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Length and age composition of commercial grey mullet landings from the west coast setnet fishery (GMU 1), 1997–98

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Objective 2

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Report Title	Length and age composition of commercial grey mullet landings from the west coast setnet fishery (GMU 1), 1997-98
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7. Objective

Objective 2 - To conduct sampling to determine the length and age composition of grey mullet taken by the west coast North Island commercial setnet fishery (GMU 1) during the 1997/98 fishing year.

8. Executive summary and conclusions

Grey mullet setnet catches from the west coast of the North Island were sampled for length and age information between December 1997 and September 1998. A total of twenty landings were sampled for length information. During the first six months of the programme 369 sets of otoliths were also collected (random samples) and these were used to describe an age-length key. Conclusions from the study were as follows:

1. West coast set net catches from the 1997-98 fishing year were comprised of male and female grey mullet aged between three and twelve years.
2. A strong cohort of five year-old mullet was present in these catches
3. Female grey mullet were more prevent in the catches and made up approximately two-thirds of the sample landings.

4. Growth analysis indicates female grey mullet are consistently larger than males of the same age
5. Thin section preparation was superior to baking methods for clarity of otolith readings.
6. Ages obtained in the study using otoliths were similar to those from other studies, however both the timing of ring deposition and the annual nature of the rings is yet to be confirmed for New Zealand grey mullet.
7. The length weight relationship for New Zealand grey mullet should be recalculated using a new set of observations from the GMU 1 stock.

9. Data Storage

Grey mullet length and age data were stored on the Ministry of Fisheries *market* and *age* databases held by NIWA.

10. Methods

Introduction

The New Zealand grey mullet (*Mugil cephalus*) fishery is worth approximately $2-3 million dollars per annum. Most of the commercial catch is sold locally, principally as bait. The average annual commercial catch from GMU 1 over the last four fishing years has been in the order of 800 tonnes, in 1997-98 the total annual catch was 730 tonnes (Table 1). Annual reported commercial catches from GMU 1 have all been markedly lower than the annual Total Allowable Commercial Catch (TACC) (1006t) since the inception of the Quota Management System (QMS) in 1986 (Annala *et al.* 1998) (Table 1).

Table 1: **Reported landings (t) of grey mullet by Fishstock from 1983–84 to 1995–96 and actual TACs (t) for 1986–87 to 1995–96**

Fishstock	GMU 1		GMU 2		GMU 3		GMU 7		GMU 10			
QMA (s)	1 & 9		2 & 8		3, 4, 5 & 6		7		10		Total	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1983–84*	1142	–	6	–	5	–	7	–	0	–	1160	–
1984–85*	1069	–	5	–	0	–	15	–	0	–	1089	–
1985–86*	881	–	10	–	0	–	10	–	0	–	901	–
1986–87†	595	910	3	20	<1	30	0	20	0	10	598	990
1987–88†	751	941	3	20	0	30	0	20	0	10	754	1021
1988–89†	792	963	3	20	0	30	0	20	0	10	795	1043
1989–90†	907	990	2	20	0	30	4	20	0	10	913	1070
1990–91†	875	994	2	20	1	30	<1	20	0	10	879	1073
1991–92†	848	1006	1	20	2	30	1	20	0	10	852	1086
1992–93†	711	1006	<1	20	<1	30	0	20	0	10	712	1086
1993–94†	743	1006	<1	20	<1	30	0	20	0	10	706	1086
1994–95†	776	1006	0	20	<1	30	10	20	0	10	787	1086
1995–96†	840	1006	0	20	<1	30	<1	20	0	10	840	1086
1996–97†	870	1006	<1	20	1	30	<1	20	0	10	872	1086

* Fisheries Stat Unit data.
† Quota Management System data.

Although not a major recreational species (Bradford 1996), grey mullet is of high traditional importance to Maori. Northern Iwi consider the harbours and the rivers of the North Island sacrosanct. Some Iwi believe harbour and river fish stocks, including grey mullet, are in decline as a result of environmental mismanagement and over-fishing. In recent times, issues concerning the availability of grey mullet in the various North Island bays, harbours and estuaries has been the cause of much sector group conflict.

Concern over the sustainability of grey mullet has been heightened by the lack of definitive scientific knowledge.The New Zealand *M. cephalus* appears to be reasonably similar to *M. cephalus* in other parts of the world in respect to growth, early life history, habitat use and spawning cycles. However virtually nothing is known of stock abundance, stock age structure and stock integrity (Anon 1989; Boubee 1985; Wells 1976). Consequently, it has not been possible to assess the status of the New Zealand grey mullet stock. It is unknown whether current levels of exploitation will support Maximum Sustainable Yield (MSY) or move the stock toward MSY (Annala *et al* 1998).

The Northern grey mullet fishery is managed as one unit (GMU 1) in a relatively large area, under a single annual commercial TACC (Figure 1). In the 1997-98 fishing-year, approximately 80% of the GMU 1 catch came from west coast harbours and the Lower Waikato river (Figure 1; Table 2). Rangaunu Bay and the Firth of Thames were important fishing areas for grey mullet on the east coast (Figure 1).

***Table 2*: Weight (tonnes) and percentages of annual grey mullet catches by fishing method for the West and East coasts of the North Island in the 1997-98 fishing year**

	BS / DN	FN	RN	SN	Total
West coast	40	2	200	332	574
%	7%	0%	35%	58%	
East Coast	0	0	8	148	156
%	0%	0%	5%	95%	

* BS / DN, beach seine / drag net; FN, fyke net; RN, ring net; SN, set net.

Methods used to target grey mullet in the 1997-98 fishing-year were; setnet, beach seine/dragnet, ring-net and drift-net (Table 2). Although these methods are distinct in terms of application and relative fishing effort, all are subject to the same mesh size restrictions and therefore are likely have similar length selectivity characteristics. In the 1997-98 fishing year setnet accounted for 66% of the GMU 1 catch (Table 2).

During the 1987-88 fishing year the grey mullet setnet fishery on the west coast was sampled for age (Anon 1989). The 1987-88 catch-age estimates were based on 35 commercial landings sampled for length and a random sample of 178 otolith aged fish taken from the Manukau harbour and lower Waikato river (Anon 1989). Results showed the fishery was largely comprised of fish aged between three to eleven years. There was a greater proportion of females in the catches, which is possible due to females having higher average size than males resulting in them being differentially selected by the fishing gear.

Literature review

Grey mullet (*Mugil cephalus*) occurs widely throughout the world at sub-tropical and temperate latitudes (Thomson 1963) and is taken in a variety of commercial and recreational fisheries, as well as being an important aquaculture species. Grey mullet principally inhabit slow-moving river systems, estuaries and shallow coastal areas where they feed on organic material which is sifted from bottom sediments and surface ooze (Thompson 1966). Adult grey mullet are reported to move into coastal waters during spring to spawn. Juveniles become abundant within estuarine habitats during late summer and early autumn (Su & Kawasaki 1996; Ditty & Shaw 1996; Koutrakis *et al* 1994; Adams & Tremain 1995). Although grey mullet is found over most of coastal New Zealand, as far south as the Otago Peninsula, highest densities occur around the northern half of the North Island, and it is from this northern area that 95% of the annual commercial harvest is taken (Annala *et al.* 1998).

There are several studies reported in the world literature on grey mullet age and growth. Most of these studies used length frequency modalities and/or scale-reading to determine age (Thomson 1966). There are few published studies on age and growth determined from otoliths (de Silva 1980). Reported growth rates in grey mullet are variable, which is likely a result of the wide latitudinal range over which the species is found. In studies where growth rates have been assessed relative to sex, the average size of female *M. cephalus* has always been found to be larger than males of the same age (Anon 1989; Ibáñez-Aguirre & Gallardo-Cabello 1996; Ibáñez-Aguirre & Lleonart, 1996). In warm temperate and subtropical waters growth ceases in mid-winter and is greatest in mid-summer (Thomson 1963). However, some of the published studies have been on warm subtropical to tropical populations, in which other patterns of growth may occur (Grant & Spain 1975; Ibáñez-Aguirre & Gallardo-Cabello 1996; Shireman 1964). In these cases, interpretation of the usual annual temperature-related growth structures (annuli on scales, rings or zones in otoliths) can be complicated by the presence of additional marks possibly caused by spawning migrations across water bodies of differing temperature and salinity (Luther 1963, Thomson 1966). The interpretation of annuli in scales and otoliths can be further complicated in tropical species by extended, and possibly variable, spawning seasons. Where spawning seasons are protracted, several size groups of juveniles may comprise one year class, they may associate by size, and these size groups may be differentially distributed around an estuary, making the recognition of age groups from length modes difficult.

