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Stock assessment of blue warehou (*Seriolella brama*) in New Zealand waters

P. L. Horn

NIWA
PO Box 893
Nelson

N. W. Bagley

NIWA
PO Box 14-901
Wellington

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Ministry of Fisheries, Wellington

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1. EXECUTIVE SUMMARY

Catch histories were formulated for four assumed biological stocks of blue warehou (i.e., Northwest, Central East, WCSI, and Southern). A model incorporating catch history and biological parameters was used to obtain estimates and bounds of virgin biomass, and current biomass for the Northwest, Central East, and WCSI stocks. Current biomass may be above 50% B_0 for WCSI, below 50% B_0 for Central East, and between 10 and 70% of B_0 for the Northwest stock. All these assessments are highly uncertain as no series of relative abundance indices is available for any of these stocks.

The Southern stock was similarly assessed, but incorporated relative abundance indices from trawl surveys. MIAEL estimates and bounds of virgin biomass, current biomass, and yield were calculated. The base case model run indicated that current biomass is between 54 and 72% of B_0, but the information indices were less than 1%, so this assessment is also highly uncertain. An alternative base case proposed by the Middle Depth Species Working Group markedly increased the B_{max} bound, leading to a higher MIAEL estimate of B_0 and wider bounds around the estimate of current biomass (54–92% of B_0). The abundance index series provided little information on the current state of the stock relative to virgin biomass. Assumptions about the proportion of spawning biomass available to the fleet (p_{out}) markedly influence the assessment.

Mean landings levels from 1986 to 1997 and subsequent estimates of MCY were calculated for all four biological stocks and for the administrative Fishstocks. The TACs for each Fishstock were all at least double the estimates of MCY. The MIAEL model estimate of MCY for the Southern stock was in the range 1040 to 5660 t.

2. INTRODUCTION

Blue warehou, also known as common warehou, belong to the family Centrolophidae (raftfishes), represented in New Zealand waters by six genera (McDowall 1982). Of these, four genera (*Tubbia, Schedophilus, Centrolophus*, and *Icichthys*) are represented by species not occurring in commercial quantities. The genus *Hyperoglyphe* is represented solely by bluenose, *H. antarctica*, which is commercially important. Four species make up the genus *Seriolella* (McDowall 1982): of these, three species are of considerable commercial importance, blue warehou, silver warehou *(S. punctata)*, and white warehou *(S. caerulea)*. Gavrilov (1976, 1979) and Gavrilov & Markina (1970) gave the first detailed accounts of the biology and distribution of the three commercial warehou species in New Zealand waters.

Blue warehou are widespread in southern New Zealand coastal waters, occur patchily along the west coast of the North Island, and are uncommon or rare on the northeast coast

(McDowall 1982). Migrations have been described as extensive and dependent on water temperature (Gavrilov 1979). Blue warehou also occur off southeastern Australia where annual catches of up to 3000 t have been estimated (Smith 1994).

Stock assessment information is given in the annual background documents and plenary reports 1985 to 1998, the latest of which is Annala *et al.* (1998). Hurst (1985) provided the initial yield estimates for blue warehou. Hurst & Jones (1988) and Jones (1988) provided a background to the initial stock assessment, including CPUE analysis of the domestic setnet fishery and target trawl fishery in EEZ area F. Some of the earlier yield estimates were revised in 1996 after a revision of the methodology (Annala & Sullivan 1996). A MIAEL stock reduction model (Cordue 1993, 1995) incorporating catch history, relative abundance indices, and estimates of growth parameters was used to assess WAR 3 south of Banks Peninsula (Bagley *et al.* 1998).

This document provides preliminary discussion on likely biological stocks of blue warehou. Catch histories for these stocks are presented, and the stocks are modelled using the least squares and single-stock MIAEL estimation techniques of Cordue (1993, 1998). Estimates of MCY based on average catch histories are updated.

3. STOCK ASSUMPTIONS

Blue warehou are currently administered as six Fishstocks (Figure 1). Reported landings of blue warehou by administrative Fishstock and fishing year since 1982–83 are presented in Table 1. The bulk of the landings originate from WAR 3 and WAR 7. No landings have been recorded from WAR 10, and landings are negligible from WAR 1. Before constructing catch histories for use in modelling, it is necessary to consider the likely distribution of any distinct biological stocks, and whether combinations of landings by Fishstock will adequately represent landings by biological stock.

Bagley *et al.* (1998) examined seasonal trends in landings and known spawning locations and suggested the existence of four possible biological stocks, as follows.

i). A southern population, mainly off Southland but perhaps extending into the Canterbury Bight. The main spawning time is November in inshore waters east and west of Stewart Island. Subsequently referred to as the "Southern" stock.

ii). A central eastern population, located off the northeast coast of the South Island and southeast coast of the North Island (including Cook Strait), spawning mainly in the northern area in winter-early spring and also in autumn off Kaikoura. The "Central East" stock.

iii). A southwestern population which spawns on the west coast of the South Island in winter. The "WCSI" stock.

iv). A northwestern population which may spawn off New Plymouth in winter-spring, and occurs from Tasman Bay north. The "Northwest" stock.

They noted that this stock structure is very tentative. There may be overlap between some stocks, and the Northwest and Central East groups may be a single stock.

The following stock modelling is conducted assuming the existence of the four biological stocks described above (Figure 2). Unfortunately, these stocks are poorly represented by any combination of QMAs, so catch histories for the assessments could not be derived simply from landings summaries by QMA.

4. CATCH HISTORIES

The catch history for the Southern stock, from 1970 to 1997, was derived from Bagley *et al.* (1998). Catch histories for the three other stocks are derived here for the first time. The catch data for blue warehou come from a variety of sources, and were allocated to the four assumed biological stocks as follows.

1. Landings from inshore vessels by port of landing from 1936 to 1983 (from Annual Reports on Fisheries). Landings into a particular port were allocated to the stock area in which the port was situated, except for Nelson/Motueka where landings were known to have derived from Tasman Bay as well as the east and west coasts of the South Island. Of the Nelson/Motueka landings, 10% was estimated to have been taken from the Central East stock off the Marlborough coast (*from* Fenaughty & Bagley 1981). Estimated landings into Nelson from the WCSI stock were available from years 1967, 1968, and 1976–1982 (authors' unpublished data). For other years, where no estimates of landings derived from WCSI were available, the mean proportion from the known years (41% of total Nelson/Motueka landings) was applied.

