Examination of redeye roundherring size and age data – towards developing a growth curve for the redeye stock assessment

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Redeye roundherring (*Etrumeus whiteheadi*) in South African waters is exploited by the pelagic purse seine fishery, which primarily targets anchovy (*Engraulis encrasicolus*) and sardine (*Sardinops sagax*). In spite of a relatively large adult biomass (averaging 1.3 million tons over the last 10 years), redeye catches have been low, averaging 50 000 tons per annum over the last 10 years. The redeye fishery is currently managed with an annual Precautionary Upper Catch Limit (PUCL) of 100 thousand tons. Furthermore, the Operational Management Procedure for sardine and anchovy (de Moor and Butterworth 2008) makes provision for some by-catch of adult sardine [3500 t] with redeye. Only once in the history of the fishery, has the industry managed to come close to this PUCL (92 thousand tons in 1997). In view of the under exploitation of the redeye resource and possibility of expanding the fishery, work has been directed at assessing the status of the redeye to support the management of the resource. Implicit in such an assessment is the requirement for information on the age and growth of the species.

Some effort has been directed collecting age data for redeye from analyses of otolith structure (Geja *et al.* in prep.), specifically, counts of the numbers of putative annual growth zones. Application of this approach assigns individual fish to age groups on an annual time scale. Since redeye appear to spawn for most the year (Roel and Melo 1990), any given age group contains a broad size range of fish, presumably encompassing fish spawned at intervals over the period of a year. The age group assignments, particularly of the 0+ age group, do not capture this complexity, and the growth models fitted to these data are not representative of the growth of the younger fish. An examination of the size structure of the population observed during the routine pelagic surveys, coupled to the application of available daily age data was conducted in order to improve the growth modeling for stock assessment purposes.

Ageing

Redeye otoliths have been routinely collected from mid-water trawl samples during all pelagic hydroacoustic abundance surveys since 2004. Otoliths collected during the 2005 and 2006 November Spawner Biomass surveys were sub-sampled for age determination. A stratified-random sub-sampling scheme was employed to ensure that the age data would be representative of the size distribution observed during the surveys. The age data collected from the otoliths were in fact age group assignments that are based on the number of putative

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annuli (hyaline zones considered to represent the end of a year of growth). A fish with no annuli visible in the otolith will therefore be considered to be still in its first year of growth, and will consequently be assigned to the 0+ age group. This age group will therefore encompass fish ranging in age from 0 to 0.99 years of age. A fish that displays one annulus in its otoliths will have completed its first year of growth and be in the second year of growth at the time of sampling, and will be assigned to the 1+ age group. The 1+ age group will therefore encompass all fish of between 1 and 1.99 years of age. Similarly, the 2+ age group will encompass all fish of between 2 and 2.99 years of age displaying 2 annuli in their otoliths. The age data are illustrated in Figure 1 as size-at-age plots for the 2005 and 2006 samples respectively. The parameters of the von Bertalanffy growth models fitted to the data from the two years were:

2005:	L_∞= 20.6	2006:	L_∞= 21.7
	K = 0.39		K = 0.35
	t_0 = -2		t_0 = -2

The variability in size within age group 0+ is clearly apparent in these figures.