There have only been two ageing studies conducted on the New Zealand grey mullet (Wells 1976; Anon 1989). The authors of these reports claim to have aged grey mullet on the basis of hard structure increments (scales: Wells (1976); otoliths: Anon (1989)). However, in neither report is clear evidence presented for the annual nature of the chosen structures, although results are consistent with grey mullet ageing studies in other temperate countries (e.g., Shireman 1964, Thomson 1966, Stewart 1993). The Anon (1989) authors prepared each otolith by breaking and baking. The otolith was then mounted in plasticine, the sectioned surface smeared with immersion oil, and the otolith read using a binocular microscope. No mention is given in the report as to which month(s) the otolith material had been collected or how otolith structure was interpreted. In particular, the authors also fail to provide a clear description of the otolith in terms of identifying the location of the first annual ring. They do, however, state that their age calibration was in part based on length cohort observations of 1+

and 2+ mullet. Results presented in Anon (1989) suggest New Zealand grey mullet mature at three to four years, and reach at least twelve years in age.

More recently, Ibáñez-Aguirre & Gallardo-Cabello (1996) document how they aged *M. cephalus* from Tamiahua Lagoon, Veracruz, Mexico using otoliths. Otoliths were stored dry, and for viewing were immersed whole in xylol and read using transmitted light. Under these conditions the "slow growth rings appear lighter and the fast growth rings opaque." The authors collected monthly samples to determine the annual pattern of ring formation. The fast growth (opaque) bands were formed on the edge from March to August (summer), during the period of most active feeding, and the slow growth (hyaline) bands from October to February, during spawning and the related period of migration.

Sample collections

The GMU 1 stock management zone encompasses the northern half of the North Island. The boundaries extend from Cape Runaway on the east coast to Tirua Point on the West coast (Figure 1). Catch-per-unit-effort (CPUE) analysis undertaken in 1997 suggests that the east and west coast stock components of GMU 1 have different abundance signals (McKenzie 1998). At present the east and west coast areas of GMU 1 are considered separate for stock assessment purposes. Catch sampling during 1997-98 was confined to the west coast setnet fishery.

As specified in the Ministry tender no specific season was recognised in the sampling design. A total of twenty length frequency samples were collected at regular intervals between December 1997 and September 1998 and these are deemed representative of the 1997-98 total commercial catch. Grey mullet landings are generally small ranging between 200 - 600 kg, consequently there is little advantage in sub-sampling landings and many landings were measured in their entirety. Fish were measured to the nearest centimetre below the fork length.

Anon (1989) found evidence of sex related differential growth in grey mullet. Although it would have been desirable to sex each grey mullet measured this was not possible without cutting the animal and devaluing its sale value. Instead a random sub-sample of 369 animals were collected to provide information on sex and age. Data from these animals were used to define an age/sex-length key for application to the larger length sample.

Grey mullet length and age data were stored on the Ministry of Fisheries *market* and *age* databases held by NIWA.

Otolith preparation

Two methods were used to prepare grey mullet otoliths for reading: baking, embedding, and sectioning; and embedding and thin sectioning. All otoliths were sectioned transversely through the nucleus. Ageing of whole grey mullet otoliths was not attempted due to the anticipated difficulty in reading otoliths from larger fish (after brief examination of a few), despite the use of this procedure by Ibáñez-Aguirre & Gallardo-Cabello (1996).

Otoliths to be baked were marked with a fine pen across the nucleus, baked for approximately 4 minutes at 280°C, and embedded in ordered rows in an epoxy resin (Araldite K 142) block, with the dorso-nuclear marks aligned. The resin block was cut through the inscribed otolith axes with a high-speed diamond saw, providing transverse hemi-sections. The section faces were read under reflected light, and paraffin oil was used to increase visual perception of the banding pattern.

Thin sections were prepared following the standard NIWA procedure (*see* Stevens & Kalish (1998)). The straightest dorso-nuclear otolith prism was marked on its distal surface with a fine pen. Four or five otoliths were then embedded with their marks in alignment in an epoxy resin mould. The mould was then sectioned using a dual-bladed diamond saw. After being attached to a microscope slide with a thermoplastic cement, the sliced section was ground to a thickness of ~300 ± 100 µm and polished, before viewing under transmitted, or on occasion, reflected light. Under transmitted light, both bright- and dark-field illumination techniques were used.

To decide on the best otolith preparation for grey mullet ageing, eleven otolith pairs were selected from a representative size range of fish (25-46 cm), with one otolith of each pair baked and sectioned and the other prepared as a thin section. This sample was read by three readers. For the baked hemi-sections, each half of the otolith was read independently. Otolith margins were classified (where possible) as line (ring just visible), narrow, and wide. Often the line rings were visible on only one part of the otolith; for example, a reading of "7-line" was effectively the same as "6-wide".

The reading procedure adopted for reading the main sample was as follows: Each otolith section was read once by two different readers, who recorded a ring count and marginal category (line, narrow, wide). At this stage fish length was unknown to the otolith readers. The same two readers together then read each section, working from a digitally-captured image on a screen display where the magnification and lighting conditions could be adjusted as appropriate. Two new readings were obtained, discussed, compared with the earlier readings, checked against fish length, and a final reading (ring count plus marginal category) assigned to the otolith.

Data analysis- Estimates of proportions at length and age

The calculation of proportions and variances at length and age were derived from the length frequency samples and age-length keys in accordance to procedures described in Davies & Walsh (1995). The age and length proportions are assumed to characterise the west-coast grey mullet setnet fishery between December 1997 and September 1998. Proportions at age were calculated for male and female setnet recruits. It was assumed that that age and sex were distributed randomly within each sampled length class (Southward 1976).

Length compositions were converted to age distributions by application of an appropriate age-length key using the approach of Garvaris & Garvaris (1983) and Davies & Walsh (1995). Data collected to create an age/sex length key were first "smoothed" by fitting normal curves to the observed length distributions within each age class. The normal curves were fitted to derive proportional estimates for length categories not represented by real observations. The smoothed age/sex length key was then applied to the catch length frequency observational data.

Estimates of von Bertalanffy growth parameters

Unbiased estimates of mean length-at-age are required to derive von Bertalanffy (VB) growth parameters. The sex specific age-length key was used to generate male and female VB growth estimates which were assumed to be unbiased. Fish younger than three years of age were not present in the commercial landings. However, data for 1+ grey mullet were available from beach seine samples taken in March 1987 (Anon 1989 Appendix 1). These data were amalgamated with the age-length key for each sex under the assumption that the length distribution of 1+ animals is the same for each sex, and the growth of these animals was not significantly disparate from the commercial sample animals. The number of 1+ fish in the 1987 sample was scaled to be comparable in magnitude to the number of three year old grey mullet obtained in the catch-samples. This was done to give the 1987 data a relatively high weighting in the VB fits.

VB parameter estimates were obtained by maximum likelihood minimisation. VB parameter values for male and female grey mullet were compared using a likelihood ratio test (Kimura 1980).

Revised estimates of length/weight relationship

Length weight parameters published in Ministry of Fisherys 1997 plenary document are inconsistent with length/weight data collected in 1987 by the Ministry of Fisheries (unpublished data). The length weight equation (Equation 1) was fitted to the 1987 data and alternative parameters derived. No comparable data was collected in 1997.

$$Weight\ (g) = aLength\ (cm)^b \qquad \textbf{(Equation 1)}$$

11. Results

Otolith ageing

A total of 369 otolith pairs were collected over the periods January-February and May-July 1998.

