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Analysis of commercial catch and effort data from the QMA 2 alfonsino-bluenose trawl fishery, 1989–94

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1. EXECUTIVE SUMMARY

The BNS 2 TACC has been substantially over-caught in the last two fishing years; by 37% in 1992–93 and 51% in 1993–94. Most of the over-catch is attributable to an increase in the reported bycatch of bluenose taken by the alfonsino and gemfish target trawl fisheries. Catch and effort data from the alfonsino and bluenose target trawl fisheries were analysed to investigate trends in bluenose CPUE relative to alfonsino. The analysis revealed a change in the areal distribution of alfonsino target fishing, with an increase in the effort on fishing grounds yielding higher catch rates of bluenose. There was also an increase in the proportion of trawls conducted during the morning and evening, when the catch rate of bluenose could be expected to be relatively high. Both factors are likely to have contributed to the substantial increase in the catch of bluenose taken in the alfonsino-bluenose trawl fishery.

2. INTRODUCTION

2.1 Landings and TACCs

Reported landings from the bluenose and alfonsino fisheries within QMA 2 (BNS 2 and BYX 2 fishstocks, respectively) are presented in Table 1. Since the 1987–88 fishing year, the annual bluenose catch has steadily increased. Total catches remained within the TAC from 1986–87 to 1990–91, but exceeded the TACC in each of the last three years. The BNS 2 TAC was over-caught by 37% in 1992–93 and 51% in 1993–94.

Compared to the increase in reported landings of bluenose, the annual catch of alfonsino has remained relatively constant since 1986–87, at a level of about 1300–1700 t.

2.2 The QMA 2 bluenose (BNS 2) fishery

Most of the bluenose catch in QMA 2 is taken by trawl and lining methods: a small amount is taken by setnet (Table 2).

The bluenose target line fishery increased substantially in 1990–91 and maintained an annual catch of about 330 t from 1990–91 to 1993–94. There is a small bycatch of bluenose in the ling, gemfish, and hapuku/bass target line fisheries.

The proportion of the total bluenose catch taken by the trawl fishery increased from 49% in 1991–92 to 62.6% in 1993–94. In recent years, most of the bluenose trawl catch has been reported as a bycatch of the target alfonsino fishery, and to a lesser extent the target gemfish fishery. The proportion of the bluenose trawl catch taken in these two fisheries increased from 39% in 1991–92 to 88% in 1993–94. Since 1990–91, the proportion of the bluenose catch reportedly taken by the target bluenose trawl fishery has steadily declined and was negligible in 1993–94.

A very small proportion of the BNS 2 catch is taken by setnet, either targeting bluenose or as a bycatch of the ling setnet fishery.

2.3 Alfonsino-bluenose trawl fishery

The alfonsino trawl fishery developed from early 1983 after exploratory fishing between Cape Palliser and Cape Kidnappers (Horn & Massey 1989)(Figure 1). Fishing was initially concentrated on the Palliser Bank and this area accounted for most of the BYX 2 catch taken during the 1982–83 and 1983–84 fishing years. During the last decade, alfonsino catches from Palliser Bank have remained relatively stable at about 20–30% of the annual catch (Table 3).

Fishing on the Paoanui Ridge began in 1985 and the annual alfonsino catch increased steadily between 1984–85 and 1987–88 (*see* Table 3). Most of the catch assigned to the "Other" area in Table 3 before 1988–89 is also considered to have been taken from the Paoanui ground (P. Horn, NIWA pers. comm.), so the Paoanui fishery may have accounted for up to 60% of the 1987–88 total reported catch. In recent years, the alfonsino catch from this area has steadily declined from 76% in 1990–91 to 17% in 1993–94.

Large catches of alfonsino were taken from the Tuaheni Bank in 1984 (Horn & Massey 1989) and accounted for 30% of the 1984–85 reported catch. However, annual catches steadily declined and were insignificant in the 1988–89 and 1989–90 fishing years. Subsequently, catches increased to account for 10–15% of the reported catch in the most recent years.

Other areas between Cape Palliser and Cape Kidnappers supporting smaller alfonsino fisheries are Motukura Bank, Kaiwhata Bank, Madden Canyon, and the Ritchie Banks (*see* Figure 1). Annual catches from the Motukura Bank have been sporadic, accounting for about 30% of the catch in 1984–85 and 1989–90, but generally less than 10% in most years. Catches were negligible in 1990–91 and 1991–92, but steadily increased to account for 10% of the reported catch in 1993–94.

Before 1989–90, the catch of alfonsino from Madden Canyon was negligible. However, annual catches steadily increased from 1989–90 to represent 20% of the reported catch in 1993–94. The Ritchie Banks has been fished since 1985 (Horn & Massey 1989), but accurate catch statistics for this area are available only from 1989–90 onwards. The Ritchie Banks accounted for 21% and 14% of the total alfonsino catch taken during the 1992–93 and 1993–94 fishing years, respectively. Historically, the Kaiwhata Bank has contributed only a minor component of the annual alfonsino catch (*see* Table 3).

In general, the areal distribution of bluenose trawl catch follows the development of the alfonsino fishery. Between 1982–83 and 1987–88 most of the catch was taken from the Palliser Bank and the Paoanui Ridge. However, since 1990–91 the proportion of the total catch taken from both grounds has declined. During the 1993–94 fishing year, the Motukura, Madden, and Ritchie fishing grounds accounted for 67% of the total bluenose catch.

In recent years the fishery has been dominated by a fleet of about eight trawlers operating from Nelson, Napier, and Wellington, predominantly using midwater trawl gear fished close to the bottom.

2.4 Bluenose-alfonsino catch composition

During the development of the alfonsino trawl fishery, the ratio of bluenose to alfonsino (BNS:BYX) in the reported trawl catch increased rapidly to peak in the 1986–87 fishing year (Figure 2). The BNS:BYX catch ratio subsequently declined to a minimum in 1990–91 fishing years, but has increased in recent years. Since the introduction of the QMS, the annual ratio of bluenose:alfonsino from the trawl catch has remained below the ratio of the BNS 2 to BYX 2 TACs in each fishing year except 1986–87.

The development of the trawl fishery was dominated by catches from the Palliser and Paoanui grounds. Both areas were characterised by an initial low proportion of bluenose in the catch, followed by a rapid increase in the bluenose bycatch ratio, and a subsequent decline in bluenose bycatch. For the Palliser ground, the ratio of bluenose in the catch has continued to decline in recent years. In contrast, the ratio of bluenose in the catch composition from the Paoanui fishery has increased since 1990–91.

The Tuaheni Bank trawl fishery has generally yielded a relatively low bycatch of bluenose (ratio BNS:BYX less than 0.4). The ratio of bluenose to alfonsino fluctuated over the catch history, but increased steadily since the 1990–91 fishing year.

The ratio of bluenose to alfonsino catch aggregated from the Motukura and Madden fishing grounds was relatively stable over the limited catch history at about 0.5.

Some members of the fishing industry involved in the alfonsino-bluenose trawl fishery attribute the recent over-catch of the BNS 2 TAC to an increase in the abundance of bluenose on the fishing grounds. The relative increase in the BNS:BYX ratio taken from the Tuaheni Bank and Paoanui Ridge since 1990–91 may provide some support for this claim. However, in recent years these fisheries have taken only 20–30% of the total alfonsino catch and, therefore, could not account for the extent of the increase in bluenose catch.