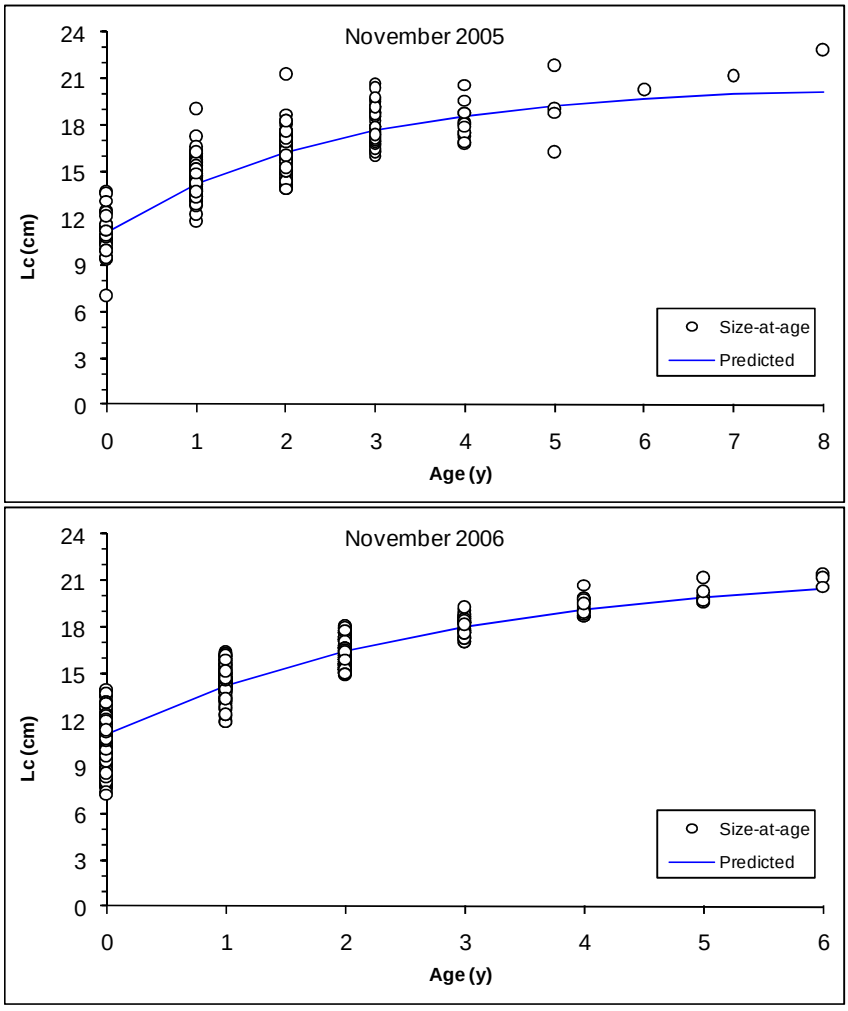


Figure 1: Redeye size-at-age from the 2005 and 2006 samples.

The distribution of size classes within each age group are illustrated in Figure 2. Examination of these figures suggests some error in age group assignments, particularly with regard to age groups 1+ and 2+. It is likely that most of the fish in the 2005 13.5 – 15.0 size classes are in fact 1+ fish, rather than 2+ as is illustrated. A similar observation applies to the 15.0 – 15.5 size classes in the 2006 data. In both data sets, it is also likely that there are some errors in the classification of 0+ fish in the 13 and 13.5 cm size classes. It may also be that most of the 3+ fish falling in the 16 to 17 cm size classes in the 2005 data are in fact 2+ fish. In general, it would therefore appear that most 0+ fish span the size classes below about 13 cm, 1+ fish range from about 12 cm to 17 cm, 2+ fish dominate the 16 to 17.5 cm size classes while 3+ fish fall within the 17 to 19 cm size classes.

