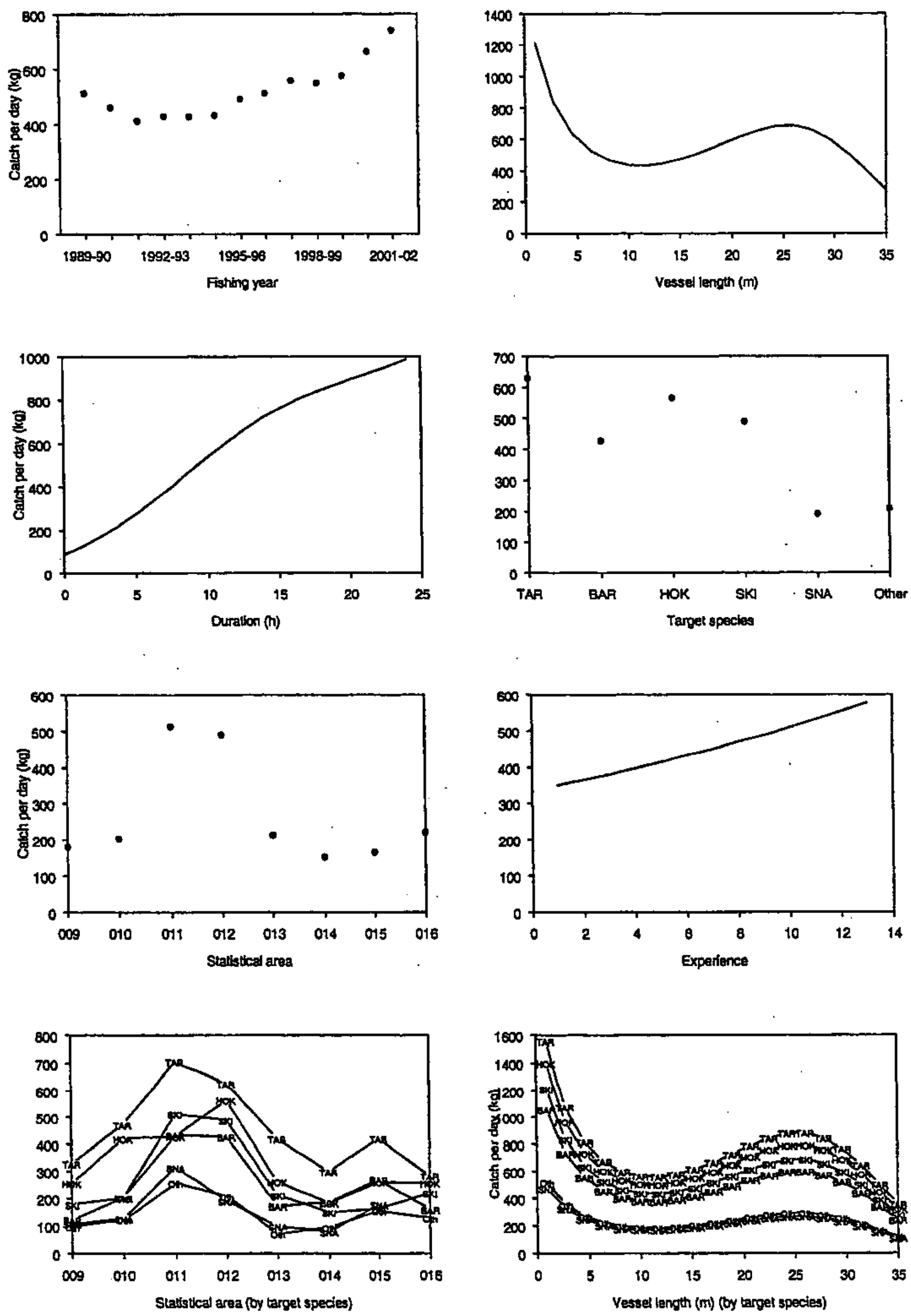

Figure 8: Expected catch rates (kg per day) for median values of fixed parameters for the TAR 2 and Statistical areas 009 & 010 fishery, all vessels.

3.3 Pegasus Bay/Cook Strait descriptive analysis

The Pegasus Bay/Cook Strait fishery consists of Statistical Areas 017–021 and extends from Cook Strait to Banks Peninsula on the east coast of the South Island. Landed catches increased over the time period from about 800 t to 1500 t (Table 11). Seventy-four percent (range 67–78%) of the estimated catch reported from TCEPR and CELR records account for the landed catch that had a matching tow from Statistical Areas 017–021. Estimated catches reported on TCEPR forms fluctuated between 5 and 17%, but there has been no consistent trend.

Table 11: Annual tarakihi catch (t) reported from the Pegasus Bay/Cook Strait fishery from TCEPR, CELR, and the landed catch from vessels that fished in Pegasus Bay/Cook Strait. The estimated catch from the TCEPRs is also presented as a percentage of the total estimated catch and the estimated catch from both the TCEPR and CELR records is presented as a percentage of the landed catch from vessels that fished in Pegasus Bay/Cook Strait. All values are rounded to the nearest tonne.

	CELR	TCEPR	Total	Landings	% TCEPR	% Landed
1989–90	498	51	549	816	9	67
1990–91	540	87	627	953	14	66
1991–92	678	111	789	1 012	14	78
1992–93	657	85	742	950	11	78
1993–94	567	47	614	836	8	73
1994–95	855	47	902	1 198	5	75
1995–96	716	100	816	1 160	12	70
1996–97	693	141	834	1 320	17	63
1997–98	745	51	796	1 056	6	75
1998–99	803	40	843	1 076	5	78
1999–00	811	82	893	1 160	9	77
2000–01	1093	75	1 168	1 516	6	77
2001–02	1001	135	1 136	1 508	12	75
Total	9657	1 052	10 709	14 561	10	74

Bottom trawling was the major method used (56% vessel days) (Table 12) and accounted for 69% of the tarakihi catch (Table 13). In the bottom trawl fishery, effort fluctuated between 1038 to 1410 vessel days per year with a flat trend. Catch was relatively constant, but increased in the last two years. Unstandardised CPUE indices increased over the time period, and fluctuated between 0.33 and 0.63 t per vessel-day (Table 14).

Set netting is also a significant method of fishing for tarakihi (43% of effort and 31% of catch). Effort ranged from 659 to 1126 vessel days per year and there was a decreasing trend from 1991–92 to 2001–02 (see Table 12). Tarakihi catch ranged from about 142 to 369 t per year, but is highly variable (see Table 13). Unstandardised CPUE varied from 0.18 to 0.53 t per day and remained relatively flat from 1989–90 to 1999–2000, followed by an increased in the two years (Table 14).

Table 12: Summary of effort (vessel-days when tarakihi was caught and or targeted) in the Pegasus Bay/Cook Strait fishery by fishing method from 1989–90 to 2001–02.

Fishing year	Bottom trawl	Set net	Other
1989–90	1 038	804	0
1990–91	1 165	943	3
1991–92	1 149	1 126	0
1992–93	1 073	1 090	3
1993–94	1 087	995	3
1994–95	1 353	1 053	15
1995–96	1 161	822	62
1996–97	1 308	782	27
1997–98	1 077	985	30
1998–99	1 061	659	34
1999–00	1 066	726	37
2000–01	1 410	842	28
2001–02	1 222	700	7
Total	15 170	11 527	249
% of total	56	43	1

Table 13: Summary of estimated catches (t) of tarakihi in Pegasus Bay/Cook Strait fishery by fishing method. All values were rounded to the nearest tonne.

Fishing year	Bottom trawl	Setnet	Other
1989–90	407	142	0
1990–91	389	239	0
1991–92	471	317	0
1992–93	422	320	0
1993–94	415	199	0
1994–95	594	306	1
1995–96	585	224	6
1996–97	646	183	4
1997–98	534	261	1
1998–99	642	199	2
1999–00	662	227	2
2000–01	824	340	4
2001–02	768	369	0
Total	7359	3326	20
% of total	69	31	<1

Table 14: Comparison of unstandardised CPUE (catch (t) per vessel day) of tarakihi by fishing method in Pegasus Bay/Cook Strait fishery from 1989–90 to 2001–02.

Fishing year	Bottom trawl	Setnet	Other
1989–90	0.39	0.18	0.00
1990–91	0.33	0.25	0.03
1991–92	0.41	0.28	0.00
1992–93	0.39	0.29	0.02
1993–94	0.38	0.20	0.01
1994–95	0.44	0.29	0.07
1995–96	0.50	0.27	0.10
1996–97	0.49	0.23	0.18
1997–98	0.50	0.27	0.04
1998–99	0.61	0.30	0.07
1999–00	0.62	0.31	0.08
2000–01	0.58	0.40	0.16
2001–02	0.63	0.53	0.01

3.3.1 Bottom trawl fishery

Estimated catches of tarakihi for the bottom trawl fishery by statistical area are given in Table 15. Thirty-two percent of the tarakihi catch came from Statistical Area 017 (Cook Strait), and 66% from Statistical Areas 018 & 020 (Pegasus Bay). The catch from Statistical Area 017 has an increasing trend, while catches from Statistical Areas 018 & 020 were variable.

Table 15: Estimated catch (t) of tarakihi for the bottom trawl fishery by statistical area in Pegasus Bay/Cook Strait from 1989–90 to 2001–02. All values rounded to the nearest tonne; 0, catches less than 500 kg; –,no catch.

	Statistical area				
	017	018	019	020	021
1989–90	115	98	0	193	2
1990–91	58	185	0	144	1
1991–92	86	124	-	260	1
1992–93	100	160	-	144	17
1993–94	101	113	0	194	7
1994–95	175	231	3	180	4
1995–96	192	211	-	178	4
1996–97	220	110	-	314	2
1997–98	211	79	-	241	4
1998–99	265	105	-	272	0
1999–00	233	96	-	330	3
2000–01	307	221	-	281	15
2001–02	299	204	-	247	18
Total	2 362	1 937	3	2 978	78
% of total	32	26	0	40	1

Catches of tarakihi in the bottom trawl fishery by target species are given in Table 16. Forty percent (range 19–52%) of the annual catch since 1989–90 was from tows targeting tarakihi. Tows targeting red cod accounted for 25% of the tarakihi catch and tows targeting barracouta a further 16%. Tows targeting flatfish, hoki, warehou, and other species caught a further 2–9% of the tarakihi each.

Unstandardised CPUE indices by statistical area and target species are shown in Table 17. In most areas the indices were variable and showed no distinctive trend, apart from Statistical Area 017 which had an increasing trend since 1994–95 in all three target fisheries.

Vessel and fishing characteristics for bottom trawl vessels are given in Figure 9. Vessel length became more truncated in 1994–95. There was a decrease from a mean of about 18.5 m to less than 17.5 m. Vessel power has increased over the time period from a mean of about 150 kW to 200 kW.

The recorded *headline height* was about 6 m from 1989–90 to 1992–93, then decreased to 4 m in 1993–94, followed by a slow increase back up to 6 m in 2001–02. The mean *wingspread* remained relatively consistent at about 28 m, but there is some variability. This could be due to the definition of wingspread (i.e. distance between the doors, or the net wingspread) or again, midwater trawl gear being used on the seafloor with a collapsed headline height, and a larger *wingspread* value being recorded.

Recorded mean *tow duration* increased slightly over the period from 9 h to 10 h. The recorded mean *number of tows* has remained constant at three tows per day from 1989–90 to 2000–01.

Recorded catches per day have increased steadily over the last 13 years from a mean of 350 to 600 kg.

Table 16: Estimated catch (t) of tarakihi for the bottom trawl fishery by target species in Pegasus Bay/Cook Strait from 1989–90 to 2001–02. All values rounded to the nearest tonne.

