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Assessment of jack mackerel stocks off the central west coast, New Zealand for the 1991–92 fishing year

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1. INTRODUCTION

1.1 Overview

This report gives revised estimates of instantaneous natural mortality (M) for *Trachurus declivis* and *T. novaezelandiae*, and provides an estimate of jack mackerel biomass in west coast waters between 37°30' and 41°30'S. Current annual yields for the west coast trawl fishery are calculated and values of maximum constant yield are revised. Biomass estimates for other middle depth and inshore species are also presented. M for both species of jack mackerel was recalculated using new and existing age–length data sets to create population age structures. The estimates of biomass were obtained from a trawl survey conducted using the *Cordella* in February–March 1990 and designed so as to include the same area and use the same strata as the 1981 *Shinkai Maru* survey. However, the surveys were difficult to compare and the two estimates of biomass were not considered satisfactory indices for use in a stock reduction analysis. Consequently, a biomass projection method was used to calculate virgin and current biomass.

1.2 Description of the fishery

The fishery for jack mackerels comprises two distinct operations separated by method and area: a domestic purse seine fishery in the Bay of Plenty to Gisborne and Tasman Bay to Kaikoura regions within the 12 n. mile territorial sea, and a foreign licensed and New Zealand chartered trawl fleet operating a minimum of 12 n. miles off the west coast between Raglan and Westport. Both methods take the three jack mackerel species (*Trachurus novaezelandiae*, *T. declivis* and *T. murphyi*), although proportions of each species vary between areas. Although TACs have been formulated for the total EEZ (Annala 1990), only one fishstock (JMA7, comprising the Challenger, Central West and Auckland West FMAs) is currently incorporated in the Quota Management System. Scientific Observer data indicate that about 65% (range 61–73% over the fishing years 1986–87 to 1989–90) of the catch by weight from JMA7 is *Trachurus declivis*. *T. murphyi* currently comprises only 2–3% of landings in JMA 7.

The gazetted TACC for fishstock JMA7 was set at 20,000 t in 1986 (Jones 1986). This figure was based on a trawl biomass estimate from 1981 (128,900 t) and an M of 0.3, i.e.:

$$MCY = 0.5 * 0.3 * 128,900 = 19,335 \text{ t.}$$

QAA allocations had increased the actual TACC for JMA7 to 32,026 t by the end of the 1989–90 fishing year. The current TACC has never been exceeded, with annual landings averaging 15,600 t over the period 1983–84 to 1988–89, but peaking in 1989–90 at 21,900 t. This under–catching is due to fishing patterns and low product demand rather than scarcity of the species.

2. RESEARCH

2.1 Estimates of instantaneous mortality

Estimates of total instantaneous mortality (Z) are available for several samples of both jack mackerel species over the period 1975–89 (Table 1). All samples were of trawl–caught fish aged by ring counts in broken, polished and burned otoliths. This ageing technique has been validated for a wide age range of *T. novaezelandiae* and for the first four age classes of *T. declivis* (author's unpublished data). Progression of length-frequency peaks and the examination of otolith margins were the validation techniques used. For each sample, an age–length key was constructed from the total length–frequency and the sample of otoliths read, in the following manner:

$A_t = \Sigma_z(L_z.p_{tz})$ where

A_t = the estimated proportion of fish of age t in the population,
L_z = the proportion of fish of length z in the length–frequency sample, and
p_{tz} = the proportion of aged fish of length z which were age t.

The slope of $\log_e(A_t)$ plotted against age (t) was taken as the estimate of Z. The range of ages plotted varied between samples (Table 1, Figure 1); in each case the range from the largest A_t to the oldest age class was used. This method is subject to bias if the different ages are not equally vulnerable to the gear used. Small mackerel can escape more easily through the codend mesh than large fish, but large fish are more capable of avoiding the gear. These factors could provide a compensatory effect. Vulnerabilities for all jack mackerels on the right–hand limb of the catch curve were assumed to be equal.