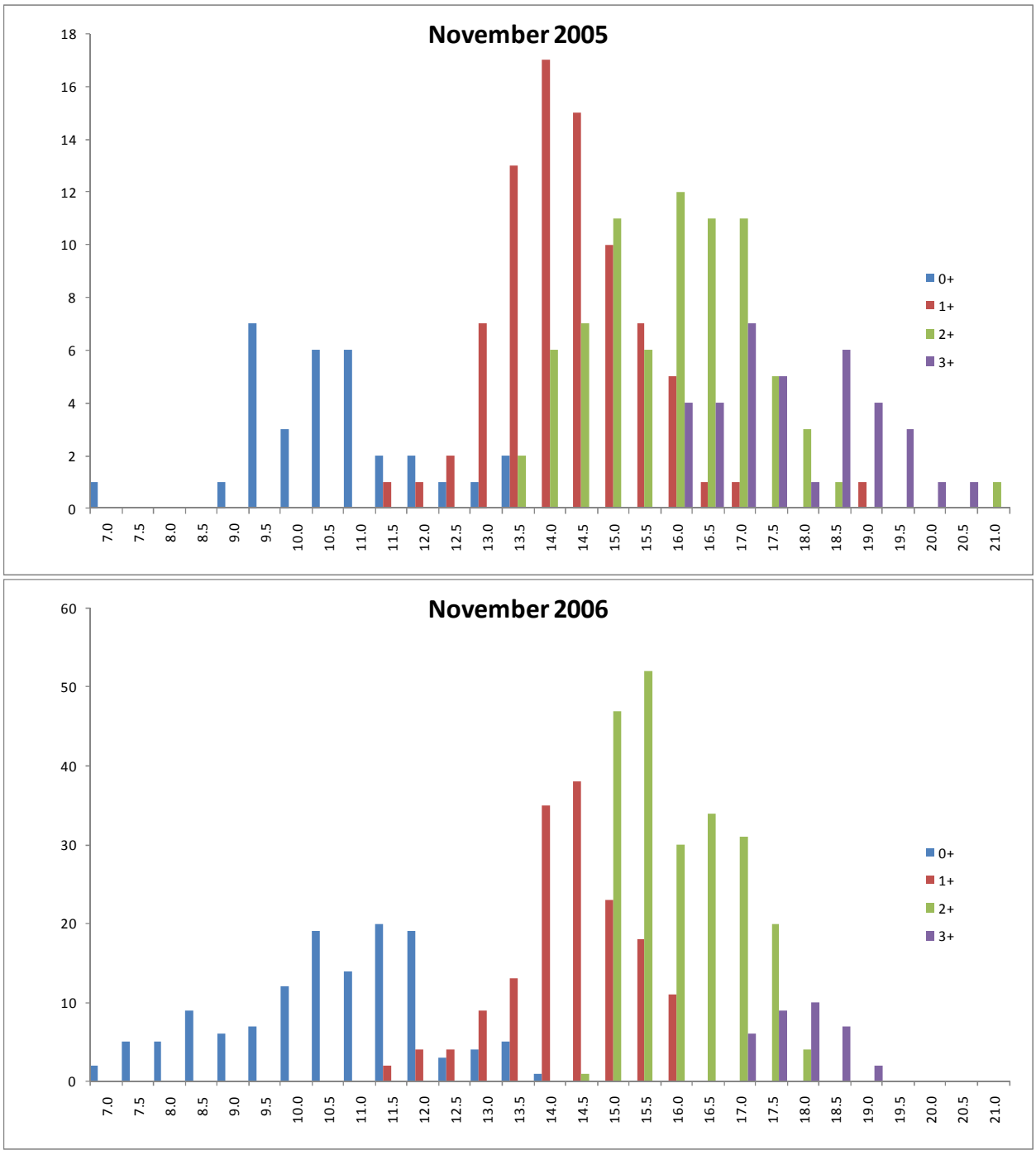


Figure 2: The distribution of size classes within redeye age groups 0+ to 3+. The older age groups are not illustrated for the purposes of clarity.

The results of an unpublished daily ageing study conducted by Miranda Waldron (University of Cape Town Electron Microscopy Unit) have been made available. Otoliths of redeye were prepared for examination by scanning electron microscopy, and counts of the total number of daily increments in each otolith recorded from micrographs of the specimens. Data from 31 fish ranging in size from 5.8 to 19 cm are illustrated in Figure 3. These data suggest that redeye roundherring reach a size of about 12 cm in a year.