Fishing year	Tarakihi	Red cod	Barracouta	Flat fish	Hoki	Warehou	Other species
1989–90	188	58	84	2	25	21	30
1990–91	148	70	90	4	28	22	26
1991–92	152	154	85	1	7	6	66
1992–93	144	126	60	2	22	7	60
1993–94	198	121	27	5	17	12	37
1994–95	210	150	113	7	67	10	38
1995–96	228	121	92	3	81	5	57
1996–97	256	126	119	6	75	17	48
1997–98	229	204	21	13	27	10	31
1998–99	397	75	56	67	11	10	25
1999–00	254	154	117	18	12	20	88
2000–01	252	277	188	13	4	29	62
2001–02	270	224	129	3	3	45	94
Total	2926	1860	1181	144	379	214	662
% of total	40	25	16	2	5	3	9

Table 17: **Comparison of unstandardised CPUE (catch (t) per day) of tarakihi in Pegasus Bay/Cook Strait bottom trawl fishery by statistical area for targeted tarakihi (TAR), barracouta (BAR) or red cod (RCO).**

	Target TAR					Target BAR				
Fishing year/ Statistical area	017	018	019	020	021	017	018	019	020	021
1989–90	0.56	0.52	-	0.56	0.37	0.49	0.36	-	0.28	0.34
1990–91	0.48	0.59	0.03	0.45	-	0.23	0.33	-	0.33	0.20
1991–92	0.64	0.63	-	0.48	-	0.22	0.37	-	0.31	0.20
1992–93	0.69	0.64	-	0.36	-	0.38	0.40	-	0.38	0.53
1993–94	0.47	0.49	-	0.34	-	0.23	0.36	0.04	0.33	2.00
1994–95	0.45	0.66	-	0.62	-	0.39	0.64	-	0.25	0.42
1995–96	0.81	0.84	-	0.71	1.20	0.28	0.70	-	0.39	0.50
1996–97	0.66	0.40	-	0.98	-	0.40	0.31	-	0.79	-
1997–98	0.96	0.66	-	0.66	0.68	0.20	0.28	-	0.31	-
1998–99	1.20	0.79	-	0.69	-	0.53	0.37	-	0.83	-
1999–00	1.50	0.95	-	0.79	1.50	0.70	0.49	-	0.85	-
2000–01	1.30	0.66	-	0.58	-	0.73	0.50	-	0.74	-
2001–02	1.40	0.52	-	0.83	0.62	0.52	0.63	-	0.66	-

	Target RCO				
Fishing year/ Statistical area	017	018	019	020	021
1989–90	0.12	0.34	-	0.34	0.03
1990–91	0.05	0.33	-	0.42	-
1991–92	0.06	0.37	-	0.44	-
1992–93	0.17	0.37	-	0.32	0.22
1993–94	0.09	0.19	-	0.50	-
1994–95	0.24	0.36	-	0.43	0.80
1995–96	0.36	0.80	-	0.54	0.40
1996–97	0.35	0.42	-	0.61	-
1997–98	0.29	0.24	-	0.59	0.60
1998–99	0.59	0.47	-	0.37	0.30
1999–00	0.26	0.41	-	0.60	-
2000–01	0.54	0.59	-	0.58	0.58
2001–02	0.40	0.47	-	0.64	0.63

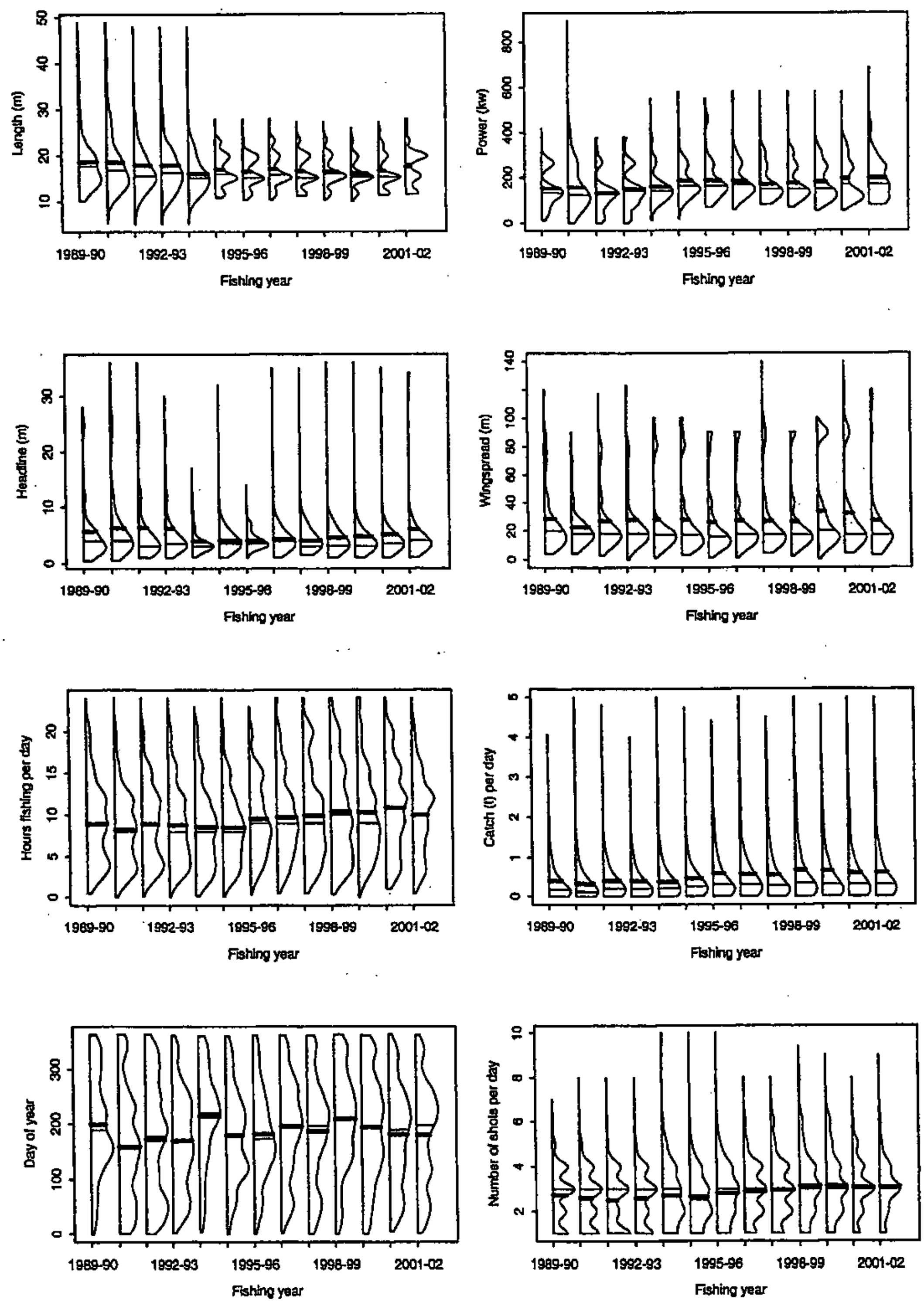

Figure 9: Distribution plots of vessel and fishing characteristics for all vessels in Pegasus Bay/Cook Strait bottom trawl fishery. Thick horizontal bars indicate the mean and thin horizontal lines indicate the median.

3.3.2 Kaikoura set net fishery

Catches by statistical area are given in Table 18. Almost all (99%) of the total catch since 1989–90 was taken from the Kaikoura coast, Statistical Area 018. Catch of tarakihi in the set net fishery are given by main target species in Table 19. Most (92%) since 1989–90 was taken from sets targeting tarakihi. Minor catches were also reported from sets targeting ling, spiny dogfish, and warehou.

Table 18: Summary of estimated catch (t) for the Kaikoura set net fishery by statistical area from 1989–90 to 2001–02.

Fishing year	017	018	019	020	021
1989–90	3	139	0	0	-
1990–91	1	236	0	0	1
1991–92	4	312	0	1	-
1992–93	2	317	-	2	-
1993–94	3	195	-	1	0
1994–95	1	305	-	0	-
1995–96	1	223	-	1	-
1996–97	1	181	0	1	-
1997–98	0	260	-	1	-
1998–99	1	198	0	1	-
1999–00	2	225	-	0	-
2000–01	0	340	-	0	0
2001–02	1	368	-	0	-
Total	20	3 299	0	8	1
% of total	<1	99	<1	<1	<1

Table 19: Summary of estimated catch (t) for the Kaikoura set net fishery by target species from 1989–90 to 2001–02.

Fishing year	Tarakihi	Ling	Spiny dogfish	Warehou	Other
1989–90	136	4	1	0	0
1990–91	232	2	1	1	3
1991–92	306	2	3	0	6
1992–93	308	1	7	-	4
1993–94	178	0	15	2	4
1994–95	273	0	29	1	4
1995–96	175	2	10	3	35
1996–97	152	1	23	4	3
1997–98	237	6	13	-	5
1998–99	195	3	0	0	1
1999–00	223	2	0	-	2
2000–01	281	21	0	0	38
2001–02	348	6	0	5	9
Total	3 044	50	102	16	114
% of total	92	2	3	0	3

3.4 Pegasus Bay/Cook Strait CPUE analysis

3.4.1 Bottom trawl fishery

From 1989–90 to 2001–02 253 bottom trawl vessels fished in the Pegasus Bay/Cook Strait fishery and caught about 7300 t of tarakihi (Table 20). This resulted in about 15 000 records used in the analysis for all vessels data set. Restricting the data to core vessels resulted in a 33% reduction in records to about 10 000 and a 21% reduction in catch to 5700 t (37 vessels).

Table 20: Summary of data used in the final standardised CPUE analysis for Pegasus Bay/Cook Strait bottom trawl fishery by vessel selection. No. records, the number of accepted records; Catch, estimated catch (t) from accepted records; No. vessels, number of unique vessels from accepted records. The total in the No. vessel column indicates the number of unique vessel contributing to the accepted records for all years combined. The catch totals may differ from those presented in the descriptive analysis as these are accepted records. See methods for explanation.

	Core vessels			All vessels		
Fishing year	No. records	Catch (t)	No. vessels	No. records	Catch (t)	No. vessels
1989–90	498	255	20	1 030	405	76
1990–91	534	238	21	1 160	388	74
1991–92	702	323	22	1 146	470	62
1992–93	732	325	24	1 044	405	58
1993–94	669	274	25	1 082	408	68
1994–95	935	473	26	1 344	587	74
1995–96	796	466	27	1 153	581	70
1996–97	971	523	28	1 304	644	79
1997–98	833	479	24	1 068	531	61
1998–99	839	579	23	1 060	642	66
1999–00	809	582	23	1 062	659	59
2000–01	1 040	690	23	1 374	809	66
2001–02	728	529	23	1 193	750	67
Total	10 086	5 735	37	15 020	7 279	253

The predictor variables selected by the stepwise regression model for the Pegasus Bay/Cook Strait bottom trawl fishery are shown in Table 21. Four variables were selected using the core vessels data set with a total r^2 of about 31%, with *Vessel* explaining 16% of the deviance. For the all vessels data set, eight variables including two interaction terms were selected with a total r^2 of 34%. *Duration* explained most of the residual deviance (13%).

Table 21: Selected variables and the percentage of deviance explained (r^2) from the stepwise multiple regression algorithm for Pegasus Bay/Cook Strait fishery by vessel selection.

Core vessels		All vessels	
Selected variable	r^2	Selected variable	r^2
Vessel	16.18	*Duration*	12.5
Duration	25.41	*Target species*	22.4
Target species	30.01	*Vessel width*	25.9
Year	31.07	*Vessel power*	29.2
		Target species:Vessel width	31.0
		Month	32.2
		Target species:Month	33.4
		Year	34.4

The standardised indices are shown in Figure 10 and are listed in Appendix C, (Table C1). Both the core vessels and all vessels have similar trends, with a gradual increase over the period. These indices show a similar pattern to the unstandardised indices apart from the first few years.

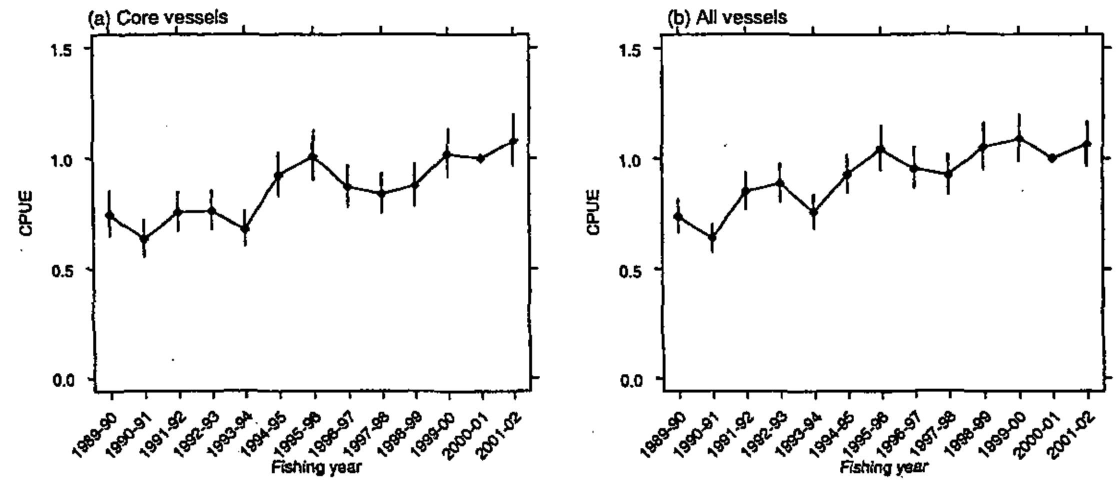

Figure 10: Relative year effects and 95% confidence intervals for Pegasus Bay/Cook Strait bottom trawl fishery.

The effects of the selected variables for the different models are shown in Figure 11 (core vessels) and Figure 12 (all vessels). Expected catch rates ranged between 100 and 600 kg per day for the core vessels. *Duration* showed similar trends for both core vessels and all vessels data sets with an increasing catch rate for a longer tow *duration*. *Target species* also showed similar trends with higher expected than catch rates for vessels targeting tarakihi.

For the all vessel data set, vessels with engines producing 350 to 600 kW and vessels with a width of 2–10 m had higher expected catch rates. Higher than expected catch rates also occurred in October to May, and were about half for the remainder of the year.

The diagnostic plots for the different models and data sets are shown in Appendix C, (Figure C1 (core vessels) and Figure C2 (all vessels)). The diagnostics for the fixed effects indicate a reasonable pattern in the residuals, but the Q-Q plots indicate a deviation from the normal distribution of the residuals at the lower end, suggesting that very small values of catch rate are not well predicted. This suggests that the models can be improved, and there may be violations of model assumptions.

