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An update of stock assessment for ling (*Genypterus blacodes*) stocks LIN 3, 4, 5, and 6 for the 1997–98 fishing year

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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1. EXECUTIVE SUMMARY

Updated bounded estimates of biomass and yield are presented for Fishstocks LIN 3 and 4 combined, and LIN 5 and 6 combined (excluding the Bounty Platform), using the MIAEL estimation technique. These estimates supersede those for virgin biomass and MCY calculated last year using the same technique. Additional data (i.e., new trawl survey indices, CPUE series, and proportion-at-age data) included in the model this year resulted in the biomass and yield estimates being more confidently defined within the given bounds.

Changes in the length-frequency distributions and population age distributions of Chatham Rise ling (LIN 3 and 4) over an 8-year period are examined. No declines in fish size or increases in the rate of total instantaneous mortality are apparent. Variations in year class strengths appear to be relatively small.

2. INTRODUCTION

Ling are currently managed as eight Fishstocks, although five of these (LIN 3, 4, 5, 6, and 7) produced about 95% of recent landings. Horn (1993a) presented preliminary estimates of virgin biomass (B_0) and MCY for the five main Fishstocks from stock reduction analyses that were constrained to give particular levels of mean instantaneous fishing mortality (F) over the known period of exploitation. However, this method produced point estimates only of B_0 (upon which MCY was based) which were very sensitive to the chosen value of mean F.

Horn & Cordue (1996) presented bounded estimates of B_0 and MCY for Fishstocks LIN 3, 4, 5, 6, and 7 using the MIAEL estimation technique of Cordue (1993, 1996). This method produces an "information index" which is a percentage measure of how well the unknown quantity is pinpointed within its given bounds; 100% implies exact knowledge. The model inputs comprised biological data, catch histories, and relative abundance indices from trawl surveys. The estimates were for LIN 3 and 4 combined, and LIN 5 and 6 combined (excluding ling from the Bounty Platform), as this combination of QMAs is likely to represent biological stocks (Horn & Cordue 1996). The estimate of B_0 for LIN 7 was poorly defined within the bounds (the information index was 0%) because no series of relative abundance indices was available for that stock.

New MIAEL estimates of virgin and current biomasses, and yields, for Fishstocks LIN 3 and 4, and LIN 5 and 6 are presented below, following the inclusion of additional data in the model. The new data comprise reported landings for the most recent fishing year, additional trawl survey indices from the Chatham Rise and Campbell Plateau, series of standardised CPUE indices from the Chatham Rise and Puysegur Bank (from Ballara in prep.), and catch-at-age data (from Horn 1993a).

Under an adaptive management regime, TACCs for LIN 3 and 4 were increased by about 30% from the beginning of the 1994–95 fishing year. FIB scientists estimated that that level of increase would allow a decline in biomass to be detected by trawl surveys of the Chatham Rise (with *c.v.*s less than 10%) over the 5 years following the increase (Horn & Cordue 1996). Annual summer length-frequency distributions are available since 1989–90 (excluding 1990–91), and age-frequency distributions are available from two samples before and one sample since the TACC increases. These data series are examined below to see if they exhibit any changes which might be attributable to fishing pressure.

3. STOCK ASSESSMENTS

3.1 MIAEL estimates of biomass and yield

Two biological ling stocks have been assessed using the MIAEL estimation technique of Cordue (1993) and applying the risk-based definition of MCY (Francis 1992). The bounds on virgin biomass required by the MIAEL technique were derived using the model-based approach of Cordue (1996). The two ling stocks correspond to groupings of administrative Fishstocks and are denoted accordingly: LIN 3 and 4, and LIN 5 and 6 (excluding ling from the Bounty Platform).

An age-structured, two-sex population model was used in the assessments: the biological parameters (Table 1) are mainly from Horn (1993b). The proportion spawning (90%) is an educated guess and the spawning stock recruitment steepness of 0.75 follows the recommendation of Francis (1992) when there is no other information. (It is higher than 0.5 used by Punt & Japp (1994), but their figure was fairly arbitrary, after their estimation attempt yielded the unrealistically low value of 0.2.) A recruitment variability parameter (*rsd*) is required in the processes used to establish bounds for virgin biomass (Cordue 1996) and estimate yields (Francis 1992). An *rsd* of 0.4 was taken as representative of ling stocks from Myers *et al.* (1995).

The proportion recruited to the fishery at each age (*see* Table 1) is different to that reported by Horn & Cordue (1996). It is now assumed that recruitment to the fishery is based more on fish size than on stage of sexual maturity. Ling on the Campbell Plateau (the smallest fish at age of any stock) appear to be fully recruited to the fishery at age 8 (Horn 1993a). Because females are significantly larger at age 7 than males, a slightly higher proportion of females than males is assumed to be recruited to the fishery at that age. Recruitment is assumed to be comparable between sexes at ages less than 7 as length at age is not significantly different between sexes over this range.

Catch histories are given for both stocks in Table 2. Estimated landings from the Bounty Platform since 1992 were subtracted from the total reported landings from LIN 5 and 6 to give the catch history used to model the LIN 5 and 6 stock (Table 2). The population model allows for pre-spawning season catches (constant fishing mortality over 12 months) and spawning season catches (taken as a point mass during an instantaneous spawning season), but for both stocks the fishing-year catch has been assumed to occur during the prespawning season with no spawning season catch. "Mid-season" in the model and in this paper refers to the spawning season, but as there is no spawning season catch, "beginning", "mid", and "end" of the spawning season are all equivalent. "Pre-season" in the model and in this paper is the beginning of the pre-spawning season, i.e., the beginning of the year.

Relative biomass indices from research trawl surveys are available for LIN 3 and 4 (Table 3) and LIN 5 and 6 (Table 4). Ballara (in prep.) calculated series of standardised CPUE indices from the longline fishery on the Chatham Rise (LIN 3 and 4) and the trawl fishery on the Puysegur Bank (LIN 5) (Table 5).

Proportion-at-age data were obtained from otolith samples collected during two trawl surveys from each of the two areas (i.e., December 1989 and January 1992 on the Chatham Rise, and November 1989 and November 1991 on the Campbell Plateau). The full data sets have been reported previously (Horn 1993a). Age-frequencies were calculated by sample, by sex, with *c.v.*s for each year class. Data included in the model were from all fully recruited year classes (i.e., those 8 years or older) with *c.v.*s less than 0.6 (although most *c.v.*s for included year classes ranged from 0.2 to 0.4). For the Chatham Rise (LIN 3 and 4), included year classes were 8–17 for males and 8–19 for females. For the Campbell Plateau (LIN 5 and 6), included year classes were 8–18 and 8–19 for males and females, respectively.

The bounds on virgin biomass were obtained by combining, where available, bounds generated from the catch histories (with assumptions about exploitation rates) and the magnitude of the relative biomass indices (with assumptions about the proportionality constants relating expected value of the index to the true biomass; in this case a trawl q). Catch history bounds on virgin biomass and assumed bounds on the maximum exploitation rates are given in Table 6. The maximum exploitation rate of $r_{max} = 0.6$ means that it is inconceivable that more than 60% of the beginning of season biomass could have been caught by the fleet (for any of the stocks). The minimax exploitation rate (r_{mmx}) is interpreted as the minimum conceivable exploitation rate in the year when exploitation was highest. Different rates were used to reflect beliefs about the relative exploitation levels of the stocks.