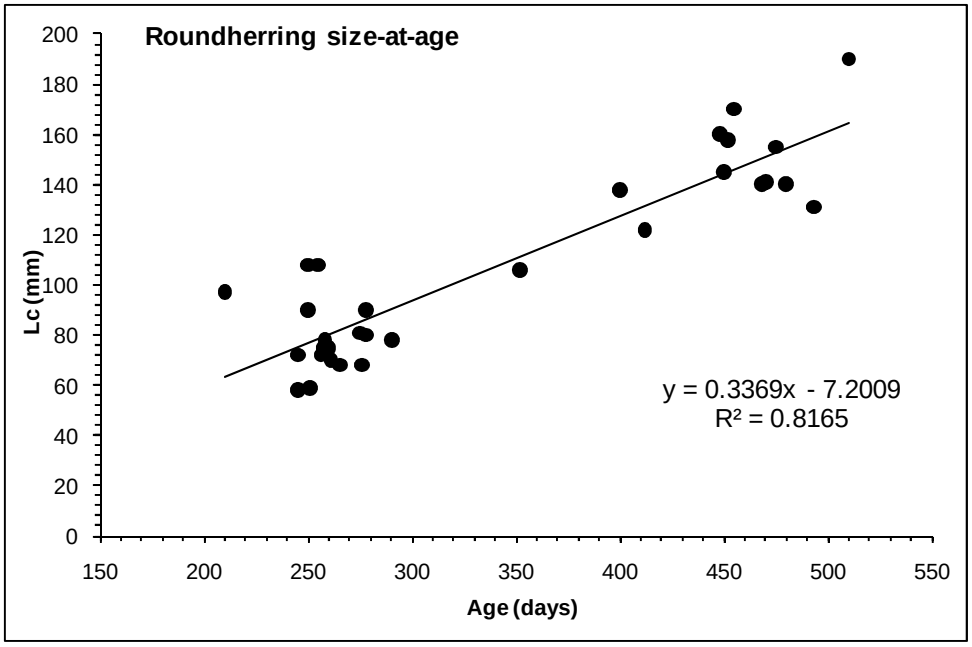


Figure 3: Size-at-age data arising from the daily ageing study of Miranda Waldron.

Size distribution

Sampling of pelagic fish species during the routine pelagic hydroacoustic abundance surveys includes measurements of the lengths of a minimum of 100 fish per trawl (more fish are measured if the size distribution is not unimodal). These data are raised to the population level using the acoustic weighting factors described by de Moor and Butterworth (2009). Length frequency distributions of redeye from the November Spawner Biomass Surveys over the period 2000 – 2009 are illustrated in Figure 4.

