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Analysis of commercial catch and effort data from the gemfish (SKI 1) trawl fishery, 1988–89 to 1993–94

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1. EXECUTIVE SUMMARY

A regression analysis of gemfish catch and effort data from the QMA 1 (part of SKI 1) commercial trawl fishery is presented. Standardised catch rates from the fishery declined by over 50% during the period 1988–89 to 1991–92, and remained at around 40% of the 1988–89 index for the 1992–93 and 1993–94 fishing years. Since 1991–92 there has been a considerable shift in the areal distribution of the commercial catch with the development of the gemfish fishery off the northern west coast of the North Island (QMA 9, part of SKI 1). Catches have steadily increased from this area which in 1993–94 accounted for 43% of the total SKI 1 trawl catch.

2. INTRODUCTION

The gemfish 1 (SKI 1) fishstock includes the area around the northern North Island from Tirua Point on the west coast to North Cape (QMA 9, statistical areas 042–048) and North Cape to Cape Runaway on the east coast (QMA 1, statistical areas 001–010). This area supports an important seasonal bottom trawl fishery for gemfish. The catch increased in 1988–89 following an increase in the TACC from 632 t to 1139 t due to decisions by the Quota Appeal Authority. Since 1988–89, annual catches have remained relatively stable between 1000 and 1300 t (Annala 1995).

There is considerable uncertainty regarding the stock assessment of the SKI 1 fishery. The estimate of yield (MCY) of 77790 t was based on the average catch for the period 1988–89 to 1993–94 (Method 4, $MCY = cY_{av}$: Annala 1995). However, there is some concern regarding the applicability of this method, given that the catch history represents a short period following the expansion of the fishery, and that during this period the catch was constrained by the TACC.

MAF Fisheries sampled the SKI 1 commercial catch annually between 1989 and 1994. The results and a description of the commercial fishery were presented by Langley *et al.* (1993). This report updates the review of the fishery and documents the results of an analysis of catch and effort data from the commercial fishery.

3. DESCRIPTION OF THE FISHERY

Most of the catch from the SKI 1 fishery is taken during late autumn and winter. In general, fishing begins in April and peaks in May and June. Catch rates decline in late June and catches are negligible during July when gemfish are unavailable to the commercial fleet. There is a secondary peak in the catch during August and early September (Figure 1).

The fishery is conducted by inshore trawl vessels operating from Auckland, Onehunga, and Tauranga. Since 1988–89, the fleet has included a core of about 25 vessels, which in recent years has expanded with the entrance of additional vessels into the fishery. Fishing is conducted using bottom trawl gear, with most of the catch taken from the 250–350 m depth range.

During the period 1988–89 to 1991–92, most of the annual catch was taken between North Cape and Cape Runaway (QMA 1), in particular from the Poor Knights Shelf (statistical area 003) and through the Bay of Plenty (statistical areas 008, 009, and 010) (Table 1, Figure 2). Fishing generally began in the Bay of Plenty during mid April, and spread to the Poor Knights Shelf in early May. Most of the catch during August and September was from the Bay of Plenty (Figure 3).

There have been several changes in the seasonal patterns in the fishery since 1991–92; the fishing season has begun earlier than in the preceding years, with catches taken during early April (*see* Figure 1); the proportion of the QMA 1 catch taken from the August-September fishery in the Bay of Plenty has declined; and there has also been a considerable shift in the areal distribution of the catch, with an increasing proportion of the catch taken from the northern west coast of the North Island, off Reef Point (Tauroa Point). In 1993–94, this area accounted for 46% of the total target trawl catch (*see* Table 1).

The seasonal and areal trends in the commercial catch, and the gonadal development data collected from the sampled catch, suggest that the QMA 1 fishery is exploiting a prespawning northward migration of gemfish (Langley *et al.* 1993) during April to June. Catches of gemfish from the Bay of Plenty in August and September are generally dominated by post-spawning fish. Fish taken from the northern west coast of the North Island (QMA 9) during June were also in the pre-spawning stages of gonad development. However, the stock relationship between the east and west coast fisheries is unknown.

4. METHODS

4.1 The Data

All bottom trawls targeting gemfish conducted within QMA 1 (statistical areas 001–010) during the period 1988–89 to 1993–94 were initially considered in the analysis. Data were extracted from the *vessel-details, trawl-header, trawl-detail, catch-header, effort-catch, specified-header,* and *specified-catch* tables of the Catch Effort database. The following data were available.

Vessel-details vessel information.

- overall length, breadth, draught, and tonnage of vessel
- power of vessel engine(s)
- year the vessel was built

Trawl-header, trawl-detail individual trawl details, 1989–94.

- vessel-id
- date
- time of start and end of tow
- latitude and longitude at start of tow
- depth of bottom (m)
- estimated catch of gemfish (kg)

Effort-header, effort-catch catch and effort data summarised by statistical area and day, 1989–1994.

- vessel-id
- date
- statistical area
- total hours fished
- total number of tows
- estimated catch of gemfish (kg)

Specified-header, specified-catch individual trawl details, 1988–1989.

- vessel-id
- date
- time of start and end of tow
- latitude and longitude at start of tow
- depth of bottom (m)
- catch of gemfish (kg)

The following checks were performed on the data.

- total daily catch by a vessel within 0–10 000 kg range.
- trawl start position within area of known fishing grounds.
- start time earlier than end time.
- depth of trawl greater than 200 m.
- number of trawls completed during a day within 1–5 range.
- total hours fished per day within the range 0.5–20.
- average trawl duration within 1–8 h range.
- reported statistical areas are consistent with seasonal trend in fishery.
- duplicate records.

Obvious errors were corrected and records containing unresolvable errors were deleted from the database.

Most (80%) of the catch and effort data were reported in summary format, i.e., by day fished and statistical area (*effort-catch* data), so it was necessary to transform individual trawl data to a comparable format. Trawl data extracted from *trawl-detail* and *specified-catch* tables were assigned to a given statistical area based on the start position of the trawl. The associated catch and effort (number of trawls and hours fished) data were aggregated to the level of vessel, fishing day, and statistical area.

Two additional variables, season and seasonday, were defined to describe the seasonal trends in the fishery. Season was defined as either pre-spawning (April–June), mid-season (July) or post-spawning (August–September). Seasonday was defined relative to the peak in the mean catch rate of the fleet for a given statistical area, season, and fishing year. The variables included in the analysis are summarised in Table 2.

4.2 Regression Analysis

Indices of relative abundance were calculated from commercial CPUE data using a multiple regression technique developed by Doonan (1991) and Vignaux (1992).