For LIN 3 and 4 and LIN 5 and 6, the catch history bounds were refined by combining them with index-generated bounds (Table 7). The assumptions about the minimum and maximum trawl q for *Tangaroa* on ling were taken from Cordue (1996). These were preliminary figures used for LIN 3 and 4; they have not been refined and have been applied to LIN 5 and 6 as well. The same is essentially true for the expansion factor which was applied to the "raw" index-bounds. This is a safety factor which expands the bounds sufficiently to ensure that they will (with a very high probability) contain the true virgin biomass. The factor derived by Cordue (1996) was 0.32; this has been rounded up to 0.35 to provide an extra safety margin.

The intersection of the catch-history-generated bounds and the expanded index-generated bounds for each stock was used as the range of B_0 for MIAEL estimation.

Estimates of virgin and current biomasses from the base case model runs are given in Table 8 with their information indices. At this stage, the size of the stocks within the given bounds is not well known (information indices for B_0 are 28% and 23%). The biomass trajectories for the minimum and maximum estimates of B_0 and MIAEL estimates of midseason biomass in 1997 for LIN 3 and 4 and LIN 5 and 6 are presented in Figure 1. Yield estimates are given in Tables 9 and 10.

The model fits to the relative abundance index series are shown in Figure 2 (trawl survey indices) and Figure 3 (CPUE indices). Two example fits to the proportion-at-age data (one good and one bad) are shown in Figure 4.

Sensitivity analyses were conducted to examine the effects of changing some parameters or excluding some data series (Table 11). For both biological stocks, catch-at-age and CPUE data provide little information relative to that obtained from the trawl survey indices. Estimates of B_0 are relatively insensitive to changes in M, but CAY is sensitive to variations in this parameter. Changing the assumptions about the minimum and maximum exploitation rates markedly alters the range and MIAEL estimates of B_0. For LIN 3 and 4, using CPUE Index 2 instead of Index 1 causes a reduction in the estimates of B_0 and CAY.

An estimate of the effect of fishing the stocks at the current TACC was derived by calculating the probability that the biomass in 1999 would be less than in 1998 (Table 12). The MIAEL estimates indicated that given catches at the TACC there is a strong probability ($p = 0.76$) that both stocks would decline in the short term (although the information index for the LIN 5 and 6 probability is very low). Current catch levels are less than current TACCs (particularly for LIN 5 and 6), so continued fishing at current levels would decrease the probability of a decline.

3.2 Population structure of Chatham Rise ling (LIN 3 and 4)

Length-frequency distributions of ling, by sex, from seven summer trawl surveys of the Chatham Rise are presented in Figure 5. All the distributions have been scaled to represent the population of ling available to the trawl in the survey area. The last six surveys are comparable as they were carried out using the same vessel and fishing gear. Though differences in the shapes of the length-frequency distributions are apparent between samples, there is no consistent trend. Much of the variation occurs in the smaller size classes and is probably related to variations in year class strengths.

Changes in the distributions of larger (older) fish were examined, by sex, in the following manner. Reference points of the mean fish length at age 7 years (70 cm for males and 75 cm for females) were identified, and the sums of all fish greater than these lengths were obtained from each of the scaled length-frequency samples. The sums of two further subsets of length ranges were obtained for each sex, i.e., fish larger than the mean size of those caught by the longline fishery (greater than 96 cm for males, and greater than 120 cm for females), and fish larger than 85% of those caught by the longline fishery (greater than 110 cm for males, and greater than 140 cm for females). The numbers of fish in the subsets were expressed as a proportion of those 7 years and older (Table 13). None of the regressions through the four sets of percentages were significantly different from a horizontal line, indicating that the proportions of fish in the larger size classes had remained relatively constant over the time period examined.

Age structures of the ling population available to the research trawl were calculated for three trawl survey samples using the method described by Horn (1993b) and are presented in Figure 6. The distributions from the AEX8903 and TAN9106 surveys have been presented previously (Horn 1993a), but some additional age-length data applicable to the AEX8903 survey has been incorporated in the most recent analysis. Estimates of instantaneous total mortality (Z) were derived from the slope of the right hand limb of the age distribution (Table 14). Estimates using age classes 8–27 were not significantly different between samples, and were the same or slightly higher than the best estimate of M (0.18) from Horn (1993a).

Estimates of Z derived from the most recently recruited age classes (8–17 years) exhibit an increasing trend over time, with the 1997 estimate being significantly greater than those from the two earlier samples. However, it is possible that the Z estimate over this range has been influenced by the progression of a group of slightly stronger than average year classes. In 1989, year classes 10–15 appear on or above the thin regression line in Figure 6. In 1992, year classes 12–17 are on or above the thin regression line. [Note that a ling in November is still in the same year class in the following January, so the 1989 and 1992 samples are essentially separated by 2 years.] In 1997, year classes 17–22 appear relatively prominent. Thus, in the first two samples, the relatively strong year classes flattened the 8–17 year regression, producing estimates of Z that were less than the best estimate of M. By 1997, the influence of the stronger year classes had been largely removed and Z increased to a value greater than M.

4. DISCUSSION

The relatively constant size and age structures of the ling population on the Chatham Rise (LIN 3 and 4) since 1989 indicate that recent fishing pressure is not depleting any particular size range of fish, and that the level of instantaneous fishing mortality is probably low relative to natural mortality. Variation in year class strengths is indicated, but the level of variation appears to be less than that for other major New Zealand commercial species (e.g., hoki and southern blue whiting) where a few strong year classes can dominate the fishery. However, the variation in ling year class strengths can influence estimates of Z based on a relatively narrow age range.

The MIAEL assessment of two biological ling stocks (LIN 3 and 4, and LIN 5 and 6 excluding the Bounty Platform stocks) has been updated with the addition of catch-at-age data and CPUE series of relative abundance. For both stocks, the catch-at-age and CPUE data provide little information relative to that obtained from the trawl survey indices. However, the information indices for the MIAEL estimates of B_0 are much improved since the original assessment last year (Horn & Cordue 1996) owing largely to an additional trawl survey point for each stock.

The CPUE data for LIN 3 and 4 are considered useful as they appear to show a consistent trend. Two series were used in the model, and the longer series (using all longline vessels rather than auto-longliners only) is recommended for future use in the 'base case' model run. The Puysegur trawl series for LIN 5 shows no consistent trend and is probably influenced by factors other than fish abundance (Ballara in prep.). The continuation of this series is not recommended, though a useful series may be derived by analysing all trawls targeting ling on the Puysegur Bank and Stewart-Snares shelf areas. However, any future analysis of CPUE in LIN 5 and 6 may be confined to longline data.

The current status of ling stocks LIN 3 and 4, and LIN 5 and 6 are uncertain. Minimum and maximum mid-season 1997 biomasses range from levels well below B_{MAY} (24% B_0) to levels over 80% of virgin biomass (*see* Figure 1). However, for most levels of virgin biomass, current biomass is predicted to be above B_{MAY}. The (MIAEL) estimates of B_0 are not based on information that is sufficient to rule out low or high levels of virgin biomass, but the information indices are much improved since last year's assessment, even though the bounds have remained essentially unchanged.