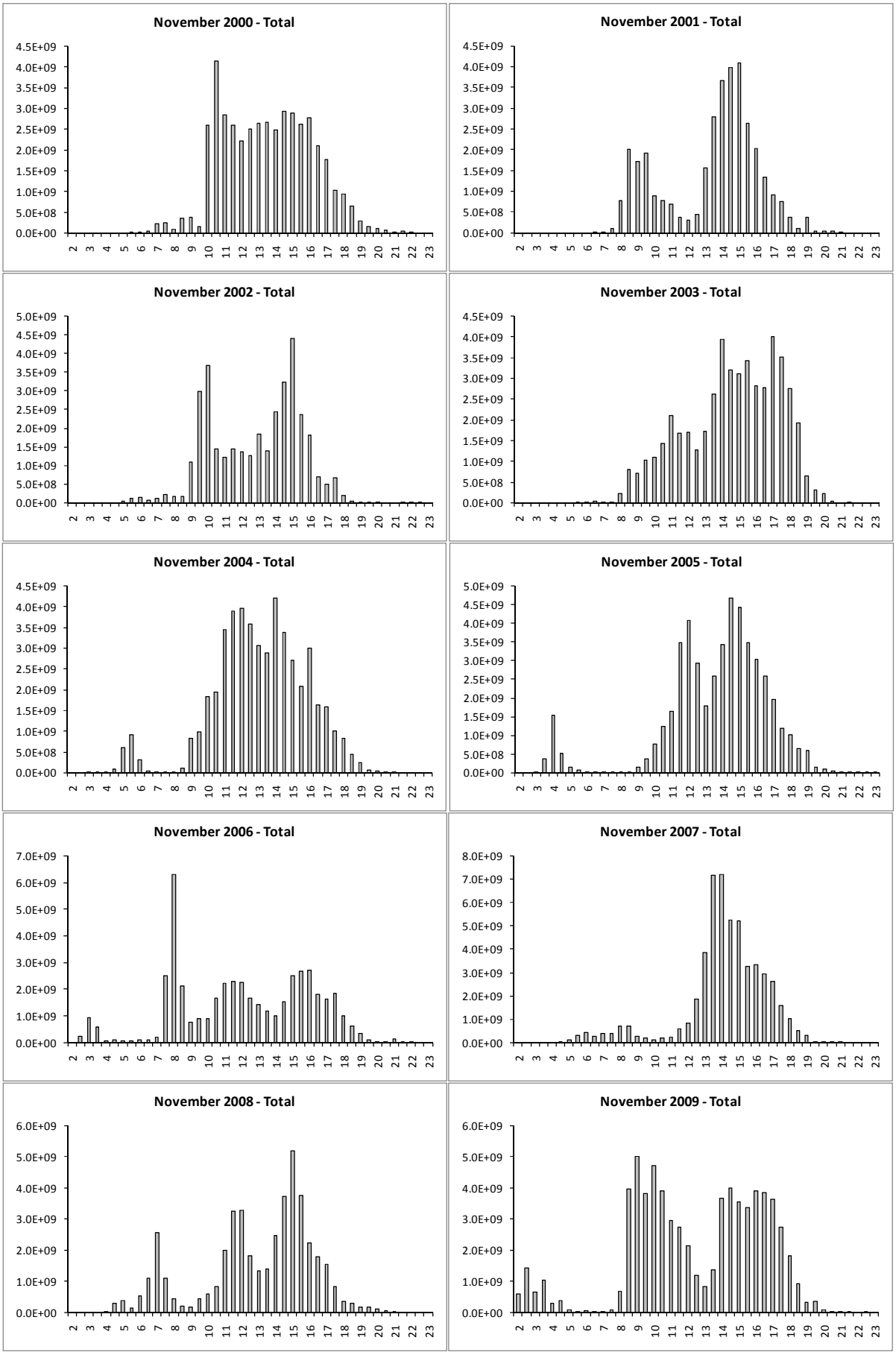
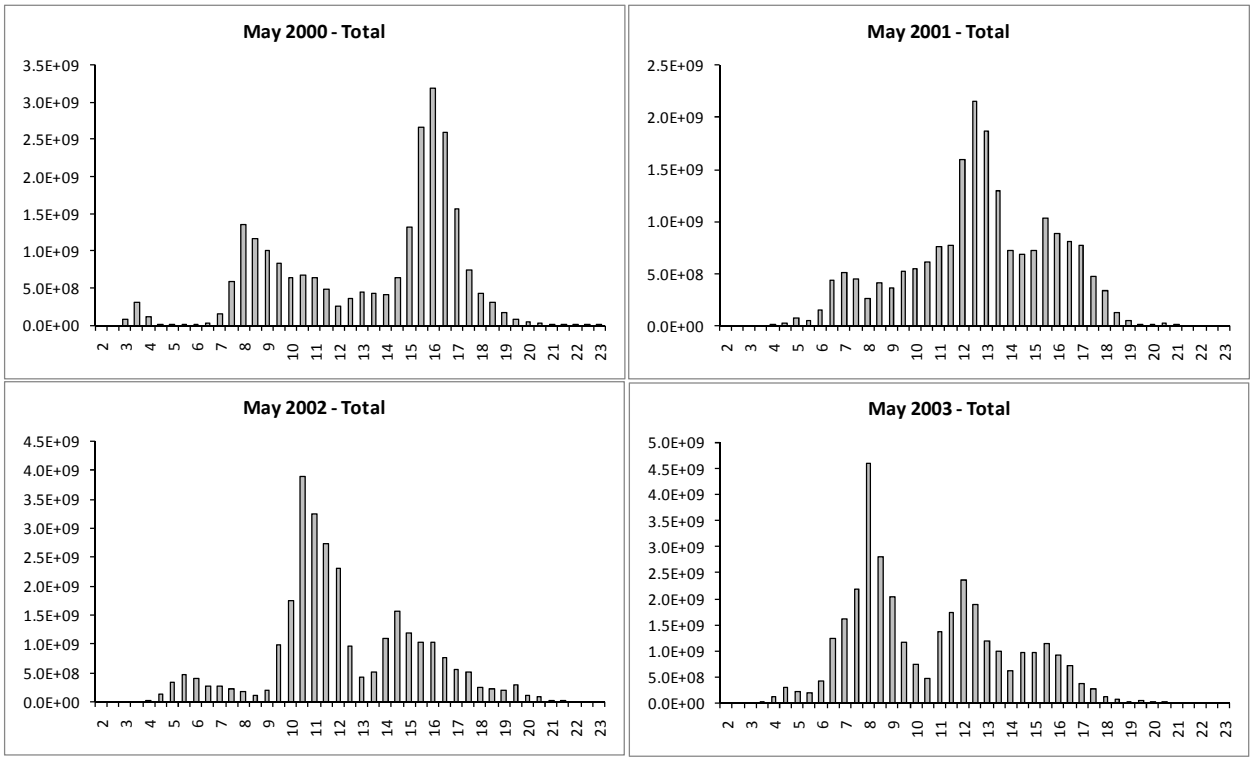


Figure 4: Raised length frequency distributions of redeye from the November Spawner Biomass Surveys over the period 2000 – 2009.

