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An investigation of the effect of temporal variation in growth rate of Umbrina robinsoni on biological reference point estimates calculated using per-recruit models

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Short Communication

An investigation of the effect of temporal variation in growth rate of *Umbrina robinsoni* on biological reference point estimates calculated using per-recruit models

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The effect of temporal variation in growth rate on per-recruit model outputs was investigated by comparing biological reference points obtained using growth curves derived for *Umbrina robinsoni* populations from False Bay, on the south coast of South Africa, sampled 10 years apart (1991–1993 and 2001–2003), and applying the two different age–length keys to length frequency data collected over the period 1991–1993 (n = 1 389) for the estimation of total mortality (Z), fishing mortality (F) and spawner biomass per recruit (SB/R). The SB/R and yield per-recruit (Y/R) curves constructed using biological data collected during the two different time periods were very similar, with target and threshold reference points differing only moderately (11%). This suggests that for long-lived species, the frequency of age and growth studies can be at least the lifespan of a cohort if they are to be assessed with a per-recruit approach. The use of the more recent length-at-age data, however, resulted in lower estimates of F (0.61 y^{-1} vs 1.05 y^{-1}) and a slightly higher spawner biomass per-recruit ratio (19.5% vs 14.5%) for the earlier period. The reduced estimate of F when using the more recent dataset was likely due to a bias towards older fish caused by small sample size, the philopatric nature of *U. robinsoni*, and possible recruitment collapse. This highlights the importance of having a large, representative sample of length-at-age data for construction of age–length keys.

Keywords: growth rate variation, management, Sciaenidae, slender baardman, stock assessment

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Introduction

Data requirements for per-recruit stock assessment models are considerably less rigorous than those required for more intensive models such as virtual population analyses or dynamic age-structured production models, but do require accurate data on the length–weight relationship, age/size at maturity (t_m), natural mortality (M), fishing mortality (F) and growth parameters (Butterworth et al. 1989). The collection, sectioning and ageing of large numbers of otoliths is nevertheless expensive; and often difficult to justify for stocks, such as *Umbrina robinsoni*, that generate small economic returns. The cost of age and growth studies is also influenced by the frequency with which age–length keys are updated. Owing to possible temporal variation in growth, it is generally accepted that catch should be aged each time that length measurements are collected for mortality estimation (Griffiths et al. 1999). In this paper, the growth of *U. robinsoni* from False Bay, on the South African south coast, for the periods 1991–1993 and 2000–2003 are compared, and the impacts of failing to update growth rates and length-at-age are evaluated with per-recruit analysis.

Material and methods

For details on biological data collection, mortality estimates and per-recruit analysis, see Hutchings and Griffiths (2010a). The three parameter von Bertalanffy growth model was fitted to False Bay *U. robinsoni* length-at-age datasets collected 10 years apart (1991–1993 and 2001–2003). The resultant growth models and model parameters were compared using likelihood ratio tests (Draper and Smith 1966). Approximate joint 95% confidence regions around L_∞ and k were determined by conditioning on t_0, conducting 1 000 parametric bootstraps and using the percentile method to determine the 95% confidence interval for each

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parameter. Observed mean length-at-age for the two time periods was also compared using *t*-tests and Mann-Whitney *U*-tests (Zar 1996). Further details on growth curve fitting and the likelihood ratio tests used are provided in Hutchings and Griffiths (2010b).

Spawner biomass per-recruit (SB/R) and yield per-recruit (Y/R) curves were constructed using the two different growth models. Target (F_{SB40}) and threshold (F_{SB25}) reference points were calculated for the two time periods. In order to investigate the effect of temporal variation in growth rate on estimates of total mortality (*Z*) and *F*, these values were calculated using the age–length keys constructed from data collected during the two time periods and applied to random length frequency data collected during the period 1991–1993 (n = 1 389). The length frequency data collected during the earlier period was used for this comparison due to the superior sample size. Current (1990–1993) SB/R and Y/R values were calculated using each of the age–length keys.

Results

Three-parameter von Bertalanffy growth curves fitted to the observed length-at-age data for the two time periods sampled at False Bay are shown in Figure 1. Although likelihood ratio tests show significant differences (p < 0.05) for the fitted curve and the estimated L_∞ parameter, comparison of fitted curves 95% confidence intervals (Figure 1) indicates very similar growth in False Bay during these two time periods (curves are parallel with overlapping confidence limits up to 13 years age). There is an indication that fish sampled during 2001–2003 were slightly larger at age and attained a larger maximum size than fish sampled during 1991–1993. Statistical tests of the mean length-at-age only show this difference to be significant for 3- to 6-year-olds (Table 1). The approximate joint 95% confidence regions around L_∞ and k are also close together in parameter space (Figure 2), which suggests that the statistically significant differences in fitted growth curves may not represent real differences in growth between the two periods.