Commercial catch and effort data from the alfonsino-bluenose trawl fishery was analysed further to investigate:

a. trends in the catch rate of bluenose relative to alfonsino.
b. trends in fishing patterns that could contribute to an increase in bluenose bycatch.

3. METHODS

3.1. Data

All trawls in QMA 2 for which the target species was reported as bluenose or alfonsino between 1989–90 and 1993–94 were considered in the analysis. Data were extracted from the *trawl-detail* and *trawl-header* tables of the Catch Effort database. For each tow the following data were available.

- Vessel identification number
- Date
- Time of start and end of tow
- Latitude of start of tow
- Longitude of start of tow
- Target species

- Gear type
- Depth of bottom (m)
- Depth of groundrope (m)
- Estimated alfonsino catch (kg)
- Estimated bluenose catch (kg)

The following checks were performed on the data.

- Range check on the size of catch; bluenose catch 0–10 000 kg, alfonsino catch 0–15 000 kg
- trawl start position consistent with location of known fishing grounds
- start time earlier than end time of trawl
- depth of ground rope less than depth of bottom
- depth of ground rope greater than 150 m

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

Trawls were assigned to each of the following main fishing areas based on the trawl start position: Tuaheni Bank, Ritchie Banks, Paoanui Ridge, Motukura Bank, Madden Canyon, Kaiwhata Bank, Palliser Bank. The data are summarised in Appendix 1.

3.2. Regression Analysis

Trends in alfonsino and bluenose CPUE data were investigated using a multiple regression technique developed by Doonan (1991) and Vignaux (1992).

The CPUE index of log (catch per tow) was chosen for the analysis. Catch per tow was chosen in preference to catch per hour as the CPUE index because

1. catch per tow is more strongly related to the catch landed from the fishery than catch per hour;
2. catch per hour is not an appropriate index when trawl duration may be constrained by the topography of the areas fished; and
3. midwater trawls are often of relatively short duration and, therefore, an index of catch per hour would be sensitive to errors in the reported start and end times.

In each analysis, the predictor variables fishing year, individual vessel, area, gear (bottom trawl or midwater trawl), month, target species (BNS or BYX), hour (start of trawl) were considered as categoric variables. Bottom depth and the height of the net off the bottom (bottom depth – depth of groundrope) were described by a polynomial function. Because the logarithm of zero is undefined, zero catches were assigned a nominal catch of 1 kg.

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 stepwise regression procedure was continued until the remaining variables contributed no significant explanatory 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 amount of 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 the addition of an extra variable in the model explained less than 1% of the variation in the estimate of CPUE.

For alfonsino the model has the form:

$$C_t = CPUE_t = M + S_{i,t} + G_{j,t} + Y_{k,t} + D_{l,t} + H_{m,t} + T_{n,t} + \varepsilon_t$$

Similarly, for bluenose:

$$C_t = CPUE_t = M + D_{l,t} + S_{i,t} + H_{m,t} + G_{j,t} + V_{p,t} + \varepsilon_t$$

where $CPUE_t$ is the catch per unit effort for the t^{th} tow,
M is the overall mean for $\log(CPUE_t)$,
$S_{i,t}$ is the regression coefficient for the i^{th} month,
$G_{j,t}$ is the regression coefficient for the j^{th} area,
$Y_{k,t}$ is the regression coefficient for the k^{th} year,
$D_{l,t}$ is the regression coefficient for the l^{th} bottom depth,
$H_{m,t}$ is the regression coefficient for the m^{th} hour,
$T_{n,t}$ is the regression coefficient for the n^{th} target species,
$V_{p,t}$ is the regression coefficient for the p^{th} vessel,
ε_t is the error in $\log(CPUE_t)$

Regression coefficients for each of the variables included in the respective models were examined to describe trends in the standardised catch rate of alfonsino and bluenose. Relative indices were calculated from each model for area and year where these variables explained a significant proportion of the variation in log(catch per tow). The area of the tow is included in the model as a categoric variable and the regression coefficients represent the difference in catch rate between areas. A relative area index for alfonsino and bluenose can be estimated from the area coefficients as (*after* Doonan 1991):

$$\hat{A}_i = \exp(\hat{G}_i - \hat{G}_{Tuaheni})$$

where $\hat{G}_i$ is the area coefficient for area i, $\hat{G}_{Tuaheni}$ is the area coefficient for the Tuaheni fishing ground, and $\hat{A}_i$ is the estimate of the area effect in area i relative to the area effect of the Tuaheni area. The variance of the estimate is:

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

where

$$\sigma^2 = Var(\hat{G}_i) + Var(\hat{G}_{Tuaheni}) - 2Cov(\hat{G}_i, \hat{G}_{Tuaheni})$$

Similarly, a relative year index of alfonsino CPUE was calculated from the year regression coefficients using the equation:

$$\hat{E}_i = \exp(\hat{Y}_i - \hat{Y}_{1989})$$

where $\hat{Y}_i$ is the year coefficient for year i, $\hat{Y}_{1989}$ is the year coefficient for the 1989–90 fishing year, and $\hat{E}_i$ is the estimate of the year effect in year i relative to the year effect of the 1989–90 year.

4. RESULTS

4.1 Alfonsino CPUE

The first variable included in the model was month (categoric). This was followed by the categoric variables area and year. Bottom depth of the trawl gear was included in the model at the fourth iteration as a quadratic variable. Hour and target species were both included as categoric variables. The six variables included in the model explained 17% of the variation in log(catch per tow) (Table 4).

The regression coefficients for the variable month indicate seasonal variation in the alfonsino CPUE (Figure 3). Standardised catch rates were lowest between February and June, reached a peak during July and September, and were moderate between October and December.

Fishing area explained a significant proportion of the variance in log(catch per tow) and an examination of the regression coefficients reveal differences in alfonsino CPUE between fishing grounds. Highest catch rates were achieved from Palliser Bank, Paoanui Ridge, Ritchie Banks, and Tuaheni and smaller catches were taken from Madden Canyon, Motukura, and Kaiwhata Bank (*see* Table 8).

The year coefficients from the regression model indicate standardised catch rates were variable between fishing years, but reveal no general trend (Table 5). In addition, year coefficients were derived for each of the main fishing grounds by separately fitting data from each ground to the generalised alfonsino log(catch per tow) model. For each area, standardised catch rates were highest in 1990–91. However, no consistent trend in catch rate was apparent between fishing grounds during the period 1991–92 to 1993–94 (Tables 6 and 8).

The relationship between standardised alfonsino catch rate and bottom depth was described by a cubic function. The standardised catch rate increased from 200 m bottom depth to a broad peak between 300 and 500 m, and declined with increasing depth below 500 m (Figure 4).

Hour coefficients were examined to describe the diurnal trend in alfonsino catch rates. No trend in catch rate was apparent between 0000 and 1500 hours. However, there is an indication that standardised CPUE may decline from 1500 to 2300 (*see* Figure 3).

Target species was included as the sixth variable in the regression model, with higher catch rates achieved when alfonsino was reported to be the target species than when taken as a by-catch of the bluenose target fishery.

