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Analysis of commercial catch and effort data from the northern gemfish (SKI 1 and SKI 2) trawl fishery, 1988–89 to 1994–95

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1. EXECUTIVE SUMMARY

In this paper the fisheries for gemfish in SKI 1 and SKI 2 are briefly described and the results of standardised catch per unit effort (CPUE) analyses of the gemfish fisheries are presented.

The fishery in SKI 1 is a trawl fishery targeting gemfish migrating north in April, May, and June to spawn; in some years gemfish are also caught in late August and September as they return southwards. In SKI 2 gemfish are also caught mainly by trawlers targeting them, but some are also taken by trawlers targeting other species such as scampi, tarakihi, and hoki. The SKI 2 fishery operates through most of the year except for June and July when gemfish appear to be absent from the area. At this time they are believed to migrate northwards into SKI 1 to join the northwards spawning migration.

The results of the CPUE analyses showed a steep decline in CPUE in the gemfish fisheries in both SKI 1 and SKI 2. The declines were steep from the fishing year 1988–89 to 1991–92 in SKI 1 and from 1989–90 to 1992–93 in SKI 2. The pattern of decline was very similar in both areas though the steep decline continued in SKI 2 for 1 year longer than in SKI 1. In both areas the decline since has been only small. The CPUE in both areas in 1994–95 was about 30% of the levels in 1988–89 in SKI 1 and in 1989–90 in SKI 2.

2. INTRODUCTION

Methods previously used to estimate MCY based on commercial landings data are no longer considered to be appropriate (Annala & Sullivan 1996) and there are currently no estimates of yield for any gemfish stocks. A standardised catch per unit effort analysis for gemfish caught in QMA 1 (SKI 1) during fishing years 1988–89 to 1993–94 showed a decline of about 60% in the standardised catch rates (Langley 1995).

In this paper this analysis has been updated with the inclusion of data from the 1994–95 fishing year, and a similar analysis has been carried out for the gemfish fishery in SKI 2 for the fishing years 1989–90 to 1994–95.

2.1 THE NORTHERN GEMFISH FISHERY (SKI 1 and SKI 2)

The fishery for gemfish in SKI 1 (QMA 1 and QMA 9 in Figure 1) is a trawl fishery which targets gemfish on their annual spawning migration. The fishery peaks during April, May, and June, and in some years there is a minor fishery in late August and September as the fish return from the northern spawning grounds.

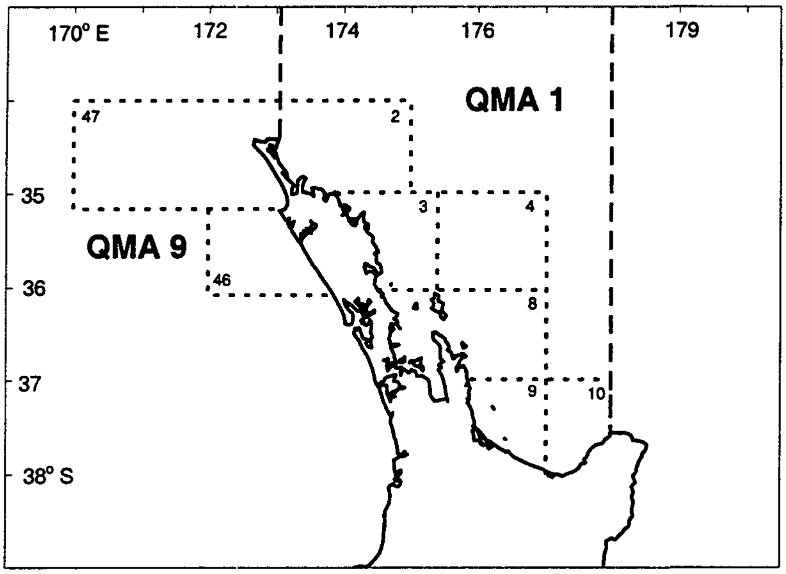

Figure 1: Statistical and Quota Management Areas within the SKI 1 fisheries.

Before 1990–91, the proportion of the total SKI 1 catch from statistical areas 46 and 47 was less than 1%, but since then has steadily increased to comprise 516 t out of a total of 900 t (57.5%) in 1994–95 (Table 1), reflecting the high catch rates that can be achieved in this area. Tows made in QMA 9 have been excluded from this analysis, as the relationship between these fish and those caught in QMA 1, is unknown.

The gemfish fishery in SKI 2 off the east coast of the North Island (Figure 2) is exploited by inshore vessels operating out of Napier, Wellington and Gisborne. The fishery began largely as a bottom trawl fishery, but since the 1991–92 fishing year an increasing proportion of the catch has been taken by midwater trawl (33% in 1993–94, and 61% in 1994–95). This target fishery operates throughout the year, except for June and July when the fish are assumed to migrate north to spawn in the SKI 1 area; it is thought that gemfish in SKI 1 and SKI 2 are a single stock. Most of the catch in SKI 2 is taken between Mahia Peninsula and Cape Palliser (i.e., statistical areas 013, 014, and 015, *see* Figure 2) in the 250–350 m depth range, with most being taken in statistical area 014 (Table 2).