Comparison of section/bake and thin section preparation

Slightly closer reader agreement was obtained using thin section preparation methods but overall comparable readings were obtained with both thin-section and baking preparation methods (Table 3). All readers agreed that thin section proportions were easier to interpret (categorised as poor, average, good, more were judged to be good), and that increment margins were easier to classify as line, narrow, or wide. The initial eleven test otolith sections at ~ 200 µm were considered to be slightly too thin, and slightly thicker sections were used in subsequent preparations. Based on the evaluation, thin sections were chosen as the preferred method for the sample of 369 fish to be aged.

Table 3: **Comparative reading of grey mullet otoliths prepared by baking and sectioning, and by thin-sectioning**

Length	Sex	Baked cross-section						Thin section		
		Reader 1		Reader 2		Reader 3		Reader 1	Reader 2	Reader 3
25	F	1w	2l	2l	2l	1w	1w	1w	1w	1w
30	M	4l	4l	3n	3n	2w	3n	3w	3n	3n
30	F	3w	3l	–	3n	3	3	4w	3n	3n
32	M	4n	3n	3n	3n	3n	3l	3n	3n	3n
32	F	5n	5l	4n	4n	4l	4l	4n	4n	3n
35	M	7w	7n	–	7n	6	6	7n	7l	6w
35	F	4w	4n	4n	4n	4l	4l	4w	4n	4n
42	F	8l	10n	8w	8w	8	–	9l	8w	8l
42	F	10l	9n	8w	9	8l	8l	9l	8w	9l
42	F	10n	9n	8n	9	8l	–	8w	8n	8w
46	F	10n	10n	10l	10l	9w	9l	11n	10l	10l

Otolith interpretation

In thin otolith sections, under transmitted light and bright-field illumination (Figure 2, Figure 3 top), a series of opaque (dark) and translucent (pale, or clear) growth zones were visible. The dark zones were generally narrower than the clear zones. Unless otherwise specified, this use of "opaque" and "translucent" is the standard nomenclature in this account.

Under dark-field illumination (Figure 3 bottom) the relative brightness of the zones reversed (i.e., the dark zones became pale and vice versa), but the relative width of the zones remained the same. Although a direct comparison could not be made, the bright-field pattern of zones appeared similar to the pattern of narrow dark (dark brown) and light (pale brown) zones observed in the initial sample of baked preparations.

In thin sections the pattern of opaque and translucent zones was best observed in the regions either side of the longitudinal sulcus and this is where counts were generally made (*see* Figure 2, top). Both sides were counted if possible. Whenever possible the zones parallel to the medial surface and extending to the dorsal tip of the otolith were also counted, as well as those extending partway towards the ventral tip, to confirm the sulcal counts. The zones generally became split and difficult to interpret near the ventral tip, and were compressed and unreadable in the dorso-lateral region.

The count was generally of the number of complete opaque zones (i.e. opaque zones with some translucent material outside them). In some cases where there was an opaque zone right on the edge it was counted, and given a line marginal category. The pattern of wide and narrow zones observed in the grey mullet otoliths is documented in other temperate species as corresponding to "winter" (narrow dark) and "summer" (broader, translucent or pale) growth (Beckman and Wilson 1995). In snapper (*Pagrus auratus*) and trevally (*Pseudocaranx dentex*) the narrow winter band is usually not visible in otolith preparations until late spring (Walsh *et al* 1999). As the grey mullet samples were taken in only two sampling periods (January-February and May-July) we are unable to confirm when the annuli were laid down. We have made our interpretation of otolith annuli comparable to that for snapper, i.e. relative to the time of year the otoliths were collected wide margin otoliths had one added to the ring counts; narrow and line margin otoliths were counted exactly. The assumption is made that the adjusted ring counts represent age, and these have been made relative to a cohort "birthday" of January 1st. Evidence supporting this assumption can be found in Anon (1989). In this report it was shown that male and female grey mullet in late stages of gonad development were most common in November and December commercial catches. The report also states that small 0+ grey mullet (TL < 35 mm) were most prevalent in beach seine samples taken in February and March.

Zone counts were made on all 369 otoliths as thin-section preparations. Experience gained from the initial reading trial meant that zone counts made independently by the first two readers were in good agreement, and full agreement was easily reached when the 369 readings were repeated, compared, and discussed. There was an 75% agreement on zone count and marginal category, and 90% agreement when zone counts were adjusted for marginal category (e.g. 4w and 5l were considered equivalent). The remaining readings (10%) differed by only ± 1, with the first reader having twice as many +1 counts. Two otoliths were considered unreadable. When the otoliths were re-read in collaboration, the discrepancies were recognised as being in the more difficult otoliths to interpret; they were easily resolved, although the resulting ages were considered less reliable. Ages were thus obtained for 367 fish after the final reading (Appendix 2).

Sample collections

Estimates of catch at length and age

Readings from the 367 aged grey mullet were used to describe an age-length key representing both sexes combined (Appendix 2). There were too few observations of female grey mullet aged 12 and males aged 11 and 12 with which to calculate normal distributions of length at age. Normalised age-length keys for each sex are given in Appendix 3.

Setnet and ringnet were the two most important commercial fishing methods catching grey mullet from the west coast GMU 1 stock in the 1997–98 fishing year comprising 58% and 35% of the landed catch respectively (Table 2). Twenty-one west coast setnet landings were sampled in 1997-98 which represented approximately 9% of the total reported landings made by the method (Table 4).

***Table 4*: Summary of the catch (total number and weight of landings) and samples (number of landings and weight sampled, and number of fish measured) for all methods combined for the 1997-98* fishing year**

		Number of landings			No. of fish	Weight of landings (t)		
Method	Period	Total	Sampled	% of total	measured	Total	Sampled	% of total
All	Whole year	240	21	9	3309	332	4	1

The length composition of 1997-98 setnet catches appeared to be normally distributed about a mean length of 36 cm. The Mean Weighted Coefficient of Variation (MWCV) over this distribution was 0.19 (Figure 4; Appendix 4).

The fishery was made up of age classes from three to twelve with a dominant cohort of five year old clearly evident (Figure 5; Appendix 5). The MWCV for the sex combined age distribution was 0.125. Fitting the normalised sex/age length key showed that the relative year class strengths of male and females were similar in the catches (Figure 6). However, females were more dominant and made up approximately two thirds of the catches (Appendix 6).

Estimates of von Bertalanffy growth parameters

Female age class three was not used in obtaining a VB fit because it was suspected this age class was incompletely selected by the gear. For the same reason, age class four was excluded from the male VB fits.

Plots of the VB fits for each sex and the log residuals are given in Figures 7 & 8. The maximum likelihood test of coincidence between the male and female VB fits indicates the growth dynamics of the two sexes are statically distinct: $\chi^2 = 20.015$ d.f = 3 P= 0.0001 (Table 5). The main difference appears to lie in the L infinity component of the VB relationship, with females attaining a larger overall size than males $\chi^2 = 5.653$ d.f = 1 P= 0.017 (Table 5). The rate of growth (K) between the two sexes was similar, as was T_0 (Table 5).

Table 5: **Male and female VB parameters and likelihood ratio tests of similarity of curve parameters (*after* Kimura 1980)**

sex	Base case	Coincident		*k*	
	40.5602	39.0634	39.5757	40.3707	40.5838
Females k	0.4308	0.4693	0.4797	0.4411	0.4294
	0.2019	0.2343	0.2631	0.2174	0.1989
	37.3448	39.0634	39.5757	37.6977	37.2975
Males k	0.4689	0.4693	0.3583	0.4411	0.4734
	0.1916	0.2343	0.0106	0.1492	0.1989
RSS	2 244.6701	2 659.6109	2 354.8160	2 249.0520	2 244.7845
c^2		20.0153	5.6527	0.2301	0.0060
df		3.0000	1.0000	1.0000	1.0000
P		0.0002	0.0174	0.6314	0.9382

<u>Revised length-weight relationship</u>

A least squares fit to 1987 length weight data set (both sexes combined) produced different parameter values to those published in Annala *et al* (1998); a= 0.0424 b=2.8260 *cf* a= 0.0360 b= 2.7537 (Figure 9).