The available data do not suggest any reason for concern about current stock sizes of LIN 3 and 4 and LIN 5 and 6 (excluding the Bounty Platform stocks). Recent catch levels and current TACCs are probably sustainable in the short term at least. MIAEL estimates indicate that by fishing at the level of the current TACCs there is a probability of about 0.76 that both biological stocks would decline (although the information index for LIN 5 and 6 is very low). Current stock sizes are estimated to be above levels that can support the MSY. Current TACCs for LIN 3 and 4 and LIN 5 and 6 are all lower than the estimates of CAY for these stocks.

The status of the Bounty Platform ling stock is unknown. However, biological parameters are available for this stock (Horn 1993b) and a relatively accurate catch history can be easily obtained. There has been extensive bottom longlining in this area since the 1991–92 fishing year, so a CPUE series could probably be derived for this fishery.

5. ACKNOWLEDGMENTS

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Table 1: Biological parameters used for ling stocks

	LIN 3 and 4		LIN 5 and 6	
	Male	Female	Male	Female
Natural mortality	0.18	0.18	0.18	0.18
Growth parameters				
L_{inf}	119.0	160.1	95.1	125.7
K	0.108	0.076	0.194	0.113
t_0	−1.24	−1.05	0.16	−0.67
Length-weight relationship				
a (x 10^{-3})	1.26	1.26	1.39	1.39
b	3.29	3.29	3.27	3.27

Both stocks:

Steepness SRR = 0.75
Plus group: 30 years and older
Proportion spawning = 90%

Proportion recruited to the fishery at each age (maturity is assumed to coincide with recruitment).

Age	Male	Female
1	0.0	0.0
2	0.0	0.0
3	0.0	0.0
4	0.0	0.0
5	0.1	0.1
6	0.3	0.3
7	0.7	0.8
8+	1.0	1.0

Table 2: Catch history for LIN 3 and 4 and LIN 5 and 6 (excluding the Bounty Platform). Landings for 1997 have been assumed. Estimated landings from the Bounty Platform (part of LIN 6) are also given

	Catch (t)		
	LIN 3 and 4	LIN 5 and 6 (excl. Bounty)	Bounty (part LIN 6)
1972	0	0	0
1973	250	500	0
1974	382	1 120	0
1975	9 392	1 210	0
1976	19 536	3 900	0
1977	26 049	3 891	0
1978	8 977	3 254	0
1979	3 201	6 397	0
1980	1 700	5 200	0
1981	833	4 437	0
1982	1 522	2 402	0
1983	1 446	2 559	0
1984	1 658	3 474	0
1985	1 423	3 107	0
1986	1 523	3 578	0
1987	1 776	2 815	0
1988	1 842	3 923	0
1989	1 897	2 715	0
1990	2 463	3 212	0
1991	4 791	5 023	0
1992	7 146	6 622	700
1993	6 346	8 047	1 000
1994	6 091	5 909	800
1995	7 751	7 234	800
1996	7 588	8 174	1 000
1997	8 000	8 000	

Table 3: Mid-season indices of spawning biomass for LIN 3 and 4. The *c.v.*s are those used in the model. The indices are from *Tangaroa* trawl surveys of the Chatham Rise in January of the following year

Year	Index (t)	*c.v.*
1991	8 930	0.15
1992	9 360	0.15
1993	10 130	0.15
1994	7 360	0.15
1995	8 430	0.15
1996	8 550	0.15

Table 4: Indices of recruited biomass for LIN 5 and 6. The *c.v.*s are those used in the model. The indices are from *Tangaroa* trawl surveys of the Southern Plateau in November (Series 1, mid-season) and May (Series 2, pre-season)

Year	Series 1 (t)	*c.v.*	Series 2 (t)	*c.v.*
1991	24 100	0.15	–	–
1992	21 950	0.15	42 330	0.10
1993	29 910	0.15	37 540	0.10
1996	–	–	32 520	0.10

Table 5: Mid-season indices of recruited biomass from standardised CPUE analyses of longline catches on the Chatham Rise (LIN 3 and 4), and trawl catches on the Puysegur Bank (LIN 5) (from Ballara in prep.). The *c.v.*s are those used in the model. For LIN 3 and 4, Index 1 was used in the base case model run and comprises only auto-longlining data, and Index 2 comprises all longline data and was used in a sensitivity test

Stock	Year	Index 1	*c.v.*	Index 2	*c.v.*
LIN 3 and 4	1990	–	–	1.00	0.35
	1991	–	–	0.83	0.35
	1992	1.00	0.35	0.90	0.35
	1993	0.76	0.35	0.73	0.35
	1994	0.72	0.35	0.69	0.35
	1995	0.60	0.35	0.64	0.35
LIN 5	1989	1.00	0.35		
	1990	1.18	0.35		
	1991	0.75	0.35		
	1992	1.18	0.35		
	1993	0.80	0.35		
	1994	0.72	0.35		
	1995	1.15	0.35		

Table 6: Catch history generated bounds on virgin biomass for ling stocks, with the minimax (r_{mmx}) and maximum (r_{max}) exploitation rates assumed (the years in which these occurred are in parentheses)

Stock	r_{mmx}	r_{max}	$B_{min}(r_{max})$ (t)	$B_{max}(r_{mmx})$ (t)
LIN 3 and 4	0.05 (1977)	0.6 (1977)	61 300	460 000
LIN 5 and 6	0.01 (1993)	0.6 (1995)	51 300	718 000

Table 7: Bounds used for the trawl survey proportionality constants (q) and the resulting bounds on virgin biomass ('000 t), before and after expansion by a factor of 0.35

Trawl time series	q_{min}	q_{max}	Raw bounds	Expanded bounds
Chatham Rise (LIN 3 and 4)	0.03	0.72	61.8–310	40.2–419
Southern Plateau (LIN 5 and 6, Nov.)	0.03	0.72	76.0–761	49.4–1027
Southern Plateau (LIN 5 and 6, May)	0.03	0.72	88.8–1284	57.7–1733

Table 8: Least squares (LSQ) estimates, and bounded MIAEL estimates with information indices (Ind.), of virgin biomass (B_0), midseason biomass in 1997 (B_{mid97}), and beginning of season biomass in 1998 (B_{beg98}). Biomass estimates and bounds are presented either as tonnes or as a percentage of B_0

Estimate	Fishstock	LSQ	MIAEL	Bounds	Ind. (%)
B_0	LIN 3 and 4	175 000	150 000	61 300–419 000	28
	LIN 5 and 6	114 000	147 000	57 700–718 000	23
B_{mid97}	LIN 3 and 4	71%	59%	5–88%	74
	LIN 5 and 6	54%	47%	14–93%	57
B_{beg98}	LIN 3 and 4	154 000	80 200	8 000–449 000	45
	LIN 5 and 6	86 100	67 800	15 000–811 000	32

Table 9: Model estimates of B_{MCY} and MCY (as a percentage of B_0), and MCY (t). The estimates for LIN 5 and 6 do not include fish on the Bounty Platform. Ind., MIAEL information index