The CPUE index of log (catch per hour) was chosen for the analysis. Catch per tow was not considered as an appropriate index of CPUE, given that the trawl duration had increased in the most recent years (Tables 3 and 4). Because the logarithm of zero is undefined, zero catches were assigned a nominal catch of 1 kg (55 records).

Two alternative models were considered in the analysis.

1. Categoric vessel model
   Individual vessel effects described using the categoric variable vessel. The data set was restricted to those vessels fishing during at least 3 years during the period 1988–89 to 1993–94. The data set represented a total of 25 vessels, accounting for between 77 and 98% of the annual gemfish catch from QMA 1 (*see* Table 3).

2. All data model
   All data included in the model and vessel effects described by variables overall length, breadth, draught, l*b*d (length*breadth*draught), tonnage, year built, and power. The data included in the model are summarised in Table 4.

For each model, the CPUE estimate was regressed against each of the predictor variables to determine which explained the most variability in the CPUE. This selected variable was then included in the model and the CPUE regressed against the selected variable and each of the other predictor variables to determine the next most powerful variable. The step wise regression procedure was continued until the remaining variables contributed no significant power to the model.

At each iteration, the predictor variable with the most explanatory power for the CPUE was chosen using the Sum of Squares for Regression (*SSR*) as a measure of the amount of variability in the data explained by the variables included in the model (Brook & Arnold 1985). The total variability in the data is the Total Sum of Squares (*SST*). The ratio of *SSR* to *SST* is the proportion of the variability explained by the model (R^2). The iterations were continued until an F test showed that the increase in *SSR* from an extra variable was not significant at the 1% level.

$$F_{1,N-k}=\frac{\Delta SSR}{SSE/(N-k-1)}$$

where N is the number of records in the sample, k is the number of variables already used in the regression, ΔSSR is the increase in *SSR* due to the addition of the extra variable, and *SSE* is the Sum of Squares of the Error (before adding the extra variable). However, because of the large number of degrees of freedom n-k-1 (about 2500), even if ΔSSR is as small as 20, the F test will still be significant at the 1% level (F at least 6.6). It was decided not to carry the procedure on until the addition of another variable became statistically insignificant, because the effect of the extra variables is marginal well before this point (Vignaux 1992). An arbitrary cut off of 3% was chosen (following Vignaux 1992), i.e., the additional variable did not improve *SSR* by 3%.

The categoric vessel model was of the form:

$$C_t \;=\; CPUE_t \;=\; M + V_{i,t} + D_{j,t} + Y_{k,t} + S_{l,t} + A_{m,t} + \varepsilon_t$$

Similarly, for the all data model:

$$C_t \;=\; CPUE_t \;=\; M + T_{p,t} + D_{j,t} + Y_{k,t} + S_{l,t} + A_{m,t} + \varepsilon_t$$

where $CPUE_t$ is the catch per unit effort for the t^{th} tow,
M is the overall mean for $\log(CPUE_t)$,
$V_{i,t}$ is the regression coefficient for the i^{th} vessel,
$T_{p,t}$ is the regression coefficient for the p^{th} variable l*b*d,
$D_{j,t}$ is the regression coefficient for the j^{th} seasonday,
$Y_{k,t}$ is the regression coefficient for the k^{th} year,
$S_{l,t}$ is the regression coefficient for the l^{th} season,
$A_{m,t}$ is the regression coefficient for the m^{th} statistical area,
ε_t is the error in $\log(CPUE_t)$

For each model, a relative year index was estimated from the year coefficients as (*after* Doonan 1991):

$$\hat{A}_i = \exp(\hat{Y}_i - \hat{Y}_{1988\text{-}89})$$

where $\hat{Y}_i$ is the year coefficient for year *i*, $\hat{Y}_{1988\text{-}89}$ is the year coefficient for the 1988–89 fishing year, and $\hat{A}_i$ is the estimate of the year effect in year *i* relative to the year effect of the 1988–89 fishing year. The variance of the estimate is:

$$S^2_{\hat{A}_i} = \hat{A}_i^2 \exp(\sigma^2)\,[\exp(\sigma^2) - 1]$$

where

$$\sigma^2 = Var(\hat{Y}_i) + Var(\hat{Y}_{1988\text{-}89}) - 2Cov(\hat{Y}_i, \hat{Y}_{1988\text{-}89})$$

5. RESULTS

The two CPUE models are very similar in form. The first variable included in the categoric vessel model was vessel (categoric). The categoric variable vessel was not included in the fitting procedure for the all data model, and was replaced in the model by the variable l*b*d (quadratic). The remaining variables included in both models were the quadratic variable seasonday, followed by the categoric variables fishing year, season, and statistical area. The five variables included in the categoric vessel and all data models explained 25% and 24% of the variation in log(catch per hour), respectively (Tables 5 and 7).

The predictor variables describing the dimensions and displacement of each vessel are highly correlated. Consequently, once the variable l*b*d was included in the all data model, the remaining vessel variables did not contribute significantly to the explanatory power of the model. For those vessels included in the categoric vessel model, there was a positive correlation between the individual vessel regression coefficients and the variable l*b*d (R^2 = 0.55).

The performance of the polynomial function describing the relationship between the seasonday variable and standardised catch rate was investigated. For each fishing year and each of the main statistical areas fished, the predicted relationship was compared with the residuals from the regression of log(catch per hour) against the categoric vessel variable. The polynomial function included in the categoric vessel model appears to adequately describe the mean seasonal trend in catch rates across both the fishing years and statistical areas (Figures 4 and 5).

The regression coefficients and relative year effects for each year included in the analysis are given in Tables 6 and 8. The year indices derived from both models are very similar and indicate that standardised catch rates declined by over 50% from 1988–89 to 1991–92. Standardised catch rates have subsequently remained relatively constant from 1991–92 to 1993–94 at around 40% of the 1988–89 index (Figure 6).

The main difference between the two sets of indices is the extent of the decline between the 1990–91 and 1991–92 fishing years, with the all data model revealing a more pronounced decrease in standardised catch rate. The extent of the decline may be attributed to about 12 vessels entering the fishery since 1990–91. It is presumed that these vessels were less experienced in the fishery, and consequently depressed the CPUE index. Most of these vessels were excluded from the categoric vessel model, having fished for fewer than three seasons.