12. Discussion

Similar readings were obtained from section-and-bake and thin-section otolith preparation techniques for a sub-set of the main otolith sample. However, relatively clear interpretations of annual structure in grey mullet otoliths were obtained using thin section preparations and otoliths prepared in this way were easier to read. Thin section preparation also appeared to offer greater scope for refinement than section-and-bake procedure. This may explain why the level of reader variation obtained in the main otolith sample (all of which were thin-sectioned) was lower than observed in the preliminary sample. As far as we can ascertain from the literature, this is the first study in which otolith thin sections have been used to age grey mullet.

Ages based on otolith ring counts suggest the west coast setnet fishery in 1997-98 was largely based on grey mullet aged between three and twelve years. Comparable results were obtained when the fishery was sampled in 1987-88 Anon (1989), and we believe the interpretation of otolith structure and ageing was similar for the two studies.

The current study has brought to light ambiguities in the interpretation of grey mullet annual structures which should be investigated in future research. One feature that was difficult to interpret was a narrow translucent inner ring or band, within but near the edge of the opaque centre of the otolith (*see* Figure 2, top). In some otoliths it was essentially complete, as shown, in others only part of this ring was visible. In the initial set of eleven otoliths, this ring was considered to be separate from a more typical "ring 1" just outside it, and either clearly included or excluded from counts. As the main set of otoliths was being read, however, more variation in the position of this ring to "ring 1" became apparent, and in many cases the two were closely linked. On the basis of relative ring spacing, it was decided to interpret this structure as part of the first ring. The first ring thus became rather difficult to define, but in most cases it was judged to be a combination of the narrow translucent ring and a somewhat diffuse opaque zone outside it. The cause of this narrow ring is unknown, but it is considered to be formed during the 0+ year, and although it appears to be formed rather late during the first growing season, it could mark the move from marine to estuarine waters. Defining the position and appearance of the first annual ring should be a priority in any future work. Although the circumstantial evidence for annual deposition in grey mullet otoliths is strong, this is yet to be confirmed experimentally. The seasonal timing of ring deposition is also not clearly understood, and could be better described with further research i.e. is it a winter ring, and/or a spawning mark in mature fish?

A single dominant cohort of five-year-old grey mullet was evident in the 1997-98 catch sampling data from the commercial fishery. It appears that variation in recruitment is high in the west coast stock. Since the fishery is based on relatively few year classes this may, in part, explain the marked changes in abundance (with a recent decline) claimed by sector groups. The latest year available in the CPUE series analysed by McKenzie (1998) was the 1996-97 fishing year. The CPUE index for this year was not particularly strong, probably because (as four-year olds) the 1993 year class was not fully recruited. It would be highly desirable to track the progression of the 1993 cohort through into subsequent years in the west coast fishery. This would not only enable an estimate of total mortality to be derived but also provide insight into the degree, and magnitude, of stock recruitment variation and would help to validate the ageing methodology.

Results from growth analysis supported earlier work in showing female grey mullet grew to a larger size than males. Females were systematically larger than males over all recruited age classes. Sex related differences in growth may in part explain the predominance of female grey mullet in commercial catches.

Gill nets are known to be highly size selective (Millar & Holst 1997), Anon (1989) showed that small changes in mesh size altered the length composition of grey mullet catches. However, the Anon data are limited and the selectivity characteristics of commercial gill nets are yet to be adequately described for grey mullet. It is not known how the age composition observed in the 1997-98 setnet catch samples relates to the underlying age composition of the stock. It is likely that both the younger and older age classes are under-represented in the commercial fishery. The growth estimates, which are based on the commercial age proportions, may therefore be biased low, in particular the L infinity parameter. It is recommended that research be undertaken to describe the selectivity characteristics of commercial gillnets for grey mullet.

It is likely that length weight parameters published in Annala (1997) for grey mullet are erroneous. The source of the published figures is not provided in the Plenary document, however these parameters are inconsistent with parameters derived from raw data collected by the Ministry in 1987. It would be advisable to recalculate a length weight relationship for grey mullet using a new set of observations from the GMU 1 stock.

13. Conclusions

1. West coast set net catches from the 1997-98 fishing year were comprised of male and female grey mullet aged between three and twelve years.
2. A strong cohort of five year-old mullet was present in these catches
3. Female grey mullet were more prevent in the catches and made up approximately two-thirds of the sample landings.
4. Growth analysis indicates female grey mullet are consistently larger than males of the same age
5. Thin section preparation was superior to baking methods for clarity of otolith readings.
6. Ages obtained in the study using otoliths were similar to those from other studies, however both the timing of ring deposition and the annual nature of the rings is yet to be confirmed for New Zealand grey mullet.

7. The length weight relationship for New Zealand grey mullet should be recalculated using a new set of observations from the GMU 1 stock.

14. Acknowledgments

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Appendix 1: Length frequency of one year old grey mullet derived from 1987 beach seine sample (Anon 1989).

One year old grey mullet	
Length (cm)	Frequency
9	3
10	15
11	24
12	27
13	18
14	7
15	2
16	1

Appendix 2 : Age length key derived from otolith samples collected from grey mullet fisheries in GMU1 in 1997-98

Length (cm)	Age (years)															No. Aged
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	2
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	1.00	0	0	0	0	0	0	0	0	0	0	1
30	0	0	0	0.43	0.57	0	0	0	0	0	0	0	0	0	0	7
31	0	0	0	0.15	0.77	0	0	0.08	0	0	0	0	0	0	0	13
32	0	0	0	0.23	0.74	0	0	0.03	0	0	0	0	0	0	0	31
33	0	0	0.06	0.16	0.68	0.06	0	0	0	0	0	0.03	0	0	0	31
34	0	0	0.02	0.02	0.74	0.09	0.02	0.04	0	0.07	0	0	0	0	0	46
35	0	0	0.03	0.03	0.63	0.16	0.03	0.03	0.05	0.03	0.03	0	0	0	0	38
36	0	0	0	0.02	0.56	0.14	0.04	0.10	0.10	0.02	0.02	0	0	0	0	50
37	0	0	0.02	0.02	0.30	0.16	0.05	0.09	0.12	0.21	0	0.02	0	0	0	43
38	0	0	0	0.04	0.44	0.13	0.07	0.07	0.04	0.18	0.02	0	0	0	0	45
39	0	0	0	0	0.38	0	0.08	0.15	0.23	0.15	0	0	0	0	0	13
40	0	0	0	0.06	0.06	0.24	0.06	0.24	0.12	0.24	0	0	0	0	0	17
41	0	0	0	0.08	0	0	0.25	0	0.33	0.33	0	0	0	0	0	12
42	0	0	0	0	0.08	0.17	0.08	0.08	0.25	0.17	0.17	0	0	0	0	12
43	0	0	0	0	0	0	0	0	0	1.00	0	0	0	0	0	2
44	0	0	0	0	0	0	0	0	1.00	0	0	0	0	0	0	1
45	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0.50	0.50	0	0	0	2
47	0	0	0	0	0	0	0	0	0	0	1.00	0	0	0	0	1
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total																367

Appendix 3: Raw sex / age / length data and normalised sex / age length key for grey mullet from GMU1 fisheries in 1997-98