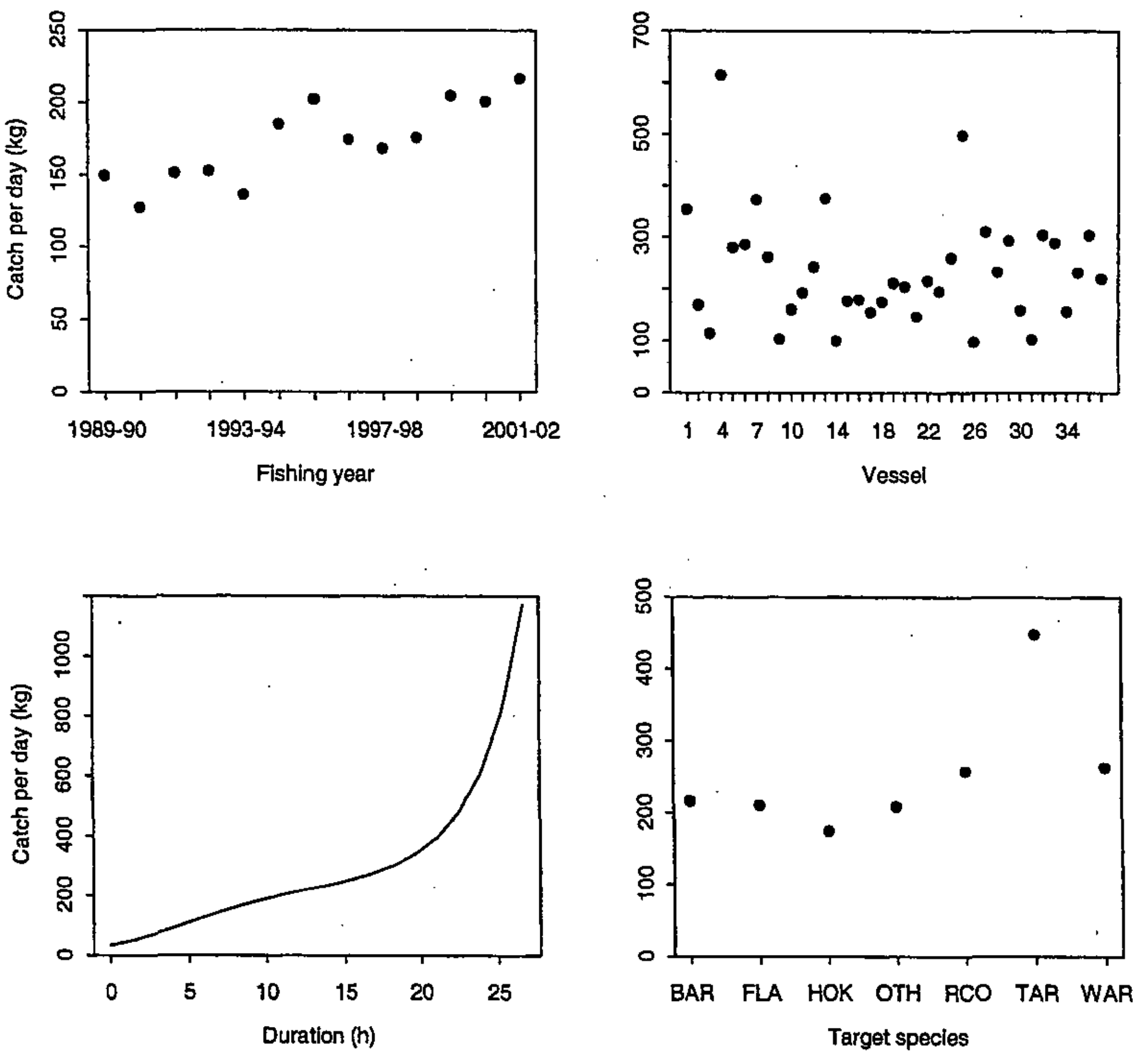

Figure 11: Expected catch rates (kg per day) for median values of fixed parameters for the Pegasus Bay/Cook Strait bottom trawl fishery, core vessels.

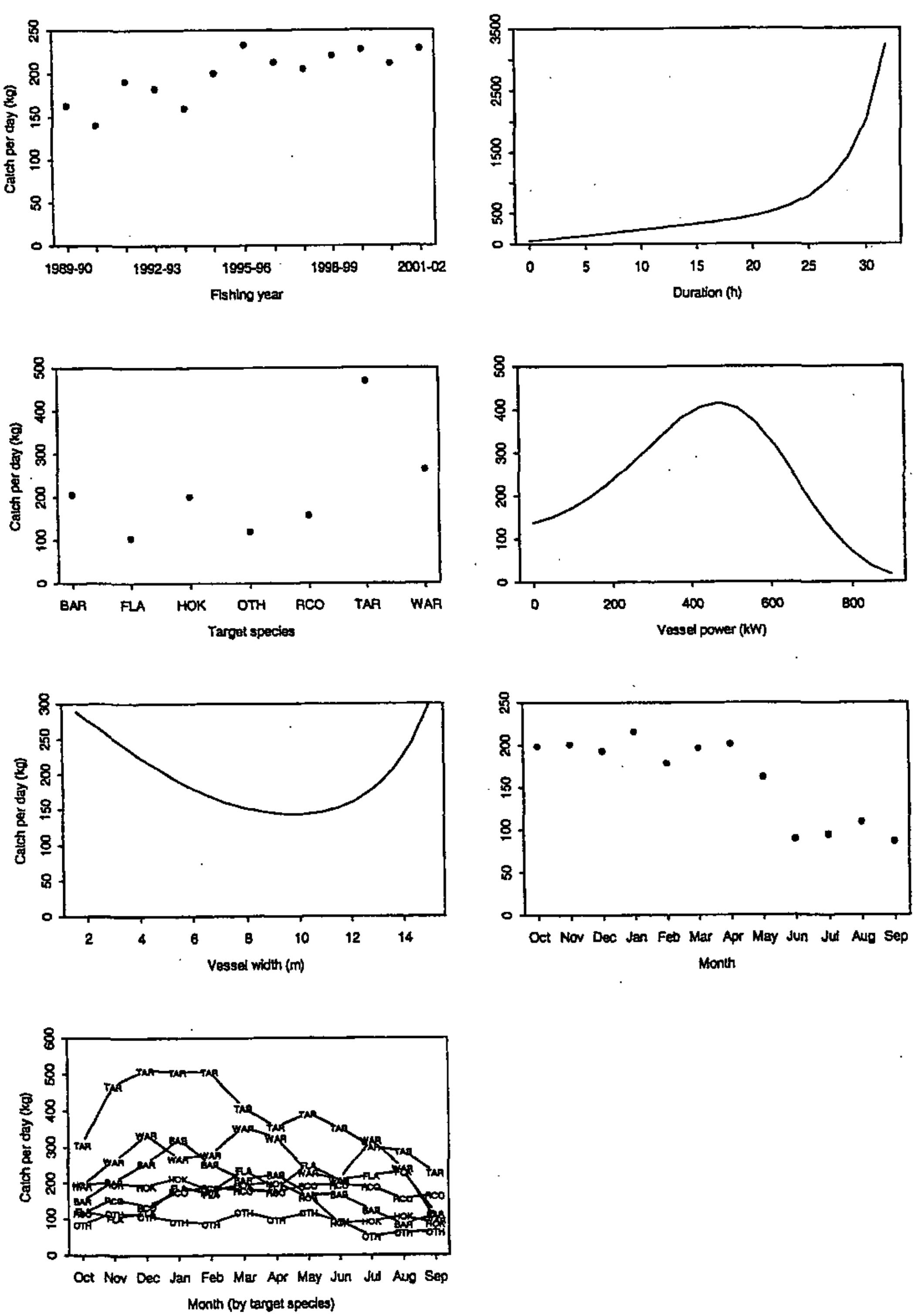

Figure 12: Expected catch rates (kg per day) for median values of fixed parameters for the Pegasus Bay/Cook Strait bottom trawl fishery, all vessels.

3.4.2 Kaikoura set net target fishery

The set net fishery for CPUE analysis consists of sets that targeted tarakihi and fished in Statistical Area 018. This resulted in 27 vessels from 1989–90 to 2001–01 catching about 3025 t of tarakihi (Table 22).

Table 22: Summary of data used in the final standardised CPUE analysis for the Kaikoura set net target fishery. No. records, the number of accepted records; Catch, estimated catch (t) from accepted records; No. vessels, number of unique vessels from accepted records. The total in the No. vessels column indicates the number of unique vessels contributing to the accepted records for all years combined. The totals in the catch column may not equal those in the descriptive analysis as these are accepted records. See methods for an explanation.

Fishing year	No. records	Catch (t)	No. vessels
1989–90	618	134	12
1990–91	703	230	9
1991–92	797	302	13
1992–93	801	305	9
1993–94	637	176	7
1994–95	693	272	7
1995–96	512	174	8
1996–97	469	149	9
1997–98	661	237	7
1998–99	549	194	6
1999–00	611	222	8
2000–01	538	281	8
2001–02	538	348	8
Total	8 127	3 025	27

The predictor variables selected by the stepwise regression model for the Pegasus Bay/Cook Strait set net target fishery are shown in Table 23. Four variables were selected with a total r^2 of 51%, with *vessel* explaining most (27%) of the deviance. Other variables selected included *net length, month,* and *year.*

Table 23: Selected variables and the percentage of deviance explained (r^2) from the stepwise multiple regression algorithm for the Kaikoura set net target fishery.

Selected variable	r^2
Vessel	26.5
Net length	43.2
Month	49.6
Year	51.0

The standardised indices are shown in Figure 13 and listed in Appendix C, (Table C1). The indices are relatively flat from 1989–90 to 1999–2000 apart from a decline in 1993–94, and an increase in the last two years. These indices show a similar pattern to the unstandardised indices apart from the first few years.

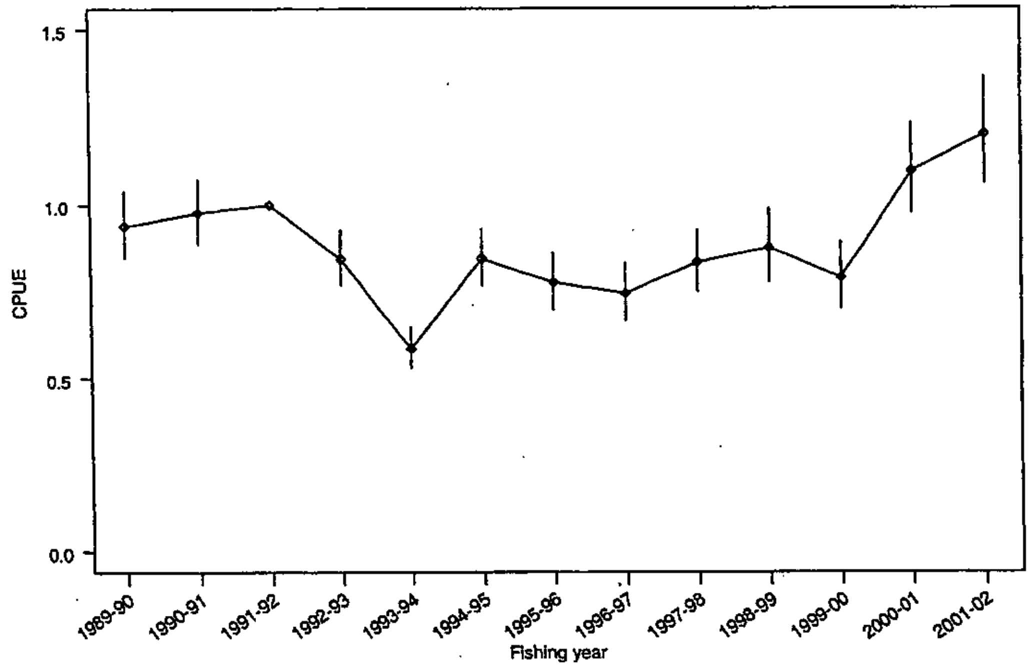

Figure 13: Relative year effects and 95% confidence intervals for Kaikoura set net fishery.

The effects of the selected variables are shown in Figure 14. Expected catch rates ranged from 20 to 450 kg per day for *vessel*. Highest catches were expected where the *net length* was between 1000 and 3000 m. There was no clear seasonal pattern for *month*, but there appear to be higher catch rates for the summer periods and at the end of the fishing year.

The diagnostic plots for the different models and data sets are presented in Appendix C Figure C3. The diagnostics for the fixed effects indicate a reasonable pattern in the residuals, but the Q-Q plots indicate a deviation from the normal distribution of the residuals at the lower end, suggesting that very small values of catch rate are not well predicted. This suggests that the models can be improved, and there may be violations of model assumptions.