Table 1: Total gemfish catch (t) and total number of hours fished (in italics) for each statistical area in SKI 1 and each fishing year

Statistical area	Fishing year						
	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95
QMA 1							
002	0.0	0.0	0.0	0.5	15.0	38.8	36.7
	0.0	*0.0*	*3.0*	*36.0*	*77.9*	*191.3*	*190.8*
003	44.3	252.4	292.2	256.9	222.5	260.1	247.7
	130.5	*538.0*	*878.6*	*544.9*	*565.5*	*679.4*	*560.1*
004	0.0	0.0	0.0	1.1	55.0	11.2	5.4
	0.0	*0.0*	*0.0*	*45.0*	*233.9*	*118.7*	*33.7*
008	94.2	271.3	82.1	169.3	431.6	150.1	72.5
	193.0	*1 287.1*	*494.6*	*1 549.5*	*3 277.3*	*1 117.1*	*575.8*
009	67.9	272.0	242.0	199.1	114.9	33.8	16.6
	201.0	*1 080.6*	*1 710.8*	*1 893.7*	*1478.0*	*536.1*	*344.9*
010	157.4	158.8	237.3	68.9	17.5	0.4	3.4
	601.7	*829.8*	*1 237.2*	*801.0*	*463.3*	*27.4*	*103.2*
QMA 9							
046	0.0	0.3	0.0	0.0	0.9	108.2	91.8
	0.0	*3.0*	*0.0*	*0.0*	*3.5*	*156.4*	*216.6*
047	0.6	1.2	7.9	57.2	114.6	340.3	425.8
	0.0	*7.9*	*40.0*	*353.0*	*330.1*	*580.9*	*953.6*
Total SKI 1	364.4	956.0	861.5	752.9	972.0	943.0	900.0
	1 126	*3 746*	*4 364*	*5 223*	*6 429*	*3 407*	*2 978*

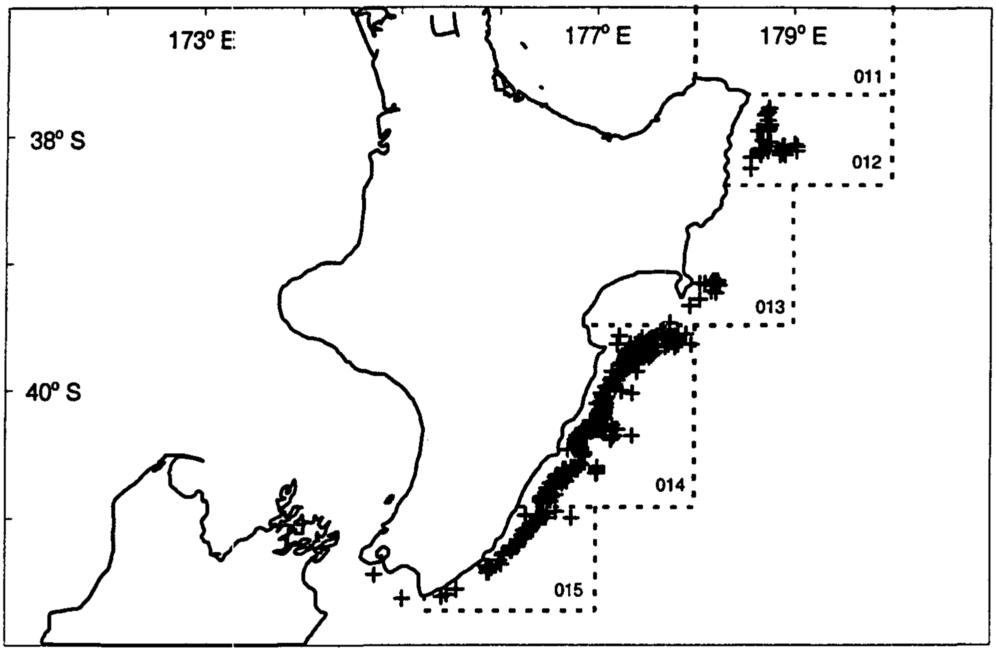

Figure 2: Statistical areas and tow start positions during the period 1989–90 to 1994–95 within the SKI 2 fishery.

Table 2: Total catch (t) and total number of hours fished (in italics) for each statistical area in SKI 2 and each fishing year

						Fishing year
	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95
Statistical area						
013	33 786	67 043	101 293	49 042	25 045	7026
	270	*482*	*1072*	*657*	*377*	*195*
014	535 616	246 303	556 731	427 283	470 640	189 704
	2326	*1769*	*3835*	*5071*	*4739*	*2634*
015	106 876	113 384	100 152	118 884	31 159	60 909
	619	*868*	*751*	*899*	*649*	*674*
Total	676 278	426 730	758 176	595 209	526 844	257 639
	3215	*3119*	*5659*	*6626*	*5765*	*3503*