2. Estimated landings by deepwater vessels from 1970 to 1977 (Bagley *et al.* 1998). These landings were allocated equally to the WCSI and Southern stocks.

3. Reported deepwater catch by EEZ area from 1978–79 to 1987–88 (Bagley *et al.* 1998). Landings by EEZ area to 1983 were allocated to stocks as follows: Central East — B, C_M; Southern — C-, D, E, F; WCSI — G; Northwest — H. No deepwater statistics are available for blue warehou for the fishing year 1980–81 and an average for the years 1979–80 and 1981–82 was used.

4. Reported landings by statistical area by inshore and deepwater vessels from 1983–84 to 1987–88 (FSU database). Landings by statistical area were allocated to stocks as follows: Central East — 1–21; Southern — 22–31, 49–51; WCSI — 32–35; Northwest — 36–48.

5. Estimated landings by statistical area by all vessels from 1988–89 to 1997–98 (MFish Catch and Effort database). This database records the estimated catch of the top five species (by weight) by tow from deepwater vessels and the top five species by tow or day for inshore vessels. Because blue warehou may not always be in the top five species per tow or day, this data source will underestimate total landings. Consequently, for each fishing year, landings by stock were pro-rated up so that the total landings from the four stocks combined equalled the total reported landings for that year.

6. Estimates of recreational catches. Recreational fishing surveys indicated that about 10 t were taken from the Central East stock in 1992–93 and the Southern stock in 1991–92. Recreational landings from other stocks were negligible (Annala *et al.* 1998). A recreational catch of 10 t annually was allocated to the Central East and Southern stocks from 1988 to the present.

There may have been some misreporting of blue warehou as white or silver warehou. The species code WAR may have also been used generically to record any one of the three commercial species of warehou. Reported catches from both the QMS and FSU data in water over 400 m deep on the east coast of the South Island and waters south of New Zealand are likely to be either white or silver warehou. The extent of the misreporting is unknown, and it is not clear whether the true catches of blue warehou would be higher or lower than the recorded landings. No attempt has been made to error-check the data provided by MFish.

Estimated catch histories for the four proposed biological stocks are listed in Table 2.

Landings were split into spawning and non-spawning season catches (Table 2) using reported landings by statistical reporting area by month, for years 1983 to 1988, and estimated landings by statistical reporting area by month (pro-rated where necessary; see point 5 above) for years since 1989 to 1998. Spawning season was defined as October–December for the Southern stock, and July–September for the other three stocks. The mean proportion of reported landings derived from the spawning season was calculated for each stock over the years 1983 to 1988, and these proportions (Central East, 12%; WCSI, 73%; Northwest, 40%) were used to allocate landings before 1983 to spawning and non-spawning seasons. Recreational catches were allocated to the non-spawning season.

5. BIOLOGY

5.1 Stock assumptions

The assumption that there are four biological stocks has been discussed above (section 3), and is based on seasonal trends in landings and known spawning locations.

5.2 Biological parameters

Biological parameters used for all stocks (Table 3) are those derived for the Southern stock by Bagley *et al.* (1998). No biological parameters particular to the other stocks are available.

5.3 Biomass estimates

Two times series of relative abundance indices were incorporated into the model for the Southern stock: January-March (1981), March-May (1982), April (1983), and June (1986) *Shinkai Maru* trawl surveys, and February-March *Tangaroa* trawl surveys (1993–96) (Table 4). The indices from both survey series are quite variable and have relatively high coefficients of variation. The coefficients of variation applied in the model were 60% for the *Shinkai Maru* and 40% for the *Tangaroa* series. Abundance indices were calculated for adult fish above 50 cm, the size at which blue warehou are fully recruited to the fishery (Bagley *et al.* 1998).

No series of relative abundance indices are currently available for any of the other stocks.

6. STOCK ASSESSMENT

This section reports an update of the stock reduction analysis for the Southern blue warehou stock (Bagley *et al.* 1998), and new assessments for the three other biological stocks.

6.1 Estimation of fishery parameters and abundance

The four biological stocks of blue warehou were modelled using the least squares and single-stock MIAEL estimation techniques of Cordue (1995, 1998). For the Southern stock, estimates of mid-season virgin biomass B_0, biomass in mid-1999 (B_{mid99}), biomass at the start of 2000 ($B_{beg2000}$), MCY, and Maximum Annual Yield (MAY) are presented. For the three remaining stocks, no series of relative abundance indices or catch-at-age data was available, so only the best *k* estimates of B_0 and B_{mid99} and their bounds are presented. The bounds on virgin biomass were derived using the model-based approach of Cordue (1996). The model year was set to begin at 1 January for the Southern stock, and 1 October for the other stocks. The catch histories, by spawning and non-spawning season, used in the model for each stock are given in Table 2. Model input parameters used in base case assessments are given in Tables 3 and 5. The maturity ogive is from Bagley *et al.* (1998).

Steepness was set at 0.75, as recommended by Francis (1992) when there is no other information available. A sensitivity test using a steepness of 0.9 was run for the Southern stock. Recruitment variability of blue warehou is thought to be similar to hoki and therefore a value of 1 was used. The proportion spawning was determined as 1, from spawning condition data collected on the November 1986 trawl survey in Southland (Hurst & Bagley 1997).

Proportions of the Southern and WCSI stocks are probably not available to the deepwater fleets that fish them owing to the existence of closed areas. Initial estimates of the proportion of the Southern stock available to the deepwater fleet were 0.10 and 0.05 (Hurst & Bagley 1997). However, these values were increased to allow for inshore vessel catch (Bagley *et al.* 1998). The proportions used in the model (p_{out}) were 0.25 for the spawning season from 1970 to 1985, and 0.20 from 1986, the closure of the Solander Corridor in 1985 accounting for the different value from 1986. There are no data on which to base a proportion of the WCSI spawning stock available to the fleet. This stock is also fished by both deepwater and inshore vessels. An arbitrary proportion of 0.5 from 1972 (when significant deepwater catches began) was used in the model. [Note: The Middle Depths Fishery Assessment Working Group recommended that future assessments should apply the reduced p_{out} from 1979, rather than 1972.] Sensitivity tests assuming 100% of spawning fish were available were conducted for both stocks.