			MIAEL estimate		
Fishstock	B_{MCY} (% of B_0)	MCY (% of B_0)	MCY (t)	Range (t)	Ind. (%)
LIN 3 and 4	36.0	4.8	7 200	2 900–20 100	28
LIN 5 and 6	36.7	5.5	8 100	3 200–39 500	23

Table 10: Model estimates of B_{MAY} and MAY (as a percentage of B_0), CAY (t), and F_{MAY}. The estimates for LIN 5 and 6 do not include fish on the Bounty Platform. Ind., MIAEL information index

Fishstock	B_{MAY} (% of B_0)	MAY (% of B_0)	MIAEL Estimate CAY (t)	Range (t)	Ind. (%)	F_{MAY}
LIN 3 and 4	23.9	5.0	12 600	1 200–66 600	45	0.176
LIN 5 and 6	24.2	5.9	11 400	2 500–137 000	32	0.202

Table 11: Results of sensitivity analyses showing MIAEL estimates of B_0 and B_{beg98} (with information indices, Ind., %), MCY (as a proportion of B_0), and CAY. All ranges and estimates are '000 t

Fishstock	Run	B_0 range (t)	B_0 (t)	Ind. (%)	MCY % of B_0	B_{beg98} (t)	Ind. (%)	CAY (t)
LIN 3 and 4	Base	61.3–419	150	28	4.8	80.2	45	12.6
	No age data	61.3–419	144	26	4.8	68.3	43	10.1
	No CPUE	61.3–419	177	27	4.8	81.7	45	12.1
	CPUE Index 2	61.3–419	143	29	4.8	69.8	46	10.3
	No surveys	61.3–419	144	11	4.8	51.7	18	7.7
	M=0.14	70.0–419	152	35	3.7	69.8	53	8.5
	M=0.22	58.8–441	161	21	5.9	116.6	28	20.2
	r_{mmx}=0.10	61.3–242	115	36	4.8	56.7	53	8.4
	r_{mmx}=0.02	61.3–1112	187	17	4.8	68.1	32	10.1
LIN 5 and 6	Base case	57.7–718	147	23	5.5	67.8	32	11.4
	No age data	57.7–718	149	20	5.5	54.2	28	9.1
	No CPUE	57.7–718	144	22	5.5	77.9	32	13.1
	No surveys	57.7–718	248	10	5.5	160.7	16	27.1
	M=0.14	58.8–753	147	28	4.3	46.5	44	6.5
	M=0.22	57.7–686	148	18	6.8	92.1	23	17.6
	r_{mmx}=0.04	57.7–206	107	31	5.5	56.1	38	9.4

Table 12: Least squares (LSQ) estimates, and bounded MIAEL estimates with information indices, of the probability that biomass in 1999 will be less than biomass in 1998, assuming annual catch levels at the TACC from each stock. Ind., MIAEL information index

Estimate	Fishstock	LSQ	MIAEL	Bounds	Ind. (%)
P(B_{99}<B_{98})	LIN 3 and 4	0.94	0.76	0.53–1.00	25
	LIN 5 and 6	0.96	0.76	0.39–1.00	5

Table 13: Proportions (%) of ling 7 years or older (i.e., ≥ 70 cm for males, and ≥ 75 cm for females) occurring in selected size classes on the Chatham Rise. All size class measurements are in cm total length. No., number from the scaled length-frequency distribution (thousands)

Sample date	Male			Female		
	No. ≥ 70	% ≥ 96	% ≥ 110	No. ≥ 75	% ≥ 120	% ≥ 140
Nov–Dec 1989	933	20.4	4.3	720	20.4	1.8
Jan 1992	936	17.8	4.1	846	23.9	5.3
Jan 1993	962	21.2	4.3	799	24.0	6.1
Jan 1994	1 163	20.4	5.0	808	22.2	5.0
Jan 1995	798	20.1	4.3	682	20.2	4.9
Jan 1996	911	21.4	3.9	774	20.2	5.0
Jan 1997	1 131	21.9	4.7	730	16.7	6.0

Table 14: Estimates of instantaneous total mortality (*Z*) with their 95% confidence intervals (in parentheses) derived from slopes of the right hand limb of the age distributions over two age class ranges (from Figure 6). *N*, number of aged fish

Date	*N*	Age classes	*Z* (95% CI)
Nov–Dec 1989	596	8–27	0.20 (0.16–0.23)
		8–17	0.10 (0.04–0.17)
Jan 1992	517	8–27	0.19 (0.15–0.23)
		8–17	0.13 (0.06–0.19)
Jan 1997	528	8–26	0.18 (0.15–0.21)
		8–17	0.24 (0.20–0.28)