Examination of the statistical area regression coefficients from both models indicates an areal trend in the standardised catch rates. For the main statistical areas fished, there was a trend of increasing catch rates northward along the east coast across statistical areas 010, 009, 008, and 003 respectively (Table 9). Annual indices were calculated for each of these main statistical areas fished using the categoric vessel model. The annual indices derived for each area declined between 1988–89 and 1993–94 (Figure 7). However, the magnitude and timing of the decline was variable between statistical areas. Catch rates from statistical areas 008 and 009 declined substantially from 1988–89 to 1989–90, but subsequently declined at a slower rate, while catch rates in area 010 decreased steadily between 1989–90 and 1992–93. The decline in catch rates from statistical area 003 was relatively steady throughout the period although the extent of the decline was substantially less than in the other three areas.

6. DISCUSSION

The CPUE indices derived from the SKI 1 trawl fishery reveal a substantial decline in standardised catch rates since 1988–89. The decline in catch rates between 1988–89 and 1991–92 is corroborated by other indicators from commercial catch and effort data. For example, the amplitude of the seasonal peaks in unstandardised catch rates, particularly the August-September peak, clearly declined during the same period. Also the percentage of fishing days achieving a mean catch rate over of 300 $kg.h^{-1}$ declined steadily from 40% in 1988–89 to 7% in 1991–92.

Some members of the fishing industry have suggested that the decline in catch rates, and therefore the CPUE indices, is attributable in part to recent trends in the trawl fishery. The potential influence of "new" vessels entering the fishery since 1990–91 has already been mentioned. In addition, since 1990–91 there has been a considerable shift in the proportion of the QMA 1 catch taken from the prespawning (April-June) fishery. There is a valuable market for gemfish roe so the catch taken during this period provides a greater economic return than catches of spent fish from the post-spawning fishery (August-September). The increase in effort during the prespawning fishery was particularly evident in 1993–94 when virtually all the catch was taken by the end of June.

The decline in catch rates can not be directly related to the observed shift in the seasonality of the commercial fishery. Trends in the seasonal catch have occurred only since 1990–91, that is, following the major decline in standardised catch rates. The standardised catch rates actually remained relatively constant during the period 1991–92 to 1993–94, despite the recent seasonal trends.

Similarly, the entrance of "new" vessels into the fishery has occurred only since 1990–91 and, therefore, can not account for the major decline in standardised catch rates. In addition, the categoric vessel model provides a test of the sensitivity of the CPUE index to the inclusion of these vessels in the analysis. The annual indices derived from the two CPUE models are strongly correlated, indicating that the analysis is relatively robust with respect to the group of vessels included.

Catch and effort data from the northern west coast fishery (QMA 9) were not included in the regression analysis because of the short time series of data available and the uncertainty regarding the stock relationship between east and west coast gemfish. The west coast fishery steadily developed since 1991–92, following the decline in catch rates from the QMA 1 fishery. The west coast fishing grounds are substantially further from the ports of Onehunga, Auckland, and Tauranga than the main fishing areas within QMA 1. However, the increase in steaming time has been compensated for by the relatively high catch rates achieved from the west coast fishery. In fact, the catch rates from the west coast fishery have been comparable to those achieved during the development of the QMA 1 fishery in 1988–89 and 1989–90. Although only limited CPUE data are available from the west coast fishery, there is an indication that catch rates peak during mid June, around the same time as the Poor Knights Shelf (003) fishery. Therefore, it is possible that the east and west coast fisheries represent separate substocks of gemfish migrating northward along either coast. Commercial catch and effort data collected from the fishery in subsequent years may further elucidate the stock relationships within SKI 1.

The application of CPUE data as an indicator of relative abundance assumes catch rates to be directly proportional to stock size. The QMA 1 fishery is considered to exploit a single stock of gemfish and, therefore, trends in relative annual abundance should be comparable among statistical areas for this assumption to be valid. The observed variability in the annual indices derived from each of the main statistical areas introduces considerable uncertainty into the analysis. Standardised catch rates generally increased as the fishery progressed northward, suggesting an increased aggregation of gemfish before spawning. In statistical area 003 (Poor Knights Shelf), the increased aggregation may have enabled more directed fishing on gemfish in recent years. The extent of the decline in catch rates from this area was substantially lower than that derived for the other main statistical areas.

The CPUE models presented in this report are limited by the data collected from the commercial fishery and, as a result, do not include many factors that may influence gemfish catch rates. Despite the inclusion of variables defining the fishing season relative to the area fished, the models are probably inadequate to describe the complex interaction between the fishing fleet and the pre- and post-spawning migration of gemfish. Given, the limitations of the CPUE models, it is probably more appropriate to consider the annual indices as an indicator of fishery performance rather than a time-series of stock abundance indices.

ACKNOWLEDGMENTS

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Table 1: Gemfish catch (t) and effort (number of tows, in parentheses) by statistical area and fishing year

Statistical area	Fishing year					
	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
002	0.0	0.0	0.0	0.5	15.0	38.8
	(0)	(0)	(2)	(10)	(23)	(40)
003	44.3	252.4	292.2	256.9	222.5	260.1
	(32)	(218)	(316)	(220)	(281)	(234)
004	0.0	0.0	0.0	1.1	55.0	11.2
	(0)	(0)	(0)	(9)	(59)	(33)
008	94.2	271.3	82.2	170.1	431.6	156.7
	(51)	(347)	(106)	(357)	(685)	(204)
009	67.9	272.0	242.0	199.8	114.8	34.5
	(53)	(253)	(372)	(415)	(340)	(143)
010	157.4	158.8	239.5	72.6	29.8	0.3
	(147)	(203)	(264)	(185)	(130)	(2)
046	0.0	0.3	0.0	0.0	0.9	112.9
	(0)	(1)	(0)	(0)	(1)	(36)
047	0.6	1.2	7.9	57.2	114.6	308.2
	(3)	(4)	(11)	(99)	(82)	(123)
Total	364.4	955.9	863.9	758.1	984.3	922.7
	(286)	(1 026)	(1 071)	(1 295)	(1 601)	(815)

Table 2: Summary of variables included in the regression analysis. cont. indicates a continuous variable, cat. indicates a categoric variable with a given number of categories.