The maximum proportion of the beginning of season biomass that could have been caught by the fleet was set at 0.5 on the home ground (r_{hm_max}) and on the spawning ground (r_{sp_max}) for all stocks. The values of r_{hm_max} and r_{sp_max} determine B_{min}, the lowest value of B_0 that is consistent with the catch history. The minimum exploitation rates (r_{hm_mmx} and r_{sp_mmx}) are the lowest values that the exploitation rates are believed to have been in the year that the exploitation was highest. A value of 0.05 was used for the spawning and pre-spawning seasons in the base case for all stocks. Assumptions about r_{hm_mmx} and r_{sp_mmx} determine the value of B_{max}, the highest level that is believed to be feasible for B_0. The values of B_{min} and B_{max} are used as bounds for estimates of B_0. Sensitivity tests using r_{max} values of 0.8 and r_{mmx} values of 0.02 were conducted.

The Middle Depths Fishery Assessment Working Group considered that the B_{min} and B_{max} bounds used in the base case for all stocks were too narrow. Consequently, additional model runs using $r_{hm\text{-}max} = 0.3$, $r_{sp\text{-}mmx} = 0.01$, and $r_{hm\text{-}mmx} = 0.02$, are presented for all stocks.

6.2 Biomass estimation

Estimates of mid-spawning season virgin biomass (B_0), mid-spawning season mature biomass for 1998–99 (B_{mid99}), and their bounds were obtained for the Central East, WCSI, and Northwest stocks (Table 6). Although some of the estimates have relatively narrow bounds, they all have information indices of 0%, so should be considered as highly uncertain. Biomass trajectories for the base case model runs (and the $p_{out} = 1$ sensitivity run for the WCSI stock) are shown in Figure 3.

The additional runs for the Central East, WCSI, and Northwest stocks using reduced values for r_{max} and r_{mmx} had little effect on B_{min}, but markedly increased B_{max} and the best *k* estimates of current biomass. [The additional run for the WCSI stock produced results identical to those from the $r_{mmx} = 0.02$ sensitivity run (Table 6).]

Estimates of B_0 and B_{mid99} for the Southern stock are listed in Table 7. The MIAEL estimate of current biomass (B_{mid99}) as a percentage of B_0 is 63%. The information indices for all model runs are very low (all less than 3%), indicating that the point estimates of biomass are very poorly known. Thus, the uncertainty associated with this assessment should be considered to be high. The biomass trajectories for the base case model run and the $p_{out} = 1$ sensitivity run are shown in Figure 3. Model fits to the two series of trawl survey indices are plotted in Figure 4. The abundance index series provided little information on the current state of the stock relative to virgin biomass.

Estimates of B_0 were found to be relatively insensitive to the tested changes in *M* and steepness, but were affected more by changes in p_{out} and r_{max}. Estimates of B_{mid99} were also relatively insensitive to changes in *M* and steepness, but the tested increase in r_{max} and, particularly, p_{out}, did markedly reduce the estimated current biomass.

The additional run for the Southern stock using reduced values for r_{max} and r_{mmx} had little effect on B_{min}, but markedly increased B_{max}. The resulting MIAEL estimate of B_0 was about 60% higher than for the base case, but the estimate of B_{mid99} as a percentage of B_0 changed only slightly (from 63 to 71%).

6.3 Model-based estimation of Maximum Constant Yield (MCY) and Current Annual Yield (CAY)

The method to estimate MCY was MCY = $p.B_0$, where p is determined using the method of Francis (1992) such that the biomass does not drop below 20% B_0 more than 10% of the time. Estimates of MCY for model runs for the Southern stock are given in Table 8. MIAEL estimates of MCY were not calculated for the Central East, WCSI, and Northwest stocks because of the highly uncertain nature of the estimates of B_0.

The base case MCY for the Southern stock was calculated as 5% B_0; none of the sensitivity runs markedly changed this value. The MCY range for the base case run was 1040 to 1620 t. For the model run where $r_{hm\text{-}max}$ and r_{mmx} were reduced, B_{MCY} and MCY as percentages of B_0 were 58% and 5%, respectively, and the MCY range was 1060–5660 t.

CAY was estimated for two of the Southern stock model runs; the base case, and $p_{out} = 1$ (*see* Table 8). These estimates will be very unreliable because the information indices on biomass estimates were close to 0. Under a CAY harvest strategy the mean mid-season biomass (B_{MAY}) was estimated to be 38% of B_0. The sensitivity runs had little effect on this value (*see* Table 8).

6.4 Catch-based estimation of Maximum Constant Yield

The method to estimate MCY was MCY = $c.Y_{av}$, where $c = 0.8$ (based on M) and Y_{av} is the average catch over an appropriate period (Annala *et al.* 1998). The period should be selected so that it contains no systematic changes in fishing mortality or fishing effort, and no systematic changes in catch. Ideally, it should be equal to at least half the exploited life span of the fish, i.e., at least 7 years for blue warehou. Because of the nature of the blue warehou fishery (i.e., mixtures of fishing methods, target and bycatch, and inshore and deepwater), and other factors which have affected fishing success (e.g., periods of rough weather which have precluded set net fleets targeting a migratory run), it is unlikely that any periods fitting all these criteria exist for any blue warehou stock.

However, it is proposed here that the period 1986 to 1997 could be used to give an indication of landings levels which appear to have been sustained over a relatively long time. The number of small set net operators declined during the early to mid 1980s, but both set net and trawl effort targeted at blue warehou has probably been relatively stable since then. However, some fishing activities returning a bycatch of blue warehou had probably changed in a systematic way and landings in WAR 3 may have been constrained by the TACCs in the early 1990s.

Mean landings levels, and MCYs based on the period 1986 to 1997 for biological stocks, and 1986–87 to 1996–97 for administrative Fishstocks, are presented in Table 9. All the TACs for the administrative Fishstocks are at least double the size of the estimated MCYs. [Note: The sum of the Y_{av} values for the Fishstocks differs from the sum of the values for the biological stocks because of the slight differences in the time periods used.]