Examination of these distributions suggests a relatively complex size structure in the redeye population, with several modes apparent in most years. Assuming that the data are representative of the redeye population at the time of the surveys, it would appear that the 0+ age group frequently comprises two, and sometimes three sub-cohorts spawned at different times of the year. This is clearly shown in the November 2006 data where two prominent modes of 7- 8 cm and 11 – 12 cm are present, roughly corresponding to the two modes in the 0+ length frequency data illustrated in Figure 2. A third mode of 15 cm corresponds to the 1+ age group (see Figure 2). A group of small fish ranging from 2.5 to 5 cm was also sampled in some years (2004, 2005, 2006 and 2009), probably arising from the most recent spawning event in each year. This multi-modal structure appears to be a relatively consistent feature that is also apparent in the overall length frequency distributions from 2002, 2008 and 2009. In some years, however, one of these modes may be absent (e.g. the 8 cm mode in 2004 and 2005), suggesting either spawning events of low intensity, or reduced survival of the particular sub-cohort. There is also some variability in the size of the various modes, indicating growth differences between the various years (e.g. 8 cm in 2006 versus 7 cm in 2008). Application of the daily ageing data illustrated in Figure 3 to this size structure shows that fish of 8 cm are about 260 days (9 months) old, while 11.5 cm fish are 363 days (12 months) old. The size of the 1+ age group (15 cm) indicates an age of 467 days (16 months). These values suggest:

Cohort	Age (months)	"Birth" month
3 cm	4	July
7 cm	8	March
11.5 cm	12	November previous year
15.5 cm	16	July previous year

Examination of length frequency data from the May Recruit surveys reveals a similar pattern (Figure 5), again with modes at about 3 – 3.5 cm, 7 – 8 cm, 10 – 12 cm and 15 – 16 cm.