Variable	Type	Description
vessel	cat 25	vessel completing record
fishing year	cat 6	year that fishing occurred
day	cont	day of year fishing occurred
statistical area	cat 6	statistical area fishing occurred
season	cat 3	season fishing occurred
seasonday	cont	day relative to peak in year, season, statistical area catch rates
oalength	cont	overall length (m) of vessel
breadth	cont	breath (m) of vessel
draught	cont	draught (m) of vessel
l*b*d	cont	vessel oalength * breadth * draught (m^3)
power	cont	power of vessel engine (kW)
tonnage	cont	gross tonnage of vessel
year built	cont	year the vessel was built

Table 3: Summary of catch and effort data included in the categoric vessel analysis

	Fishing year					
	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
Total catch (t)	344.7	915.5	839.3	653.6	669.7	455.7
Total hours fished	1 000	3 605	4 261	4 382	4 868	2 421
Number of trawls	257	992	1 036	1 063	1 198	576
Median tow duration (h)	4.0	4.0	4.0	4.4	4.4	4.5
Number of records	125	418	450	437	491	311
Number of vessels	11	20	21	24	23	20

Table 4: Summary of catch and effort data included in the All Data analysis

	Fishing year					
	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
Total catch (t)	363.8	954.5	853.6	695.7	856.4	501.6
Total hours fished	1 126	3 736	4 324	4 870	6 096	2 761
Number of trawls	283	1 021	1 052	1 184	1 492	656
Median tow duration (h)	4.0	4.0	4.0	4.4	4.5	4.6
Number of records	139	434	459	486	629	358
Number of vessels	14	23	23	32	32	26

Table 5: Choice of variables in the stepwise regression of log(catch per hour) for categoric vessel data only, in order of importance. Numbers in the table are the multiple regression coefficient R^2

	R^2 at iteration					
Variable	1	2	3	4	5	6
vessel	12.99					
seasonday	8.63	19.97				
fishing year	4.88	15.82	21.88			
season	1.47	14.25	21.53	23.82		
statistical area	6.96	14.77	21.60	23.64	25.45	
day	1.32	13.56	21.06	22.74	24.33	26.12
SSR % Improvement		53.9	9.6	8.8	6.8	NS

Table 6 : The relative year indices from the categoric vessel model of log(catch per hour). n = sample size; regression coefficient $\hat{Y}_i$; year effect relative to 1988–89 $\hat{A}_i$; standard deviation of the year effect $S_{\hat{A}i}$

Fishing year	n	Regression coefficient	Year effect	$S_{\hat{A}i}$
1988–89	125	0.000	1.000	NA
1989–90	418	–0.507	0.718	0.105
1990–91	450	–0.725	0.572	0.084
1991–92	437	–1.141	0.463	0.070
1992–93	491	–1.278	0.407	0.061
1993–94	311	–1.299	0.391	0.063

Table 7: Choice of variables in the stepwise regression of log(catch per hour) for all data, in order of importance. Numbers in the table are the multiple regression coefficient R^2

Variable	R^2 at iteration 1	2	3	4	5	6	7
l*b*d	10.41						
seasonday	8.16	17.53					
fishing year	5.03	14.60	20.39				
season	1.77	11.75	19.24	22.67			
statistical area	6.31	12.70	19.51	22.62	23.98		
day	1.85	11.42	19.08	21.84	23.14	24.64	
oalength	7.90	10.45	17.54	20.39	22.69	24.07	24.75
breadth	8.97	10.41	17.53	20.39	22.68	24.01	24.65
draught	7.59	10.44	17.38	20.39	22.67	23.99	24.66
tonnage	8.15	10.60	17.62	20.43	22.67	24.01	24.69
year built	3.04	10.73	17.82	20.58	22.80	24.01	24.66
power	5.73	10.65	17.68	20.45	22.69	24.00	24.65
SSR % Improvement		68.4	16.3	11.1	5.8	NS	NS

Table 8: The relative year indices from the all data model of log(catch per hour). n = sample size; regression coefficient $\hat{Y}_{i'}$; year effect relative to 1988–89 $\hat{A}_i$; standard deviation of the year effect $S_{\hat{A}i}$

Fishing year	n	Regression coefficient	Year effect	$S_{\hat{A}i}$
1988–89	139	0.000	1.000	NA
1989–90	434	–0.312	0.732	0.104
1990–91	459	–0.443	0.642	0.090
1991–92	486	–0.852	0.427	0.061
1992–93	629	–0.993	0.371	0.052
1993–94	358	–0.927	0.396	0.061

Table 9: Statistical area regression coefficients from the Categoric Vessel and All Data models of log(catch per hour). n = number of records

	Categoric Vessel		All Data	
Statistical area	n	Regression coefficient	n	Regression coefficient
002	41	−2.41	45	−2.83
003	365	5.83	404	6.02
004	40	−1.71	56	−0.62
008	737	2.17	839	2.48
009	697	−1.36	753	−0.19
010	352	−2.50	408	−4.86