The MCY calculated from the average catch history for the Southern stock is comparable to the estimates of MCY obtained from the base case MIAEL model run (*see* Table 8).

6.5 Other factors

Misreporting of silver or white warehou as blue warehou may have occurred and might have inflated the catches. However, it is also possible that some quantities of blue warehou have been dumped and not recorded. Some blue warehou may also have been reported as white warehou from 1987 to 1998 when white warehou was not a quota species. Clearly, actual landings of blue warehou could be either higher or lower than those reported.

The use of one trawl survey in 1986 to determine the proportion of the Southern stock available to the fleet during the spawning season may not be an accurate indicator of the proportion of fish inside and outside the 12 mile limit, including the Solander Corridor, in all years. The proportion of the WCSI stock available to the fleet was chosen arbitrarily. The effect of these chosen proportions in the model is considerable and has increased the spawning biomass as a percentage of B_0 in the base case analyses.

The catch histories from 1936 to 1977 are derived using a number of assumptions and there is considerable uncertainty about these estimates. It is likely that blue warehou were taken by deepwater vessels before 1970, as Hurst (1988) recorded catches of barracouta from 1967, and blue warehou are often a bycatch with this species. However, no data are available to enable an estimate of the deepwater blue warehou catch before 1970. For the fishing years 1983–84, 1984–85, and 1985–86 the totals from FSU catch summaries exceeded the figures given in the plenary reports for all the blue warehou Fishstocks; the reasons for this are not known.

7. STATUS OF THE STOCKS

Problems with stock structure and insufficient information make the assessment of the four blue warehou stocks very uncertain. The estimation of the catch history of blue warehou from all "warehou" species before 1978, and the likelihood of catches of blue warehou by the deepwater fleet before to 1970, cast some doubt on the accuracy of the early catch histories used in the model. The stock structure and stock relationships for blue warehou are not well understood and more work is required to define stock boundaries. No reliable series of abundance indices is currently available for any of the stocks.

Best estimates suggest that the Southern and WCSI stocks may be at levels higher than 50% of B_0, but the Central East stock may have been reduced below this level. The bounds around the base case estimate of current biomass for the Northwest stock are very wide.

8. ACKNOWLEDGMENTS

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Table 1: Reported landings (t) of blue warehou by Fishstock, from 1982–83 to 1997–98. Data to 1996–97 are from Annala *et al.* (1998); 1997–98 data are from MFish landings summaries

Fishstock	WAR 1		WAR 2		WAR 3		WAR 7	
QMA (s)	1 & 9		2		3, 4, 5 & 6		7	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1983–84*[1]	13	–	346	–	3 222	–	702	–
1984–85*	5	–	278	–	1 313	–	478	–
1985–86*	15	–	185	–	1 584	–	955	–
1986–87†	7	30	190	480	1 330	3 210	780	910
1987–88†	7	41	204	560	976	3 223	685	962
1988–89†	12	41	177	563	672	3 348	561	969
1989–90†	17	41	201	570	814	3 357	607	1 047
1990–91†	14	41	250	570	2 097	2 528	758	1 117
1991–92†	25	41	235	570	2 514	2 528	1 001	1 117
1992–93†	15	41	199	578	2 310	2 530	539	1 120
1993–94†	16	41	233	578	688	2 530	436	1 120
1994–95†	15	41	203	578	1 274	2 530	468	1 120
1995–96†	32	41	368	578	1 573	2 530	756	1 120
1996–97†	24	41	563	578	1 814	2 530	1 436	1 120
1997–98†	19	41	401	578	2 330	2 531	858	1 120

Fishstock	WAR 8		WAR 10			
QMA (s)	8		10		Total	
	Landings	TAC	Landings	TAC	Landings‡	TAC
1983–84*	104	–	0	–	4 387	–
1984–85*	91	–	0	–	2 165	–
1985–86*	43	–	0	–	2 782	–
1986–87†	40	210	0	10	2 347	4 850
1987–88†	43	218	0	10	1 915	5 014
1988–89†	44	231	0	10	1 466	5 162
1989–90†	57	233	0	10	1 696	5 459
1990–91†	113	233	0	10	3 232	4 499
1991–92†	132	233	0	10	3 905	4 499
1992–93†	152	233	0	10	3 215	4 512
1993–94†	126	233	0	10	1 500	4 512
1994–95†	114	233	0	10	2 074	4 512
1995–96†	186	233	0	10	2 913	4 512
1996–97†	161	233	0	10	3 998	4 512
1997–98†	110	233	0	10	3 719	4 512

* FSU data.
† QMS data.
‡ Includes landings from area unknown before 1986–87.
[1] Fishing year from 1 October to 30 September.

Table 2: Estimated catch histories (t) of blue warehou from 1936 to 1999, for the four assumed biological stocks. Non, non-spawning season; Spn, spawning season; Tot, total catch. Spawning season was defined as October–December for the Southern stock, and July–September for the other three stocks. 1999 catch set at mean of 1996–1998 levels