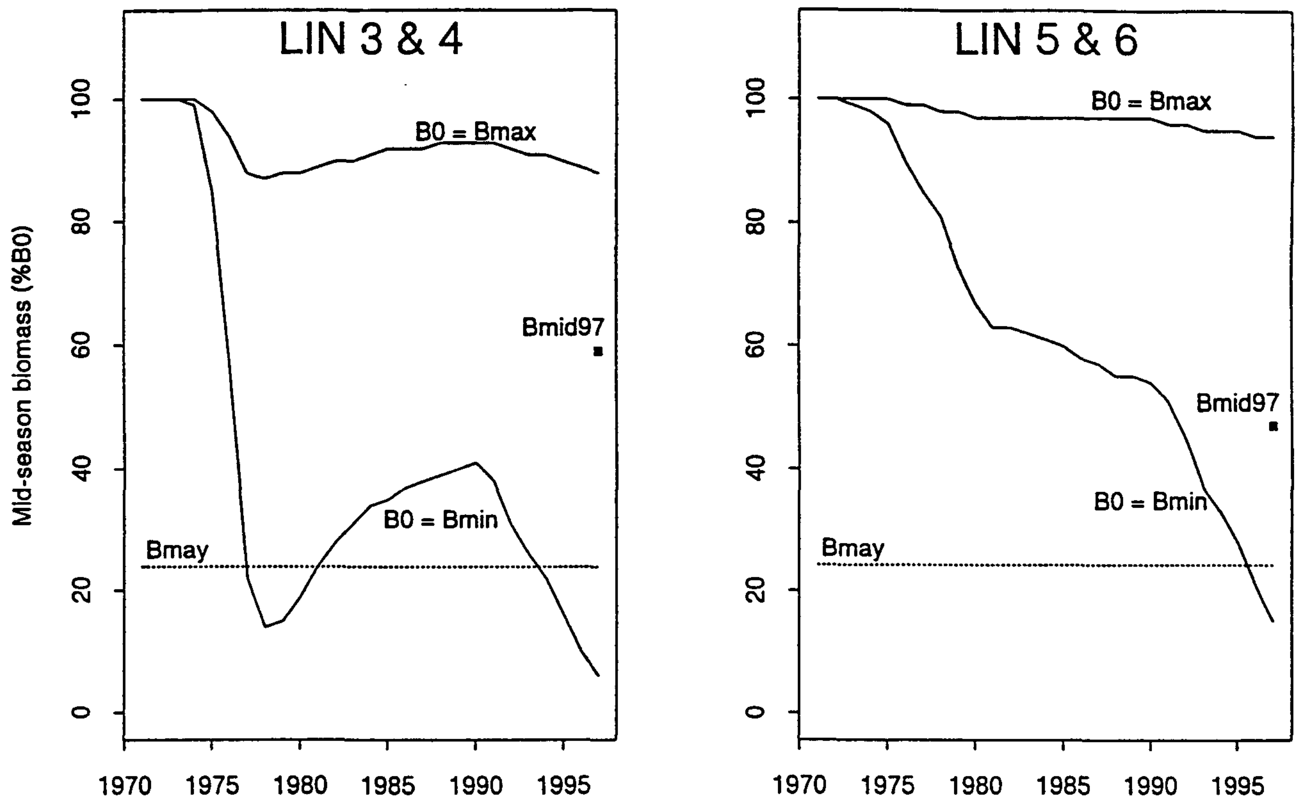
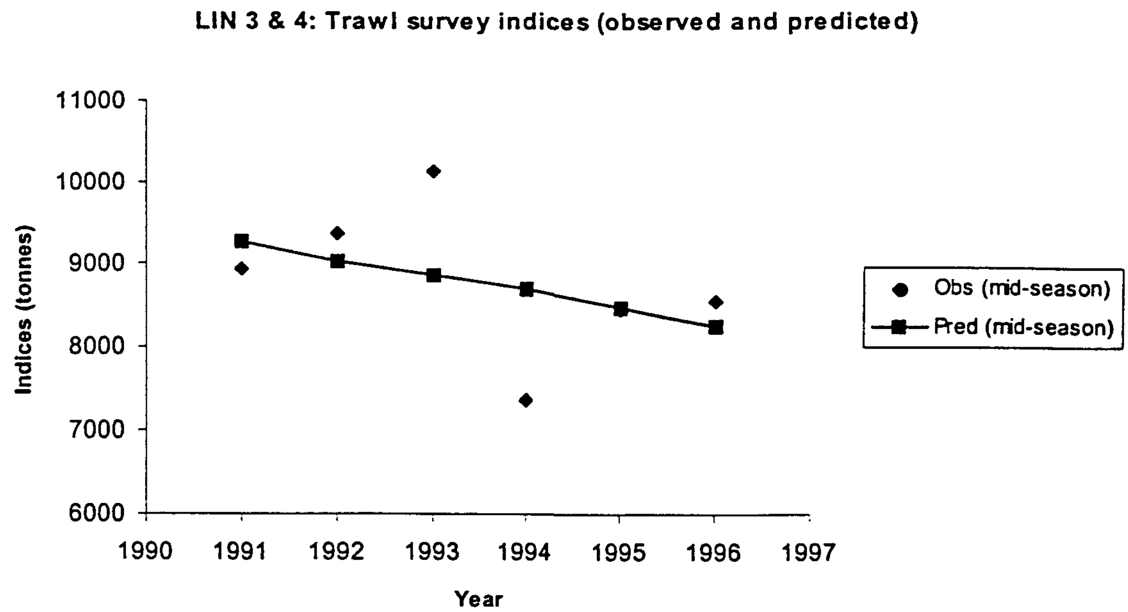


Figure 1: MIAEL estimates of biomass in 1997 and the trajectories from minimum and maximum estimates of virgin biomass, for ling stocks LIN 3 and 4, and LIN 5 and 6 excluding the Bounty Platform.



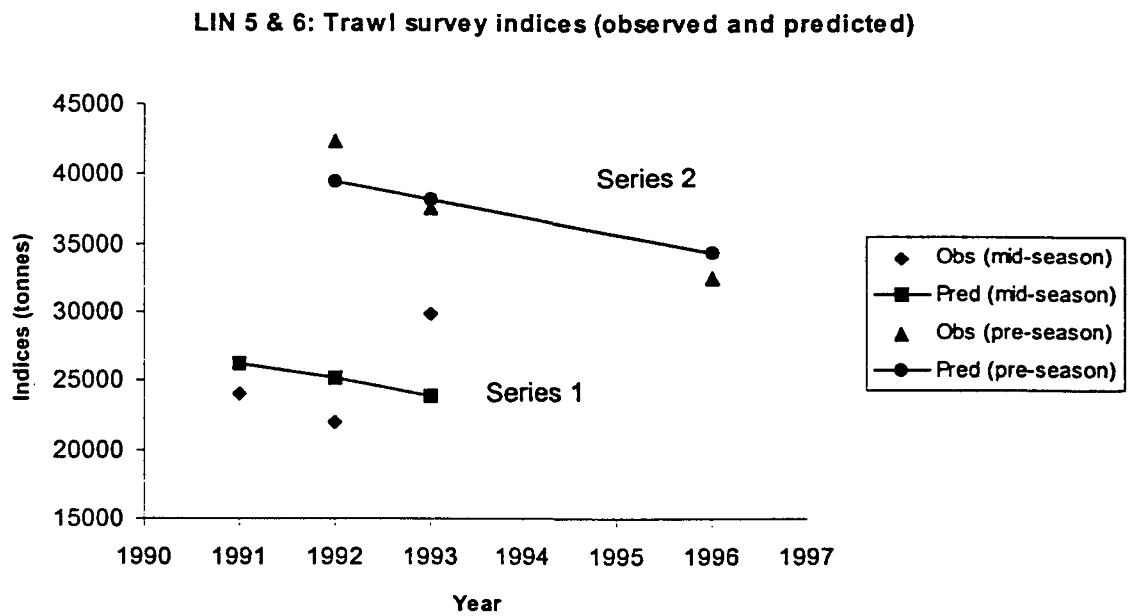


Figure 2: Model fits (predicted points) to the observed research trawl survey series. Estimated values of trawl q were as follows: LIN 3 and 4, 0.07; LIN 5 and 6 (mid-season), 0.34; LIN 5 and 6 (pre-season), 0.37. For descriptions of the indices, see Tables 3 and 4.