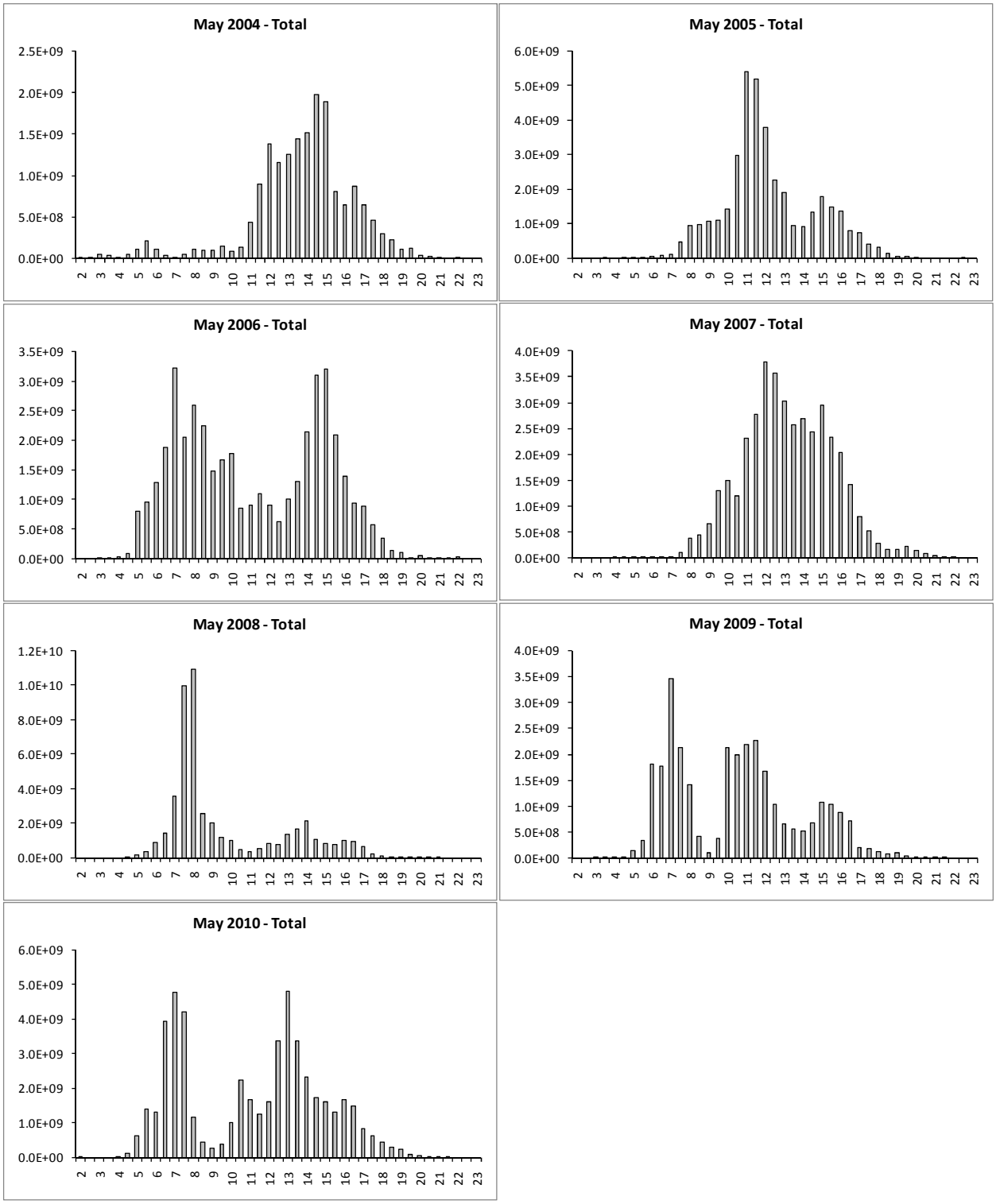


Figure 5: Raised length frequency distributions of redeye from the May Recruit Surveys over the period 2000 – 2010.

Applying a similar approach as before:

Cohort	Age (months)	"Birth" month
3 cm	4	January
8 cm	9	August previous year
11.5 cm	12	May previous year
15.5 cm	16	January previous year

It would therefore seem likely that there are three spawning events each year: the first in summer (January – March), the second in winter (May – July) and a third protracted spawning in late spring – early summer (August – November).

Redeye growth curve

A von Bertalanffy growth curve in cm and year units was fitted to the daily ageing data from Waldron (Figure 3). This resulted in a growth curve with an unrealistically high L_∞ of 215cm (Figure 6). This is unsurprising as daily ageing data usually only provide accurate relationships for young fish still in the rapid phase of their growth trajectory while the ages of larger, older fish are likely to be underestimates that do not reflect the asymptotic growth phase. This results in a von Bertalanffy model that is almost linear in nature, yielding an overestimate of the maximum size of the species. A von Bertalanffy growth curve was then fitted to both these daily ageing data as well as the length-at-ages 2 to 10 arising from the average von Bertalanffy growth curves of November 2005 and 2006 survey data (Figure 1, with $L_\infty = 21.15$ cm, $\kappa = 0.37$, and $t_0 = -2.0$). The resultant growth curve has a high $t_0 = 0.32$ (Figure 6) implying that redeye only reach 1cm between 4 and 5 months of age, contrary to suggestions (above) that they should be about 3cm at this age. A new von Bertalanffy growth curve was therefore obtained using the Waldron daily ageing data together with the average length-at-ages 2 to 10 from the November survey data, with the constraint that $t_0 \leq 0.1$ in order to obtain a growth curve consistent with all observations. The resultant growth curve, with parameter values of $L_\infty = 20.30$ cm, $\kappa = 0.94$, and $t_0 = 0.1$ is able to reasonably fit the two clusters of daily ageing data and produce a good fit to the length-at-ages 2 to 10 while maintaining a realistic length-at-age for ages less than those observed by Waldron (Figure 6).

Although a functional form more complex than von Bertalanffy could be used to fit these data and obtain reasonable behavior at small ages, the benefits to be gained by such a curve would likely be small. Thus this third growth curve is taken to be the best representation of redeye growth at this point in time and will be used to model growth in the redeye assessment (de Moor and Butterworth 2010).