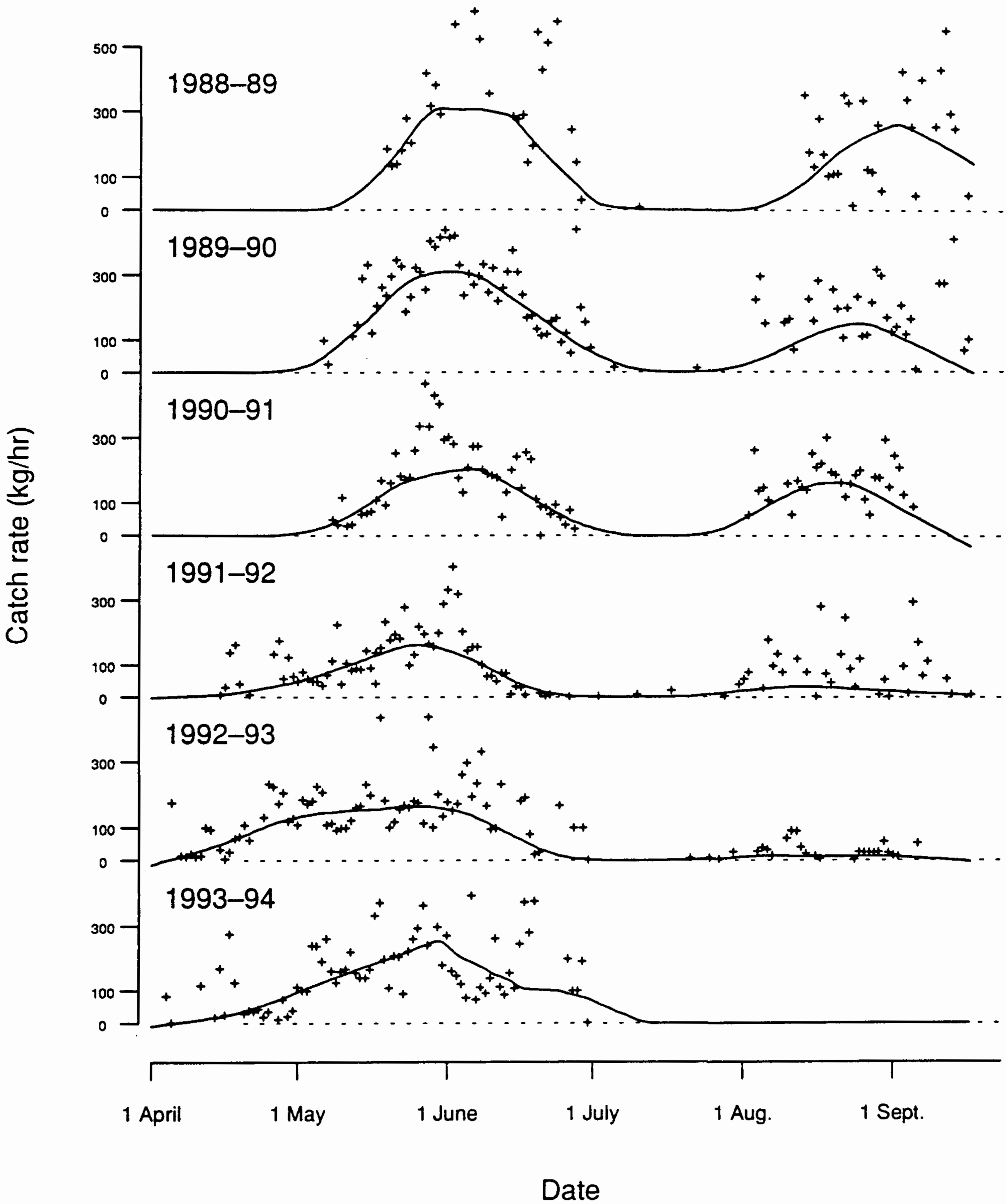

Figure 1: Mean daily catch rate (kg per hour) of gemfish by QMA 1 target trawl fishery by fishing year for the period 1988–89 to 1993–94. The lines represent a smoothed (lowess) fit to the data.

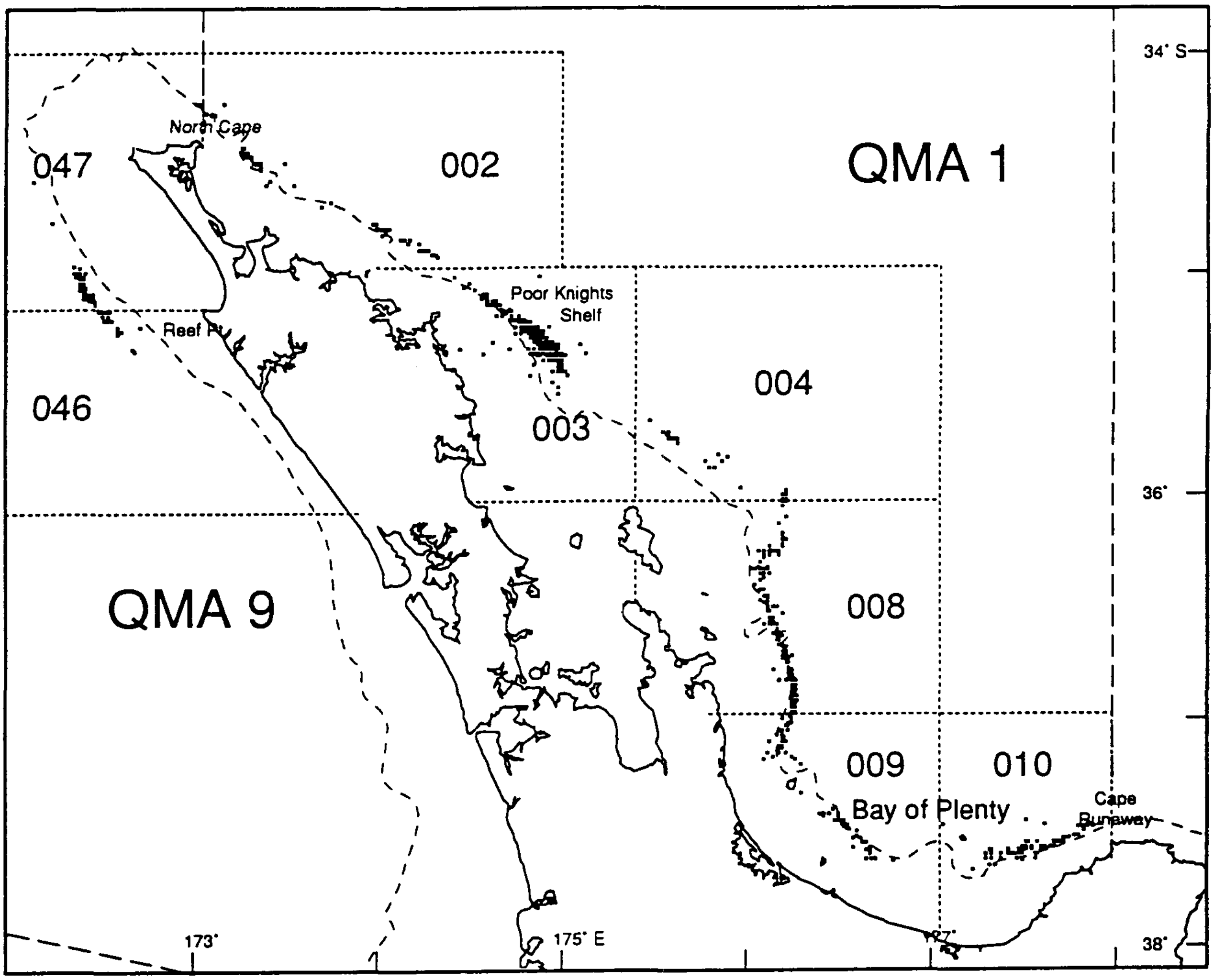

Figure 2: Distribution of trawls targeting gemfish in the SKI 1 fishery during the period 1988–89 to 1993–94. Areas defined by dotted lines represent statistical areas. The dashed line represents the 200 m depth contour. The large dashed line represents the boundaries of the QMAs.