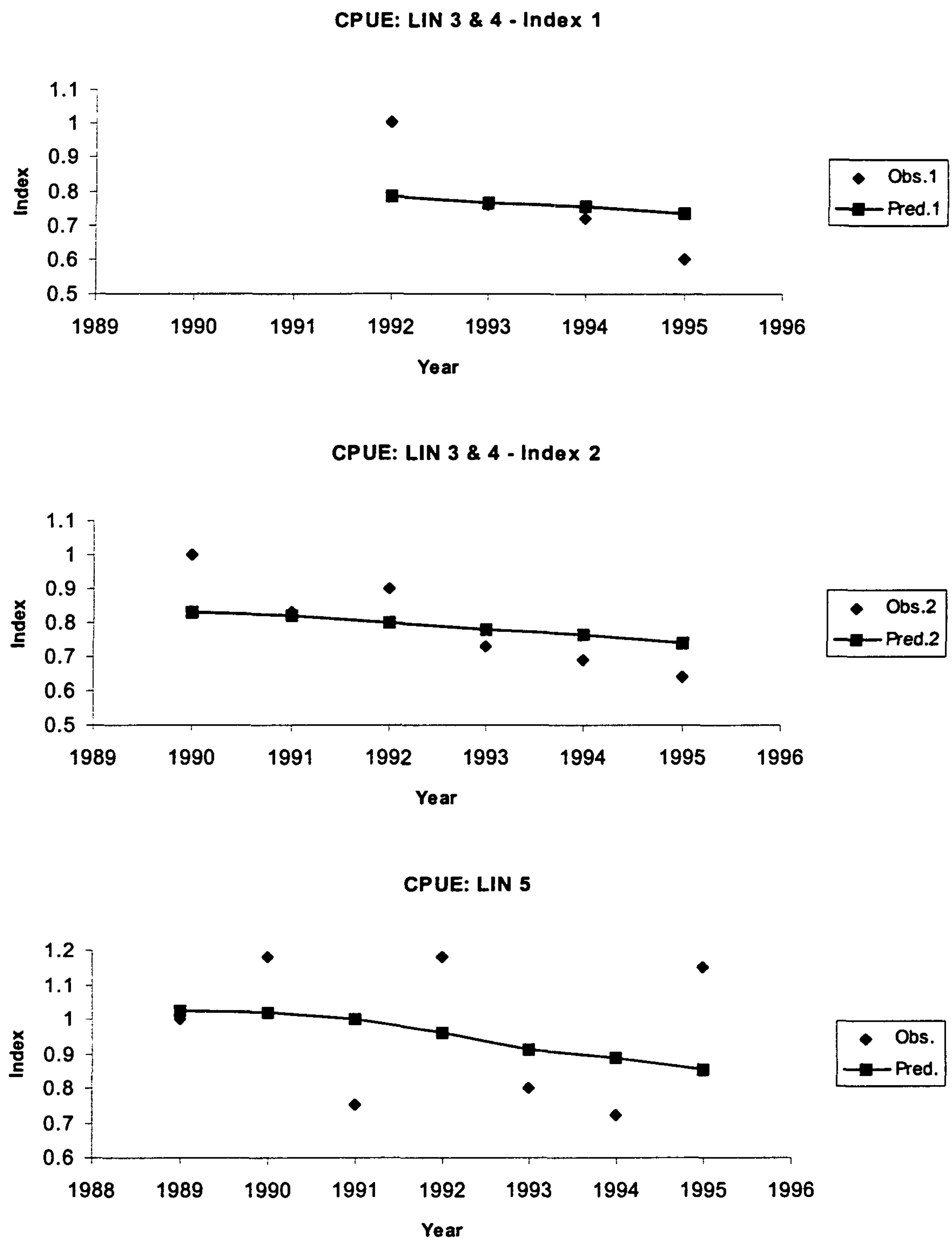
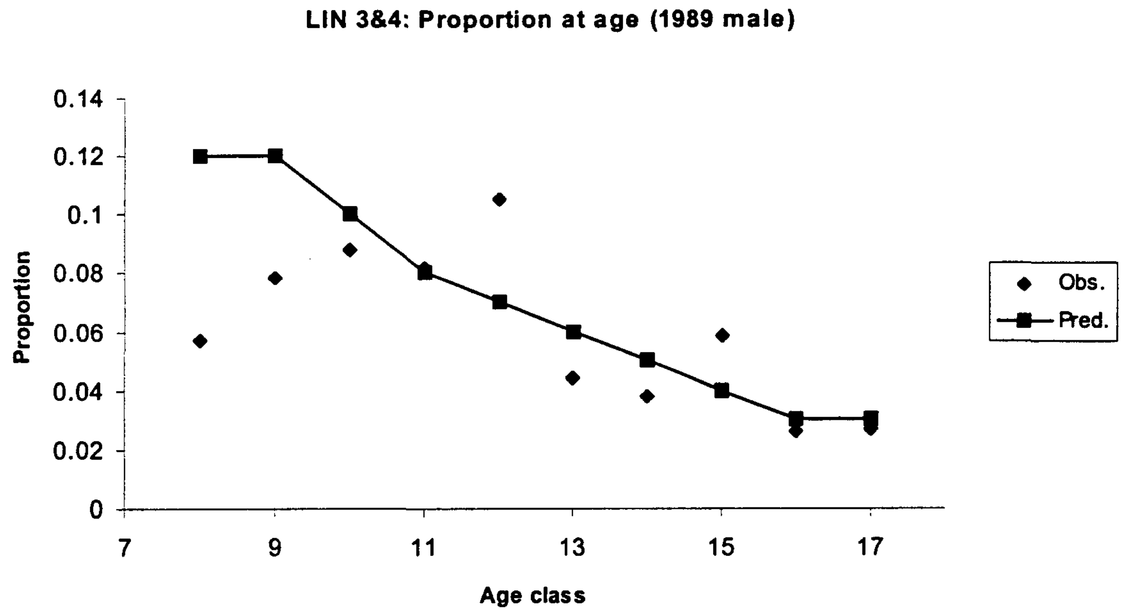


Figure 3: Model fits (predicted points) to the observed series of standardised CPUE indices. For descriptions of the indices, see Table 5.