	Southern			WCSI			Northwest			Central East		
Year	Non	Spn	Tot	Non	Spn	Tot	Non	Spn	Tot	Non	Spn	Tot
1936	0	0	0	0	0	0	0	0	0	70	9	79
1937	0	0	0	0	0	0	0	0	0	106	15	121
1938	0	0	0	0	0	0	0	0	0	92	12	104
1939	0	0	0	0	0	0	0	0	0	7	1	8
1940	0	0	0	0	0	0	0	0	0	34	5	39
1941	0	0	0	0	0	0	0	0	0	47	6	53
1942	0	0	0	0	0	0	0	0	0	49	7	56
1943	0	0	0	0	0	0	0	0	0	49	7	56
1944	0	0	0	0	0	0	0	0	0	32	4	36
1945	0	0	0	0	0	0	0	0	0	11	2	13
1946	0	0	0	0	0	0	0	0	0	18	2	20
1947	0	0	0	0	0	0	0	0	0	53	7	60
1948	0	0	0	0	0	0	0	0	0	18	2	20
1949	0	0	0	0	0	0	0	0	0	17	2	19
1950	0	0	0	0	0	0	0	0	0	46	6	52
1951	0	0	0	0	0	0	0	0	0	28	4	32
1952	0	0	0	0	0	0	0	0	0	14	2	16
1953	0	0	0	0	0	0	0	0	0	40	5	45
1954	0	0	0	0	0	0	0	0	0	60	8	68
1955	0	0	0	0	0	0	0	0	0	40	5	45
1956	0	0	0	0	0	0	0	0	0	58	8	66
1957	0	0	0	0	0	0	0	0	0	111	15	126
1958	0	0	0	0	0	0	1	0	1	94	13	107
1959	0	0	0	0	0	0	1	0	1	120	16	136
1960	1	1	2	0	0	0	0	0	0	62	8	70
1961	1	1	2	0	0	0	1	0	1	76	10	86
1962	2	1	3	0	0	0	1	1	2	95	13	108
1963	5	2	7	0	0	0	1	0	1	92	12	104
1964	7	5	11	1	1	2	2	1	3	111	15	126
1965	3	1	4	0	0	0	1	1	2	63	9	72
1966	3	1	4	1	4	5	1	1	2	27	4	31
1967	1	1	2	55	147	202	29	19	48	73	10	83
1968	2	1	3	42	113	155	77	51	128	71	10	81
1969	2	1	3	9	25	35	12	8	20	99	13	112
1970	40	20	60	47	126	173	66	44	110	102	14	116
1971	50	20	70	55	150	205	75	50	125	147	20	167
1972	490	150	640	179	485	664	46	30	76	168	23	191
1973	600	200	800	260	703	963	156	104	260	157	21	178
1974	480	170	650	244	660	904	173	115	288	184	25	209
1975	580	200	780	254	688	942	74	49	124	150	21	171
1976	1 290	390	1 680	437	1 183	1 620	185	123	308	234	32	266
1977	1 380	420	1 800	509	1 375	1 884	205	136	341	329	45	374
1978	37	58	95	321	867	1 188	316	210	526	539	74	613
1979	219	575	794	86	234	320	310	206	516	774	105	879
1980	503	1 000	1 503	117	316	433	171	114	286	592	81	673
1981	600	1 751	2 351	188	510	698	299	200	499	664	91	755
1982	699	1 060	1 759	249	673	922	118	79	197	517	70	587
1983	956	2 143	3 099	166	500	666	58	143	201	463	90	554
1984	1 392	844	2 236	202	411	613	56	67	123	616	92	708
1985	713	273	986	62	351	413	81	62	143	556	51	607
1986	1 553	556	2 109	158	573	731	170	43	213	418	66	484
1987	717	231	948	170	391	561	229	29	258	325	36	361
1988	628	162	790	195	357	552	102	20	122	349	36	385
1989	314	90	404	213	184	397	88	25	113	485	45	530
1990	516	20	536	64	255	320	82	29	110	585	51	636
1991	1 717	620	2 337	69	494	563	112	69	181	716	39	755
1992	1 684	67	1 751	128	329	457	508	40	548	561	50	611
1993	1 960	162	2 122	141	94	234	323	84	407	313	59	371
1994	375	1 099	1 474	90	185	275	131	59	190	558	49	607
1995	79	875	954	111	97	208	168	108	277	371	57	428
1996	466	554	1 020	253	249	502	157	129	286	710	91	801
1997	1 058	1 363	2 421	431	476	907	173	98	271	1 074	142	1 216
1998	509	931	1 440	109	381	490	203	46	249	1 038	90	1 128
1999	678	931	1 609	264	367	633	178	91	269	941	108	1 049

Table 3: Biological parameters for blue warehou (*from* Bagley *et al.* 1998)

Fishstock	Estimate					
1. Natural mortality (M)						
All	0.24					
2. Weight = a (length)b (Weight in g, length in cm total length)						
	Sex	*a*	*b*			
All	Male	0.015	3.09			
	Female	0.016	3.07			
3. von Bertalanffy growth parameters						
	Females			Males		
	k	t_0	L_∞	*k*	t_0	L_∞
All	0.209	–0.79	66.3	0.241	–0.46	63.8

Table 4: Trawl survey biomass indices (t) and coefficients of variation (*c.v.*) for recruited blue warehou over 50 cm

Stock	Area	Vessel	Voyage	Date	Biomass	c.v. (%)
Southern	Southland	*Shinkai Maru*	SHI8101	Jan-Mar 81	2 100	43
			SHI8201	Mar-May 82	800	62
			SHI8302	Apr 83	4 700	72
			SHI8601	Jun 86	2 000	59
Southern	Southland	*Tangaroa*	TAN9301	Feb-Mar 93	2 297	36
			TAN9402	Feb-Mar 94	1 629	38
			TAN9502	Feb-Mar 95	1 103	38
			TAN9604	Feb-Mar 96	1 615	40

Table 5: Model input parameters for the blue warehou assessments

Parameter	Estimate
Steepness	0.75
Recruitment variability	1.00
Proportion spawning	1.00
Spawning season length	0.25
Maximum exploitation on home ground ($r_{hm\text{-}max}$)	0.5
Maximum exploitation on spawning ground ($r_{sp\text{-}max}$)	0.5
Minimum exploitation at highest catch on home ground ($r_{hm\text{-}mmx}$)	0.05
Minimum exploitation at highest catch on spawning ground ($r_{sp\text{-}mmx}$)	0.05

Proportion available (p_{out}):		
	Central East	1.00 (all years)
	Southern	1.00 (1960–69), 0.25 (1970–85), 0.20 (1986–1999)
	WCSI	1.00 (1964–71), 0.50 (1972–1999)
	Northwest	1.00 (all years)

Maturity ogive	Age	2	3	4	5	6
	Male	0.10	0.25	0.50	0.75	1.00
	Female	0.10	0.25	0.50	0.75	1.00

Table 6: Best k estimates of B_0 and B_{mid99}, and their bounds (t), for the Central East, WCSI, and Northwest stocks. Results from the base case and sensitivity model runs are presented. Information indices are 0% for all estimates of B_0 and B_{mid99}. An alternative base case model (denoted as "WG") proposed by the Middle Depth Species Working Group is where $r_{hm-max} = 0.3$, $r_{sp-mmx} = 0.01$, and $r_{hm-mmx} = 0.02$