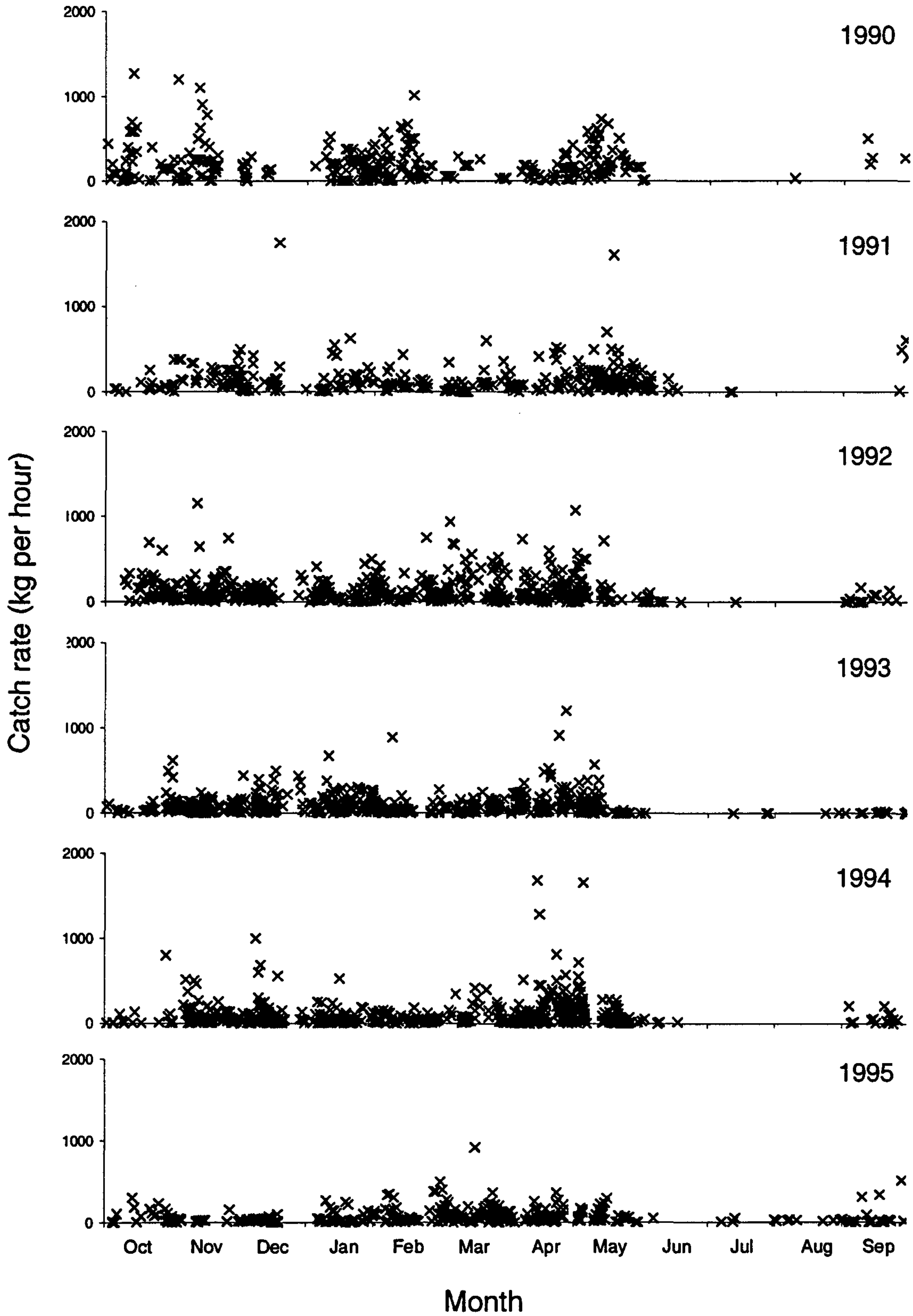

Figure 3: Catch rates (kg per hour) of gemfish in SKI 2 by month, 1989–90 to 1994–95.

Throughout fishing years 1989–90 to 1994–95, the bottom trawl fishery within QMA 2 has maintained consistent catch rates all year round, apart from during June, July, and August (Figures 3 and 4). It is currently assumed that the gemfish from QMA 2 join the fish from QMA 1 in migrating to North Cape to spawn during July. Fish reappear in the QMA 1 fishery in early August, but seem to reappear slightly later in the main statistical areas in QMA 2, consistent with a return migration from spawning further north.