The effect of these slight differences in fitted growth curves on mortality estimation and per-recruit outputs is shown in Figure 3. The SB/R and Y/R curves constructed using biological data collected during the two time periods were very similar, with target (F_{SB40} = 0.27 y^{-1} in 1991–1993; F_{SB40} = 0.24 y^{-1} in 2001–2003) and threshold (F_{SB25} = 0.51 y^{-1} and F_{SB25} = 0.45 y^{-1} respectively) reference points differing only slightly (11%). Current *Z* and *F* estimated from the 1991–1993 length frequency data using the two different age–length keys was, however, considerably different (42% reduction in *F* when using the 2001–2003 age–length key). Despite the substantially lowered estimate of *Z* and *F* when using the more recent age–length key, estimated stock status was only slightly improved (SB/R = 14.5% SB/R$_{F=0}$, SB/R = 19.5% SB/R$_{F=0}$ using 1991–1993 and 2001–2003 age–length keys respectively).

Table 1: Statistical comparison of mean length at age of False Bay *U. robinsoni* sampled 10 years apart. Student's *t*-test or Mann-Whitney *U*-statistic is given

Age (y)	Mean length (TL, mm)			
	1991–1993 (n, SD)	2001–2003 (n, SD)	Statistic	p
1	160 (1)	243 (3, 28)	–	
2	321 (15, 25)	328 (14, 44)	U = 101.5	p > 0.05
3	382 (55, 28)	420 (29, 36)	t = 5.22	p < 0.001
4	463 (116, 40)	481 (34, 35)	t = 2.39	p < 0.05
5	510 (22, 37)	538 (25, 29)	t = 2.84	p < 0.01
6	581 (24, 43)	601 (12, 48)	t = 1.23	p < 0.05
7	622 (7, 57)	597 (3, 16)	U = 5.5	p > 0.05
8	665 (2, 14)	656 (3, 96)	U = 2	p > 0.05
9	629 (4, 34)	712 (8, 36)	U = 1	p > 0.05
10		743 (10, 77)	–	
11	658 (2, 32)	704 (1)	–	
12		783 (2, 29)	–	
13	780 (1)		–	
15		793 (1)	–	
16		805 (1)	–	
18		774 (1)	–	

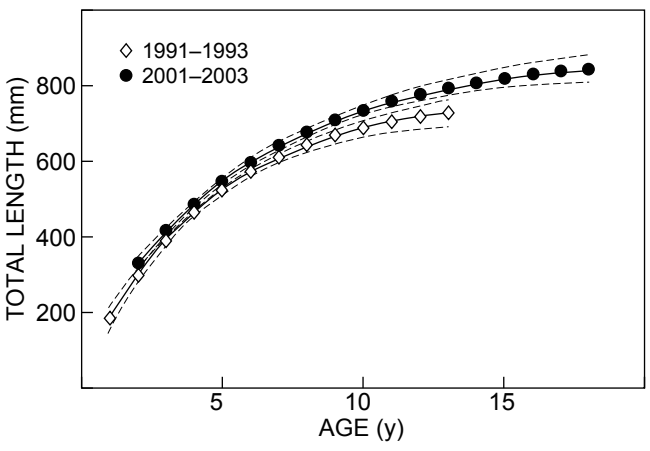

Figure 1: Three-parameter von Bertalanffy growth curves fitted to length-at-age data for *U. robinsoni* sampled at False Bay 10 years apart. Dashed lines indicate 95% confidence limits of the fitted curves

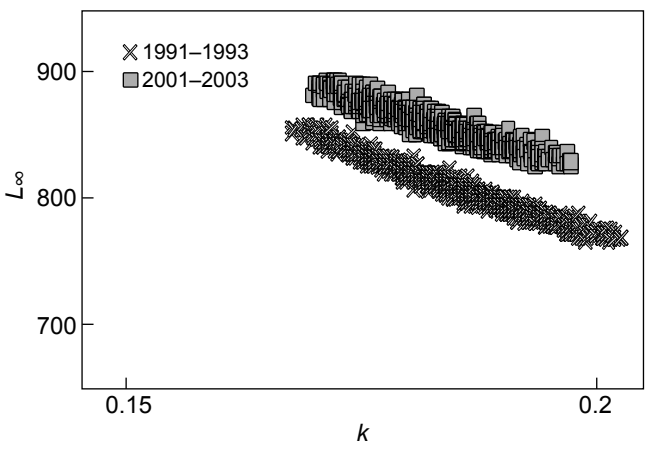

Figure 2: Approximate joint 95% confidence regions around von Bertalanffy parameters L_∞ and k calculated by conditioning on t_0 and conducting 1 000 bootstraps for *U. robinsoni* sampled at False Bay during 1991–1993 and 2001–2003