		B_0		B_{mid99}	
Stock	Model run	best k	Range	best k	Range
Central East	Base case	6 540	5 650 – 7 620	580	220 – 2 390
	WG	9 810	6 000 – 17 670	4 870	740 – 12 870
	$r_{max} = 0.8$	6 450	5 510 – 7 620	280	80 – 2 390
	$r_{mmx} = 0.02$	8 000	5 650 – 11 840	780	220 – 6 790
	$M = 0.20$	7 390	6 490 – 8 460	560	210 – 2 430
WCSI	Base case	9 210	8 750 – 9 700	5 670	5 180 – 6 230
	WG	12 830	8 750 – 19 890	8 790	5 180 – 16 710
	$r_{max} = 0.8$	8 060	6 770 – 9 700	3 740	2 420 – 6 230
	$r_{mmx} = 0.02$	12 830	8 750 – 19 890	8 790	5 180 – 16 710
	$M = 0.20$	9 860	9 120 – 10 690	5 470	4 660 – 6 490
	$p_{out} = 1$	8 060	6 770 – 9 700	3 740	2 420 – 6 230
Northwest	Base case	3 580	2 420 – 5 630	580	180 – 3 870
	WG	5 540	2 390 – 17 760	3 880	210 – 16 170
	$r_{max} = 0.8$	3 560	2 390 – 5 630	400	110 – 3 870
	$r_{mmx} = 0.02$	4 780	2 420 – 11 490	730	180 – 9 770
	$M = 0.20$	3 950	2 790 – 5 840	570	180 – 3 760

Table 7: Southern stock. Least squares (LSQ) and best k estimates of biomass, and MIAEL estimates of p, biomass (MIAEL) and information indices (Info.), for base case and sensitivity model runs. All biomass estimates for B_0 and $B_{beg2000}$ are in tonnes; those for B_{mid99} and $B_{mid2000}$ are expressed as a percentage of B_0. An alternative base case model (denoted as "WG") proposed by the Middle Depth Species Working Group is where $r_{hm-max} = 0.3$, $r_{sp-mmx} = 0.01$, and $r_{hm-mmx} = 0.02$

Estimate	Model run	Bounds ($B_{min} – B_{max}$)	LSQ	best k	p	MIAEL	Info. (%)
B_0	Base case	20 750 – 32 370	32 370	25 700	0.0314	25 910	0.3
	WG	20 730 – 111 000	111 000	42 770	0.0246	44 450	0.3
	$p_{out} = 1$	13 050 – 32 400	32 400	19 870	0.0982	21 100	2.8
	$M = 0.20$	21 610 – 36 070	36 070	27 620	0.0373	27 930	0.4
	$M = 0.28$	19 960 – 29 060	29 060	23 940	0.0259	24 080	0.2
	$r_{max} = 0.8$	14 720 – 32 410	32 410	21 290	0.0715	22 080	1.5
	steepness = 0.9	20 650 – 31 780	31 780	25 420	0.0304	25 610	0.3
B_{mid99}	Base case	54 – 72	72	62	0.0293	63	0.2
	WG	54 – 92	92	70	0.0246	71	0.7
	$p_{out} = 1$	10 – 72	72	23	0.0506	25	1.3
	$M = 0.20$	47 – 71	71	57	0.0300	58	0.3
	$M = 0.28$	59 – 73	73	66	0.0233	66	0.2
	$r_{max} = 0.8$	28 – 72	72	43	0.0679	45	1.4
	steepness = 0.9	58 – 74	74	65	0.0304	65	0.3
$B_{beg2000}$	Base case	20 310 – 38 440	38 440	27 470	0.0317	27 820	0.3
	$p_{out} = 1$	4 960 – 38 490	38 490	11 670	0.0675	13 480	2.4
	$M = 0.20$	17 140 – 38 130	38 130	24 900	0.0357	25 370	0.4
	$M = 0.28$	23 210 – 38 590	38 590	29 610	0.0273	29 850	0.2
	$r_{max} = 0.8$	9 550 – 38 500	38 500	17 710	0.0645	19 050	1.6
$B_{mid2000}$	Base case	54 – 72	72	62	0.0295	62	0.2

Table 8: Southern stock. MIAEL estimates of MAY, B_{MAY}, MCY, and B_{MCY}, (all as % of B_0), and MCY and its range (t), for all the model runs. Estimates of CAY (t) are given for two model runs

Model run	MAY (% B_0)	B_{MAY} (% B_0)	MCY (% B_0)	B_{MCY} (% B_0)	MCY (t)	MCY range (t)	CAY (t)
Base case	8	38	5	62	1 300	1 040 – 1 620	2 930
WG	–	–	5	58	2 270	1 060 – 5 660	
$p_{out} = 1$	8	38	5	62	1 060	650 – 1 620	1 420
$M = 0.20$	7	37	4	60	1 230	950 – 1 590	
$M = 0.28$	10	39	6	63	1 350	1 120 – 1 630	
$r_{max} = 0.8$	8	38	5	62	1 100	740 – 1 620	

Table 9: Average landings levels (t), estimates of MCY (t, rounded to the nearest 10 t) based on an average catch history from 1986 to 1997 ($MCY = c.Y_{av}$) where $c = 0.8$, and actual TACs (t) for the administrative Fishstocks

Fishstock	Y_{av}	MCY	TAC
WAR 1 & 2	273	220	619
WAR 3	1 460	1 170	2 531
WAR 7	730	580	1 120
WAR 8	107	90	233

Biological stock	Y_{av}	MCY
Central East	599	480
Southern	1 406	1 120
WCSI	476	380
Northwest	248	200