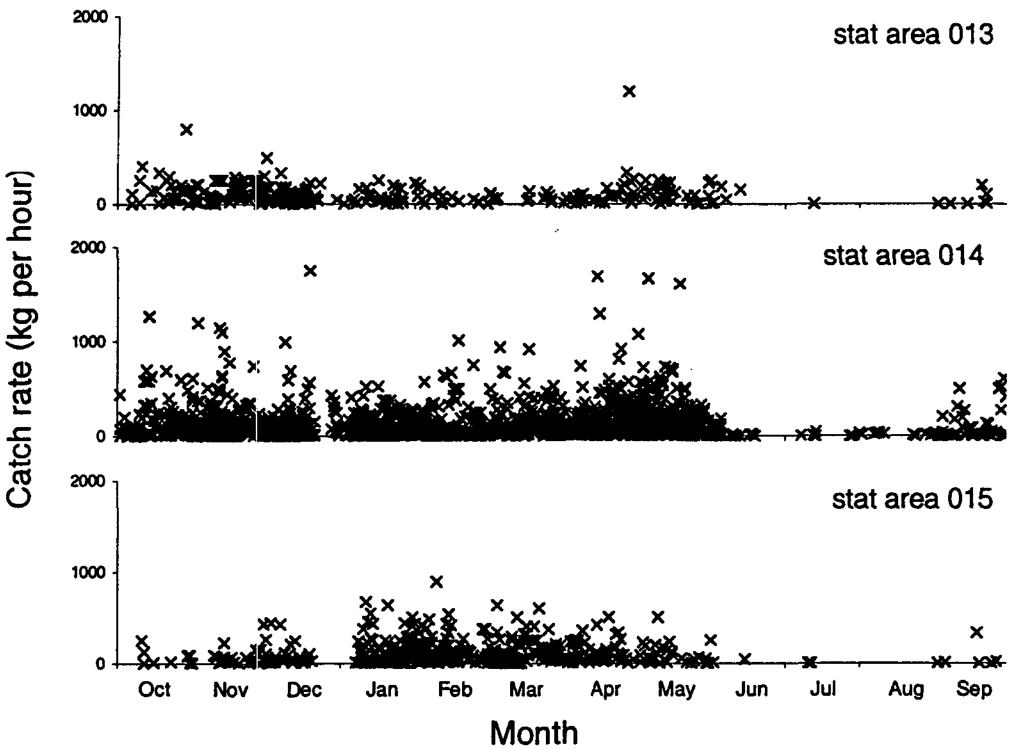

Figure 4: Catch rates (kg per hour) of gemfish by month for each statistical area in SKI 2, 1989–90 to 1994–95.

Gemfish is also taken as a small bycatch of the scampi, tarakihi, and hoki target trawl fisheries in QMA 2. In addition, QMA 2 supports small target line and set-net gemfish fisheries, and gemfish is a minor bycatch of the bluenose, ling, and hapuku/bass line fisheries.

3. METHODS

3.1 Data

Data from SKI 1 and SKI 2 were analysed separately.

All bottom trawls targeting gemfish within QMA 1 (statistical areas 001–010) from 1988–89 to 1994–95 between 1 April and 30 September, and within QMA 2 (statistical areas 013–015) at all times, were considered in the analyses. Data from QMA 1 for 1988–89 to 1993–94 were available from a previous analysis (Langley 1995). Data from QMA 1 for 1993–94 and 1994–95, and from 1989–90 to 1994–95 for QMA 2, were extracted from the Ministry of Fisheries catch-effort data system. There were only minor differences (due to updating and correction of data) between the 1993–94 data extracted for this analysis and those used by Langley (1995).

Vessels operating within these fisheries record catch effort information either on TCEPR or CELR forms. The TCEPR forms record tow by tow information, including the latitude and longitude of the start of the tow and the tow duration. The CELR forms record tow position only as a statistical area and the catch and number of hours fished are aggregated for each day, so it was necessary to summarise the data from the TCEPR forms for each vessel by day and statistical area.

A number of range checks were performed on the data:

- trawl start position within the area of known fishing grounds
- trawl duration between 0.1 and 22 hours
- number of trawls per day between 1 and 5
- total daily catch between 0 and 15 000 kg
- duplicate records

Obvious errors were corrected, and records with unresolvable errors were excluded from the analysis. The variables extracted from these data for use in the analyses are shown in Table 3.

Table 3: Summary of variables included in the regression analysis. "cont" indicates a continuous variable modelled as a simple linear variable unless otherwise indicated, "cat" indicates a categoric variable with the given number of categories in parentheses

Variable	**Description of variable**	**Variable Type**
Vessel	Fishing vessel code	cat (28)
Fishing year	Fishing year that record occurred	cat (7)
Day	Day of year relative to April 1	cont
Statistical area	Statistical area that fishing occurred	cat (6)
Season*	Pre-, during, or post-spawning	cat (3)
Seasonday*	Day relative to season peak	cont (quadratic)
Oalength	Overall registered length (m) of vessel	cont
Breadth	Breadth (m) of vessel	cont
Draught	Draught (m) of vessel	cont
l*b*d	Vessel length * breadth * draught	cont (quadratic)
Power	Vessel engine power (kW)	cont
Tonnage	Vessel gross registered tonnage	cont
Year built	Year vessel was built	cont

* Used only in the analysis for SKI 1

The variables 'Season' and 'Seasonday', used only in the analysis for SKI 1, describe changes in catch rate throughout the fishing season. The 'Season' variable had three categories, determined by whether the fishing was carried out pre-spawning (April to May), during spawning (July), or post-spawning (August and September). The 'Seasonday' variable was used to describe the number of days away from the season peak a fishing event took place. The day of year with the highest catch rate in each statistical area, for each fishing year, was defined as day zero. If there was significant fishing during the post-spawning season, a separate peak was defined for this period. Table 4 shows the days of the year (relative to 1 April) defined as the season peak for each statistical area and each fishing year.

Table 4: The day(s) of the year (starting at 1 April) representing the peak catch rate, for each statistical area in SKI 1 and each fishing year. Those with two numbers represent two peaks in fishing, one pre- and one post-spawning. – indicates no peak day was determined

	Statistical area					
	2	3	4	8	9	10
Fishing year						
1988–89	–	74	–	62	61	–, 153
1989–90	–	63, 145	–	48, 142	61, 177	49, 148
1990–91	–	78	–	59	60, 152	57, 154
1991–92	–	65	–	53	53, 128	49, 158
1992–93	75	65	33	47	39	–, 134
1993–94	81	54	41	48	49	65, 137
1994–95	52	53, 137	55	47	45	48, 123

3.2 Analysis

The data from SKI 1 and SKI 2 were analysed separately; the methods of analysis were the same, as described below.