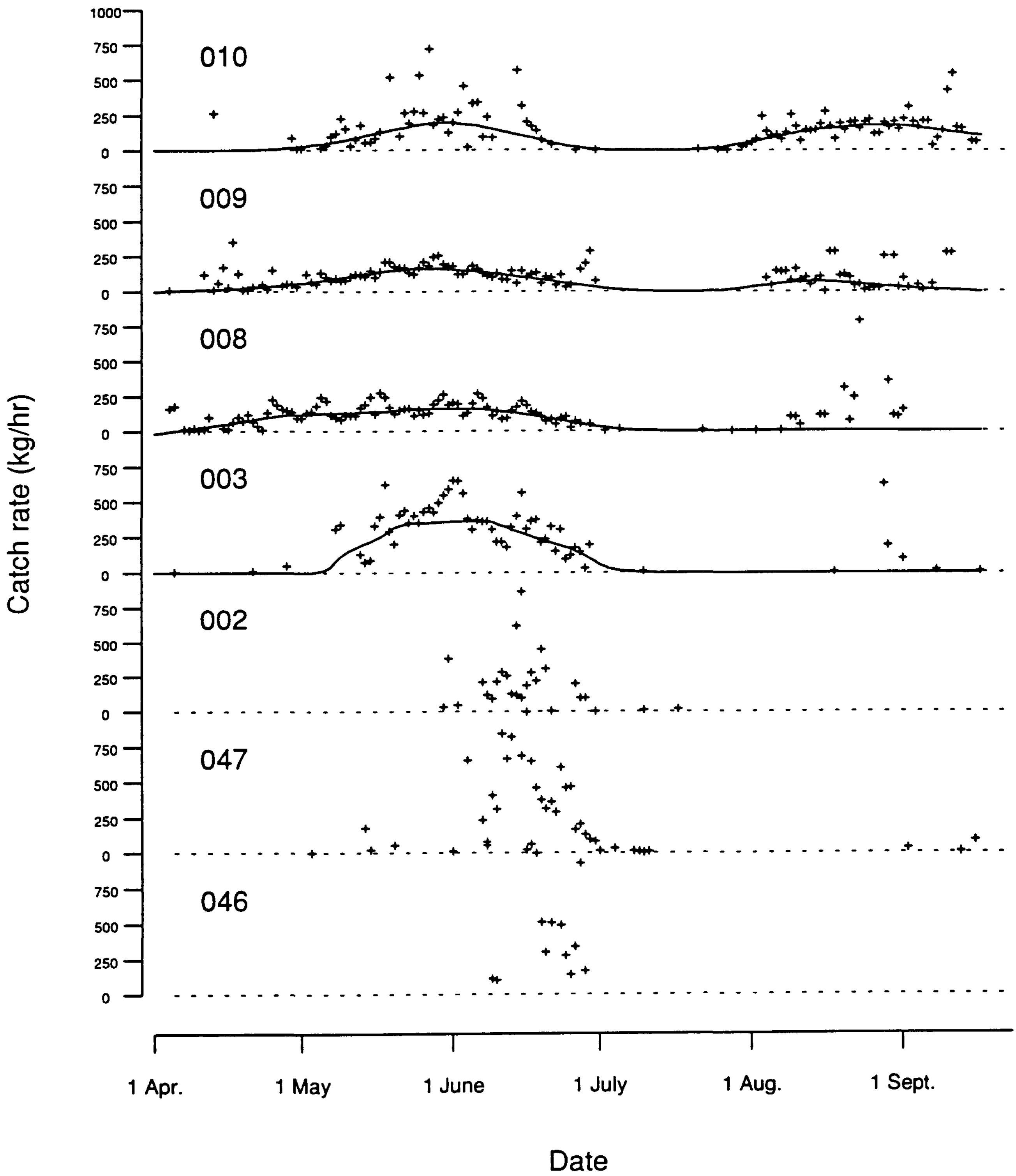

Figure 3: Mean daily catch rate (kg/hr) of gemfish by statistical area for the period 1988–89 to 1993–94. The lines represent a smoothed (lowess) fit to the data.