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Discussion

Possible explanations for the large discrepancy in estimated *Z* for the 1991–1993 period when using the two different age–length keys include: (1) potential negative bias in the estimate when using the 2001–2003 age–length key caused by inadequate sample size of age–length data; (2) the data were not representative of the exploited population as a whole (due to the influence of philopatry and spatial refugia); and (3) the possibility of collapsing recruitment.

Explanation 1

The lower 2001–2003 estimate of *Z* could be a result of the smaller length-at-age dataset (142 vs 249), which included a substantial number of large (old) fish that were captured by research seine-netting in areas not open to commercial seine operators (although shore-anglers do target the species extensively in the area). The resulting bias towards older fish in the population age distribution would have led to underestimation of *Z*. The finding that 1991–1993 SB/R was also estimated at 19.5% $SB/R_{F=0}$ when using the large 1991–1993 length frequency dataset in conjunction with the 2001–2003 age–length key, suggests that this is likely.

Explanation 2

This is related to the effects of philopatric behaviour (i.e. limited mixing of fish in a population) on the estimation of *Z* using catch-at-age methods, as discussed above. The Macassar area in False Bay, from which most of the 2001–2003 samples were obtained, has extensive areas of offshore mixed reef and sand habitat (ideal for *U. robinsoni*) that cannot be exploited by shore-anglers (limited by casting distance) or spearfishers (because of persistent low visibility and the known abundance of large sharks). It is likely that these areas act as spatial refuges for *U. robinsoni* in False Bay. As the bay population is at the southern extreme of the species' range (Hutchings and Griffiths 2005), movements in response to changes in water temperature are expected. Populations from these refuge areas appear to become temporarily available to shore-anglers (and samplers) when upwelling-induced decreases in water temperature cause an inshore movement of fish. In an analysis of False Bay shore-angling club records over the period 1938–1992, Bennett et al. (1994) noted a bimodal seasonal trend in catch rates of *U. robinsoni*, with relatively high catch rates recorded during autumn and spring (periods when upwelling-inducing south-easterly winds are strongest). Griffiths (1997) also noted a seasonal onshore (summer) and offshore (winter) movement of the sciaenid *Argyrosomus inodorus* in False Bay. By sampling *U. robinsoni* predominately from the Macassar area during periods of temporary availability during 2001–2003, it is possible that this estimate of *Z* reflects that of the refuge population rather than that of the exploited population as a whole.

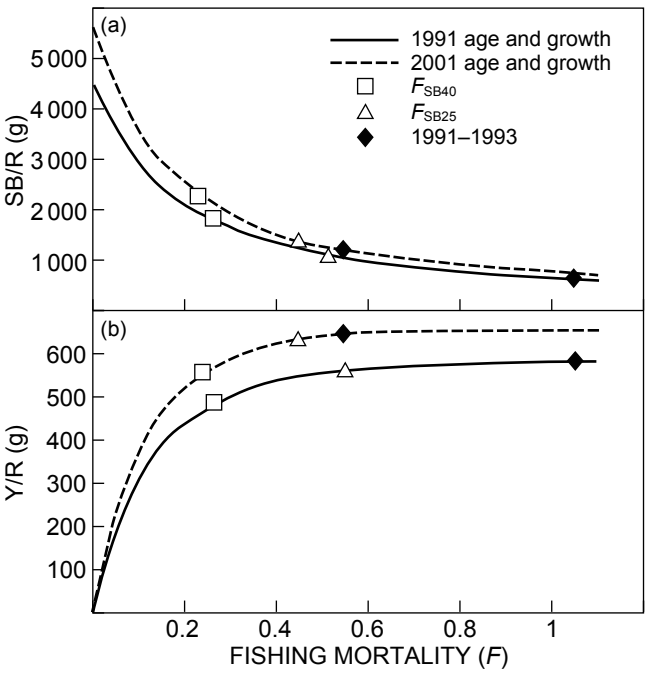

Figure 3: Relationship between fishing mortality (*F*) and spawner biomass (SB/R) and yield per-recruit (Y/R) for False Bay *U. robinsoni* using age and growth data collected at two different time periods. Squares represent the target reference point (F_{SB40}), triangles the threshold reference point (F_{SB25}) and closed diamonds the current (1991–1993) fishing mortality estimated using 1991–1993 length data and age–length keys for both periods