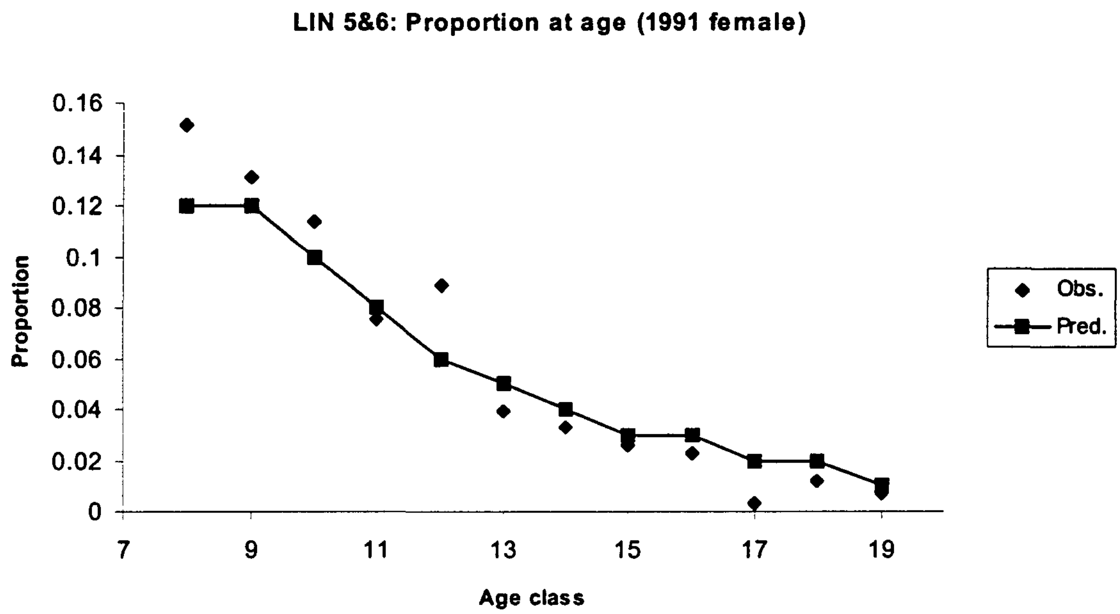
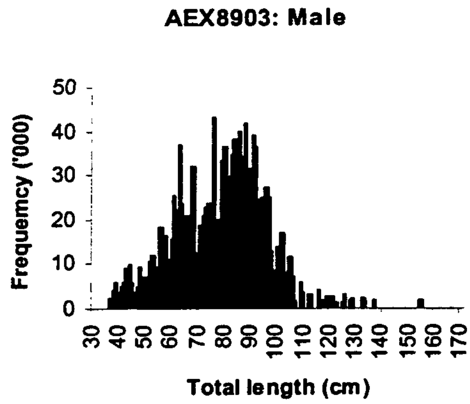
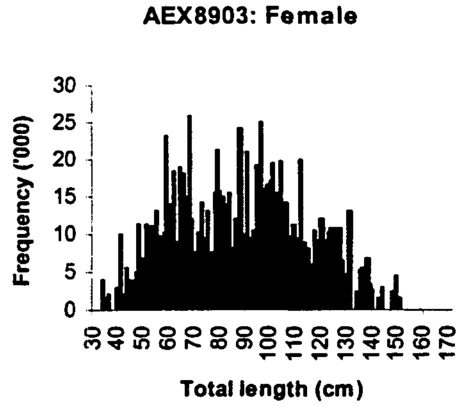
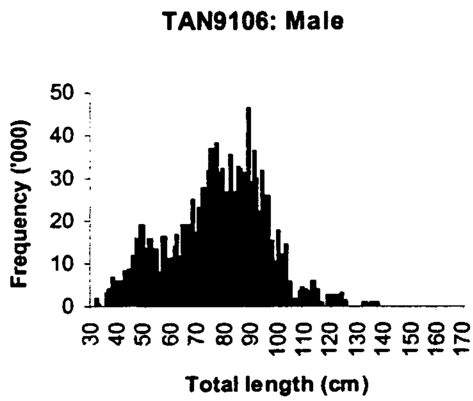
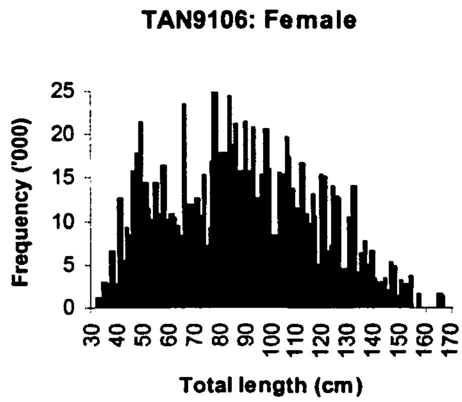


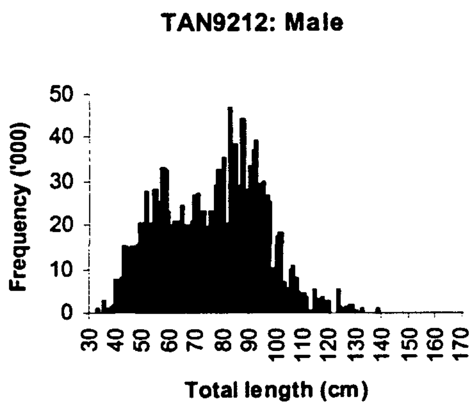
Figure 4: Example plots of bad (LIN 3 and 4) and good (LIN 5 and 6) model fits (predicted points) to observed catch-at-age data.


AEX8903: Male
Frequemcy ('000)
0
10
20
30
40
50
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
Total length (cm)


AEX8903: Female
Frequency ('000)
0
5
10
15
20
25
30
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
Total length (cm)


TAN9106: Male
Frequency ('000)
0
10
20
30
40
50
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
Total length (cm)


TAN9106: Female
Frequency ('000)
0
5
10
15
20
25
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
Total length (cm)


TAN9212: Male
Frequency ('000)
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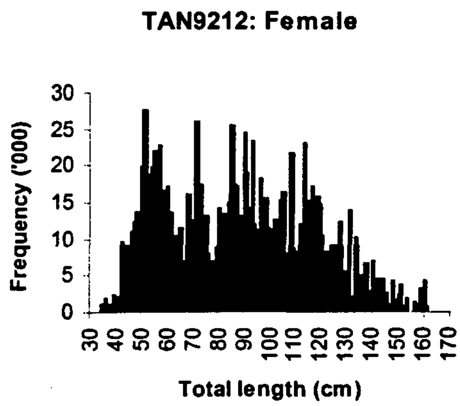
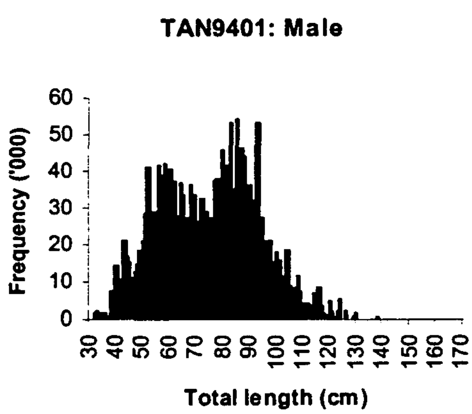
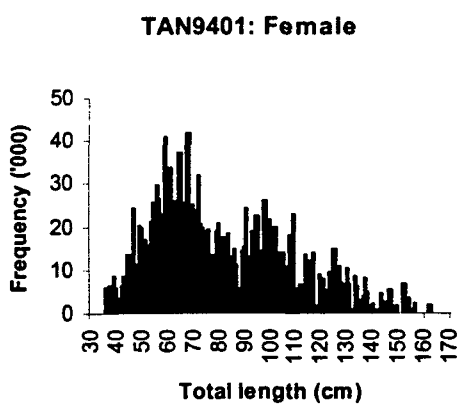
10
20
30
40
50
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
Total length (cm)


TAN9212: Female
Frequency ('000)
0
5
10
15
20
25
30
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
Total length (cm)


TAN9401: Male
Frequency ('000)
0
10
20
30
40
50
60
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
Total length (cm)


TAN9401: Female
Frequency ('000)
0
10
20
30
40
50
30 40 50 60 70 80 90 100 110 120 130 140 150 160 170
Total length (cm)