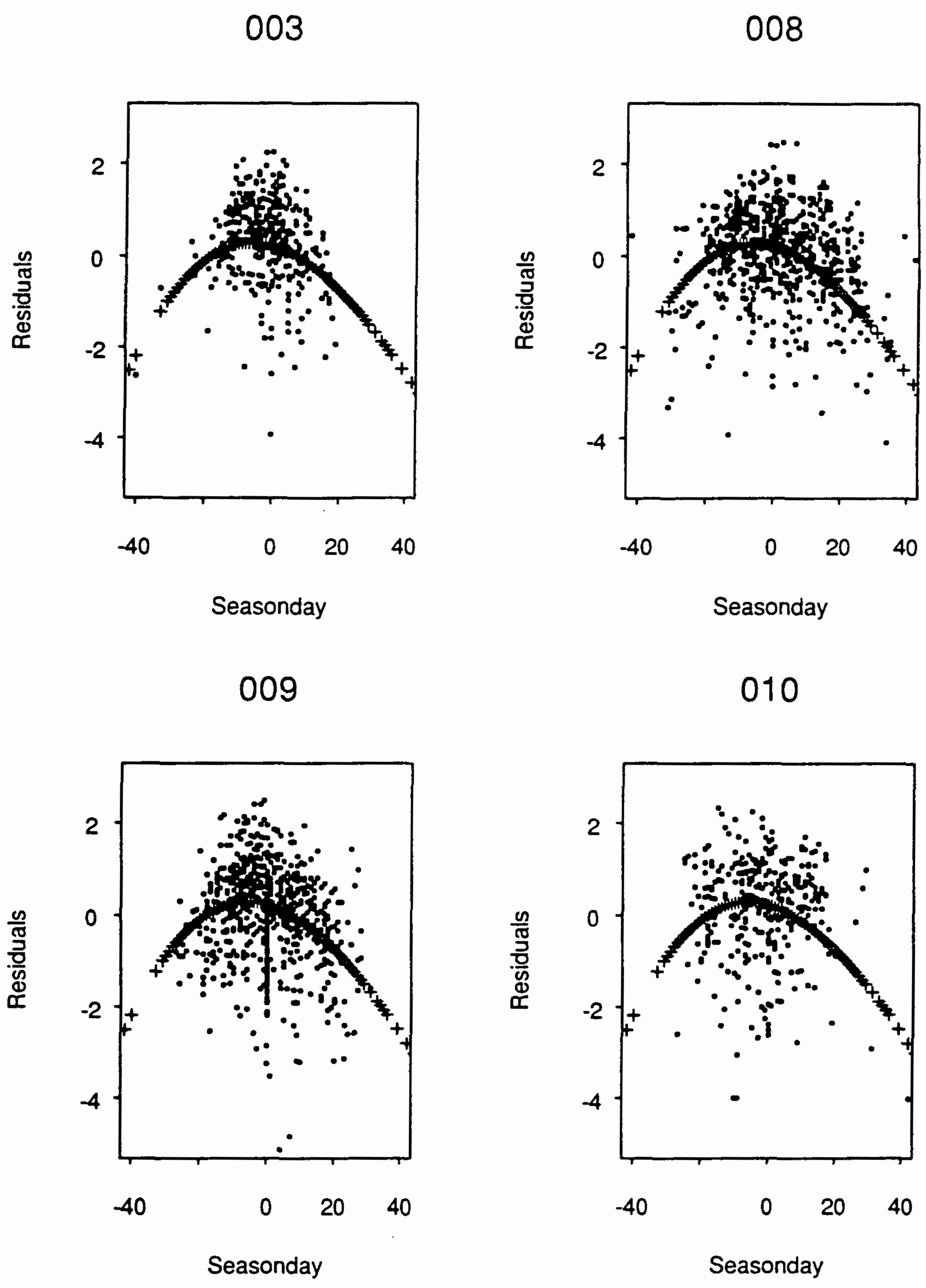

Figure 4: Performance of the seasonday polynomial function in describing the relationship between seasonday and standardised catch rates by statistical area. The crosses represent the predicted relationship; the points represent the residuals of the regression of log(catch per hour) against the categoric vessel variable.

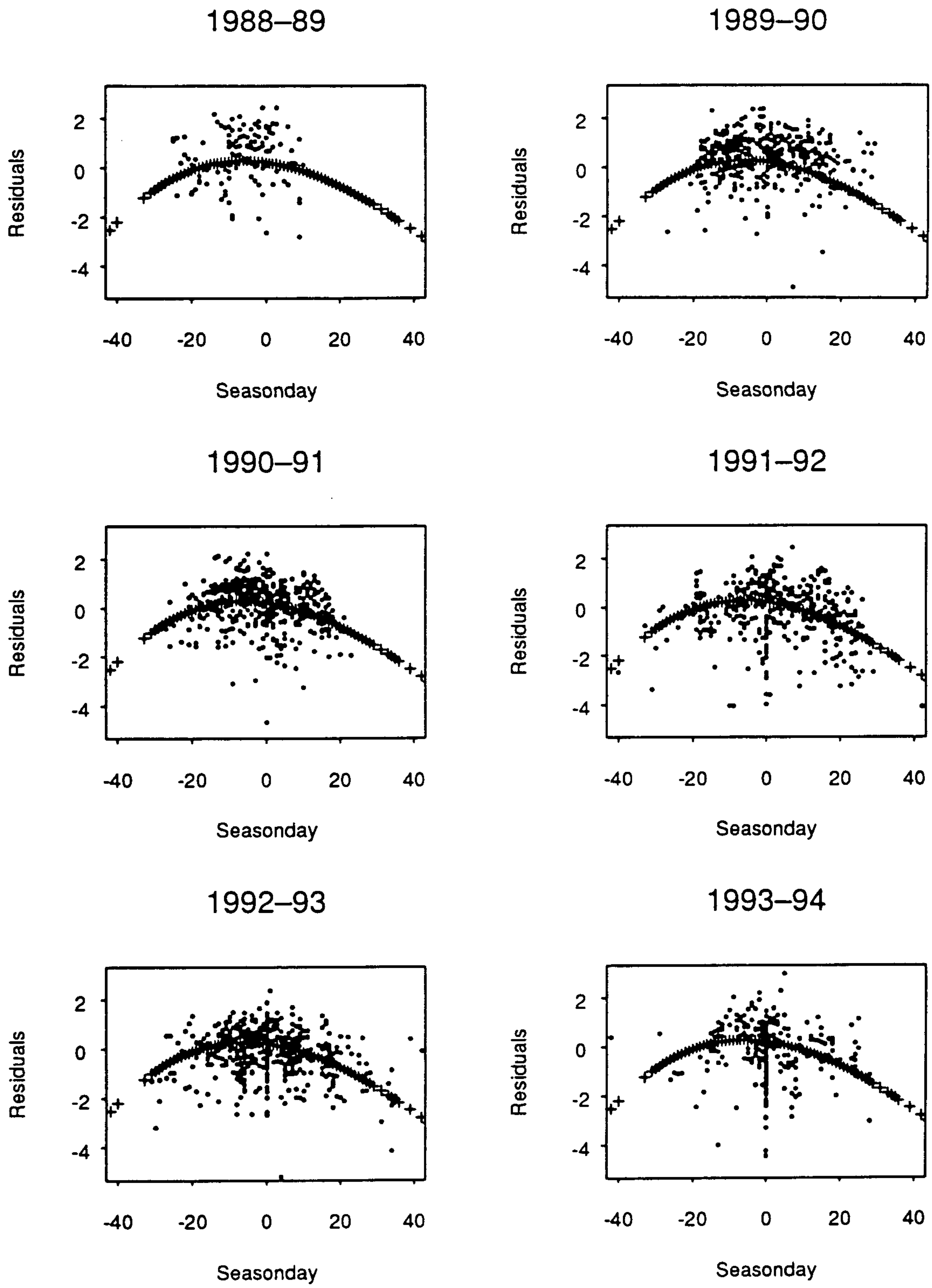

Figure 5: Performance of the seasonday polynomial function in describing the relationship between seasonday and standardised catch rates by fishing year. The crosses represent the predicted relationship; the points represent the residuals of the regression of log(catch per hour) against the categoric vessel variable.