4.2. Bluenose CPUE

Bottom depth was included in the model at the first iteration, followed by month, hour, and area. The categoric variable vessel was included as the fifth variable in the model. The five variables explained 13.8% of the variation in log(bluenose catch per tow) (Table 7).

Bottom depth of trawl explained the largest proportion of variance in log(bluenose catch per tow). The relationship between log(catch per tow) and bottom depth was described by a polynomial function, with a peak in standardised catch rate around 400 m bottom depth. Catch rates decreased steadily in depths below 500 m (*see* Figure 4).

Examination of the month coefficients included in the model of log(catch per tow) indicate a seasonal component in bluenose CPUE (Figure 5). Standardised catch rates were generally low during the January to May period, increased to a maximum between July and September, and declined during October and November. A diurnal trend in bluenose CPUE is apparent from the hour coefficients included in the regression model. The bluenose catch per tow peaked between 0200 and 0600 hours, declined between 0600 and 1200 hours, and remained relatively constant through the afternoon and evening.

Area (fishing ground) was included in the model at the fourth iteration and an examination of the regression coefficients reveals significant differences in the log(catch per tow) between areas (Table 8). Standardised bluenose CPUE was highest from Motukura Bank, Ritchie Banks and Madden Canyon, and fishing on the Kaiwhata, Palliser, and Paoanui grounds generally yielded a smaller bluenose catch.

The variable year did not explain a significant proportion of the variation in bluenose log(catch per tow) implying that standardised CPUE remained relative constant between 1989–90 and 1993–94.

4.3. Summary

For comparison, an index of relative catch rate by area was calculated for each species relative to the standardised catch rate of that species from the Tuaheni Bank fishing ground (*see* Table 8, Figure 6). The Paoanui and Palliser grounds were characterised by relatively high catches rates of alfonsino with a relatively low associated bluenose by-catch. In contrast, the Motukura Bank yielded relatively small catches of alfonsino, but the highest bluenose catch rate. Catches of bluenose and alfonsino from Madden Canyon were intermediate between the Motukura ground and the Palliser/Paoanui areas. Both Tuaheni Bank and Ritchie Banks yielded relatively high alfonsino catches, but a relatively high by-catch of bluenose was associated with the latter ground. The Kaiwhata Bank yielded poor catches of both alfonsino and bluenose.

6.0 DISCUSSION

In recent years, there has been a substantial change in the areal distribution of the reported catch and effort from the alfonsino-bluenose trawl fishery (*see* Table 3, Appendix 1). The proportion of the alfonsino catch taken from the Paoanui fishing ground declined substantially during the period 1990–91 and 1993–94. In contrast, there was a steady increase in annual catch and effort from the Motukura, Madden, and Ritchie fishing grounds during the same period. These areas are characterised by relatively high catch rates of bluenose.

Furthermore, there was an apparent change in the diurnal distribution of fishing effort between 1991–92 and 1993–94 (Figure 7). In recent years, there was an increase in the proportion of trawls conducted during the morning and evening and the proportion of trawls conducted between 0800 and 1800 hours decreased. The regression analysis indicated that the standardised catch rate of bluenose was highest during the 0400–0700 period, while alfonsino catch rates declined after 1800 hours. Therefore, trawls conducted during early morning and evening could be expected to yield a higher proportion of bluenose in the catch.

The seasonal distribution of fishing effort between 1989–90 and 1993–94 was variable. During the 1989–90 fishing year, most of the reported effort was concentrated in late autumn when bluenose catch rates were lowest, but in 1990–91 fishing effort was concentrated during spring and summer when bluenose catch rates were highest. In the most recent years, fishing effort has been more evenly distributed throughout the fishing year.

Previous analyses of catch and effort data from the alfonsino-bluenose trawl fishery have used CPUE to estimate the relative abundance of both species (Horn & Massey 1989, Ryan & Stocker 1991, Stocker & Blackwell 1991). Horn & Massey (1989) considered the most appropriate measure of CPUE to be the catch taken during a 24 hour day spent targeting alfonsino or bluenose by one trawler. The unit of effort accounts for time spent searching for fish and long "prospecting" tows that characterise alfonsino-bluenose target fishing.

The CPUE analysis presented in this report is based on the catch per tow and does not account for either searching time or tow duration. As a result, the analysis may substantially underestimate the total effort expended by the target trawl fleet and does not consider the potential for annual variability in searching time and/or tow duration. Consequently, the annual indices derived from the alfonsino regression model are unlikely to be directly related to the relative abundance of alfonsino.

The strength of the analysis is that it enables trends in the relative catchability (standardised catch rate) of bluenose and alfonsino to be investigated. The analysis did not reveal an annual trend of either increasing catch rates of bluenose or decreasing catch rates of alfonsino that would account for an increase in the catch of bluenose relative to alfonsino. However, the variable year represents the annual mean catch rate from the entire fishery and could potentially mask changes in the relative catch rate of bluenose and alfonsino on specific fishing grounds.

The model of bluenose CPUE revealed significant areal differences in catch rate within the fishery. Standardised catch rates of bluenose were highest from the Motukura Bank, Madden Canyon, and Ritchie Banks. The variables area and bottom depth in the CPUE model are highly correlated, with most trawls on the Tuaheni, Ritchie, Motukura, and Madden fishing grounds conducted within the 300–400 m depth range. In contrast, fishing on the Paoanui Ridge, Palliser Bank, and Kaiwhata Bank was deeper where bluenose catch rates are lower. Bottom depth is included in the bluenose CPUE model before the variable area. Therefore, the indices of bluenose relative catch rate derived for each area probably underestimate the true extent of the difference in catch rate between fishing grounds.

Differences in the catch rate of bluenose from each area may also be influenced by the relative exploitation of each fishing ground. During the development of the Palliser and Paoanui grounds in the early 1980s, catches were characterised by a high proportion of bluenose. The subsequent decline in the proportion of bluenose in the catch may indicate a differential exploitation rate of alfonsino and bluenose on the grounds.

Since 1990–91, most of the BNS 2 TAC over-run was attributable to an increase in the bluenose catch taken by the QMA 2 trawl fisheries, in particular the alfonsino-bluenose fishery and, to a lesser extent, the gemfish fishery. During the same period, total landings of gemfish and alfonsino from QMA 2 have remained relatively stable (Annala 1995). However, between 1991–92 and 1993–94, there was an increase in the fishing effort on Motukura Bank, Madden Canyon, and Ritchie Banks, while effort on the Paoanui Bank declined. As discussed above, the former areas are characterised by higher catch rates of bluenose. Similarly, there was an increase in the proportion of trawls conducted during the morning and evening, when the catch rate of bluenose could be expected to be relatively high. Both factors are likely to have resulted in the substantial increase in the catch of bluenose taken by the alfonsino-bluenose trawl fishery.