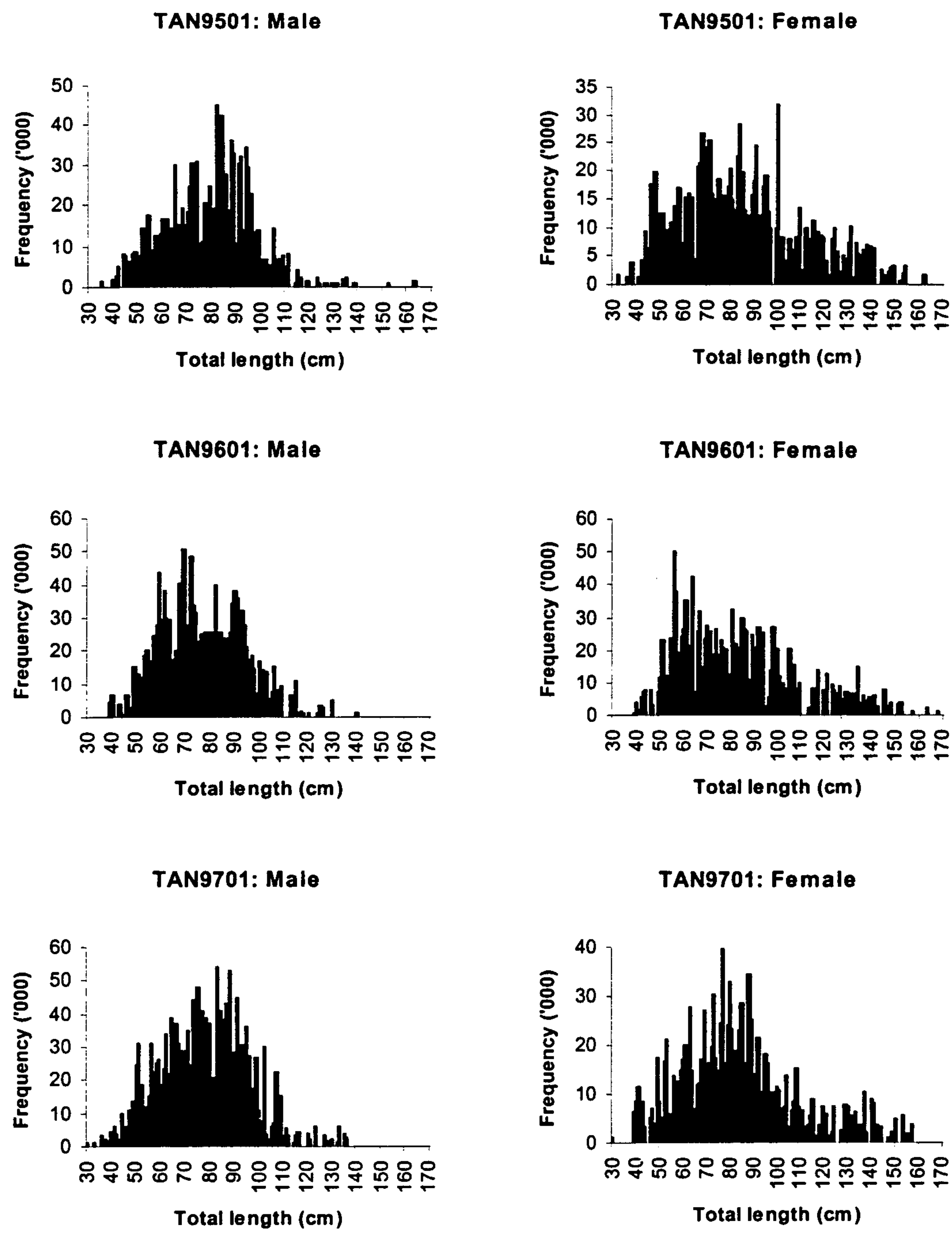


Figure 5: Length-frequency distributions, separately by sex, for ling on the Chatham Rise (LIN 3 and 4), obtained from research trawl surveys over an 8-year period. All distributions have been scaled to represent to represent the population in the survey area.

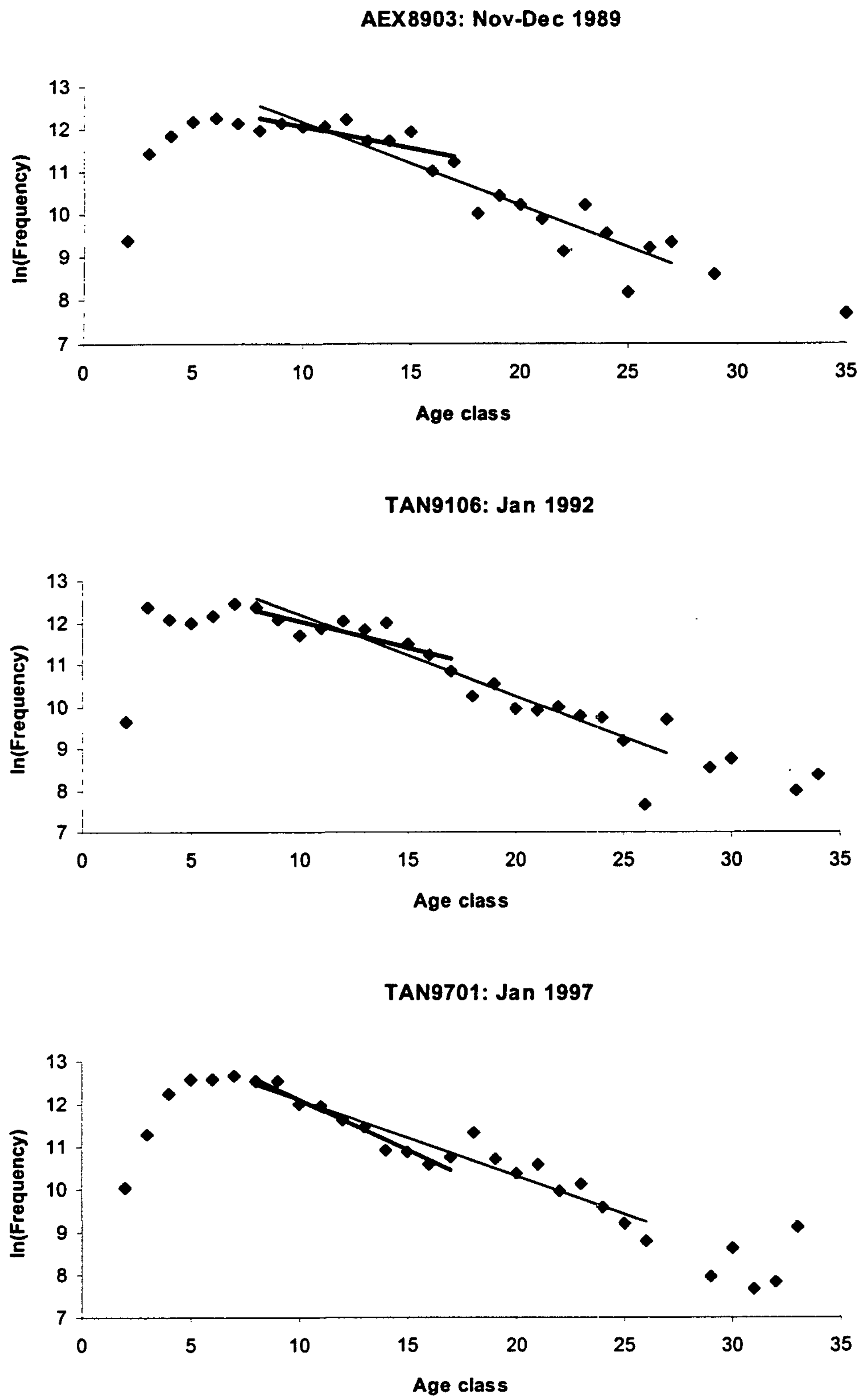


Figure 6: Estimated age-frequency distributions of ling (sexes combined) from three research surveys of the Chatham Rise. Lines on each plot show the linear regression of age against $\log_e$(frequency) for age classes 8 to 27 (thin line) and 8 to 17 (thick line).