Raw length at age by sex data for grey mullet sampled during 1997-98

Length (cm)	Females Age (years) 3	4	5	6	7	8	9	10	11	Males Age (years) 4	5	6	7	8	9	10	No. Aged
25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
30	0	1	1	0	0	0	0	0	0	1	3	0	0	0	0	0	6
31	0	1	4	0	0	1	0	0	0	1	6	0	0	0	0	0	13
32	0	5	15	0	0	1	0	0	0	2	8	0	0	0	0	0	31
33	1	4	11	0	0	0	0	0	0	1	10	2	0	0	0	0	29
34	1	1	22	1	0	0	0	0	0	0	12	3	1	2	0	3	46
35	1	1	20	1	0	0	1	0	1	0	4	5	1	1	1	1	38
36	0	1	23	4	1	1	2	0	0	0	5	3	1	4	3	1	49
37	1	1	11	5	0	3	2	2	0	0	2	2	2	1	3	7	42
38	0	1	19	6	2	3	2	2	1	1	1	0	1	0	0	6	45
39	0	0	5	0	1	2	1	1	0	0	0	0	0	0	2	1	13
40	0	1	1	4	1	4	2	3	0	0	0	0	0	0	0	1	17
41	0	1	0	0	2	0	4	4	0	0	0	0	1	0	0	0	12
42	0	0	1	2	1	1	3	2	2	0	0	0	0	0	0	0	12
43	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
44	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2
47	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
n	5	18	134	23	8	16	18	18	5	6	51	15	7	8	9	20	361
mean	32.8	34.1	35.1	37.8	39.4	37.8	39.4	40.9	40.6	32.7	33.4	35.0	36.9	35.5	36.9	37.0	
sd	4.6	3.1	2.3	2.1	2	2.9	2.5	2.7	4.2	2.8	1.9	1.3	2.3	1.1	1.4	1.64	

Raw normalised length at age by sex data for grey mullet sampled during 1997-98

Length (cm)	Females Age (years) 3	4	5	6	7	8	9	10	11	Males Age (years) 4	5	6	7	8	9	10
25	0.7	0.16	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0
26	0.6	0.23	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0
27	0.4	0.28	0.1	0	0	0	0	0	0	0.2	0	0	0	0	0	0
28	0.3	0.28	0.1	0	0	0	0	0	0	0.2	0.1	0	0	0	0	0
29	0.2	0.24	0.2	0	0	0	0	0	0	0.2	0.2	0	0	0	0	0
30	0.1	0.18	0.3	0	0	0	0	0	0	0.1	0.3	0	0	0	0	0
31	0	0.13	0.4	0	0	0	0	0	0	0.1	0.4	0	0	0	0	0
32	0	0.1	0.4	0	0	0	0	0	0	0	0.4	0	0	0	0	0
33	0	0.08	0.5	0	0	0	0	0	0	0	0.4	0	0	0	0	0
34	0	0.06	0.5	0	0	0	0	0	0	0	0.3	0.1	0	0	0	0.01
35	0	0.05	0.5	0	0	0	0	0	0	0	0.2	0.1	0	0	0	0.03
36	0	0.04	0.5	0	0	0	0	0	0	0	0.1	0.1	0	0.1	0	0.07
37	0	0.04	0.4	0.1	0	0	0	0	0	0	0.1	0.1	0	0	0.1	0.1
38	0	0.03	0.4	0.1	0	0.1	0.1	0	0	0	0	0	0	0	0.1	0.12
39	0	0.03	0.3	0.2	0.1	0.1	0.1	0.1	0	0	0	0	0	0	0	0.11
40	0	0.03	0.2	0.2	0.1	0.1	0.1	0.1	0	0	0	0	0	0	0	0.08
41	0	0.02	0.1	0.1	0.1	0.1	0.2	0.2	0	0	0	0	0	0	0	0.04
42	0	0.02	0.1	0.1	0.1	0.1	0.2	0.3	0.1	0	0	0	0	0	0	0.01
43	0	0.01	0	0.1	0.1	0.1	0.2	0.4	0.1	0	0	0	0	0	0	0
44	0	0.01	0	0	0.1	0.1	0.2	0.5	0.1	0	0	0	0	0	0	0
45	0	0	0	0	0	0.1	0.2	0.5	0.2	0	0	0	0	0	0	0
46	0	0	0	0	0	0.1	0.1	0.6	0.2	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0.1	0.5	0.3	0	0	0	0	0	0	0

Appendix 4 : Estimated proportion at length and c.v.s for grey mullet fisheries in GMU1 in 1997-98

P.i .= proportion of fish in length class — *Nt* = scaled total number of fish caught

c.v. = coefficient of variation — *n* = total number of fish sampled

Length (cm)	All methods Combined *P.i*	*c.v.*
20	0.0000	0.00
21	0.0000	0.00
22	0.0000	0.00
23	0.0000	0.00
24	0.0000	0.00
25	0.0006	1.02
26	0.0000	0.00
27	0.0003	1.02
28	0.0005	0.74
29	0.0009	0.73
30	0.0063	0.41
31	0.0211	0.37
32	0.0542	0.35
33	0.0798	0.28
34	0.1149	0.11
35	0.1421	0.15
36	0.1574	0.05
37	0.1122	0.14
38	0.1286	0.20
39	0.0556	0.18
40	0.0415	0.21
41	0.0373	0.33
42	0.0264	0.52
43	0.0085	0.41
44	0.0039	0.40
45	0.0017	0.46
46	0.0041	0.90
47	0.0020	0.69
48	0.0000	0.00
49	0.0000	0.00
50	0.0000	0.00

Nt 302 976

n 3 309

Appendix 5 : Estimated proportian at age and c.v.s for grey mullet fisheries in GMU1 in 1997-98

P.j .= proportion of fish in age class   *c.v.* = coefficient of variation

Estimates of proportion at age for both sexes combined of grey mullet from the GMU1 fishery
Otolith sample size = 365

Age (years)	Both sexes Combined *P.j.*	*c.v.*
0	0.0000	0.00
1	0.0000	0.00
2	0.0000	0.00
3	0.0147	0.43
4	0.0550	0.20
5	0.4950	0.05
6	0.1092	0.15
7	0.0446	0.26
8	0.0674	0.20
9	0.0844	0.18
10	0.1084	0.14
11	0.0162	0.42
12	0.0052	0.71
13	0.0000	0.00
14	0.0000	0.00
15	0.0000	0.00
16	0.0000	0.00
17	0.0000	0.00
18	0.0000	0.00
19	0.0000	0.00
20	0.0000	0.00

Appendix 6: Estimates of proportion at age by sex of grey mullet from the GMU1 fishery based on normalised age / sex length key

Otolith sample size = 365

Age (years)	Females *P.j.*	Males *P.j.*
3	0.0119	0.0000
4	0.0488	0.0156
5	0.3862	0.1486
6	0.0612	0.0448
7	0.0198	0.0193
8	0.0422	0.0236
9	0.0442	0.0252
10	0.0410	0.0556
11	0.0119	0.0000
Total	0.6672	0.3328