Explanation 3

Murphy and Crabtree (2001) detected an increase in abundance of adult red drum *Sciaenops ocellatus* (a North American sciaenid species) in observed age distributions, and attributed this to increased juvenile survival due to catch restrictions imposed a decade earlier. As there were no such changes in the catch restrictions for South African *U. robinsoni* over the decade of study, and fishing effort probably increased, an alternative and more concerning explanation (given that the risk of stock collapse was already high in 1991–1993) is that recruitment in the False Bay area could be collapsing. This would lead to the loss of the younger year classes in the catch-at-age data and consequently lower, inaccurate *Z*-estimate, when in reality *F* has increased. The fact that during 1991–1993, commercial beach-seines landed well over 1 000 *U. robinsoni,* whereas between 2001 and 2003 less than 100 were caught by the same operators (with approximately the same effort) suggests that this may have occurred. The influence of variable year-class strength on the estimation of *Z* cannot be discounted (e.g. a large cohort of young fish during 1991–1993, resulting in overestimation of *Z*), but even in the absence of strong, young year classes and a more than likely underestimate of *Z* and *F* obtained during 2001–2003, the False Bay *U. robinsoni* stock is still classified as collapsed.

Given the similarity in the fitted growth curves (Figures 1, 2) and the per-recruit curves (Figure 3), it is clear that the major cause of the discrepancy in 1991–1993 SB/R ratios is on account of the different estimates of *F* when using the two different age–length keys rather than changes in growth rate. As different researchers collected the data during the two time periods, there is a strong possibility that differences in measurement techniques and sampling times influenced the observed length-at-age results. The uncertainty as to

the causes of the small temporal variation in growth rate (whether it is real or simply an artefact of sample size and methodology), and the fact that it did not appreciably influence per-recruit curves or biological reference point estimates, suggests that for moderately long-lived species, the frequency of age and growth studies can be at least the lifespan of a cohort, if they are to be assessed with a per-recruit approach. The substantial difference in estimated *Z*, however, does highlight the importance of having a large, representative sample of length-at-age data for construction of age–length keys.

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References

Bennett BA, Attwood CG, Mantel JD. 1994. Teleost catches by three shore-angling clubs in the South-Western Cape with an assessment of the effect of restrictions applied in 1985. *South African Journal of Marine Science* 14: 11–18.

Butterworth DS, Punt AE, Borchers DL, Pugh JB, Hughes GS. 1989. *A manual of mathematical techniques for linefish assessment* (incorporating the report of the SANCOR Marine Linefish Programme's workshop on population dynamics, 4–6 February 1987, Cape Town). South African National Scientific Programmes (SANSP) Report 160. Pretoria: Foundation for Research and Development.

Draper NR, Smith H (eds). 1966. *Applied regression analysis.* New York: Wiley.

Griffiths MH. 1997. The life history and stock separation of the silver kob, *Argyrosomus inodorus*, in South African waters. *Fishery Bulletin, Washington* 95: 47–67.

Griffiths MH, Attwood CG, Thompson R. 1999. New management protocol for the South African linefishery. *Occasional Report of the South African Network for Coastal and Oceanographic Research* 5: 145–156.

Hutchings K, Griffiths MH. 2005. Identity and distribution of southern African sciaenid fish species of the genus *Umbrina. African Journal of Marine Science* 27: 1–21.

Hutchings K, Griffiths MH. 2010a. Assessment of South African *Umbrina robinsoni* based on per-recruit models. *African Journal of Marine Science* 32: 511–523.

Hutchings K, Griffiths MH. 2010b. Life-history strategies of *Umbrina robinsoni* (Sciaenidae) in warm-temperate and subtropical South African marine reserves. *African Journal of Marine Science* 32: 37–53.

Murphy MD, Crabtree RE. 2001. Changes in the age structure of nearshore adult red drum off west-central Florida related to recruitment and fishing mortality. *North American Journal of Fisheries Management* 21: 671–678.

Zar JH. 1996. *Biostatistical analysis.* Upper Saddle River, New Jersey: Prentice-Hall.

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