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Table 1: Reported landings (t) and TACs of bluenose and alfonsino from QMA 2 from 1986–87 to 1993–94 (Source: Annala 1995)

Fishing year	Bluenose		Alfonsino	
	Landings	TAC	Landings	TAC
1986–87	953	660	1 387	1 510
1987–88	653	661	1 252	1 511
1988–89	692	768	1 588	1 630
1989–90	766	833	1 496	1 274
1990–91	812	833	1 459	1 274
1991–92	919	839	1 368	1 499
1992–93	1 151	842	1 649	1 504
1993–94	1 284	849	1 688	1 569

Table 2: Reported bluenose catch (t) from QMA 2 by fishing method and target species from 1989–90 to 1993–94 (Source: QMS data)

Fishing method	Target species	Fishing year				
		1989–90	1990–91	1991–92	1992–93	1993–94
Line	Bluenose	36	301	371	325	331
	Ling	32	25	49	82	73
	Other	15	23	37	18	42
	Total	84	349	458	424	446
Setnet	Total	19	29	18	18	6
Trawl	Bluenose	117	147	77	55	1
	Alfonsino	432	157	313	368	503
	Gemfish	16	12	25	112	166
	Other	16	59	43	73	87
	Total	581	374	458	608	756
Total		684	753	933	1 050	1 209

Table 3: Distribution of alfonsino (BYX) and bluenose (BNS) catch (t) by the alfonsino-bluenose trawl fishery by fishing ground from 1982–83 to 1993–94. Source: 1982–83 to 1989–90 Stocker & Ryan (1991); 1990–91 to 1993–94 QMS

Fishing year		Fishing ground								
		Palliser	Paoanui	Tuaheni	Motukura	Ritchie	Madden	Kaiwhata	Other	Total
1982–83	BYX	612	0	0	0	0	0	0	46	658
	BNS	25	0	0	0	0	0	0	1	25
1983–84	BYX	640	0	0	85	0	0	0	428	1 153
	BNS	298	0	0	36	0	0	0	88	422
1984–85	BYX	30	37	307	284	0	0	26	331	1 016
	BNS	20	70	87	126	0	0	2	97	401
1985–86	BYX	449	148	238	184	0	4	3	453	1 479
	BNS	200	177	92	82	0	0	7	75	634
1986–87	BYX	292	278	140	63	0	2	68	388	1 229
	BNS	112	481	20	37	0	1	84	266	1 001
1987–88	BYX	328	367	127	3	0	0	5	319	1 151
	BNS	139	180	15	2	0	0	6	125	467
1988–89	BYX	86	48	47	51	0	0	0	987	1 219
	BNS	46	2	11	16	0	0	0	343	418
1989–90	BYX	376	264	31	479	213	0	4	84	1 451
	BNS	102	89	10	293	35	0	7	22	557
1990–91	BYX	104	644	79	7	5	12	0	431	1 282
	BNS	35	84	8	2	1	5	0	168	303
1991–92	BYX	250	594	175	0	13	69	12	151	1 264
	BNS	57	120	42	0	24	31	10	107	390
1992–93	BYX	455	330	69	46	276	159	5	80	1 420
	BNS	57	70	23	45	71	89	1	69	424
1993–94	BYX	269	214	151	127	179	247	53	44	1 282
	BNS	47	88	61	63	81	128	31	5	503

Notes (1) 1983–1988 FSU data; 1987–1994 QMS data.
(2) Area "Other" refers to catch from an unspecified area.

Table 4: Choice of variables in stepwise regression of log(alfonsino catch per tow) 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
Month	6.45						
Area	5.97	10.82					
Year	3.52	9.61	13.49				
Depth of bottom	3.32	8.74	12.19	14.79			
Hour	1.46	7.68	12.14	14.54	15.98		
Target species	1.19	8.02	12.11	14.45	15.85	16.98	
Vessel	0.71	7.21	11.61	14.09	15.41	16.57	17.52
Net off bottom	0.02	6.42	10.85	13.43	14.88	16.06	17.06
Gear type	3.80	9.00	11.81	14.58	15.52	16.68	17.50
Improvement (%)	6.45	4.37	2.67	1.3	1.19	1.00	NS

Table 5: The relative year indices from the regression model of log(alfonsino catch per tow). n, sample size; regression coefficient ($\hat{Y}_i$); year effect relative to 1989–90 ($\hat{E}_i$); standard deviation of the year effect $S_{\hat{A}i}$

Fishing year	n	Regression coefficient	Year effect	$S_{\hat{A}i}$
1989–90	364	–0.508	1.00	NA
1990–91	304	0.923	4.18	0.982
1991–92	463	–0.471	1.04	0.224
1992–93	531	0.265	2.17	0.449
1993–94	640	–0.209	1.35	0.280

Table 6: The relative year coefficients from the regression model of log(alfonsino catch per tow) for each of the main alfonsino fishing grounds. n, sample size; regression coefficient $\hat{Y}i$

Fishing	Palliser		Paoanui		Tuaheni		Madden		Ritchie	
year	n	$\hat{Y}i$	n	$\hat{Y}i$	n	$\hat{Y}i$	n	$\hat{Y}i$	n	$\hat{Y}i$
1989–90	160	–0.984	121	–0.072	13	–1.341	1	–3.681	56	–1.545
1990–91	40	1.378	223	1.013	16	1.898	13	2.113	3	4.095
1991–92	69	0.362	250	–0.608	75	–0.017	25	–0.105	16	–2.472
1992–93	184	–0.119	118	–0.066	51	–0.305	93	1.164	48	1.770
1993–94	134	–0.637	77	–0.267	101	–0.235	142	0.513	65	–1.185

Table 7: Choice of variables in stepwise regression of log(bluenose catch per tow) 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**
Depth of bottom	6.46					
Month	4.67	9.32				
Hour	4.28	8.57	11.51			
Area	5.13	8.67	11.14	12.87		
Vessel	1.51	7.42	10.29	12.36	13.89	
Gear type	1.62	6.84	9.59	11.71	13.15	14.08
Net off bottom	0.95	7.71	10.42	12.42	13.32	14.18
Year	0.91	7.03	9.92	12.13	13.37	14.12
Target species	0.18	6.58	9.31	11.52	12.96	13.86
Improvement (%)	6.46	2.86	2.19	1.36	1.02	N.S.

Table 8: Comparison of area indices from the analyses of log (catch per tow) for alfonsino and bluenose. n, sample size; $\hat{G}_i$, regression coefficient; $\hat{A}_i$, area effect relative to Tuaheni; $S_{\hat{A}i}$, standard deviation of the area effect; NA, no data

		Alfonsino			Bluenose		
	n	$\hat{G}_i$	$\hat{A}_i$	$S_{\hat{A}i}$	$\hat{G}_i$	$\hat{A}_i$	$S_{\hat{A}i}$
Palliser	587	0.61	1.13	0.249	–0.670	0.47	0.118
Paoanui	789	0.564	1.08	0.243	–0.411	0.61	0.144
Tuaheni	256	0.485	1.00	NA	0.078	1.00	NA
Motukura	108	–0.677	0.31	0.105	0.917	2.31	0.876
Ritchie	188	0.523	1.04	0.315	0.606	1.70	0.581
Madden	274	–0.016	0.61	0.150	0.389	1.37	0.396
Kaiwhata	100	–1.489	0.14	0.050	–0.909	0.37	0.152