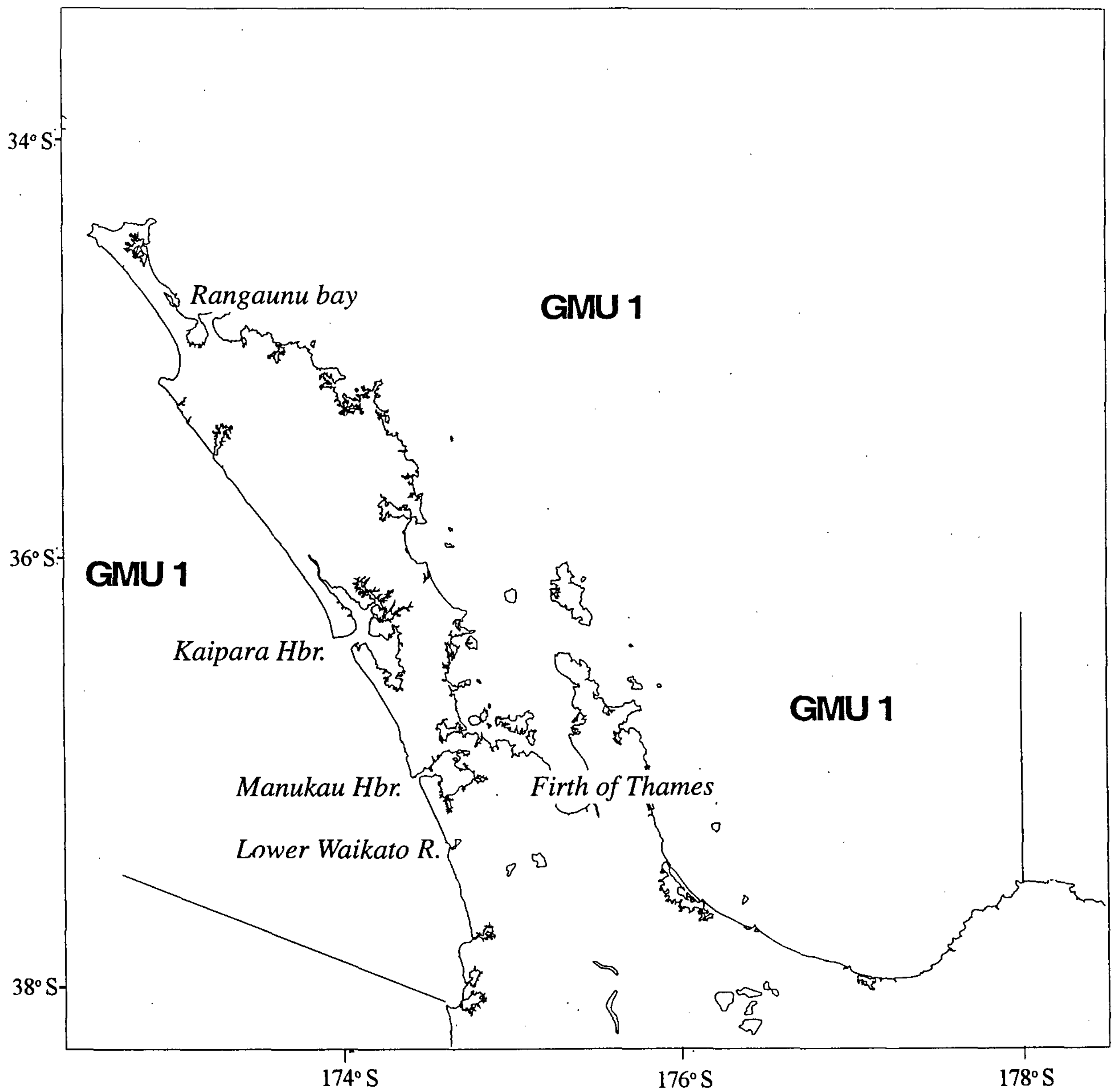

Figure 1: Stock area of GMU 1 showing principal east and west coast fishing areas

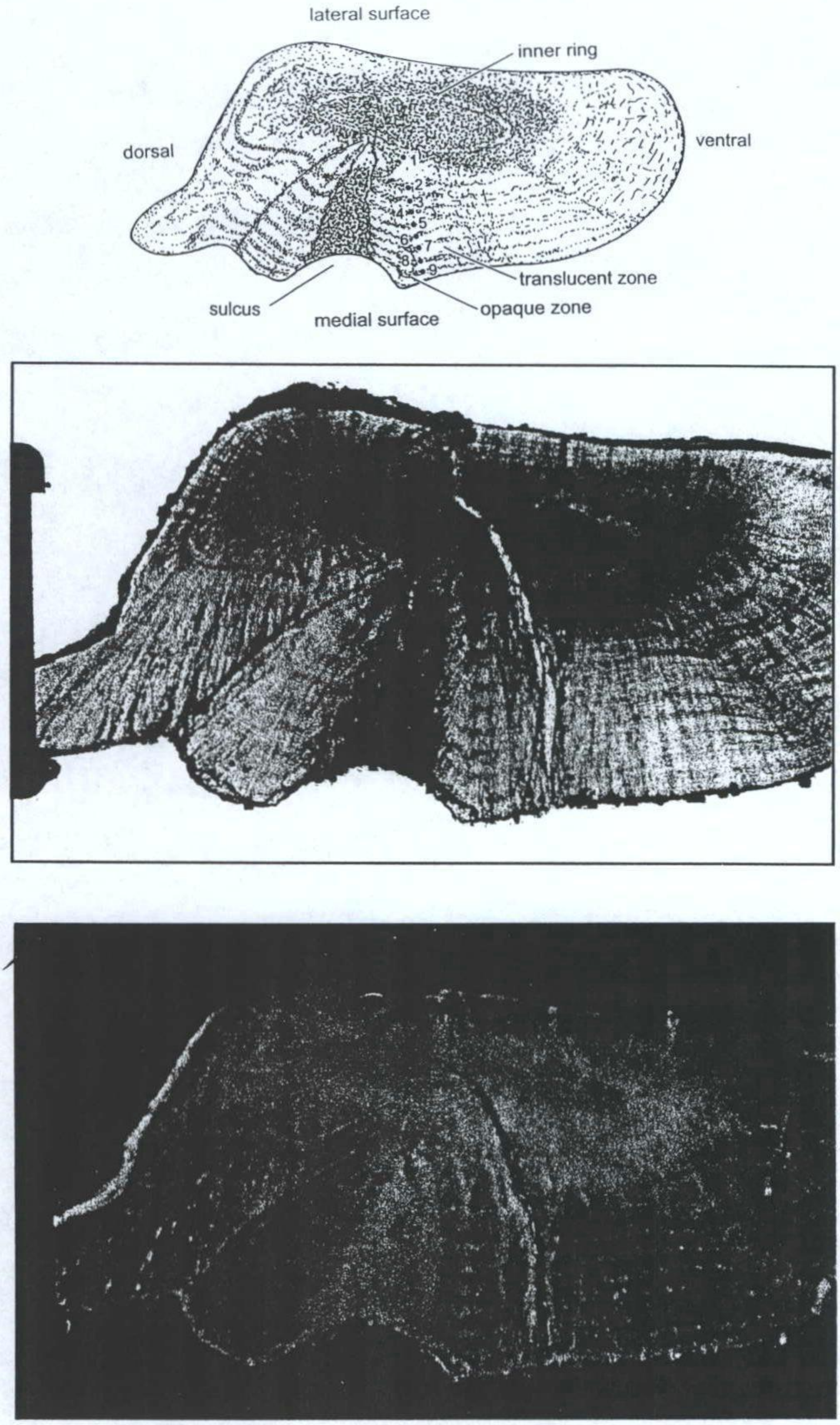

Figure 2: (Top) Diagrammatic representation of a thin section of a grey mullet otolith, viewed with transmitted light, bright-field illumination. The 9 opaque zones are counted, but the first ring incorporates part of the opaque central core plus a narrow translucent "inner ring" (see text). (Centre) Otolith thin section from a 36 cm grey mullet, transmitted light, bright-field illumination, 9 rings (ring 9 is near the edge). (Lower) Otolith thin section from the same fish, transmitted light, dark field illumination, 9 rings (which are reversed in appearance from the previous view).