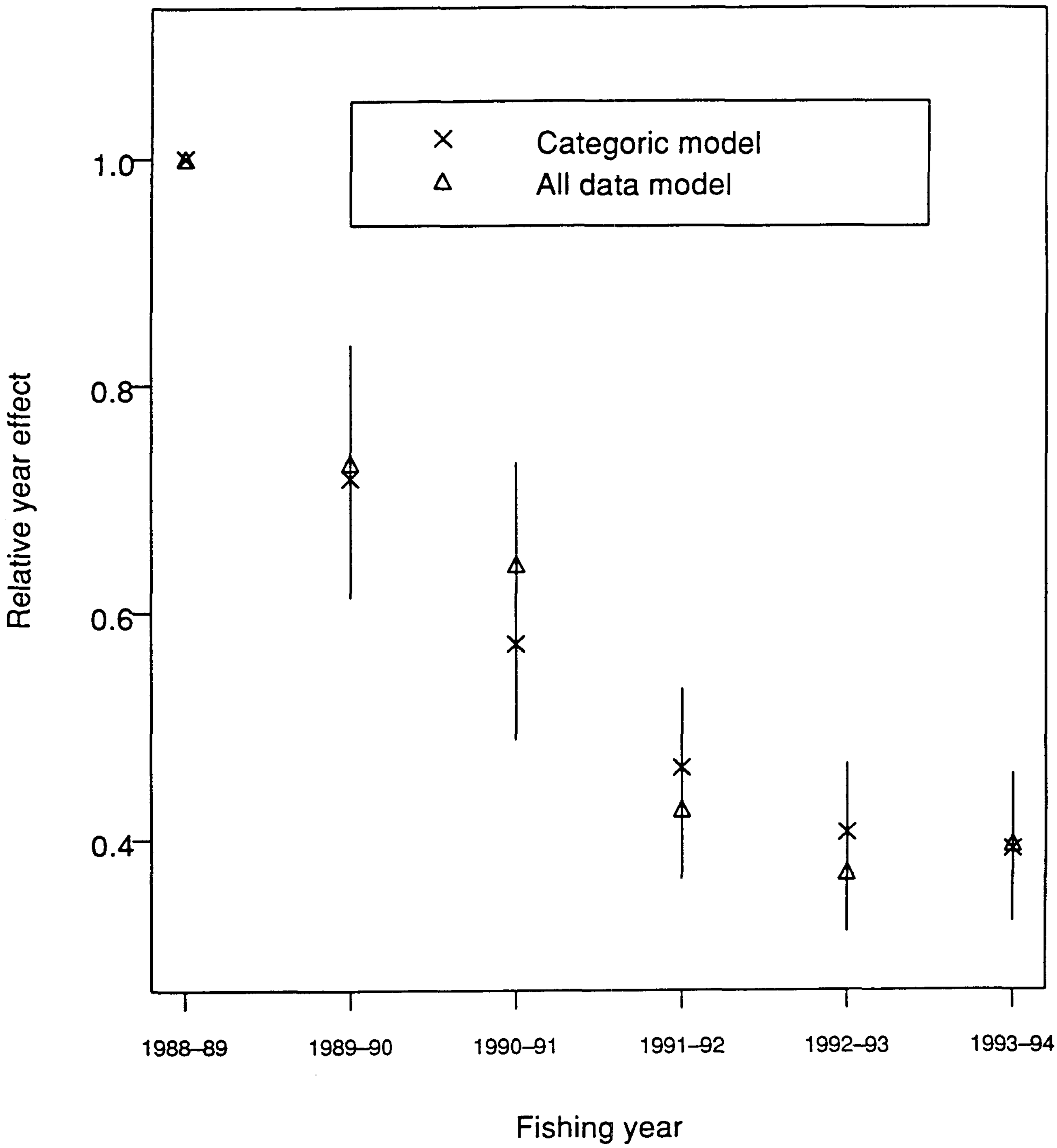

Figure 6: Relative year effects estimated from log(catch per hour) with error bars representing one standard deviation.

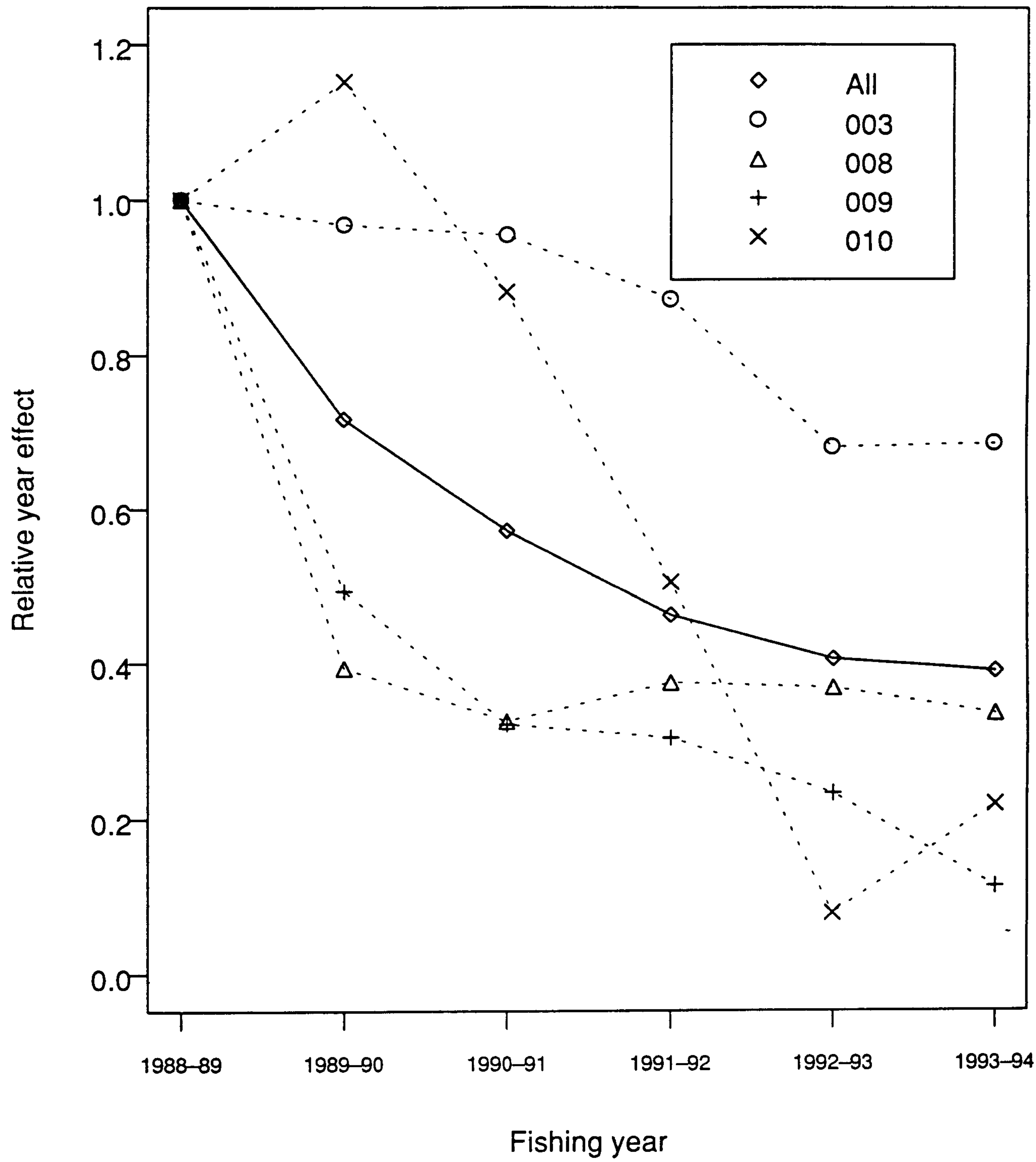

Figure 7: Relative year effects estimated from log(catch per hour) for each of the main statistical areas (categoric vessel model).