Indices of relative abundance were calculated from the commercial catch and effort data using a multiple regression technique (Vignaux 1992). The index log (catch per hour) was taken as the index of catch per unit effort (CPUE) for the analyses. Tows with a zero catch were arbitrarily assigned a catch of 1 kg in order to avoid the problem of trying to use the log of zero.

Two multiple regression analyses were carried out.

1. All data model
   All vessels were included in the analysis, with vessel effects being described by the variables overall length, breadth, draught, l*b*d, tonnage, year built, and power.

2. Categoric vessel model
   The dataset was restricted to vessels present in the fishery for at least 3 years. There were 28 separate vessels included in the analysis, and these vessels accounted for over 90% of the overall annual catch in both SKI 1 and SKI 2.

For each of these models, the CPUE estimate was regressed against each of the possible predictor variables to determine which of these variables explained the most variability in the CPUE. This selected variable was then included in the model, and the CPUE was regressed against this variable and each of the other predictor variables to find the next variable. At each iteration of the model, the sum of squares for regression (SSR) was used as a measure of the amount of variability explained by the model. This stepwise procedure was continued until the addition of an extra variable improved the SSR by less than 3%. An index of relative abundance was estimated for both models in each area (SKI 1 and SKI 2) from the year coefficients (Doonan 1991).

4. RESULTS

4.1 SKI 1

The variables included in the all data model are shown in Table 5. In iteration 1, l*b*d was the variable that explained most of the variation in CPUE. The next significant variables added were seasonday, fishing year, season, and statistical area. The addition of the day variable in iteration 7 improved the SSR by only 0.1%, and so it was not included in the model. The full model accounted for 27.4% of the total variance.

Table 5: Variables included in the all data model for SKI 1

	R^2 at iteration						
Variable	1	2	3	4	5	6	7
l*b*d	11.23						
Seasonday	7.66	17.96					
Fishing year	4.88	15.84	22.05				
Season	3.00	14.03	20.22	24.62			
Statistical area	6.73	13.55	20.27	25.07	26.32		
Day	2.29	12.64	20.07	24.36	25.89	27.36	
Overall length	9.07	11.30	18.01	22.07	24.62	26.36	27.40
Breadth	10.44	11.27	18.01	22.06	24.62	26.33	27.36
Draught	8.86	11.25	17.97	22.06	24.62	26.32	27.36
Tonnage	9.38	11.37	18.04	22.09	24.62	26.36	27.39
Yearbuilt	3.16	11.54	18.20	22.23	24.71	26.32	27.37
Power	6.99	11.43	18.16	22.17	24.64	26.32	26.32
SSR % Improvement		59.9	22.8	11.7	6.9	4.0	0.1

Table 6: The relative year effect indices calculated from the all data model for SKI 1

Fishing year	Year effect 1995 analysis	Year effect 1996 analysis	Standard error 1996 analysis
1988–89	1.000	1.000	–
1989–90	0.732	0.812	0.114
1990–91	0.642	0.652	0.090
1991–92	0.427	0.366	0.051
1992–93	0.371	0.380	0.053
1993–94	0.396	0.407	0.061
1994–95		0.313	0.050

The relative year effects for the analysis carried out in 1995 (Langley 1995), the year effects calculated from this analysis, and their standard errors calculated from the all data model are shown in Table 6 and Figure 5.

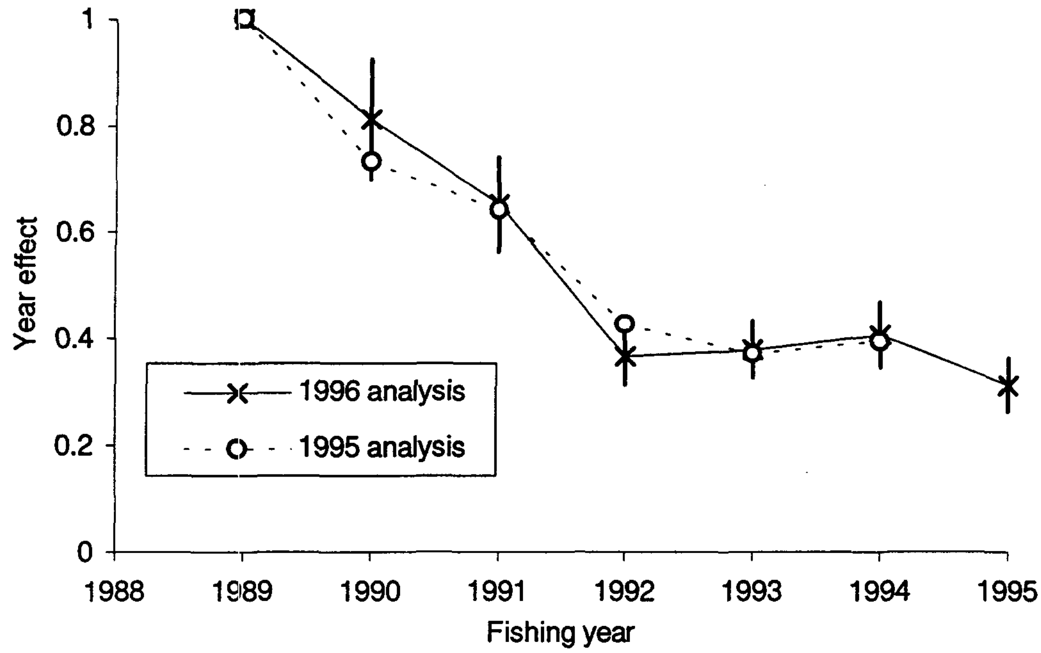

Figure 5: Relative year effect indices and standard errors (vertical bars) calculated from the all data model for SKI 1 compared with the 1995 analysis.