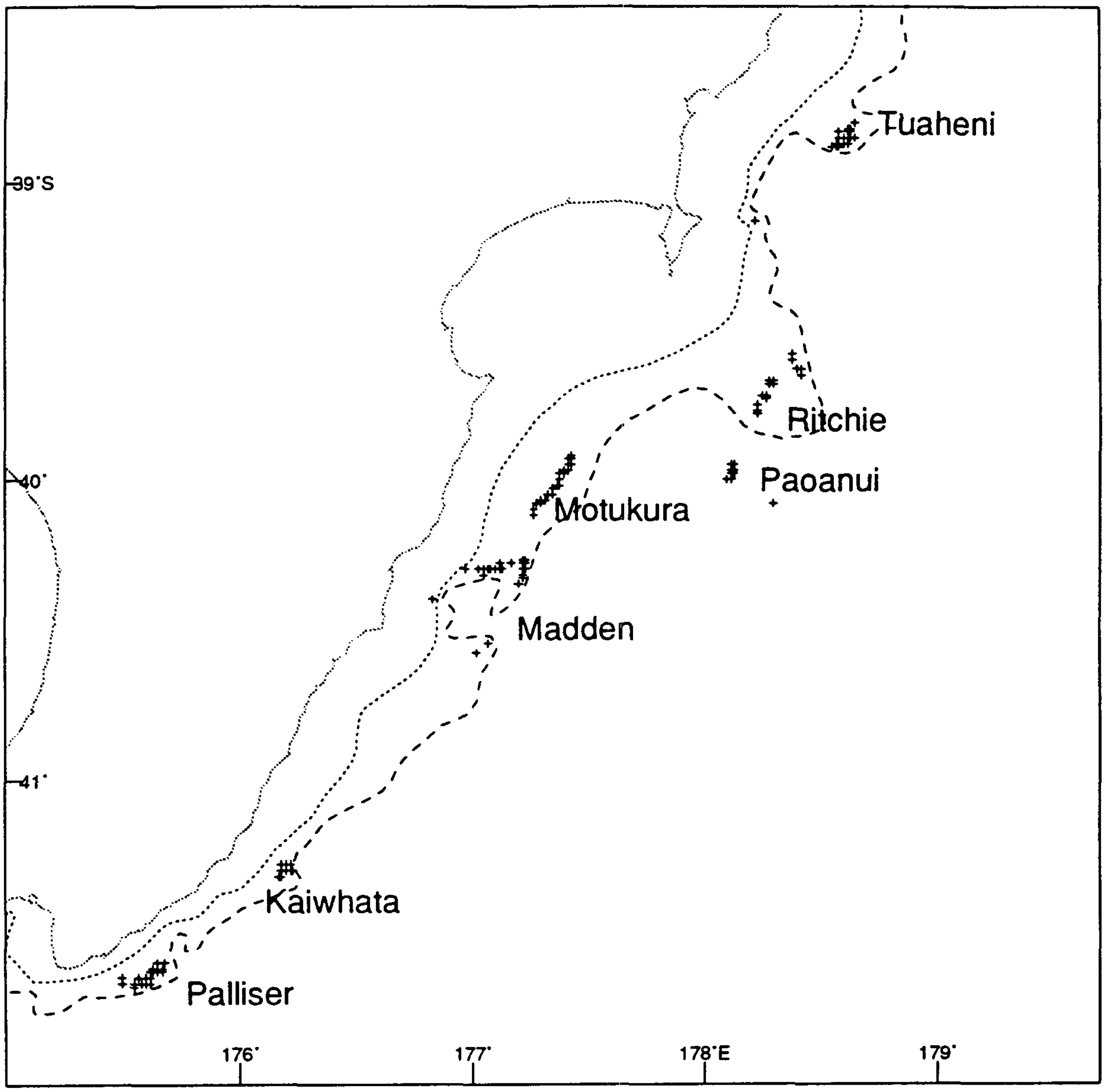


Figure 1: Distribution of trawls targeting alfonsino or bluenose in QMA 2 and reporting a catch of bluenose exceeding 100 kg during the 1993–94 fishing year (source: QMS). The dotted and dashed lines represent the 200 m and 1000 m depth contours, respectively.

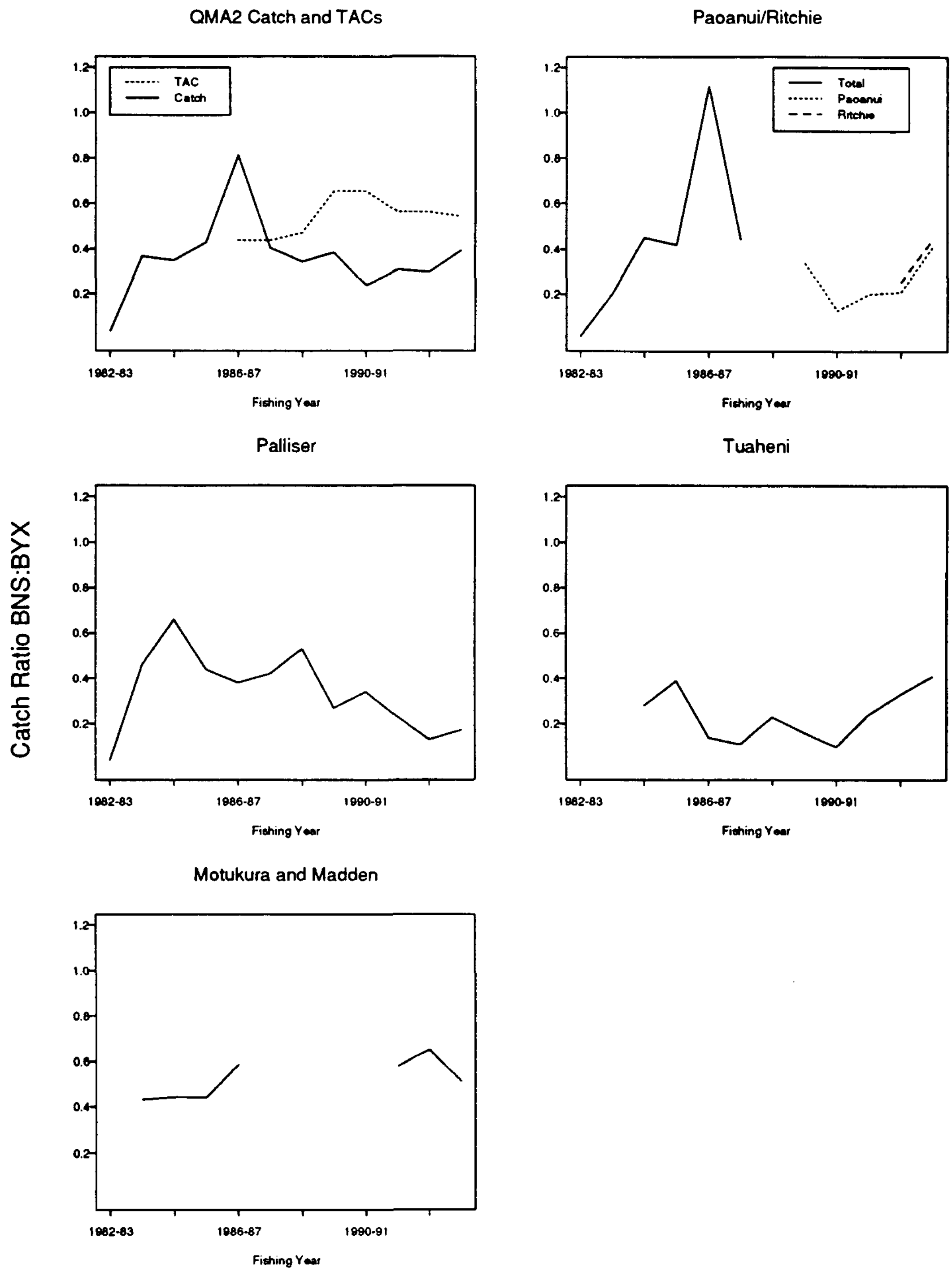


Figure 2: Ratio of bluenose to alfonsino annual landed catch from the QMA 2 alfonsino-bluenose trawl fishery by fishing ground.