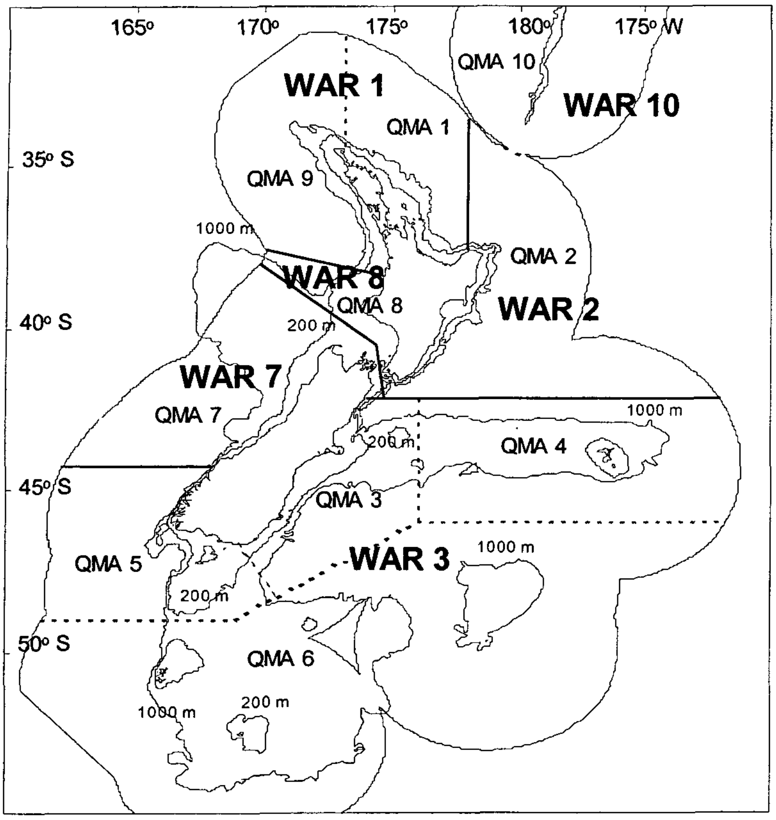

Figure 1: QMA boundaries, and blue warehou Fishstocks.

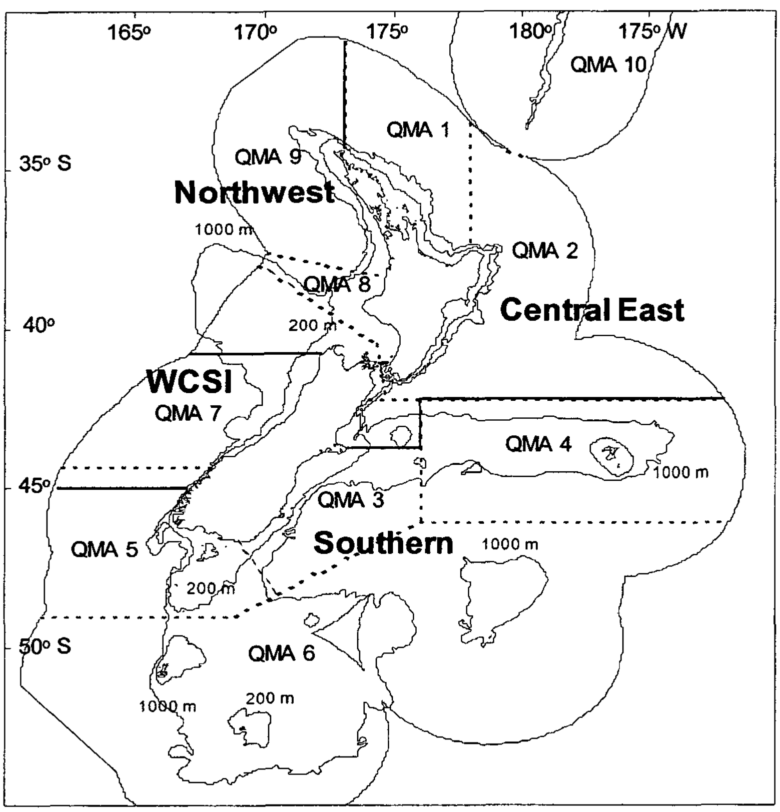

Figure 2: QMA boundaries, and assumed biological stock boundaries for blue warehou.