The variables included in the categoric vessel model are shown in Table 7. The vessel variable replaces l*b*d as the most significant variable, but the other variables were the same and entered in the same order as in the all data model analysis. The full model accounted for 29.9% of the total variance.

Table 7: Variables included in the categoric vessel model for SKI 1

	R^2 at iteration						
Variable	1	2	3	4	5	6	7
Vessel	14.83						
Seasonday	8.72	17.96					
Fishing year	4.97	18.14	25.22				
Statistical area	7.26	16.51	24.02	27.55			
Season	2.72	17.22	23.96	26.99	28.85		
Day	1.81	15.81	23.72	26.81	28.51	29.92	
l*b*d	11.31	14.99	22.59	25.53	27.79	29.08	30.10
Overall length	8.73	14.95	22.59	25.53	27.77	29.06	30.10
Breadth	10.01	14.83	22.38	25.22	27.55	28.85	29.92
Draught	7.94	14.83	22.38	25.22	27.55	28.85	29.92
Tonnage	8.59	14.84	22.42	25.28	27.64	28.92	29.94
Yearbuilt	3.68	14.92	22.45	25.34	27.66	28.95	29.96
Power	8.27	15.03	22.64	25.31	27.64	28.94	30.00
SSR % Improvement		50.9	12.7	9.2	4.7	3.7	0.6

The relative year effects for the analysis carried out in 1995 (Langley 1995), the year effects calculated from this analysis, and their standard errors calculated from the categoric vessel model are shown in Table 8 and Figure 6.

Table 8: The relative year effect indices calculated from the categoric vessel model for SKI 1

Fishing year	Year effect 1995 analysis	Year effect 1996 analysis	Standard error 1996 analysis
1988–89	1.000	1.000	–
1989–90	0.718	0.754	0.110
1990–91	0.572	0.563	0.081
1991–92	0.463	0.371	0.055
1992-93	0.407	0.396	0.059
1993–94	0.391	0.387	0.061
1994–95		0.297	0.050

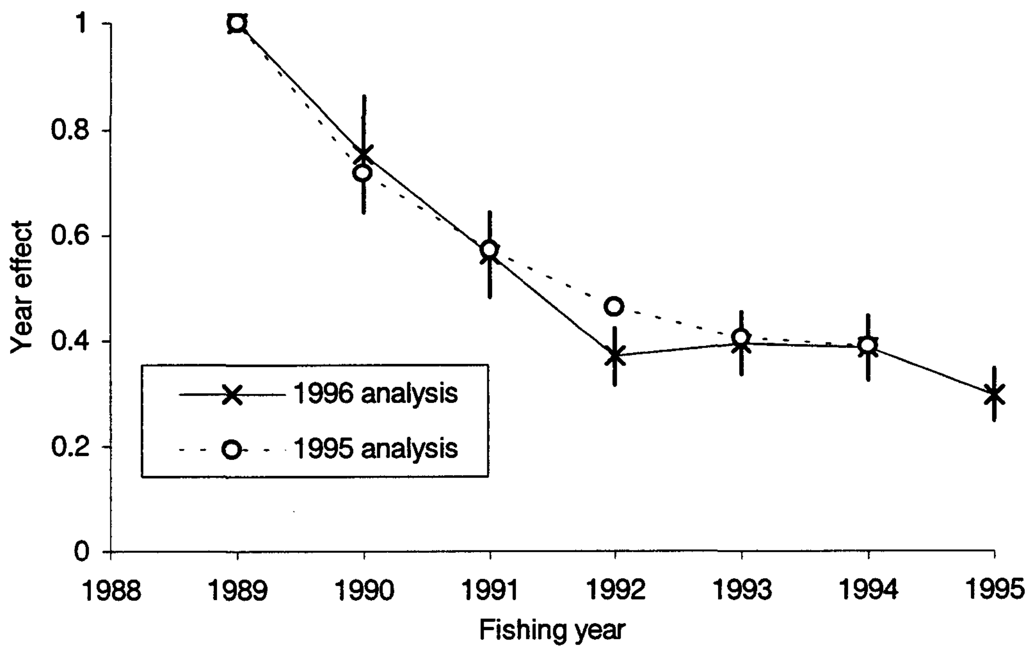

Figure 6: Relative year effect indices and standard errors (vertical bars) calculated from the categoric vessel model for SKI 1 compared with the 1995 analysis.

The year effects from the all data model and the categoric vessel model are very similar (Figure 7), reflecting the fact that most of the catch is taken by vessels experienced in the fishery (and hence included in the categoric vessel model).