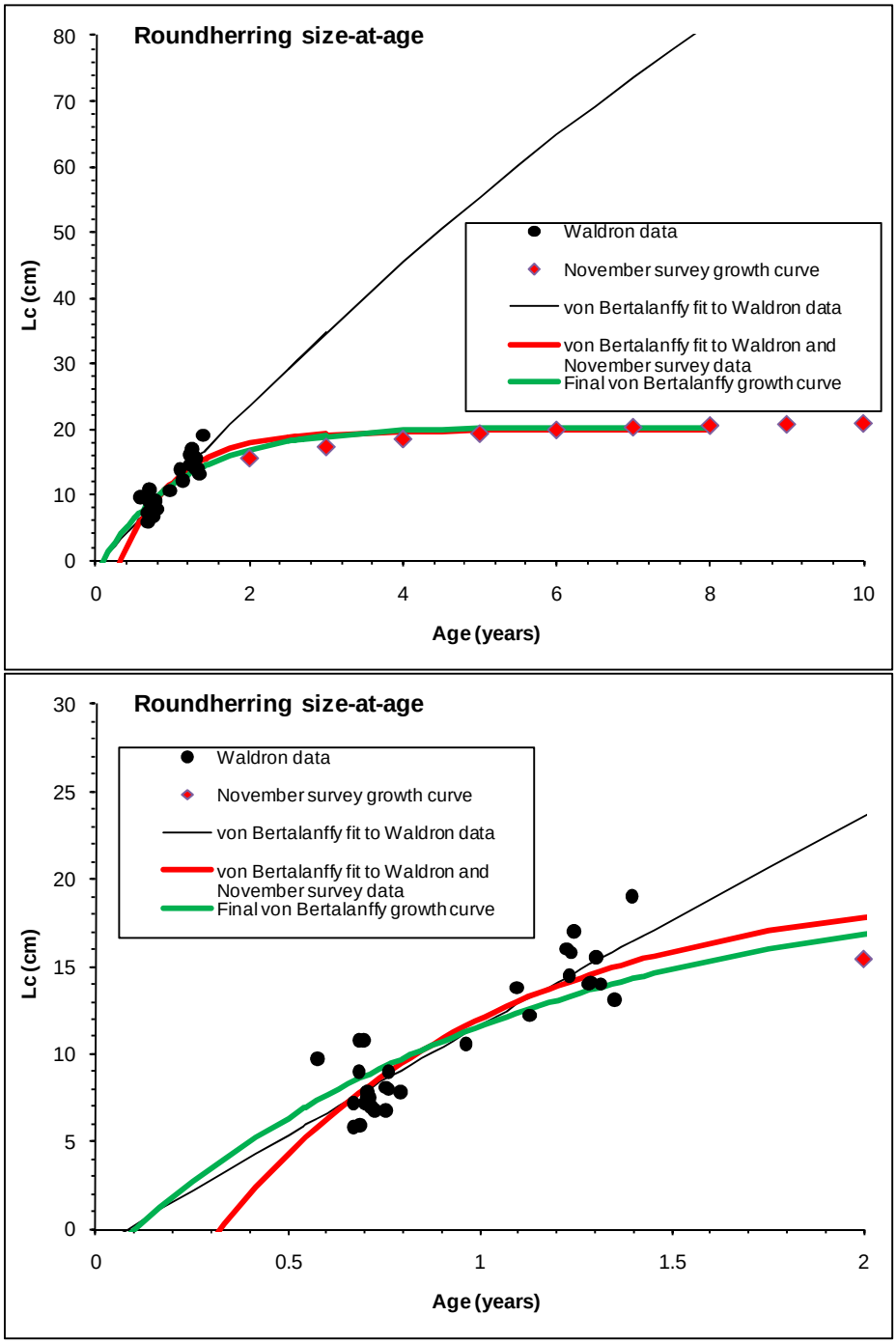


Figure 6: Von Bertalanffy growth curves obtained by fitting to i) daily ageing data from Waldron, ii) together with average lengths-at-ages 2 to 10 from the 2005 and 2006 November surveys, and iii) together with a restriction such that $t_0 \leq 0.1$.

Summary

The examination of redeye age and size distribution data has revealed the likelihood of the existence of three sub-cohorts each calendar year, an (early) summer (January – March) sub-cohort, a (peak) winter (May – July) sub-cohort and a (late) spring (August-November) sub-cohort. A von Bertalanffy growth curve has been fit to daily ageing data for young fish and length-at-age data for older fish. These two key sources of information will be used to model the redeye population.

Further work required on the ageing:

- Explore the likely error in the identification of the first annulus. This would be aimed at improving the classification of the 1+ and 2+ age groups in particular.
- Attempt to define criteria describing the otolith structure of the three cohorts in young fish. This may allow identification of which period corresponds to peak spawning/survival though identification of the "source" cohort of the older fish in the population.

References

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