Values derived from the 1975–76 Bay of Plenty samples are probably reasonable estimates of instantaneous natural mortality (M) as virtually no fishing for jack mackerels had been conducted in that area prior to 1975 (Jones 1990). Hence, M for *Trachurus declivis* and *T. novaezelandiae* are likely to be in the range 0.17–0.20. The highest estimates of Z for both species are those calculated in 1989 from the west coast trawl fishery (0.22 and 0.23). These values would comprise a component of instantaneous fishing mortality (F); an average annual catch of 12,900 t has been taken from JMA7 fishstock area since 1970 (Table 4). While it is not possible to determine F with precision from these data it would certainly be less than 0.1 and probably be less than 0.05. Table 1 suggests that F (and hence Z) may have been increasing over the past two decades. However, the residuals of the 1989 plots of $\log_e(A_t)$ against t for both species were randomly distributed around zero, suggesting that F has either been relatively constant over the period, or is so small relative to M that no curvature is apparent.

This study assumes that for both species M is constant over time and M is similar for jack mackerels from different areas. Such assumptions have been shown to be invalid for some fish stocks (Vetter 1988), so the uncertainty of the catch curve analysis presented here must be acknowledged.

The range for M proposed here (0.17–0.20) is much lower than the ranges proposed for *Trachurus declivis* in Australian waters of 0.63–0.71 (Williams and Pullen 1986) and 0.34–0.45 (Gasior and Kompowski 1982). The Australian studies calculated Z for stocks that had been only lightly fished and took that value as an estimate of M. However, these ageing studies may be flawed as they have generally used whole, rather than broken, otoliths, leading to many fish being under–aged (author's unpublished data). Under–ageing causes an inflation of the true Z value. Also the catch from the Australian purse seine fishery comprises mainly small fish probably less than 10 years old (J. Lyle, pers. comm.), a situation different to any New Zealand mackerel fishery. The analysis of a catch sample from that fishery could easily lead to estimates of M different to those derived for stocks of *T. declivis* in New Zealand, particularly if M varies with age or if the catch does not represent the total adult age range in the population.

2.2 Biomass surveys

2.2.1 Comparison of *Shinkai Maru* and *Cordella* surveys

Two biomass surveys targeting jack mackerels are available for comparison; by the *Shinkai Maru* in 1981 (Robertson et al. 1989) and the *Cordella* in 1990 (Horn in press). Both surveys covered the area fished by the trawl fleet. However, a comparison is complicated because the survey area, timing, vessel size and power, and trawl gear design all differed between surveys. In an effort to relate the efficiency of the two trawls, biomass estimates of selected species were compared. It was assumed that there had been little change in the relative abundance of non-commercial by-catch species between the two surveys because of the minimal exploitation of these species in the survey area. The methodology and analysis of this comparison is given by Horn (in press).

2.2.2 Biomass estimates

An estimate of jack mackerel biomass calculated for the 1981 *Shinkai Maru* survey has been used to provide yield estimates for the trawl fishery (Annala 1990). The estimate took the doorspread biomass, assumed areal and vertical availability both equalled 1, and that vulnerability was 0.38. This value for the vulnerability equates to using the mean of wingspread and doorspread as the width of the area swept. Biomass estimates for 14 major species from this survey have been recalculated using estimated doorspread for each tow rather than simply using a mean estimated doorspread for the whole survey (Table 2). Differences between the original and recalculated values were never more than 8%.

For the *Cordella* survey, areal and vertical availability were again assumed to be 1. As with the *Shinkai* gear, the doors, sweeps and bridles were assumed to have herded some fish towards the net mouth, but escapement in front of and through the net would have occurred. Differences in biomass estimates between the two surveys have indicated that the *Cordella* trawl was about 50% as effective as the *Shinkai* gear. Therefore, in calculating the vulnerability for the *Cordella* survey it was assumed that the width of the area swept was the mean of the wingspread and doorspread, giving $V = 0.38$, but that this value must be corrected for the relative inefficiency of the *Cordella* trawl. A relative efficiency of 0.5 was used, giving $V = 0.38 * 0.5 = 0.19$. This methodology probably provides a conservative comparison of the biomass estimates from the two surveys, i.e. the levels of biomass for the *Cordella* survey (Table 2) are likely to be relative underestimates rather than overestimates (Horn in press).