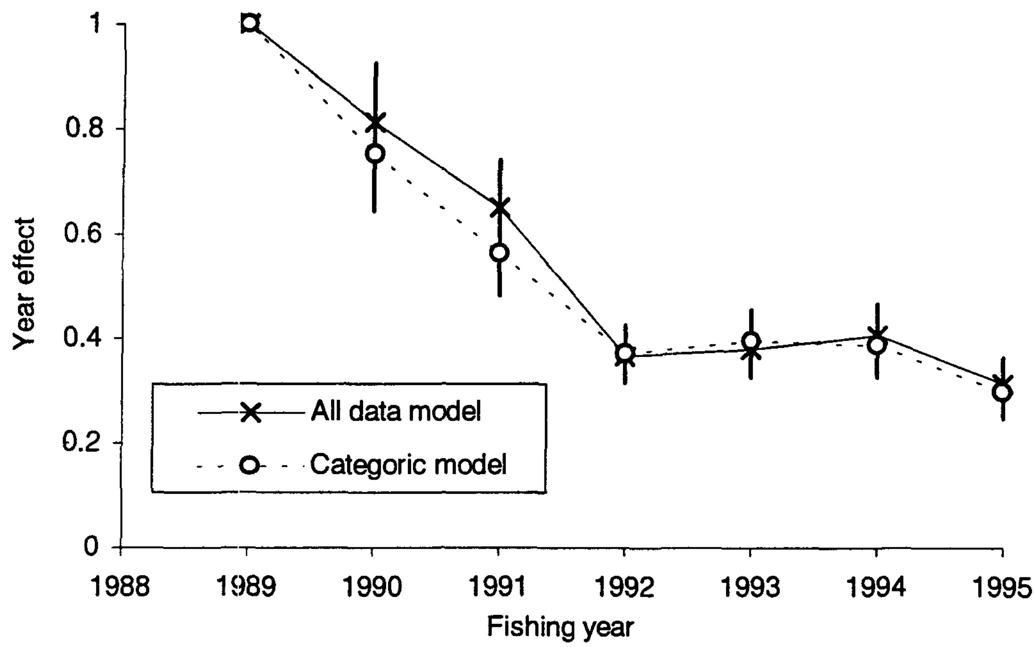

Figure 7: Relative year effect indices for both the all data model and the categoric vessel model for SKI 1.

4.2 SKI 2

The variables included in the all data model are shown in Table 9. The variable that explained the most variance in the model was month. The next significant variables added were fishing year, yearbuilt, and oalength. The four variables included in the model explained 12.8% of the total variance in log(catch per hour).

Table 9: Choice of variables included in the all data model for SKI 2

	R^2 at iteration				
Variable	1	2	3	4	5
Month	5.86				
Fishing year	4.15	10.04			
Yearbuilt	1.18	7.52	12.14		
Oalength	0.54	6.31	11.02	12.76	
Tonnage	0.04	5.86	10.34	12.15	12.82
Breadth	0.98	6.74	10.28	12.53	12.81
l*b*d	0.65	6.11	10.21	12.67	12.81
Statistical area	0.02	5.88	10.17	12.19	12.80
Draught	0.90	6.69	10.25	12.16	12.78
Power	1.07	6.09	10.76	12.16	12.77
SSR % improvement		71.3	20.9	5.11	0.47

The relative year effects and their standard errors calculated from the all data model are shown in Figure 8 and Table 10.

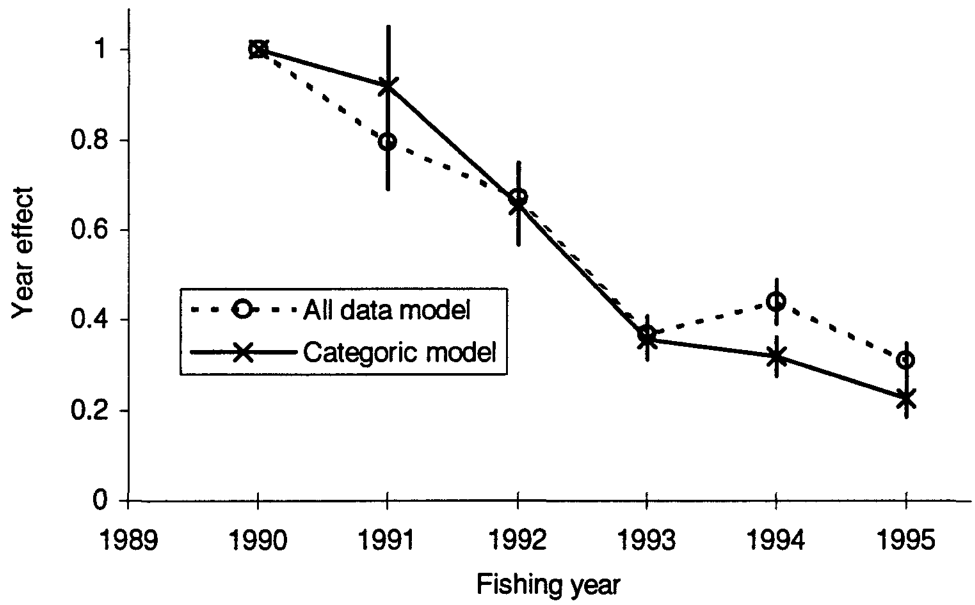

Figure 8: Relative year effect indices and standard errors (vertical bars) for the all data model and the categoric vessel model for SKI 2.