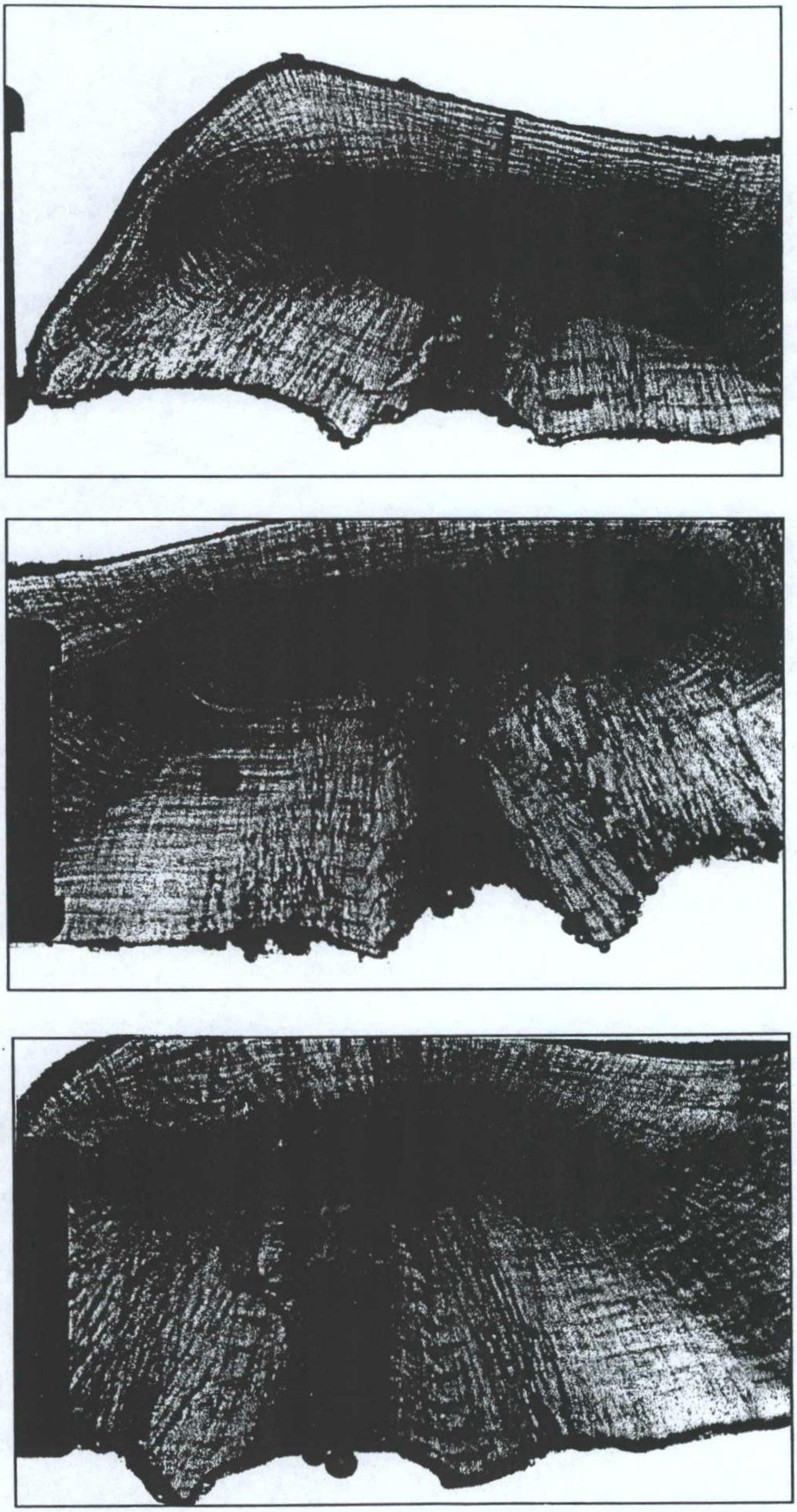

Figure 3: (Top) Otolith thin section from a 40 cm grey mullet, transmitted light, 4 rings (ring 4 is near the edge). (Centre) Otolith thin section from a 38 cm grey mullet, transmitted light, 8 rings (ring 8 is near the edge). (Lower) Otolith thin section from a 41 cm grey mullet, transmitted light, 10 rings.

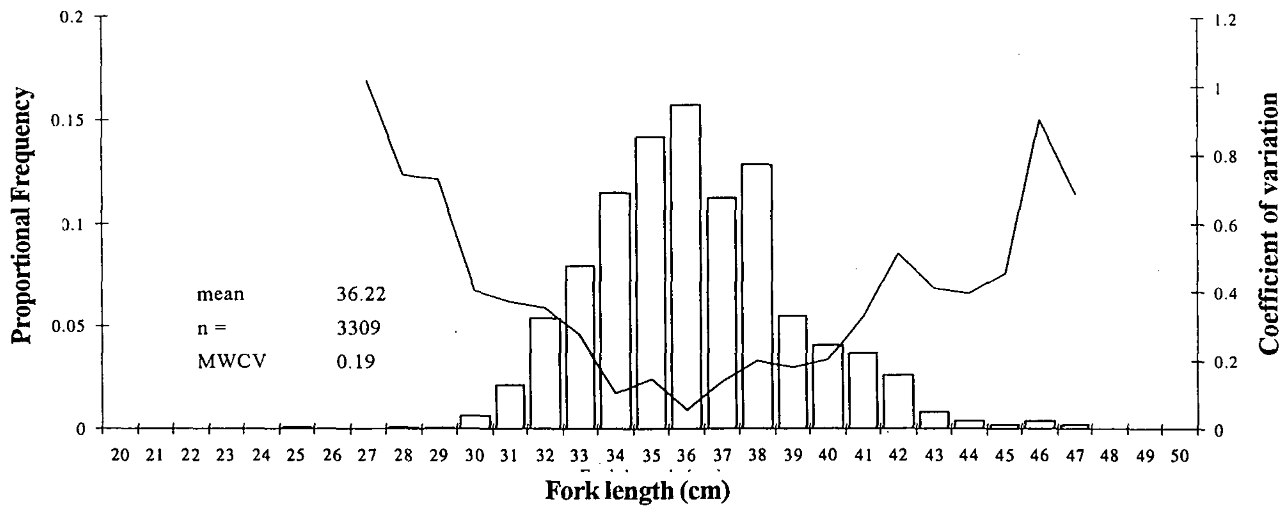

Figure 4: Mean weighted proportional length frequency and c.v. from all grey mullet sample catches

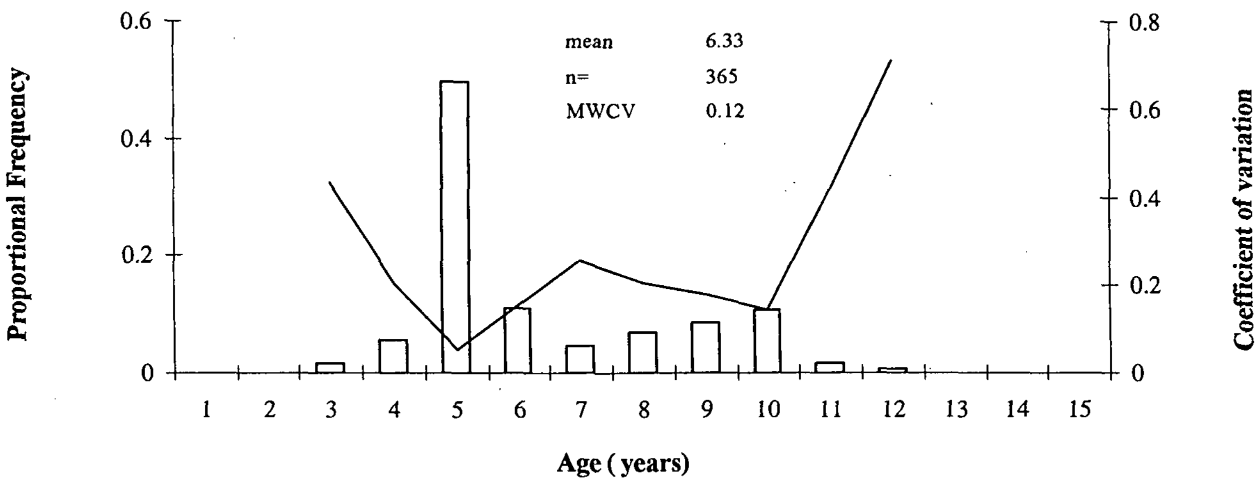

Figure 5: Mean weighted proportional age frequency and c.v. from all grey mullet sample catches (males & females combined)

Figure 6: Relative numbers of male and female grey mullet in total 1997-98 west coast setnet catch