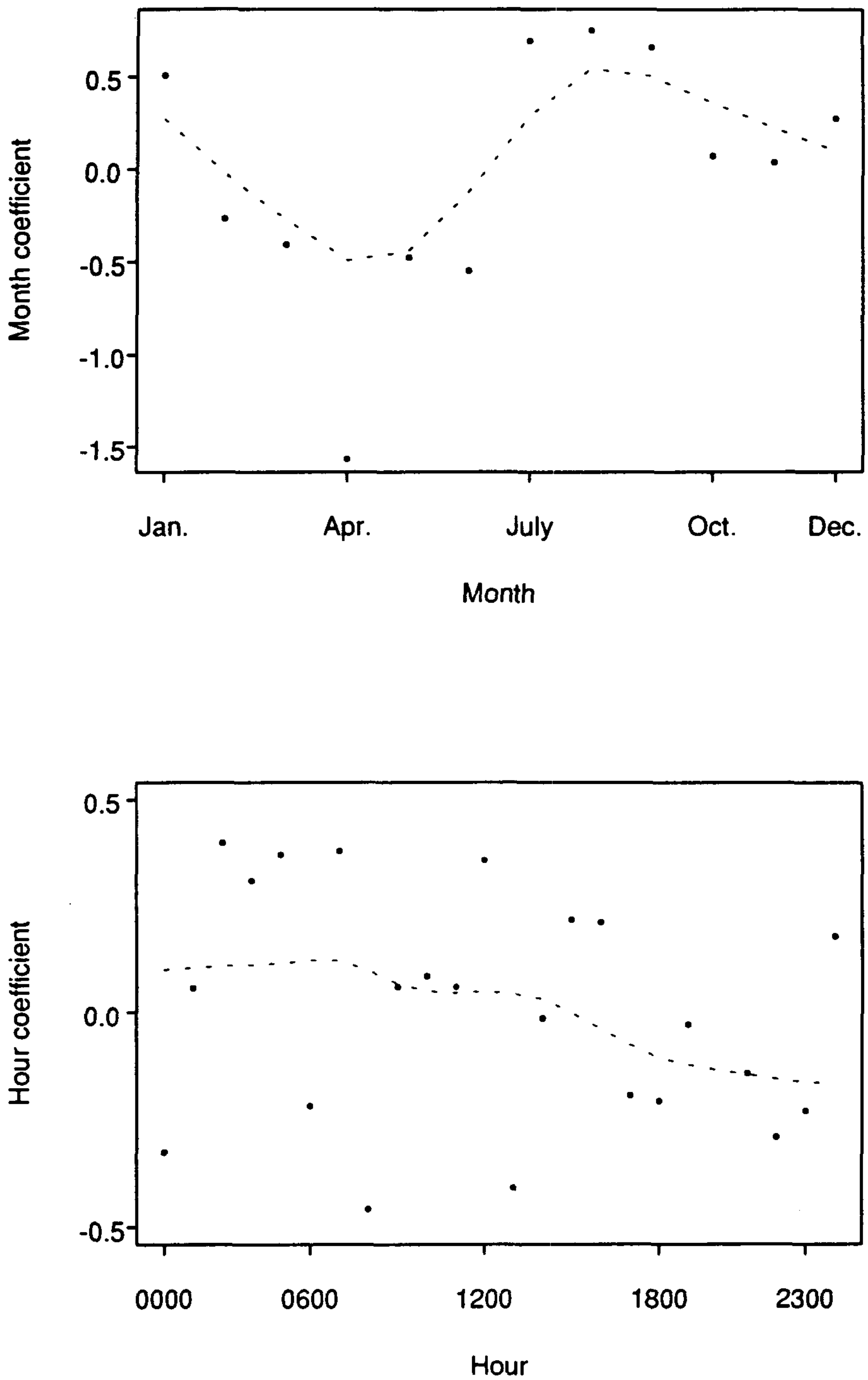


Figure 3: Month and hour coefficients from the alfonsino log(catch per tow) regression model. The line represents a smoothed fit to the data.