Table 10: The relative year effect indices calculated from the all data model for SKI 2

Fishing year	Year effect	Standard error
1989–90	1.000	–
1990–91	0.795	0.103
1991–92	0.671	0.078
1992–93	0.370	0.042
1993–94	0.441	0.050
1994–95	0.310	0.040

The variables included in the categoric vessel model are shown in Table 11. The vessel variable replaces month as the most significant variable, and the other significant variables to enter the model were month and fishing year. The three variables included in the model explained 17.6% of the total variance in log(catch per hour).

The relative year effect indices and their standard errors calculated from the full model are shown in Figure 8 and Table 12.

Table 11: Choice of variables included in the categoric vessel model for SKI 2

Variable	R^2 at iteration 1	2	3	4
Vessel	6.77			
Month	5.20	11.97		
Fishing year	4.11	11.20	17.38	
Statistical area	0.06	7.22	12.37	17.60
SSR % improvement		76.8	45.2	1.3

Table 12: The relative year effect indices calculated from the categoric vessel model for SKI 2

Fishing year	Year effect	Standard error
1989–90	1.000	–
1990–91	0.918	0.132
1991–92	0.655	0.086
1992–93	0.359	0.046
1993–94	0.320	0.044
1994–95	0.226	0.040

The year effects from the all data model and the categoric vessel model are very similar (Figure 8). The slight discrepancy in the indices for the last 2 years could be due to changes in the proportion of catch accounted for in the categoric vessel model.

5. DISCUSSION

In QMA 1, the fishery for gemfish is based on the northern spawning migration. Catch rates begin to increase from mid May and peak in June. The fish are absent during July (Langley 1995). Catch rates then increase again during August, as spent fish return from spawning. These patterns are particularly evident during the first few years of the fishery, before changes in fishing patterns led to the season being spread over a longer period.

Catch rates of gemfish in QMA 2 appear to decline around early June, and no further significant landings are made until late August and early September. This pattern is not only reflected in the target trawl fisheries, but also other fisheries in QMA 2 where gemfish are taken as a bycatch. It therefore seems likely that the fish migrate out of the area. The evidence from the distribution of gemfish in both QMAs 1 and 2 suggests that gemfish migrate from QMA 2 to QMA 1 in May and June, probably to spawn, and return in August and September. There is currently no evidence for a spawning ground for gemfish in QMA 2, and the extent of the migration to the spawning grounds off North Cape is not out of line with the migration undertaken by gemfish off the eastern New South Wales coast (Rowling 1990).

In both areas (SKI 1 and SKI 2) the results of the two models are very similar. The criteria for including vessels in the categoric analysis is their presence in at least 3 years since 1988–89 in SKI 1 and since 1989–90 in SKI 2. Almost all of the catch (over 90%) in SKI 1 is taken by the vessels now included in the categoric vessel analysis. In SKI 2 the entry of new vessels into the fishery during the last 2 years reduced the catch from vessels included in the categoric vessel analysis to about 50%; these changes may make the categoric vessel analysis less reliable than the all data analysis. The total variance explained by the respective models was similar, so it therefore seems unnecessary to continue carrying out both analyses, and it is suggested that only the all data model be carried out in future.

The year effect indices derived from both models indicate that there has been a substantial, and very similar, decline in the standardised catch rate in both areas, in SKI 1 since 1988–89 and in SKI 2 since 1989–90. This decline was most pronounced up to 1991–92 in SKI 1 and to 1992–93 in SKI 2, and has subsequently remained fairly stable at about 30% of the 1988–89 and 1989–90 levels respectively. Reasons for this decline are not clear, but recruitment appears to have been poor in recent years (Annala & Sullivan 1996). It is likely that the decline in catch rate is related to a decrease in the stock size as a result of recruitment not fully replacing fish removed by fishing. However, it is not known how well the stock size is related to the catch per unit effort index.

Langley (1995) analysed the standardised catch rates from each of the statistical areas in SKI 1 separately and showed that the northern areas generally had higher catch rates. Annual indices were also calculated for each area, and he expressed concern at the apparent variability, both between areas and in the overall analysis.

There are several factors which may account for some of these observed differences. The proportion of the catch taken in statistical areas 009 and 010 has generally declined during the period and has been insignificant since 1992–93. Catches from area 010 have been taken predominantly during the post-spawning run in August and September. The catch and timing of fishing in area 008 has fluctuated considerably between years. The total catch in area 003 has remained fairly stable, but with the decline in landings from the other areas catches from area 003 now constitute nearly 65% of the QMA 1 total. Furthermore, as Langley noted, the catch rates in area 003 are higher than in the other areas, and occur a little later in the season than in the areas further south. This suggests that the fish may aggregate in this area before moving further north to spawn. CPUE analyses become increasingly unreliable in more aggregated fisheries, and the decline in the year effect indices is often less marked than the true decline in relative biomass, an effect referred to as 'hyperstability' (Hilborn and Walters 1992). The overall analysis may therefore be being influenced by the catch rates in area 003.

Future analyses should also consider whether tows made during the post-spawning season should be included in the analysis. Most of the season's catch has already been removed from the stock during the pre-spawning season, the post-spawning run dynamics are not well understood, and catches taken post-season are predominantly in statistical area 010. The relationship between the fisheries in QMA 1 and QMA 9 also needs to be determined before any analysis can be carried out on the fishery in statistical areas 46 and 47. Given that the timing of the fisheries in these areas is similar to those at equivalent latitudes on the east coast, it is possible that the fish in QMA 9 are migrating from areas further south on the west coast of the North Island.

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