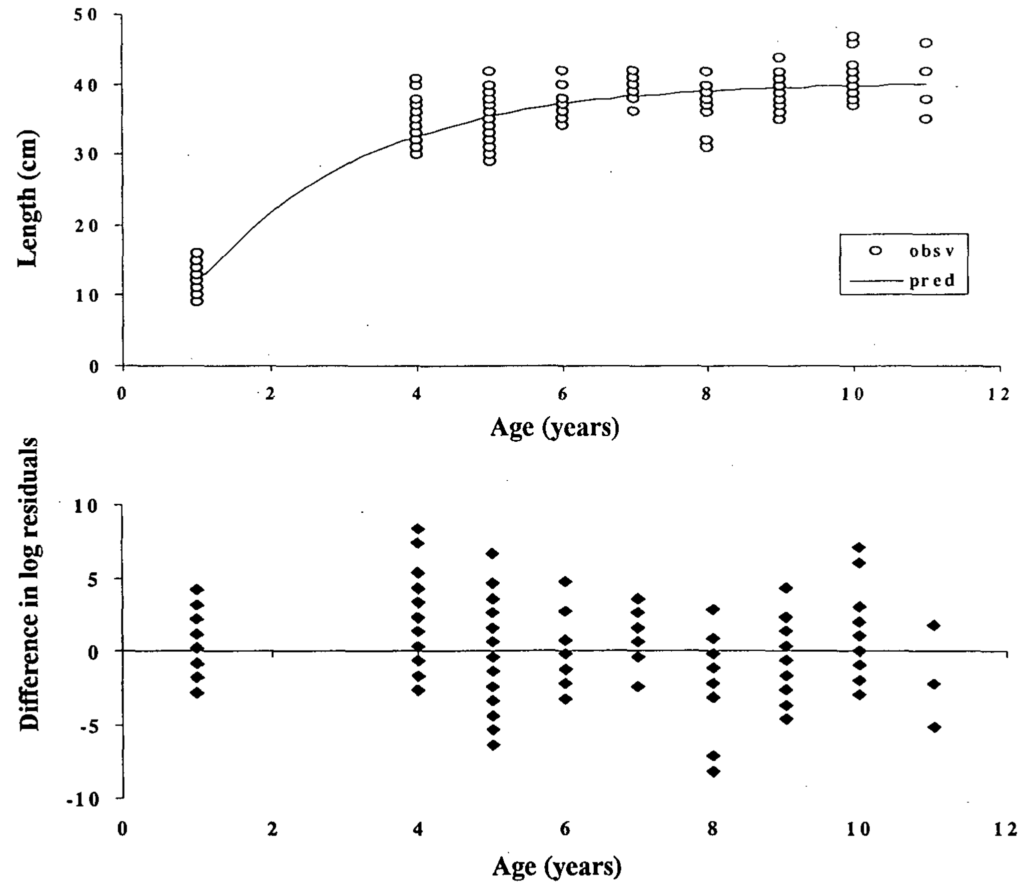

Figure 7: Maximum likelihood von Bertalanffy fit to female catch-at-age

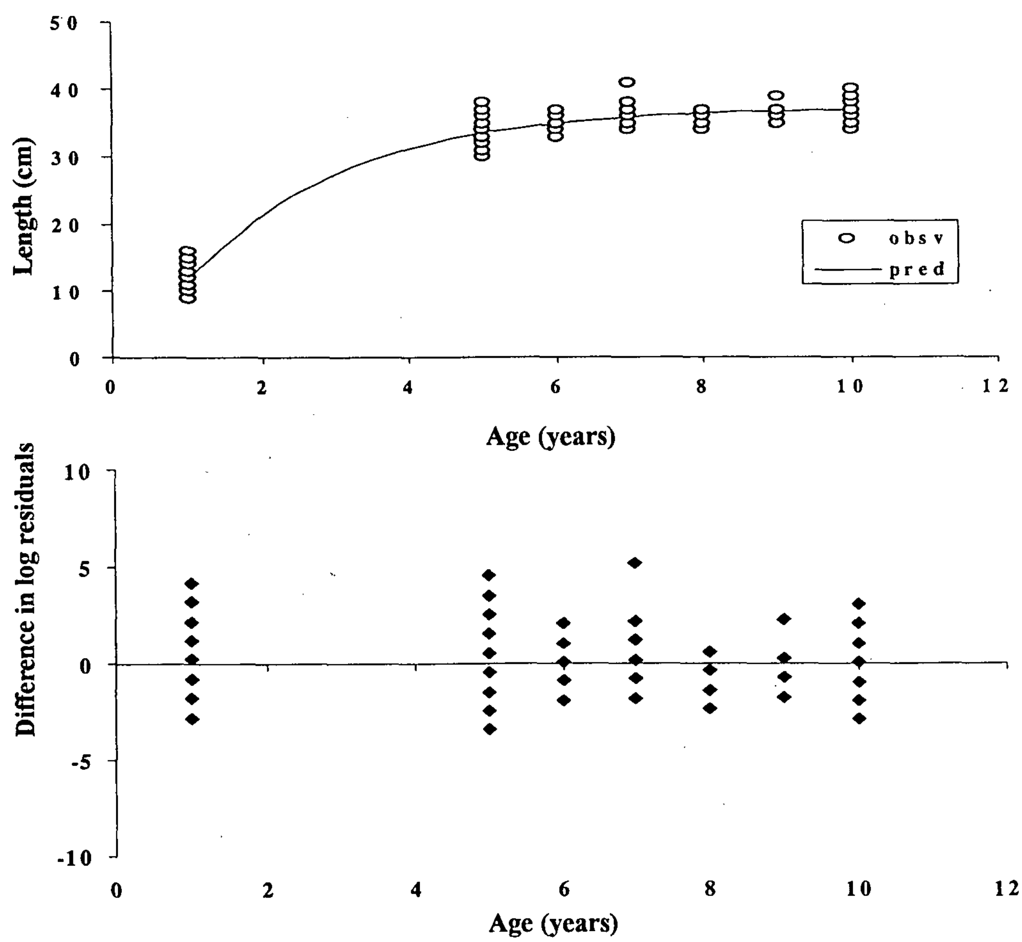

Figure 8: Maximum likelihood von Bertalanffy fit to male catch-at-age

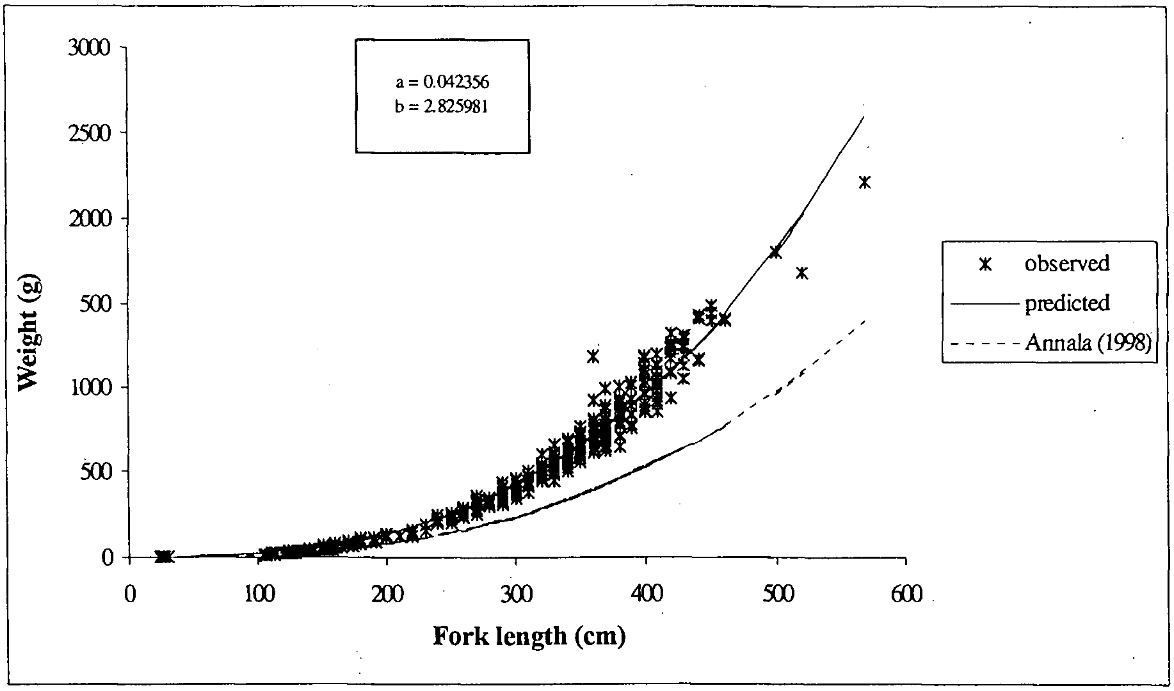

Figure 9: Revised length-weight relationship for Grey mullet based on 1987 MFish unpublished data (male and females combined)