Between–survey comparisons of biomass can be made only for the area outside the 12 n. mile boundary, and even then a confident comparison can not be made between two surveys conducted in different seasons and using gear of apparently different efficiencies. Assuming a relative efficiency of 0.5, the biomass of most species outside the 12 n. mile boundary appears to have declined or remained relatively constant (Table 2). School shark and john dory are the only species exhibiting an increased abundance. Between 1981 and 1990, combined jack mackerel biomass outside 12 n. miles decreased by 40% using a relative efficiency value of 0.5.

Before making yield calculations it was necessary to reconcile two conflicting pieces of information. The two trawl surveys indicated a 40% decline in relative biomass between 1981 and 1990, while estimates of F based on changes in population age structures indicated a low level of fishing mortality over the last 20 years. Sufficient data were available to conduct a maximum likelihood stock reduction analysis for jack mackerels in JMA7. The analysis was run for both species using the method of Francis (1990) and the data in Table 3. Given the 40% decline in relative biomass and the reported annual catches, best estimates of B_0 were 106,000 t for *Trachurus declivis* and 50,000 t for *Trachurus novaezelandiae*. However, these analyses indicated that mean F over the period 1970–90 would need to have been about 0.16. Given the current value of Z for both species of about 0.22, a past mean F of 0.16 is improbable. The most likely source of error is an incorrect estimate of the relative decline in biomass between the two surveys, a problem which could easily be caused by the difficulties in comparing the surveys and by the levels of statistical variation associated with the biomass estimates (Table 2).

Consequently, a different method was used to estimate virgin and current biomass. A series of stock reduction analyses were run using the known catch levels and a variety of estimates of B_0 to provide biomass projections. The aim was to find values of B_0 for both species that, having the catches in Table 3 applied to them, gave values of mean instantaneous fishing mortality of about 0.05 (the level of F as indicated from changes in age–length keys). The best estimates of B_0 were 200,000 t and 100,000 t for *Trachurus declivis* and *Trachurus novaezelandiae*, respectively (Table 4). These analyses also indicated that the reduction in biomass between 1981 and 1990 was 15% for both species (rather than 40% as indicated in Table 2), and that recruited biomass in 1990 for the two species was 135,300 t and 70,200 t respectively. These estimates of current biomass are assumed to be more reliable than those determined from the trawl survey.

2.2.3 Comparisons of length–frequencies

The overall length–frequencies from 1981 and 1990 differed appreciably for both species of jack mackerel (Figure 2). However, there was little change in the length-frequencies of adult fish between the surveys. Numerically, the bulk of the mackerel population are fast–growing fish less than five years old. The seasonal differences between samples and differing cohort strengths account for the differences between the length–frequencies. However, the fishery is based primarily on the adult fish (*T. declivis* >37 cm FL and *T. novaezelandiae* >28 cm FL) and over these length ranges the length–frequencies are quite comparable. (The comparability of adult population age structures from 1981 and 1989 also supports the hypothesis of little change.)

However, comparing length–frequency distributions from the 1981 and 1990 surveys may not be a reliable method to infer changes in population structure. Not only was there a seasonal difference between the surveys (which could strongly affect the distribution of any migratory species), but the 1981 survey lacked inshore sampling. Also, problems occur when comparing length–frequency distributions collected several years apart of species with moderate or fast growth rates, as variation in recruitment can influence the distribution shape more than the effects of fishing.