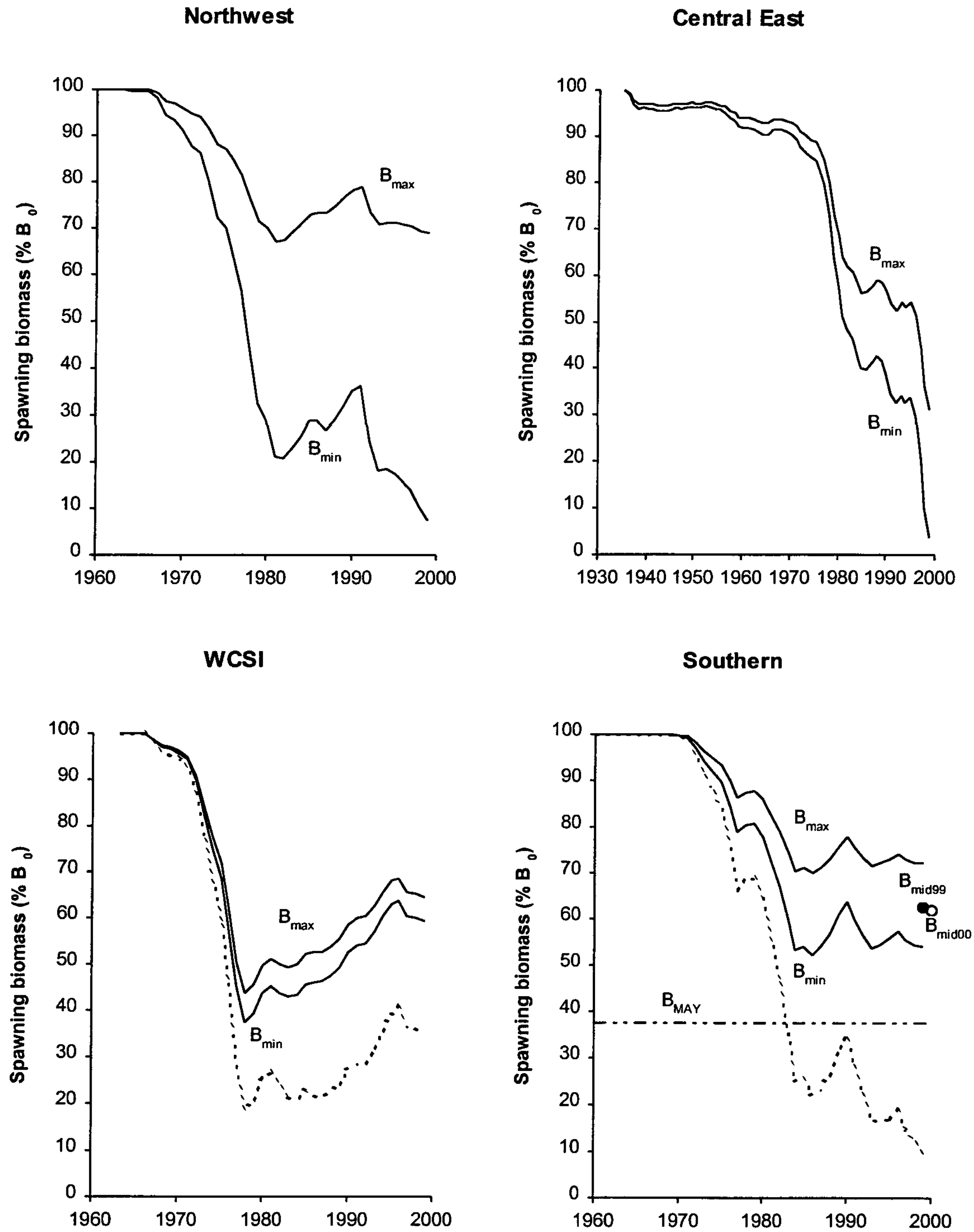

Figure 3: Estimated biomass trajectories (solid lines) for B_0 at B_{max} and B_{min} from the base case model runs for all stocks. For the WCSI and Southern stocks, biomass trajectories are also shown for the model runs where $p_{out} = 1$ (broken line for $B_0 = B_{min}$; $B_0 = B_{max}$ is identical to the base case). For the Southern stock, the MIAEL estimate of current biomass (B_{mid99}) as a percentage of B_0 is shown (filled circle), as is $B_{mid2000}$ (open circle). The horizontal broken line represents B_{MAY}.

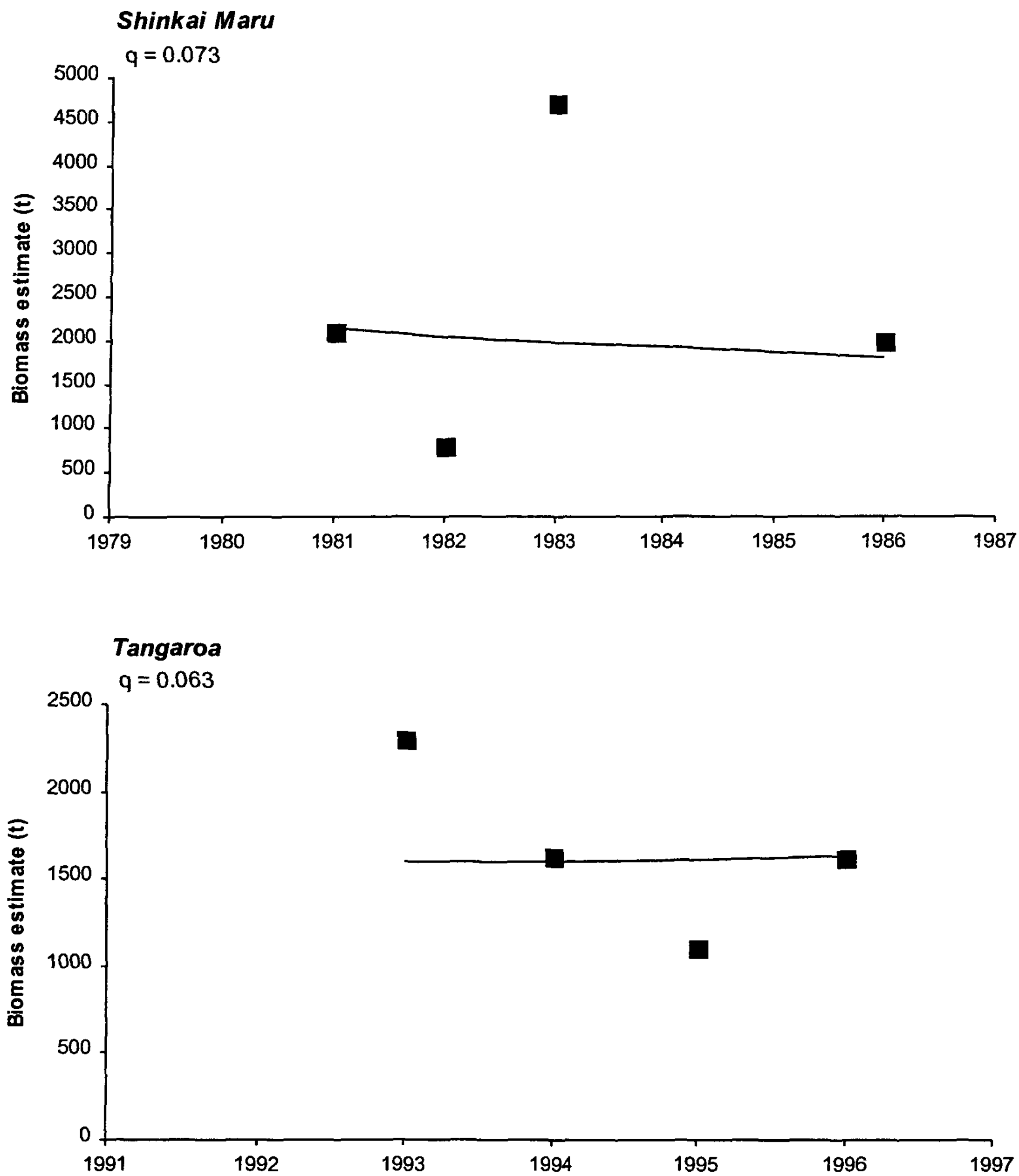

Figure 4: Model fits (solid lines) to the two series of trawl survey indices (filled squares) for the Southern stock. The estimate of trawl q for each series is given on the plot.