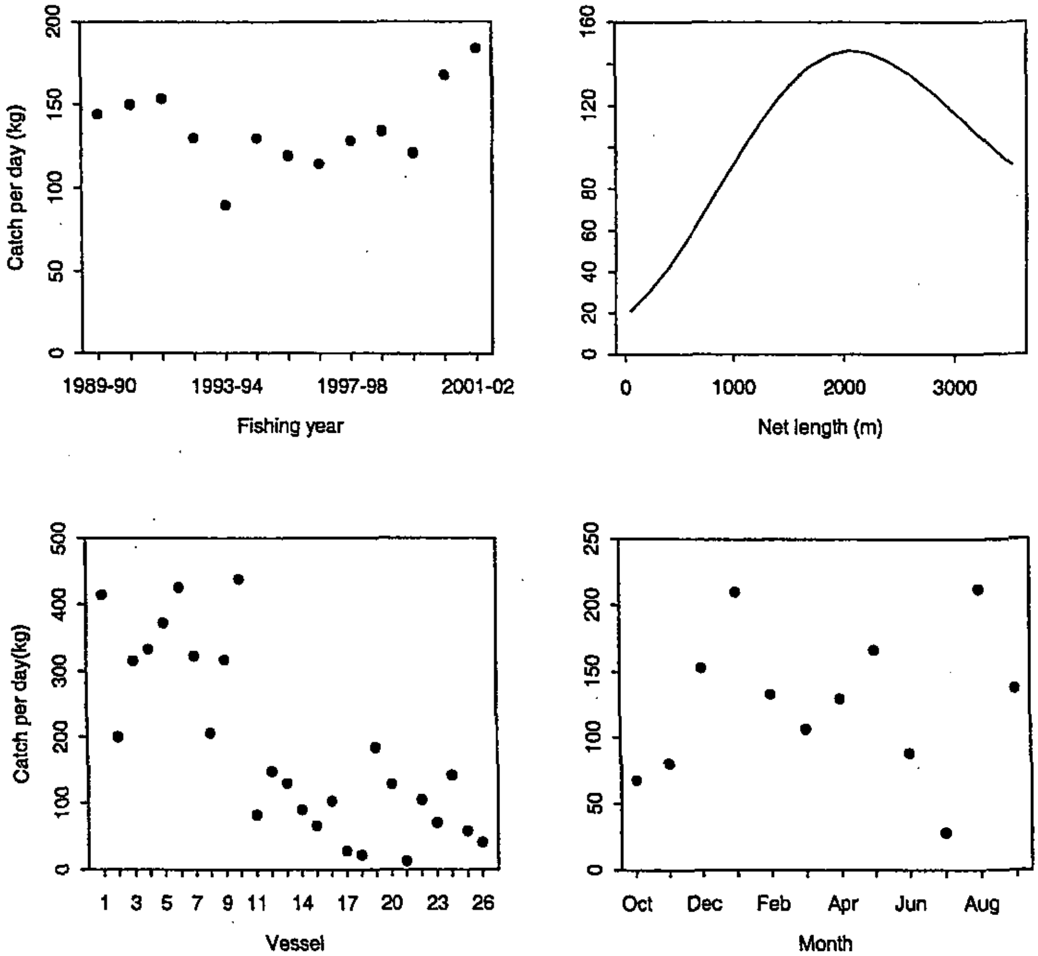

Figure 14: Expected catch rates (kg per tow) for median values of fixed parameters for the Kaikoura set net fishery.

4. DISCUSSION

Dunn et al. (2000) noted that calculation of CPUE indices does not necessarily result in an index which is related to abundance. They cautioned against the use of CPUE indices in stock assessment models until several aspects of the analysis had been evaluated and the CPUE indices themselves had been validated by fishery independent data. They recommended that CPUE analysis included discussion of:

1. definition of the relationship between CPUE and fish abundance,
2. assessment of data adequacy,
3. methods of model fitting and validation, and
4. evaluation of the CPUE index in an attempt to validate the data selection, model method, and results.

4.1 Definition of the relationship between CPUE and fish abundance

Tarakihi are largely taken by small to medium sized inshore bottom trawlers (15–25 m long) which typically carry out trips lasting 3–5 days (Field & Hanchet 2001). During the trip they will carry out a number of trawls targeting a range of inshore species to cover their quota species mix. Therefore the meaning of target species in a mixed fishery like this is difficult to interpret. Paul & Bradford (2000) noted that target species is used by fishers in several ways: the single species targeted, the main of several species targeted, the species for which most quota is still held, the main species actually caught (whether it was targeted or not), the species that legalises a subsequent bycatch trade, or simply just a logical species for that area and fishery.

In the TAR 2 fishery, most of the tarakihi caught is recorded as being targeted. However, the fishers are usually targeting a species mix of which tarakihi is the dominant species. Therefore, on any particular day, fishers may have tows targeting tarakihi, tows targeting a 50% tarakihi and 50% mix, and tows actively avoiding tarakihi. Unfortunately, this level of detail cannot be captured on the CELRs. Furthermore, changes in marketing practices have led some companies to impose trip limits on tarakihi over the past few years (normally 4–8 t per trip) and thus the fishing strategy is aimed at maximising the catch of the quota mix rather than maximising the tarakihi catch (Field & Hanchet 2001). It is possible that this change in fishing practice could have led to an artificial decrease in tarakihi over the last few years, but this may be offset by improvement in position fixing and the ability to repeat tows through the use of GPS and track plotters.

The Pegasus Bay/Cook Strait fishery is also a multispecies fishery and the bycatch trade system is widely used to offset over-catch of certain species. This means the target species reported on the CELR forms is sometimes related more to the species nominated to allow the bycatch trade (e.g., red cod) than the actual species being targeted. Therefore, the actual reported amount of targeting on tarakihi probably understates the amount of true targeting (Field & Hanchet 2001). It is unknown how this might affect the relationship between CPUE and abundance. However, improvements in position fixing and the ability to repeat tows through the use of GPS and track plotters would have increased, the catch of tarakihi over time.

For the analysis and interpretation of the indices we have assumed a simple direct relationship between CPUE and abundance. Although there are specific areas and times when tarakihi are more abundant, there is no evidence of changes in fishers behaviour (e.g., significant searching or targeting of marks) which could lead to hyperstable CPUE/abundance relationship (Dunn et al. 2000). (A hyperstable relationship is one where CPUE remains high while abundance declines.) The use of data that includes both target and not-target tarakihi should help reduce the sensitivity of the results to changes in targeting practices or recording of target species on the CELR/TCEPR forms (Field & Hanchet 2001).

4.2 Data adequacy

For the TAR 2 and Pegasus Bay/Cook Strait fisheries, the estimated catch represents a high proportion of the landed catch. Judging by the location of tows recorded from the TCEPR records and the location of catches from the statistical areas, the data appear to be accurately covering the tarakihi population.

Although a large proportion of the data in the Pegasus Bay/Cook Strait fishery was available for analysis, only 56% was taken from the bottom trawl fishery and only 40% of that was caught whilst targeting tarakihi. An equal amount of tarakihi was taken from the red cod (25%) and barracouta (16%) bottom trawl fisheries. This raises problems in the analysis because changes in tarakihi CPUE could reflect changes in the dynamics of the target fishery rather than changes in tarakihi abundance. However, raw CPUE for each of the three target fisheries showed similar trends, which gives some confidence in the model results.

4.3 Model fitting and model validation

Model fitting and model validation were considered by comparing the explanatory variables, the variation explained (r^2), the diagnostic plots, the different models, and the results of the all vessels versus the core vessels models. The variables selected were similar for the different models within each fishstock. *Target species* and *statistical area* were always selected by the stepwise regression technique in TAR 2, as vessels sometimes target tarakihi in certain areas.

One of the vessel characteristics (e.g., *vessel length*) or the *vessel* id was usually the other most important explanatory variable for the TAR 2 and Pegasus Bay/Cook Strait analysis. Vessels operating in the inshore fishery vary considerably in size and fishing power and the importance of this as an explanatory variable is consistent with our understanding of the fishery. Tow *duration* was also an important variable and was selected into the TAR 2 and Pegasus Bay/Cook Strait models.

The percentage of variation (r^2) explained by the model in each analysis ranged from 31 to 34% for the Pegasus Bay/Cook Strait bottom trawl fishery, 42–48% for the TAR 2 fishery, and 51% for the Pegasus Bay/Cook Strait setnet target fishery. These values are moderately high compared to other CPUE analyses.

The diagnostic plots for all models were similar. In general, the model developed for each of the fisheries generally overestimated the observed catch from the lower end of the range of catches. This appears to be a common problem for many CPUE analyses and probably reflects the patchy nature of fish and fisheries. The diagnostic plots appear to be particularly bad in this respect for the set net tarakihi fishery. For other analyses, the plots suggest the problem is not too serious, and the diagnostics usually improved for the vessel subset analyses.

The inclusion of Statistical Areas 009 & 010 for the TAR 2 analysis appears to have little effect on the selected variables and resulting CPUE indices. This suggests that the fish are from the same stock.

Dunn et al. (2000) recommended separate analysis of subsets of vessels that had fished in the various fisheries. In each vessel subset, similar variables were selected compared to the all vessels data set and the resulting CPUE trends were also similar, suggesting the model was not overly sensitive to the vessel selection used.

The generalised linear modelling approach of Gavaris (1980) allows standardisation of a range of factors, but only those that can be derived from the CELR/TCEPR returns. Other factors that may affect fishing, for example changes in gear, improved technology, individual's skill, and local knowledge were not considered (Dunn 2002).

4.4 Evaluation of CPUE indices

An important step in assessing the usefulness of CPUE as an index of abundance is to determine whether annual changes in CPUE reflect the abundance of tarakihi in TAR 2 and Pegasus Bay/Cook Strait by comparing the CPUE indices to fishery independent data.

The analysis in TAR 2 was based on a relatively large data set. A high proportion of tarakihi was targeted, and used in the analysis. The model had reasonably high explanatory power, reasonable diagnostics (for a CPUE analysis), and the results were similar for the all vessel and core vessel subsets. The TAR 2 CPUE indices showed an initial decline from 1989–90 to 1991–92, were stable to 1995–96, followed by a steadily increase to 2001–02. These indices are consistent with earlier results of Field & Hanchet (2001), (see Figure B1).

The only independent data were four trawl surveys carried out on the east coast North Island from 1993 to 1996 (Stevenson & Hanchet 1999). The trawl survey indices were variable, probably due to catchability difference between years, and showed no trends over time. Over the period of overlap, the CPUE indices and trawl survey indices appear to be consistent. Other information to suggest that the CPUE may reflect abundance is that most fishers tend to catch and even exceed their quota (even with active avoidance) for the last couple of years. This suggests that abundance may be increasing.

Field & Hanchet (2001) concluded that the CPUE indices appeared to be monitoring abundance. We see no reasons to change their conclusions, but we note that further trawl surveys would be required to confirm this conclusion.

The analysis in the Pegasus Bay/Cook Strait bottom trawl fishery was again based on a relatively large data set. The model had reasonably high explanatory power, but poor diagnostics. Both vessel subsets showed an increasing trend over the period. However, there has also been a steady increase for a number of other variables in the fishery, including vessel power, number of hours fished, number of shots per day, and the height of the headline (see Figure 9). The catches of tarakihi have increased over the past 7–8 years for both the target and non-target fisheries (red cod and barracouta) (Table 16). This could be due to either: 1) vessels have become better at catching tarakihi, or 2) that abundance has increased, or 3) a combination of both. There has been an increase in unstandardised CPUE in each of the statistical areas (Table 17), which suggests it might be due to increased abundance. However, as vessel power, and number of hours fished have increased, this may suggest that vessels have become better at catching tarakihi. There is little fishery-independent information with which to judge the estimated yearly CPUE indices as a measure of abundance for the Pegasus Bay/Cook Strait bottom trawl fishery. There has been only one trawl survey of this area in autumn 1987, using *James Cook* (Annala et al. 1990). Residual diagnostics provide one method for verifying model assumptions and can provide some evidence for validating that the estimated year effects are reliable. It is not clear whether these indices provide an index of abundance or not. Given the statistical properties of the model, these indices should be treated with caution.

The CPUE index derived from a highly targeted set net fishery off Kaikoura captured most of the set net data, and explained a very high proportion of the total variation. The index showed no trend over most of the period, but there was a slight increase in 1999–2000 and 2000–01. These indices also have a similar trend to that found in Field & Hanchet (2001) (Appendix C, Figure C4). However, the diagnostic plots showed poor fit to the data, particularly for low observed values. These indices are also inconsistent with the Pegasus Bay/Cook Strait bottom trawl CPUE indices, possibly due to catching different sized fish. Furthermore, the fishery appears to be based on a migrating population, and it is unclear how well this may reflect abundance of the population as a whole.

5. CONCLUSIONS

- CPUE indices calculated for TAR 2 have increased since 1996 and are probably monitoring tarakihi abundance in the area.
- The inclusion of Statistical Areas 009 & 010 had little effect on the CPUE indices for TAR 2. It appears that tarakihi caught from these statistical areas are from the same stock as TAR 2.
- It is not clear if the standardised CPUE indices from the Pegasus Bay/Cook Strait bottom trawl fishery are monitoring tarakihi abundance in the area, as there is no fishery independent data to validate them, therefore they should be treated with caution.
- CPUE indices calculated by the Pegasus Bay/Cook Strait set net fishery appear not to monitor tarakihi abundance in the area.