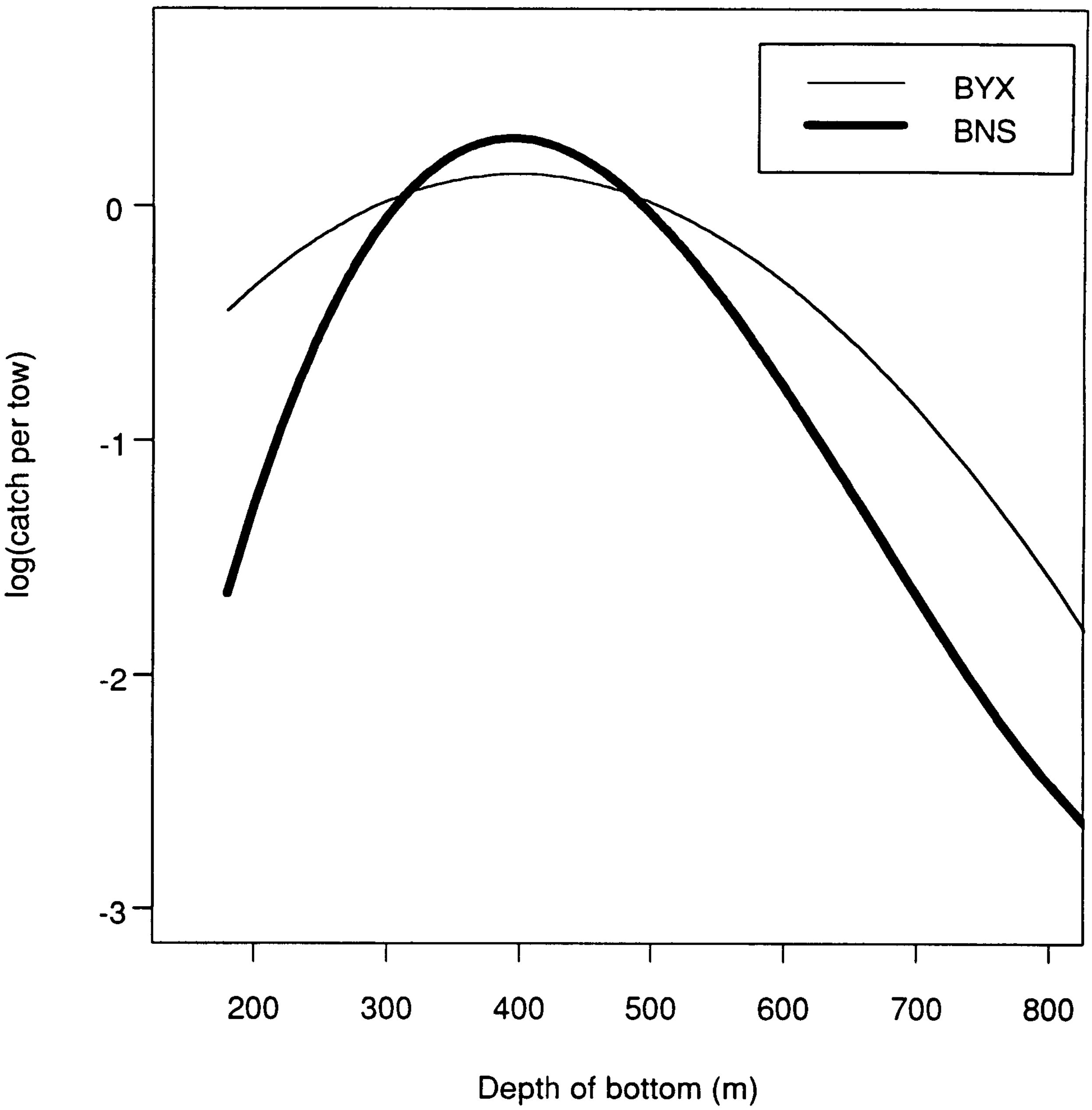
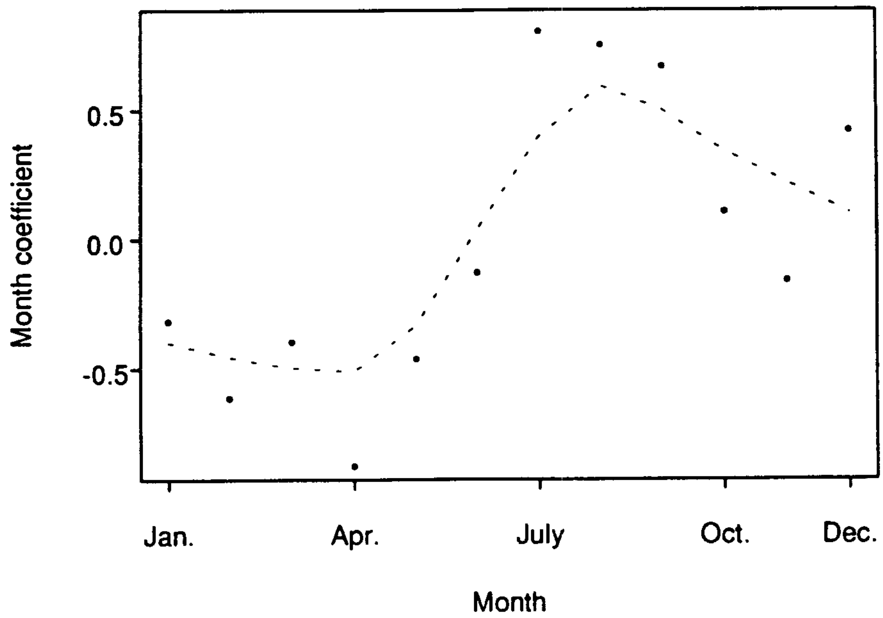


Figure 4: Relationship between alfonsino and bluenose log(catch per tow) and bottom depth.



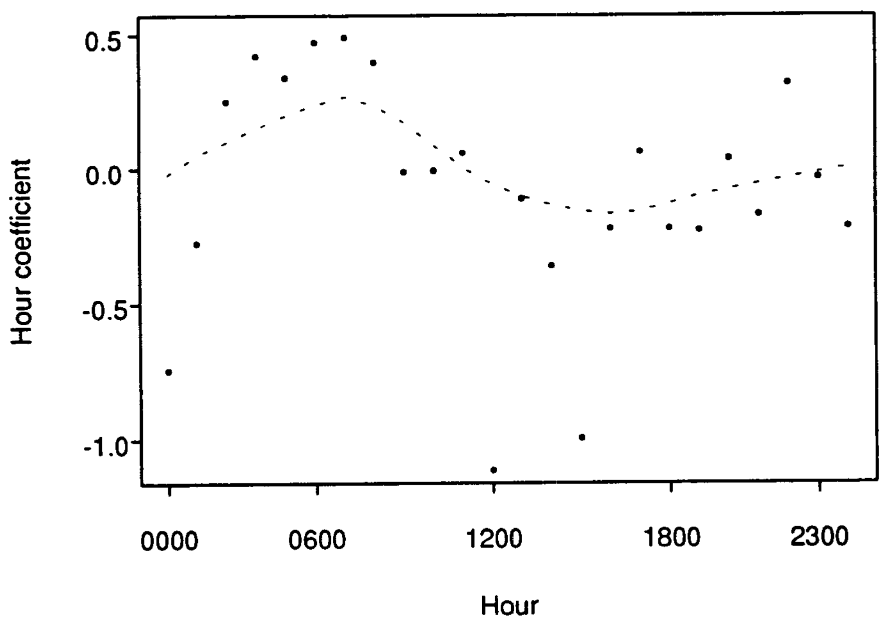


Figure 5: Month and hour coefficients from the bluenose log(catch per tow) regression model. The line represents a smoothed fit to the data.