2.2.4 *Kaharoa* trawl survey 1990

This survey was conducted in March–April 1990 by GRV *Kaharoa* in depths of 20–400 m. The survey area was inshore of a line from Farewell Spit to Stephens Island, and off the west coast of the South Island from Cape Farewell (40°30'S) to Awarua Point (44°15'S). The areas in Tasman and Golden Bays, and in depths from 25–300 m between 40°30' and 41°30'S were also sampled during the February–March 1990 *Cordella* survey. The *Kaharoa* was unlikely to have efficiently sampled jack mackerels because of the slower towing speed (3 kts), larger codend mesh (100 mm), and lower headline height (5 m) than the *Cordella* trawl, and the use during much of the survey of a trawl without lower wings. However, a comparison of biomass estimates for the survey areas in common has enabled the estimation of jack mackerel biomass in the area from 41°30' to 44°15'S. Biomass estimates from the *Kaharoa* and *Cordella*, respectively, were 307 t and 14,787 t in the Tasman and Golden Bays area, and 439 t and 9,728 t off the west coast down to 41°30'S. Conversion factors to scale *Kaharoa* biomass up to the levels estimated from the *Cordella* survey were 48 and 22 for the two areas respectively. Applying the more conservative factor (22) to the jack mackerel biomass between 41°30' and 44°15'S as estimated from the *Kaharoa* survey (565 t), it is likely that had the *Cordella* survey been extended to cover this southern area an additional resource of about 12,500 t (= 22 * 565) of jack mackerels would have been postulated. Virtually all this additional biomass would be *Trachurus declivis*.

2.3 Yield estimates

2.3.1 Yield per recruit analyses

Yield per recruit analyses were conducted for both species using von Bertalanffy parameters calculated from the three Taranaki Bight otolith samples (see Table 1) using the method of Francis (1988) (k, t_0 and L_∞ were, respectively, 0.30, -0.65 and 36 cm for *Trachurus novaezelandiae*, and 0.28, -0.40 and 46 cm for *T. declivis*), and M=0.18 (the mean value of the four estimates of Z from the Bay of Plenty samples). Yield per recruit analyses were run using the full range of estimates of M (0.17–0.20), but the model was relatively insensitive to these changes. A length at first capture of 32 cm FL was used, and knife–edge selection was assumed. The 50% selection length for jack mackerels in a trawl codend of 100 mm mesh is about 37 cm FL (Jones 1990). A fork length of 32 cm is at the 25% selection level, so the calculated values of $F_{0.1}$ (0.23 for *T. declivis* and 0.33 for *T. novaezelandiae*) would be conservative.

2.3.2 Estimation of Maximum Constant Yield (MCY)

Estimates of maximum constant yield (MCY) are presented based on both methods 1 and 3 in the Guide to Biological Reference Points (Annala 1990), ie. MCY = $^2/_3$ MSY and MCY = 0.25 $F_{0.1}$ B_0.

Deterinistic MSY values (8.82% and 14.7% of B_0 for *Trachurus declivis* and *Trachurus novaezelandiae* respectively) were calculated using a yield per recruit analysis with the parameters in Table 3. B_0 values were those obtained from biomass projections (section 2.2.2).

For *Trachurus declivis*

MCY = $^2/_3$ * 0.0882 * 200,000 t (Method 1)
= 11,800 t

MCY = 0.25 * 0.23 * 200,000 t (Method 3)
= 11,500 t

For *Trachurus novaezelandiae*

MCY = $^2/_3$ * 0.147 * 100,000 t (Method 1)
= 9,800 t

MCY = 0.25 * 0.33 * 100,000 t (Method 3)
= 8,300 t

2.3.3 Estimation of Current Annual Yield (CAY)

Individual values of $F_{0.1}$ and estimates of 1991 beginning of season biomass for both species were used to calculate CAY for JMA7 using the Baranov catch equation. Instantaneous natural mortality (M) of 0.18 was used.