6. ACKNOWLEDGMENTS

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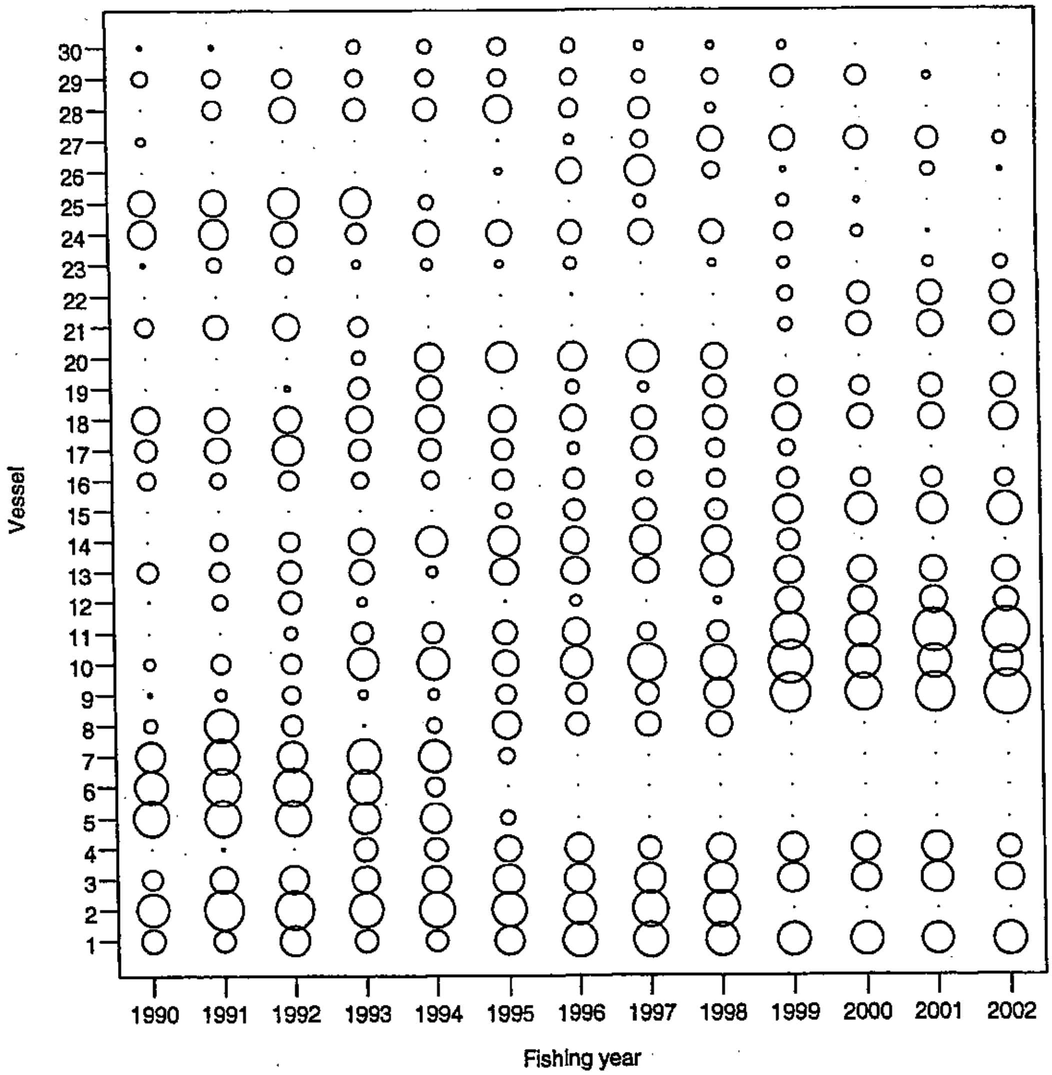
Appendix A: Vessel Selection



plot.vessel.experience.s,TAR2002/01,2003

Figure A1: Summary of the number of tows by fishing year (symbol area proportional to the number of tows) for core vessels involved in the TAR 2 fishery (excluding Statistical Areas 017, 009 & 010) CPUE analysis. (Maximum circle size = 250 tows).

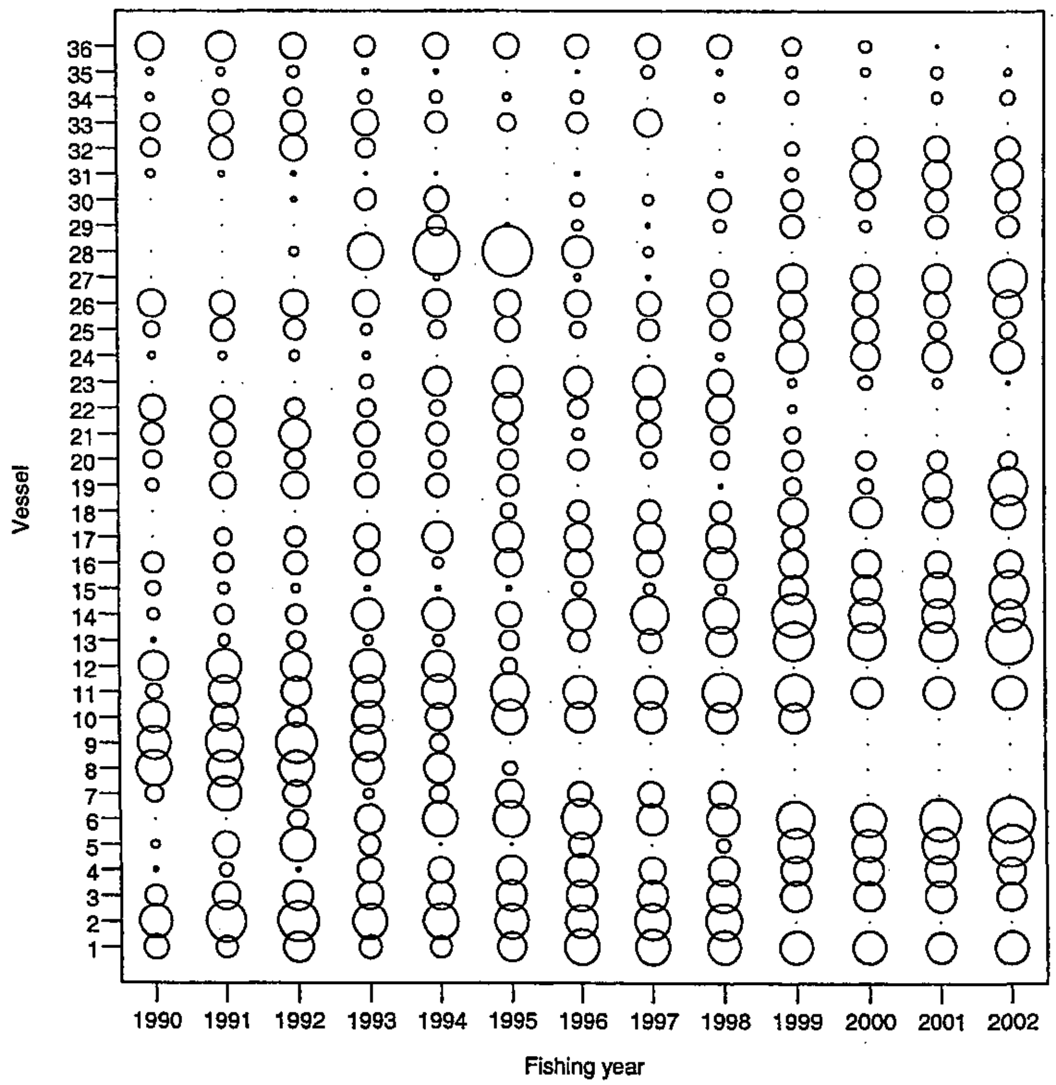


Figure A2: Summary of the number of tows by fishing year (symbol area proportional to the number of tows) for core vessels involved in the TAR 2 fishery (plus Statistical Areas 009 & 010) CPUE analysis. (Maximum circle size = 292 tows).

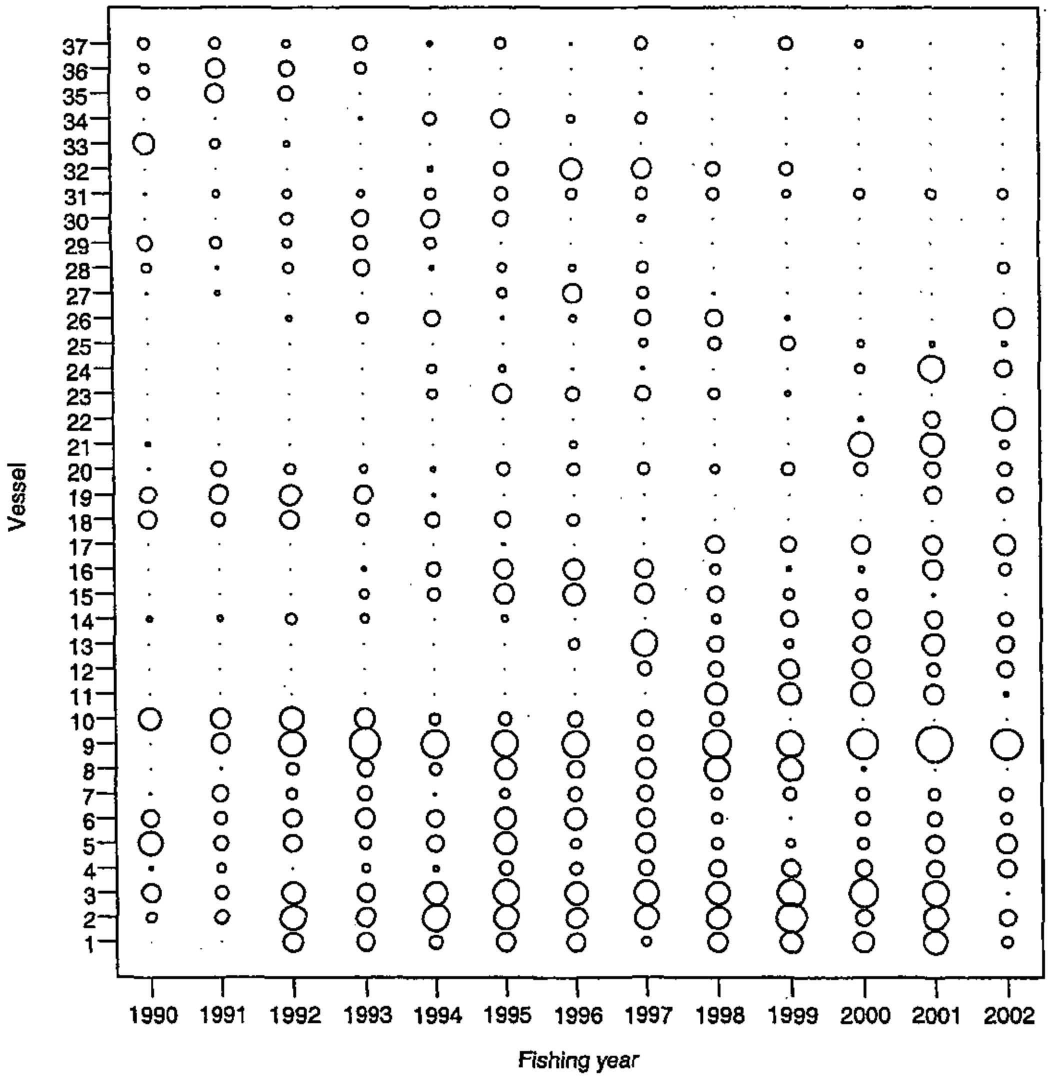


Figure A3: Summary of the number of tows by fishing year (symbol area proportional to the number of tows) for core vessels involved in the Pegasus Bay/Cook Strait bottom trawl fishery CPUE analysis. (Maximum circle size = 150 tows).