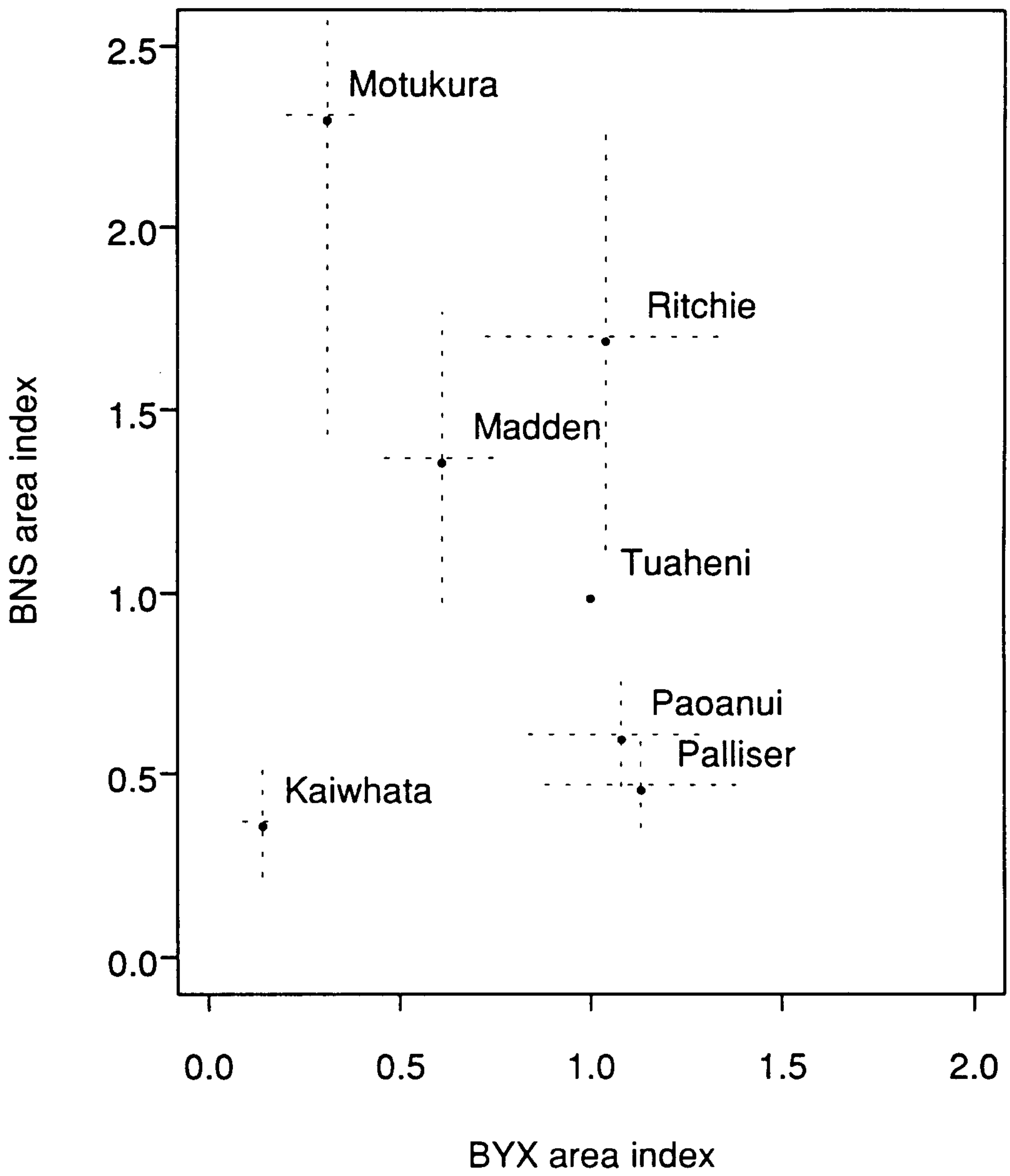


Figure 6: Comparison of bluenose (BNS) and alfonsino (BYX) relative area indices calculated from the log(catch per tow) model. The confidence intervals represent +/- one standard deviation.

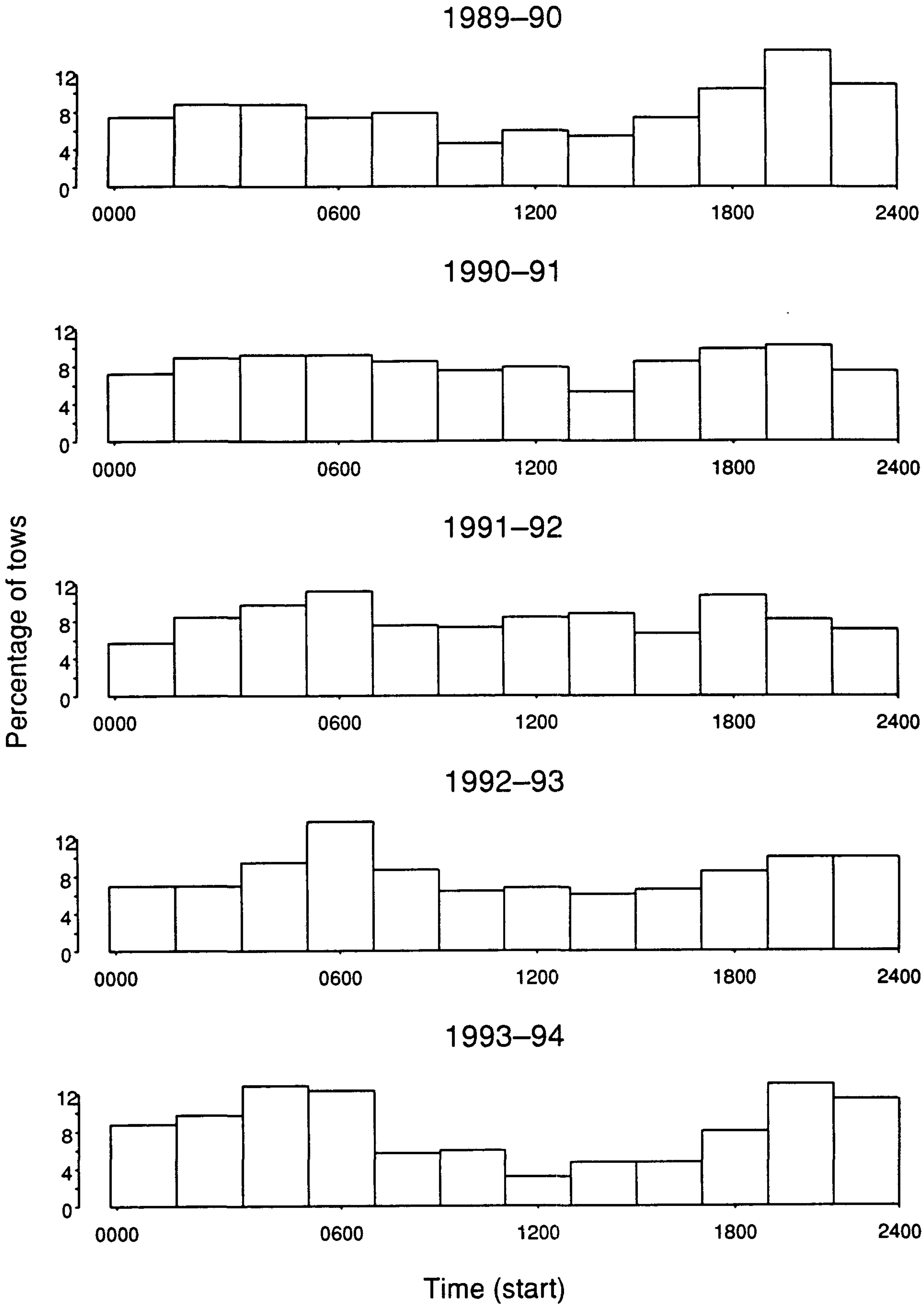


Figure 7: Diurnal distribution of fishing effort in the alfonsino-bluenose trawl fishery by fishing year for the period 1989–90 to 1993–94.

Appendix 1: Summary of alfonsino (BYX) bluenose (BNS) trawl catch (t) and effort data included in the standardised CPUE analysis (Source: QMS data)

Fishing year								**Fishing Ground**	
		Palliser	**Paoanui**	**Tuaheni**	**Motukura**	**Ritchie**	**Madden**	**Kaiwhata**	**Total**
1989–90	BYX	173	264	18	1	213	0	4	673
	BNS	37	89	3	0	35	0	7	172
	Tows	160	121	13	3	56	1	10	364
1990–91	BYX	104	644	79	7	5	12	0	851
	BNS	35	84	8	2	1	5	0	144
	Tows	40	223	16	8	3	13	1	304
1991–92	BYX	250	594	175	0	13	69	12	1 113
	BNS	57	120	42	0	24	31	10	284
	Tows	69	250	75	2	16	25	26	463
1992–93	BYX	455	330	69	46	276	159	5	1 340
	BNS	57	70	23	45	71	89	1	355
	Tows	184	118	51	30	48	93	7	531
1993–94	BYX	269	214	151	127	179	247	53	1 239
	BNS	47	88	61	63	81	128	31	498
	Tows	134	77	101	65	65	142	56	640