For *Trachurus declivis*

CAY = 152,400 t * $(1-e^{-(0.23+0.18)})$ * 0.23 / (0.23 + 0.18)
= 28,700 t

For *Trachurus novaezelandiae*

CAY = 79,500 t * $(1-e^{-(0.33+0.18)})$ * 0.33 / (0.33 + 0.18)
= 20,500 t

2.4 Dolphin by–catch

During the 1989–90 fishing year, one observed vessel targeting jack mackerels caught dolphins. Over a 3 week period, 21 dolphins were taken, all while night–fishing. The vessel was using a midwater trawl towed at about 5 kts relatively near the surface, ie. the headrope was generally within 30 m of the surface.

3. CONCLUSIONS

i. Total instantaneous mortality (Z) for the present populations of both *Trachurus declivis* and *T. novaezelandiae* is about 0.22. Instantaneous natural mortality (M) for both species is probably about 0.18, not 0.3 as has been used in previous stock assessments. (This would have the effect of reducing the previously calculated value of MCY by 40%.) Instantaneous fishing mortality (F) for the central west coast fishery is less than 0.1 and is probably about 0.05.

ii. The adult length– and age–frequencies of both jack mackerel species in 1989–90 appear to be relatively unchanged from those in 1980–81.

iii. The average annual catch since 1970 of 12,900 t is probably less than the maximum constant yield for the fishery, although the average annual catch since the 1984–85 fishing year is 17,100 t.

iv. The comparison of biomass estimates between the 1981 and 1990 surveys is complicated because of the apparent differing efficiencies of the two sets of gear, and the seasonal difference between the surveys. Based on a comparison of catch rates it appears that the *Shinkai Maru* gear was probably about twice as efficient as that used on the *Cordella.* This was conservatively compensated for in the vulnerability factors (0.38 and 0.19, respectively). Seasonal variation in fish distribution and abundance could not be compensated for.

v. In calculating yields, the estimated level of F was used rather than the estimated change in relative biomass between the 1981 and 1990 surveys.

4. MANAGEMENT IMPLICATIONS

The actual TACCs for all areas are considered sustainable in the 1991–92 fishing year. For JMA 7 estimates of B_{1991} are 76% and 79% of B_0 for *T. declivis* and *T. novaezelandiae*, respectively, and the fishery is probably still fishing down accumulated biomass. Decisions of the QAA have increased the gazetted TACC for JMA7 by 60% from 20,000 t to 32,026 t. The greatest annual catch from JMA7 was 21,900 t in the 1989–90 fishing year, and it appears unlikely that catches will increase significantly in the short term due to the current low international price for jack mackerels. For all Fishstocks catch levels greater than the current TACCs may be sustainable, at least in the short term.

5. ACKNOWLEDGMENTS

I thank Chris Francis for running the stock reduction analyses, and members of the middle depth species working group for comments on the assessment.

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Table 1. Estimates of total instantaneous mortality (Z) for *Trachurus declivis* and *T. novaezelandiae*. (* = samples where length–frequencies are probably biased towards larger fish due to a non-random method of fish selection, hence estimates of Z would be biased downwards.)

Date	Sample area	Z	Age range	No. aged
Trachurus declivis				
Dec 1975	Bay of Plenty	0.18	12-28	204
Dec 1980-Feb 1981	Taranaki Bight	0.13*	3-28	600
Oct-Dec 1981	Taranaki Bight	0.14*	2-25	178
Nov 1989	Taranaki Bight	0.23	1-26	372
Trachurus novaezelandiae				
Aug 1975	Bay of Plenty	0.20	5-21	490
Dec 1975	Bay of Plenty	0.17	7-20	215
Mar 1976	Bay of Plenty	0.18	6-22	497
Dec 1980-Feb 1981	Taranaki Bight	0.13*	2-23	487
Oct-Dec 1981	Taranaki Bight	0.21*	3-23	115
Nov 1989	Taranaki Bight	0.22	2-25	370

Table 2. Relative biomass indices (doorspread estimates with coefficients of variation) from the *Shinkai Maru* and *Cordella* surveys. V = 0.38 and 0.19 for the *Shinkai* and *Cordella* surveys, respectively. Phase 1 and 2 stations were used to calculate both groups of estimates from the *Cordella* survey.