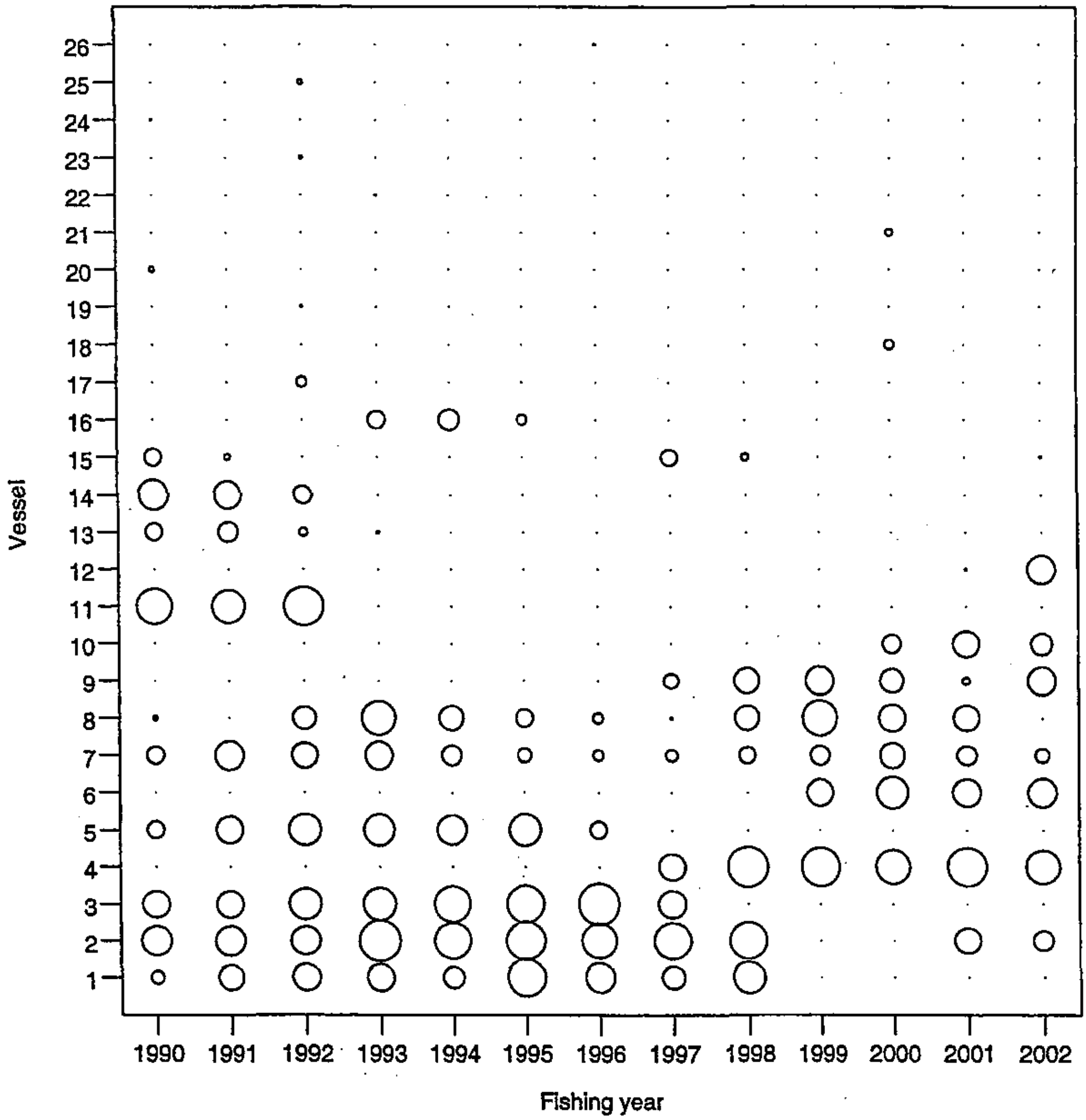


Figure A4: Summary of the number of tows by fishing year (symbol area proportional to the number of tows) for all vessels involved in the Kaikoura set net fishery CPUE analysis. (Maximum circle size = 194 tows).

Appendix B: TAR 2 CPUE analysis

Table B1: Relative year effects (and 95% confidence intervals), by year for TAR 2 (excluding Statistical Areas 009 & 010) core and all vessels, including Statistical areas 009 & 010 for core and all vessels.

	Excludes Statistical Areas 009 & 010				Includes Statistical Areas 009 & 010			
	Core vessels		All vessels		Core vessels		All vessels	
Fishing year	Index	95% CI	Index	95% CI	Index	95% CI	Index	95% CI
1989–90	1.21	1.12–1.30	1.19	1.12–1.27	0.70	0.65–0.75	1.24	1.17–1.32
1990–91	1.16	1.09–1.24	1.14	1.08–1.21	0.67	0.63–0.72	1.12	1.06–1.18
1991–92	1.00	-	1.00	-	0.56	0.53–0.60	1.00	-
1992–93	1.04	0.97–1.10	0.98	0.93–1.04	0.63	0.59–0.67	1.04	0.99–1.09
1993–94	1.01	0.94–1.08	0.98	0.92–1.04	0.62	0.58–0.66	1.04	0.98–1.09
1994–95	1.02	0.95–1.09	1.01	0.95–1.07	0.64	0.60–0.68	1.05	0.99–1.10
1995–96	0.99	0.93–1.06	1.06	1.00–1.13	0.66	0.62–0.70	1.19	1.13–1.25
1996–97	1.15	1.07–1.23	1.19	1.12–1.26	0.72	0.68–0.77	1.24	1.18–1.31
1997–98	1.16	1.09–1.24	1.21	1.14–1.29	0.75	0.70–0.79	1.35	1.28–1.43
1998–99	1.21	1.14–1.30	1.29	1.21–1.37	0.79	0.74–0.83	1.33	1.26–1.41
1999–00	1.35	1.26–1.45	1.45	1.35–1.55	0.78	0.73–0.82	1.40	1.31–1.48
2000–01	1.28	1.20–1.38	1.47	1.38–1.57	0.84	0.80–0.89	1.61	1.53–1.70
2001–02	1.43	1.34–1.54	1.62	1.52–1.72	1.00	-	1.80	1.71–1.90

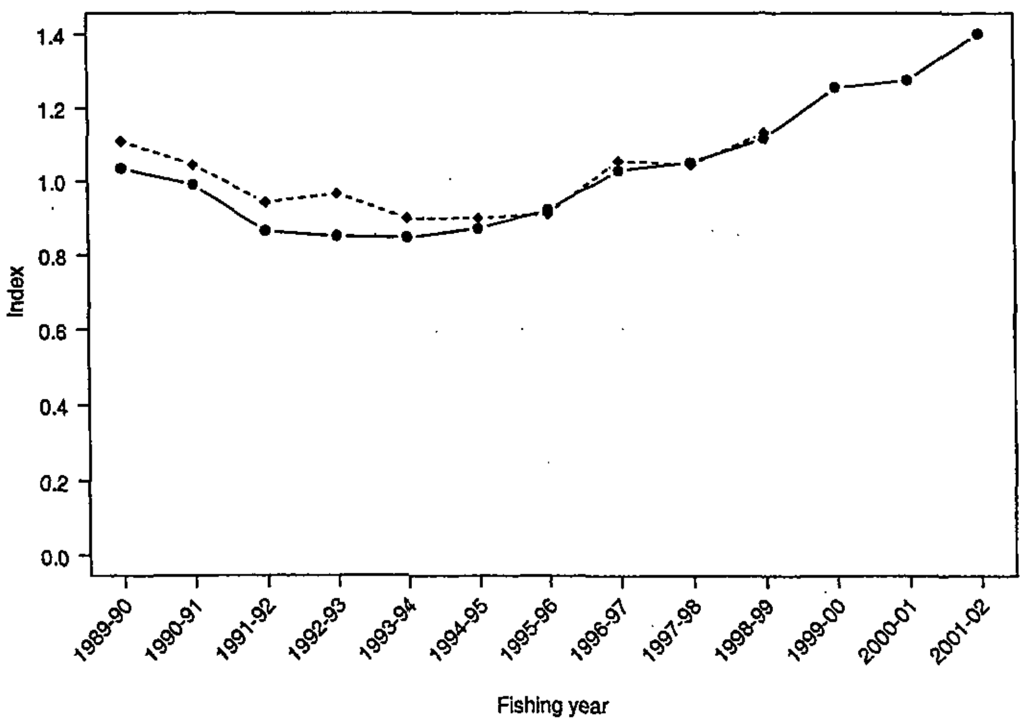


Figure B1: Comparison of the updated TAR 2, all vessels CPUE indices (circles) to the 2001 analysis (diamonds) (Field & Hanchet 2001). Note, the indices have been scaled to have mean 1.

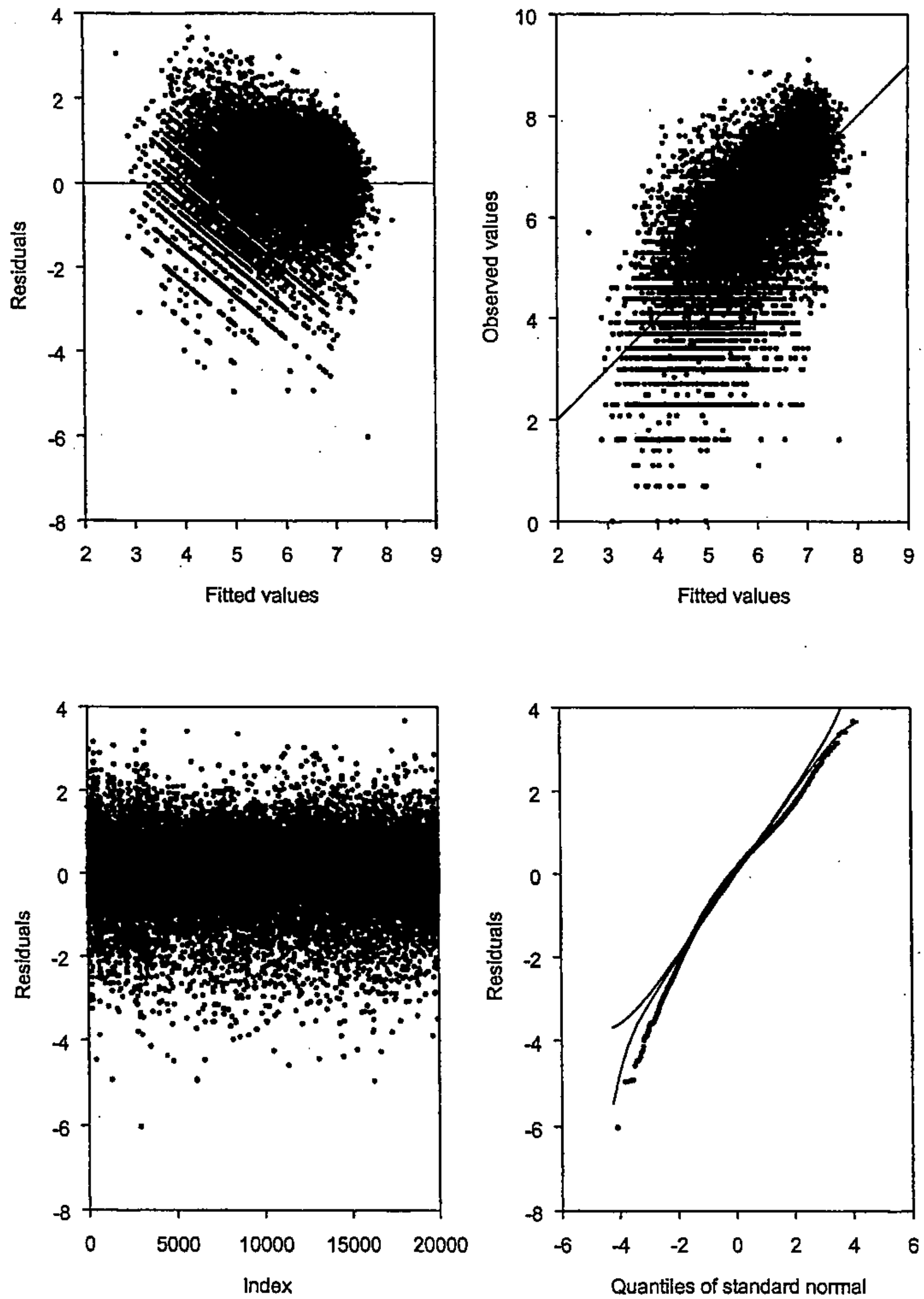


Figure B2: Diagnostic plots (log scale) of the lognormal model for TAR 2 fishery (excludes Statistical Areas 009 & 010), core vessels. Top left, fitted values versus residuals; top right, fitted values versus observed values; bottom left, plot of the residuals; bottom right, normal quartile-quartile plot and 95% confidence intervals of the residuals.

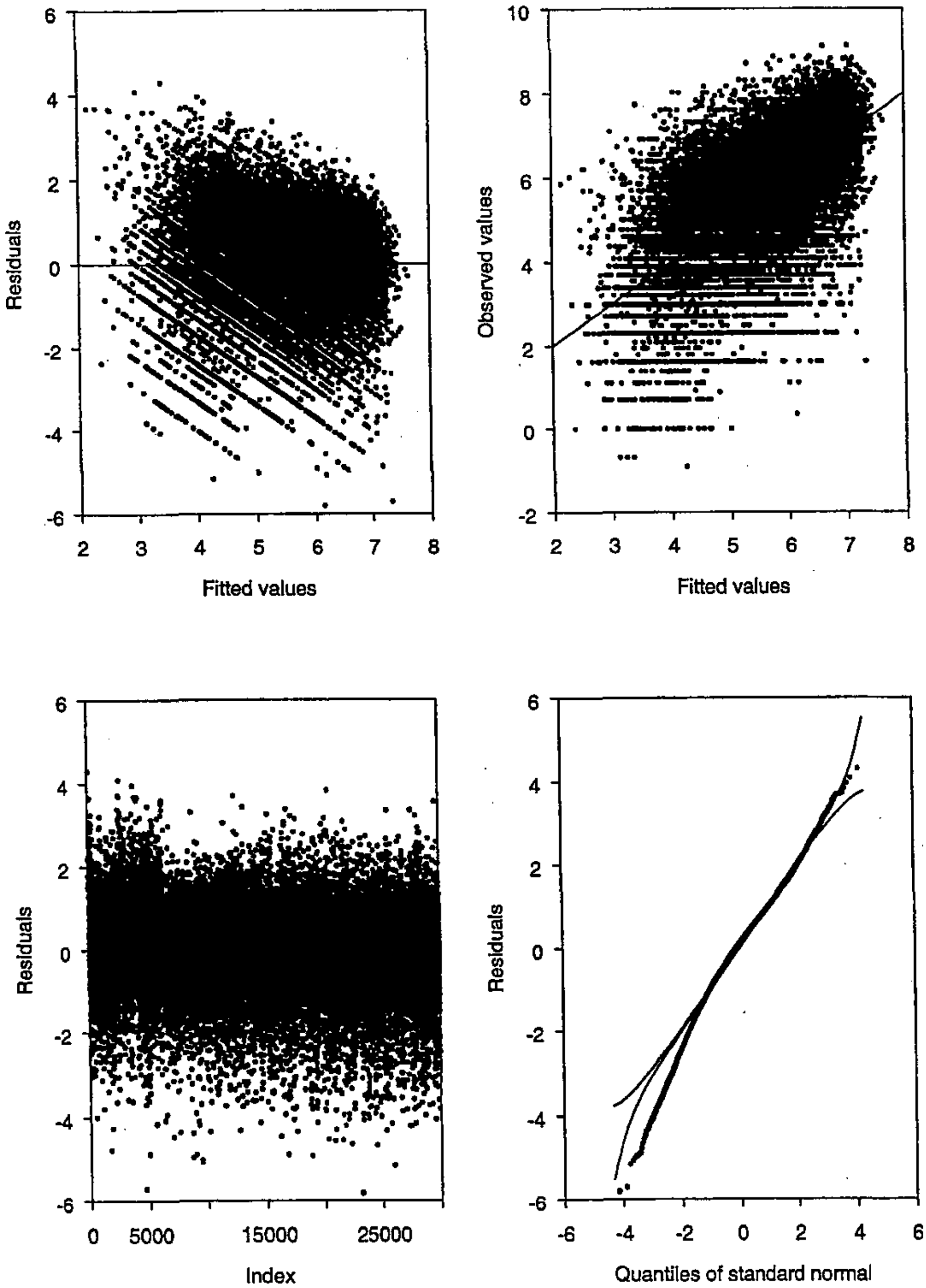


Figure B3: Diagnostic plots (log scale) of the lognormal model for TAR 2 fishery (excludes Statistical areas 009 & 010), all vessels. Top left, fitted values versus residuals; top right, fitted values versus observed values; bottom left, plot of the residuals; bottom right, normal quartile-quartile plot of the residuals.