	Shinkai Maru		*Cordella*		
	Excl. 12 n.m.		Excl. 12 n.m.	Incl. 12 n.m.	
Species	Biomass (t)	% c.v.	Biomass (t)	Biomass (t)	% c.v.
T. novaezelandiae	78 000	26.2	46 800	88 200	9.6
T. declivis	63 100	18.6	36 500	46 100	10.3
Barracouta	37 900	12.2	19 600	31 000	24.9
Tarakihi	9 300	13.0	9 400	12 200	17.5
Arrow squid	4 600	10.4	4 000	5 400	9.9
School shark	15 500	10.1	20 600	24 800	10.8
Rig	2 000	12.1	1 300	2 000	9.6
Spiny dogfish	14 700	20.2	13 700	24 300	14.7
Frostfish	17 500	12.4	14 600	16 100	19.7
John dory	1 700	11.0	3 300	4 500	7.0
Red gurnard	1 800	9.3	900	3 400	20.0
Snapper	1 500	20.5	1 600	12 300	62.5
Trevally	3 200	26.5	2 000	10 300	26.5
Stargazer	500	19.9	2 900	3 000	72.0

Table 3. Input data used in stock reduction analyses. JMD = *Trachurus declivis*, JMN = *Trachurus novaezelandiae*, JMM = *Trachurus murphyi*. For definitions of parameters see Francis (1990).

	Estimated catch (t)			
Year	Total	JMD	JMN	
1970	8 100	5 300	2 800	
1971	13 400	8 700	4 700	
1972	18 100	11 800	6 300	
1973	15 000	9 800	5 200	
1974	17 900	11 600	6 300	
1975	13 500	8 800	4 700	
1976	15 200	9 900	5 300	
1977	16 200	10 500	5 700	
1978	7 100	4 600	2 500	
1979	3 500	2 300	1 200	65% JMD, 35% JMN
1980	2 400	1 600	800	
1981	4 500	2 900	1 600	
1982	7 700	5 000	2 700	
1983	11 000	7 200	3 800	
1984	12 500	8 100	4 400	
1985	16 500	10 700	5 800	
1986	11 000	7 200	3 800	
1987	19 800	12 900	6 900	
1988	17 800	11 600	6 200	
1989	17 400	11 100	5 900	64% JMD, 34% JMN, 2% JMM
1990	21 900	14 000	7 400	

Parameters		JMD	JMN
Biomass	- 1981	79 700	147 000
	- 1990	46 100	88 200
M		0.18	0.18
L_∞		46 cm	36 cm
t_0		-0.40	-0.65
a		0.023	0.028
b		2.84	2.84
Δ		0.95	0.95
A_r		4 yrs	7 yrs
A_m		3 yrs	4 yrs

Table 4. Results of stock reduction analyses. F = instantaneous fishing mortality, begin = biomass at the beginning of the season, mid = mid–season biomass.

Trachurus declivis

Year	F	Begin	Mid
Virgin	0.00	218 800	200 000
1970	0.03	218 800	197 300
1971	0.05	213 600	190 800
1972	0.06	205 500	181 800
1973	0.06	195 200	173 500
1974	0.07	188 200	166 100
1975	0.05	180 300	160 300
1976	0.06	176 200	156 000
1977	0.07	171 600	151 500
1978	0.03	167 100	150 400
1979	0.01	169 100	153 400
1980	0.01	173 400	157 700
1981	0.02	178 000	161 300
1982	0.03	180 900	162 800
1983	0.04	181 300	162 000
1984	0.05	179 300	159 800
1985	0.07	176 600	156 000
1986	0.05	171 500	153 100
1987	0.09	170 500	149 300
1988	0.08	163 900	143 900
1989	0.08	159 400	140 000
1990	0.10	155 900	135 300