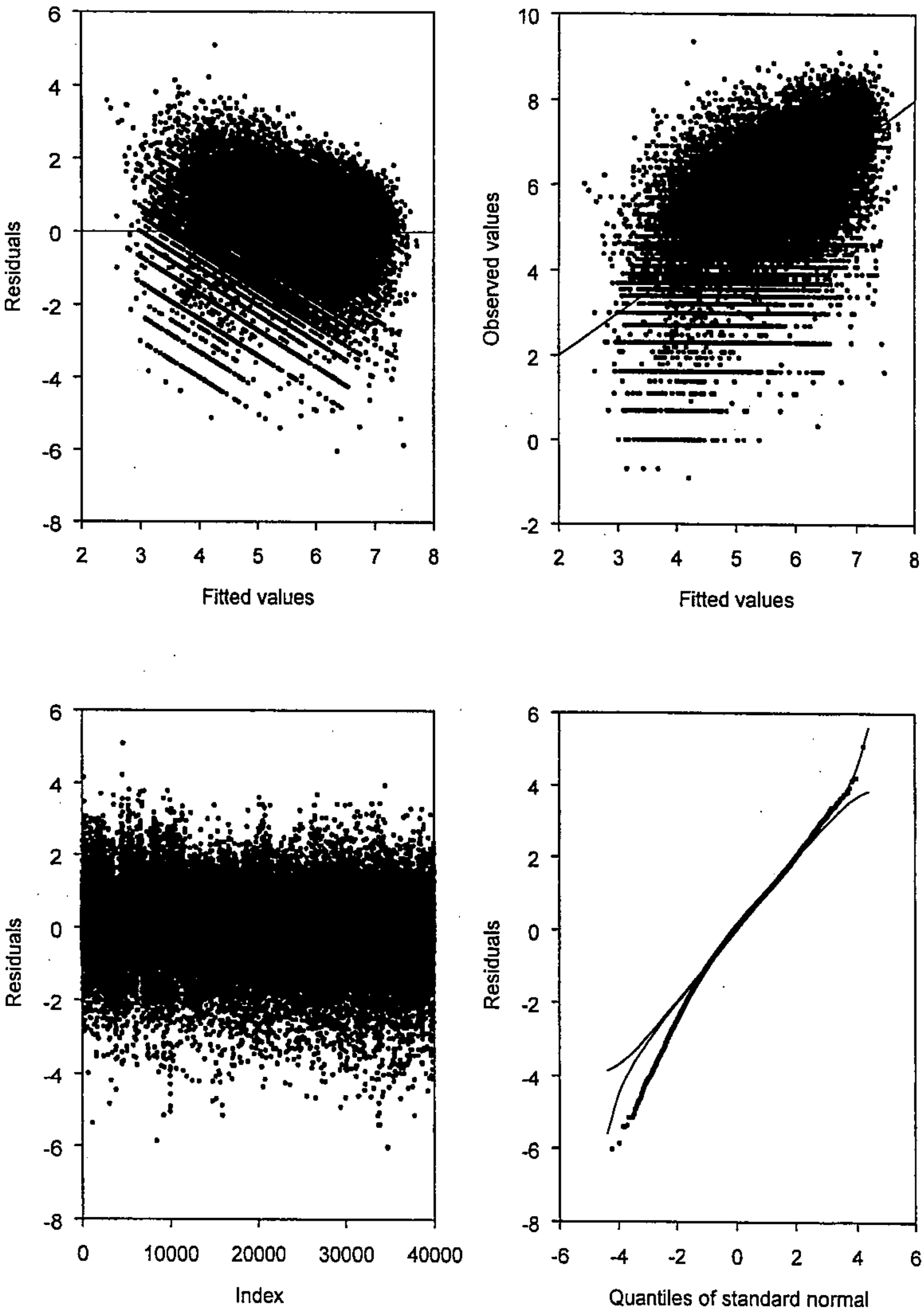


Figure B4: Diagnostic plots (log scale) of the lognormal model for TAR 2 fishery and Statistical Areas 009 & 010, all vessels. Top left, fitted values versus residuals; top right, fitted values versus observed values; bottom left, plot of the residuals; bottom right, normal quartile-quartile plot and 95% confidence intervals of the residuals.

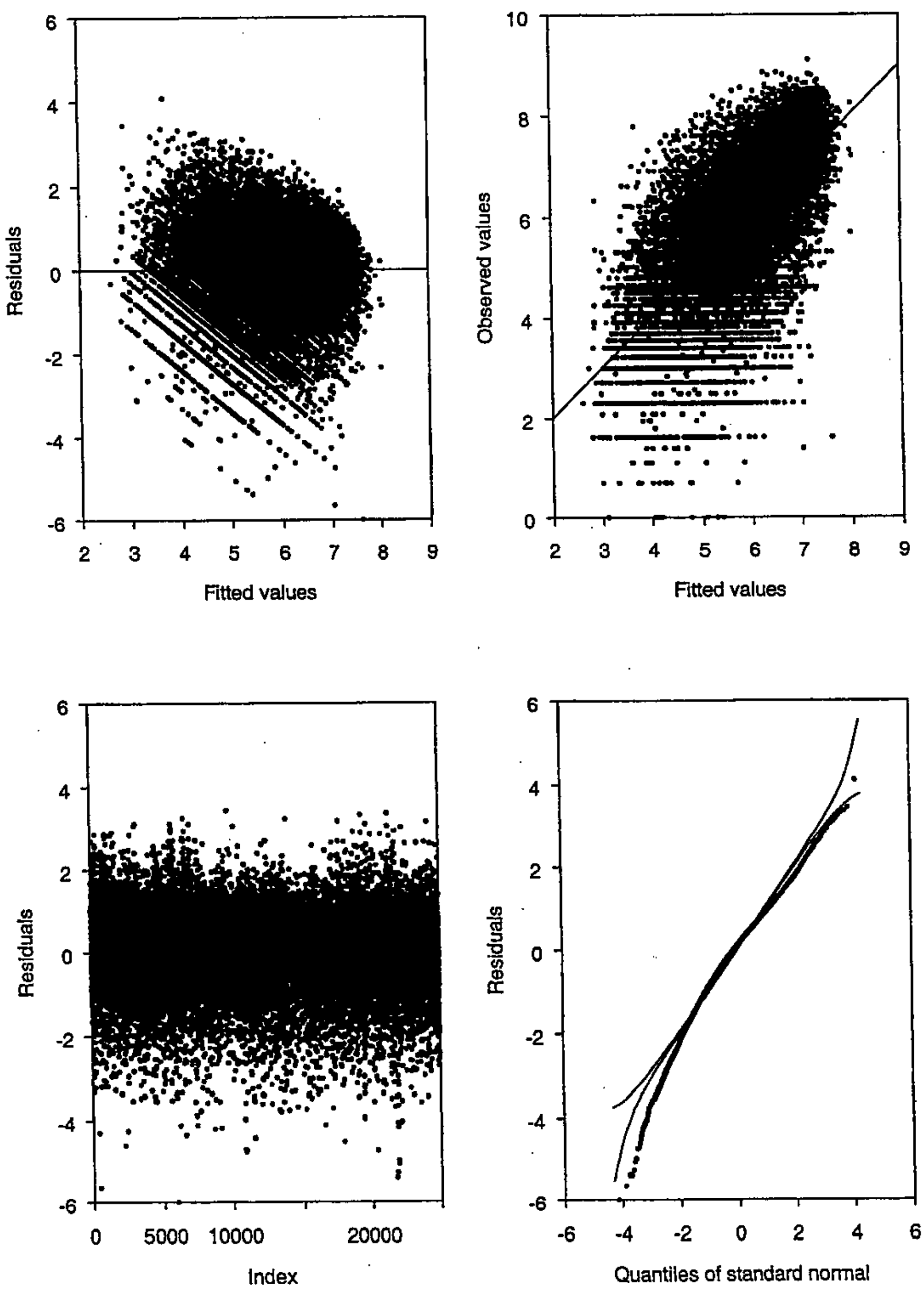


Figure B5: Diagnostic plots (log scale) of the lognormal model for TAR 2 fishery and Statistical Area 009 & 010, core vessels. Top left, fitted values versus residuals; top right, fitted values versus observed values; bottom left, plot of the residuals; bottom right, normal quartile-quartile plot and 95% confidence intervals of the residuals.

Appendix C: Pegasus Bay/Cook Strait CPUE analysis

Table C1: Relative year effects (and 95% confidence intervals), by year for Pegasus Bay/Cook Strait bottom trawl fishery, core and all vessels, and set net fishery all vessels.

	Bottom trawl fishery				Setnet fishery	
	Core vessels		All vessels		All vessels	
Fishing year	Index	95% CI	Index	95% CI	Index	95% CI
1989–90	0.74	0.64–0.85	0.74	0.67–0.81	0.94	0.85–1.04
1990–91	0.63	0.55–0.72	0.64	0.58–0.70	0.98	0.89–1.07
1991–92	0.75	0.67–0.84	0.85	0.77–0.94	1.00	
1992–93	0.74	0.66–0.83	0.88	0.80–0.98	0.85	0.77–0.93
1993–94	0.67	0.60–0.76	0.76	0.68–0.83	0.59	0.53–0.65
1994–95	0.92	0.82–1.02	0.93	0.84–1.02	0.85	0.77–0.93
1995–96	1.00	0.89–1.12	1.04	0.94–1.15	0.78	0.70–0.86
1996–97	0.87	0.78–0.96	0.95	0.86–1.05	0.75	0.67–0.83
1997–98	0.84	0.75–0.93	0.92	0.84–1.02	0.84	0.75–0.93
1998–99	0.88	0.79–0.98	1.05	0.95–1.16	0.88	0.78–0.99
1999–00	1.01	0.91–1.12	1.09	0.99–1.20	0.79	0.70–0.89
2000–01	1.00	-	1.00	-	1.09	0.97–1.23
2001–02	1.08	0.97–1.20	1.06	0.96–1.16	1.20	1.06–1.36