Trachurus novaezelandiae

Year	F	Begin	Mid
Virgin	0.00	109 400	100 000
1970	0.03	109 400	98 600
1971	0.05	106 800	95 200
1972	0.07	102 700	90 700
1973	0.06	97 800	86 800
1974	0.08	94 600	83 300
1975	0.06	90 900	80 700
1976	0.07	89 300	78 900
1977	0.07	87 400	77 000
1978	0.03	85 400	76 800
1979	0.02	86 700	78 600
1970	0.01	89 100	81 000
1981	0.02	91 500	82 800
1982	0.03	92 800	83 500
1983	0.05	92 800	82 900
1984	0.05	91 900	81 700
1985	0.07	90 400	79 700
1986	0.05	87 900	78 400
1987	0.09	87 600	76 500
1988	0.08	84 400	74 000
1989	0.08	82 400	72 300
1990	0.11	80 900	70 200

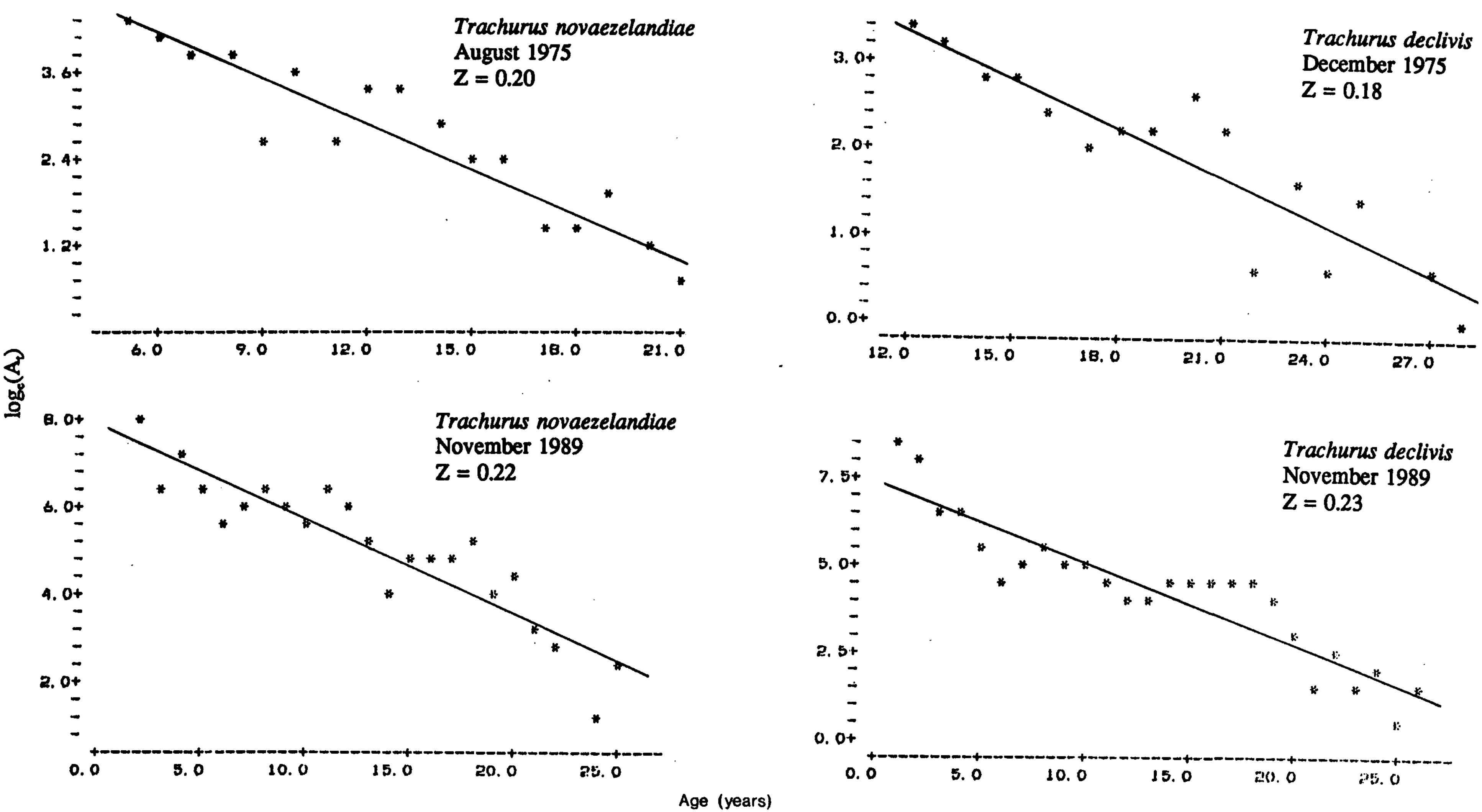

Figure 1. Plots of $\log_e(A_t)$ against age. 1975 samples from the Bay of Plenty, 1989 samples from off the central west coast. Z = slope of the regression line.

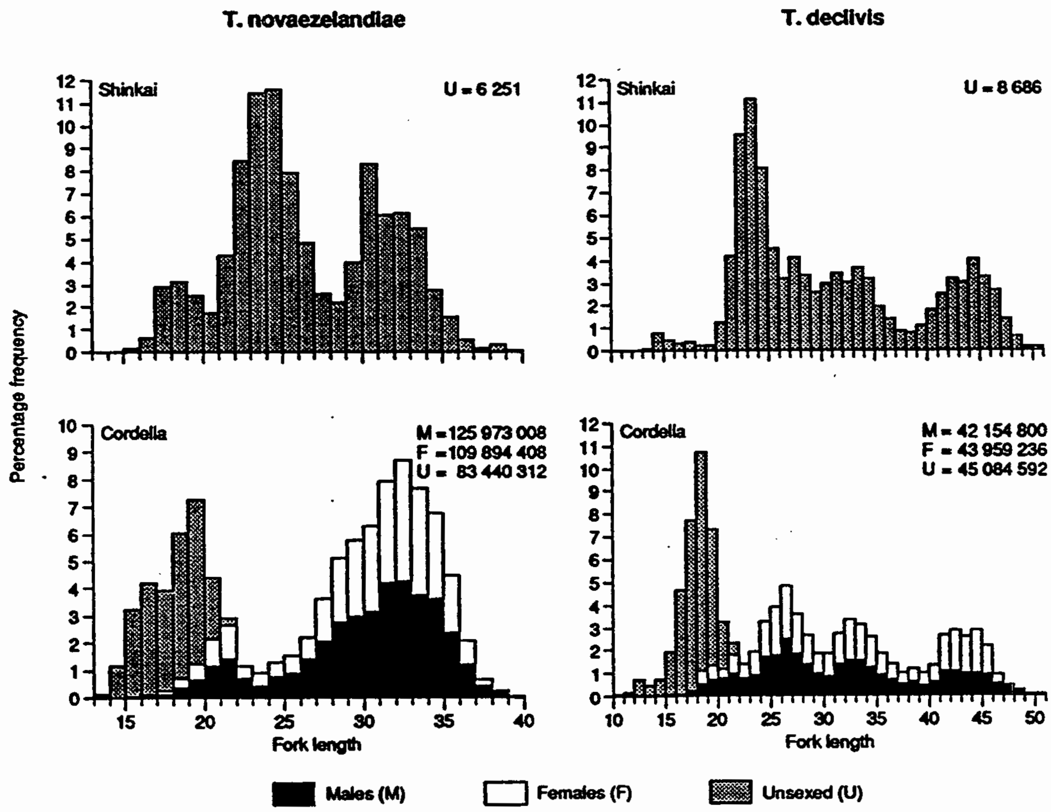

Figure 2. Whole–survey length–frequency distributions for jack mackerels, *Trachurus novaezelandiae* and *T. declivis*, from the 1981 *Shinkai Maru* (unscaled) and 1990 *Cordella* (scaled) surveys.