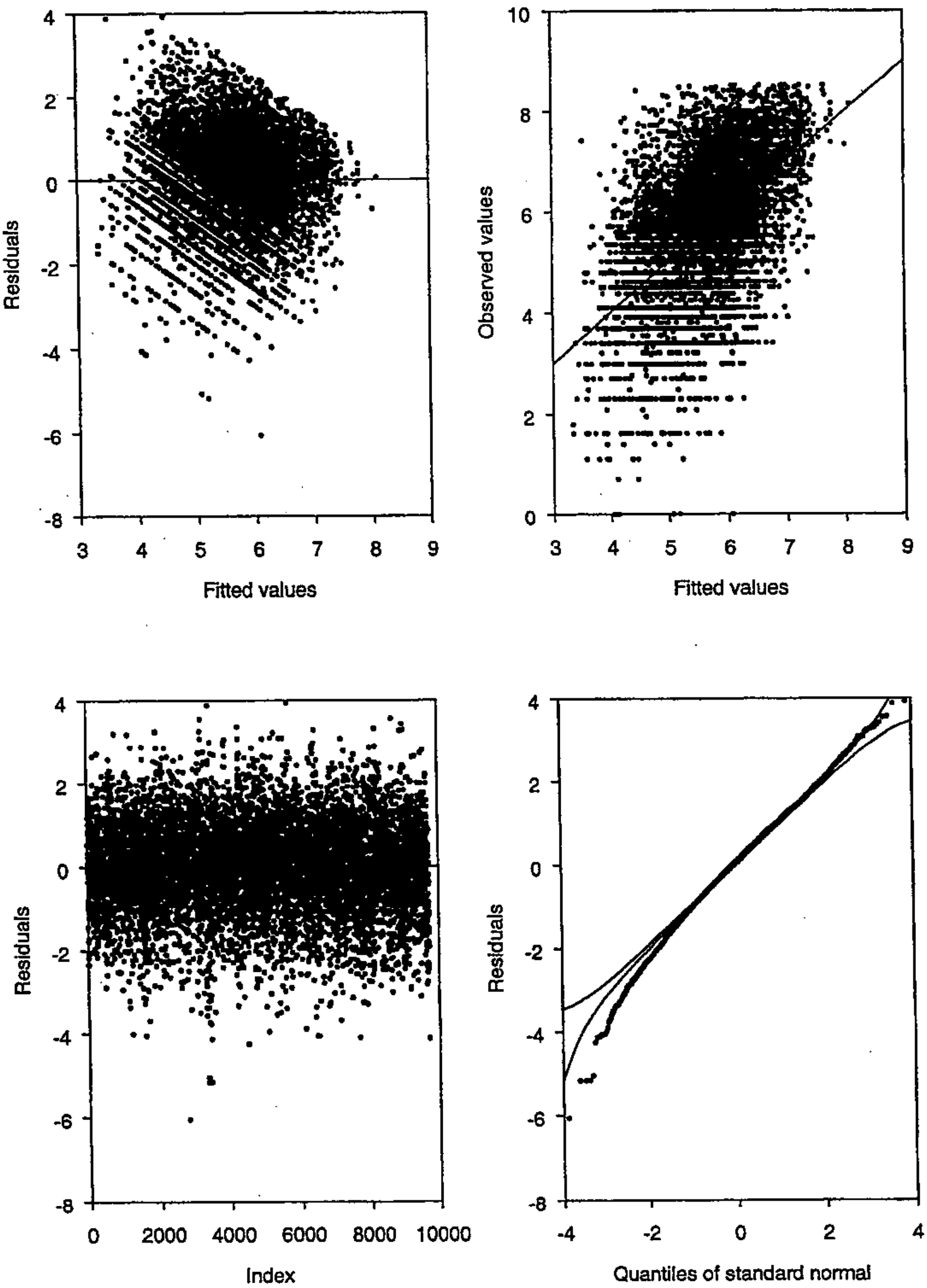


Figure C1: Diagnostic plots (log scale) of the lognormal model for Pegasus Bay/Cook Strait bottom trawl fishery, core vessels. Top left, fitted values versus residuals; top right, fitted values versus observed values; bottom left, plot of the residuals; bottom right, normal quartile-quartile plot and 95% confidence intervals of the residuals.

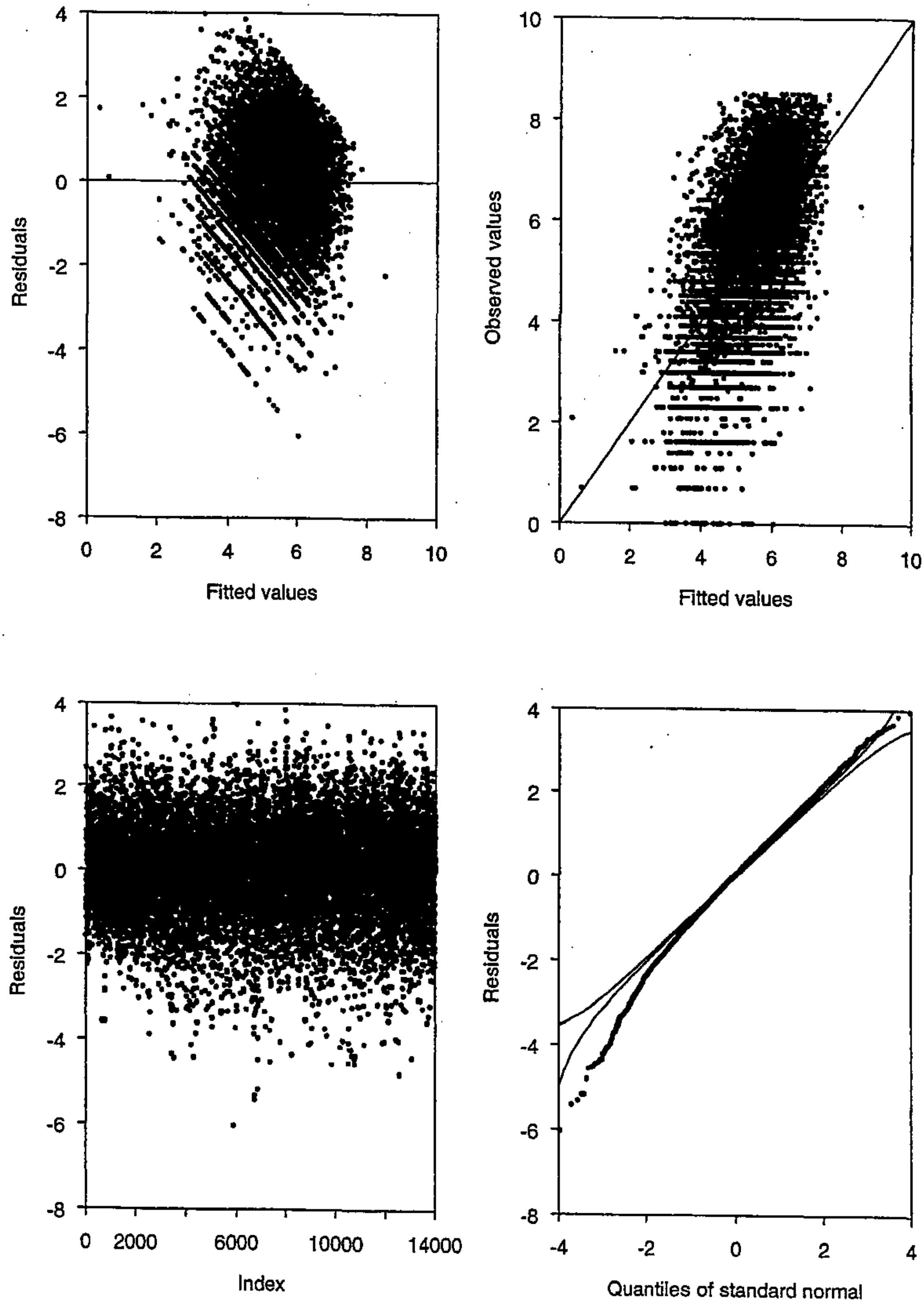


Figure C2: Diagnostic plots (log scale) of the lognormal model for Pegasus Bay/Cook Strait bottom trawl fishery, all vessels. Top left, fitted values versus residuals; top right, fitted values versus observed values; bottom left, plot of the residuals; bottom right, normal quartile-quartile plot of the residuals.

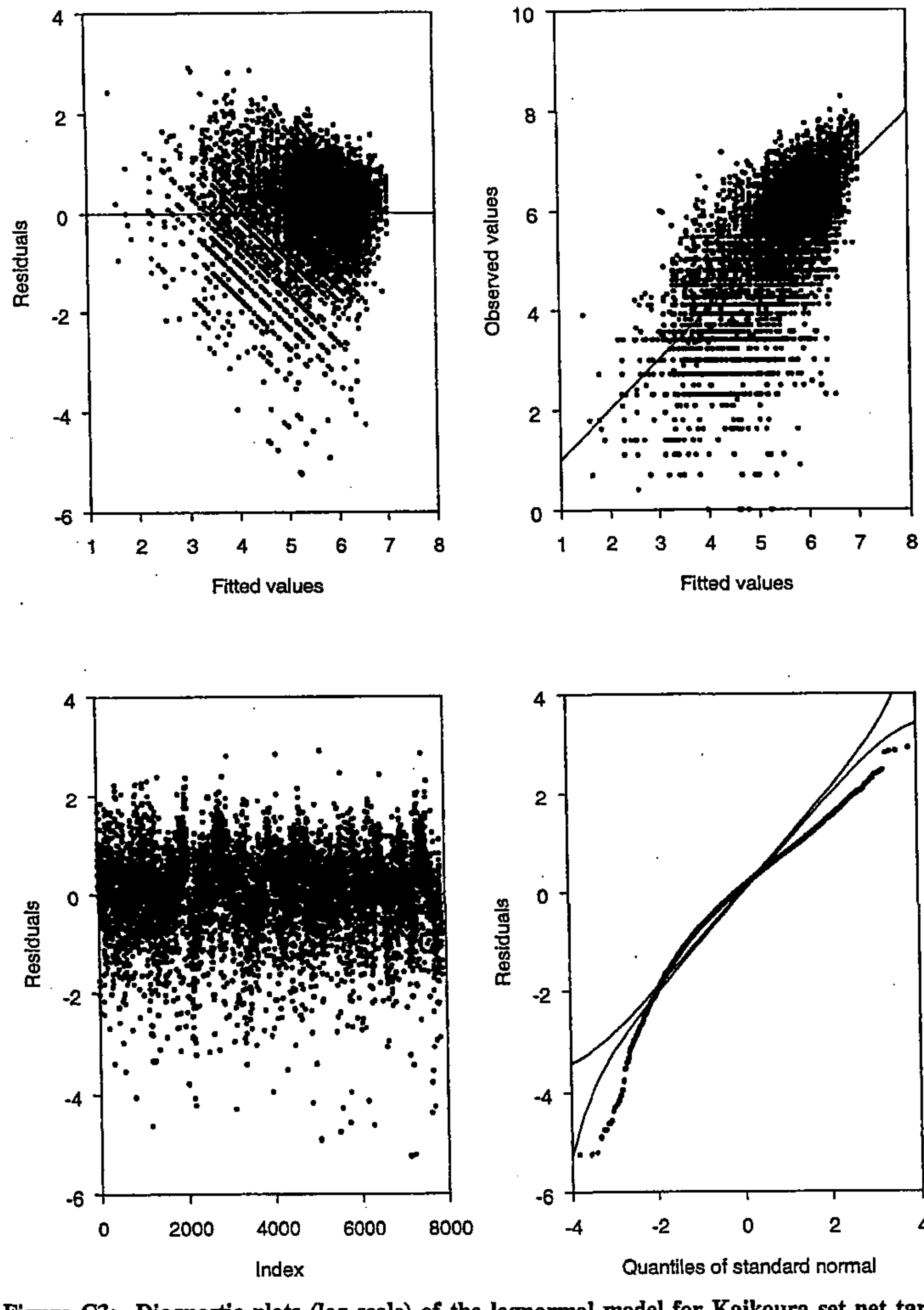


Figure C3: Diagnostic plots (log scale) of the lognormal model for Kaikoura set net target fishery, all vessels. Top left, fitted values versus residuals; top right, fitted values versus observed values; bottom left, plot of the residuals; bottom right, normal quartile-quartile plot of the residuals.

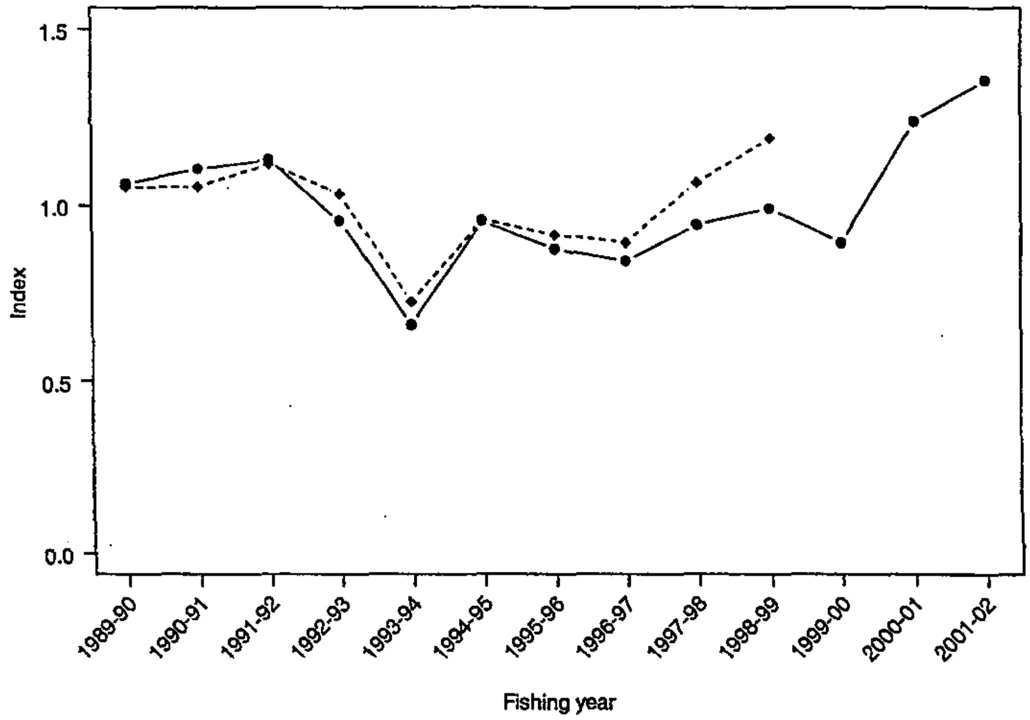


Figure C4: Comparison of the updated Pegasus Bay/Cook Strait setnet target fishery, all vessels CPUE indices (circles) to the 2001 analysis (diamonds) (Field & Hanchet 2001). Note, the indices have been scaled to have mean of 1.