

# WHAT CAN GROWTH TRAJECTORY TELL US ABOUT THE NUTRITIONAL STATE OF FISH LARVAE?

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## Abstract

The growth trajectory of marine fish larvae may vary in a predictable way depending on nutritional state. Using examples from Australian research; greenback flounder (*Rhombosolea tapirina*) and jack mackerel (*Trachurus declivis*) which were apparently not food limited, showed exponential growth. In contrast, southern bluefin tuna (*Thunnus maccoyii*) larvae, from a concentrated patch where density dependent limitation of feeding and growth was apparent, often showed linear to reducing growth over time. Southern bluefin larvae collected away from the patch, however, showed exponential growth. Furthermore, larvae of long-snouted flounder (*Ammotretis rostratus*) from the field showed strong exponential growth; however, when reared in the laboratory under inadequate conditions (poor survival), growth was linear. Thus, it appears that growth trajectory may be a useful gross indicator of larval condition. The importance of growth rate in the determination of larval survival rate and recruitment success is still open to question. For example, in some species such as King George whiting (*Sillaginodes punctatus*) maximising the chance of finding a suitable habitat for settlement through flexible larval duration may be more important than maximising growth rate in older larvae.

Growth is considered to be a major factor in larval survival through its interaction with size selective predation (Shepherd and Cushing 1980;

Smith 1985). That is, slower growing larvae will spend longer in the vulnerable stages (Bailey and Houde 1989). Growth trajectory may be examined using daily increments on a population basis or for individual larvae by backcalculation (Jenkins and Davis 1990). This paper discusses, with examples from Australian research, the use of the shape of the growth trajectory as an indicator of larval growth and condition as an alternative to a detailed comparative study of growth rates.

Work on southern bluefin tuna larvae in oligotrophic waters off the northwest of Australia indicated that there was a 25% reduction in growth inside a concentrated patch compared with outside the patch due to competition for food (Jenkins *et al.* 1991). This was reflected in growth trajectories determined from backcalculation; growth trajectories of larvae within the patch were approximately linear, in some cases negative, whilst outside the patch growth was exponential (Figure 1). This suggests that the linear growth trajectory of larvae within the patch was indicative of poor growth.

In another example from Australian research, population based growth of flounders, *Rhombosolea tapirina* and *Ammotretis rostratus*, in Port Phillip Bay was exponential (Figure 2). These species have also been reared in the laboratory under conditions of excess food by Crawford (1984). Growth of *R. tapirina* over the first 30 days in ambient seawater was exponential and the rate was similar to that of larvae from

Port Phillip Bay (Jenkins 1987). In contrast, larvae of *A. rostratus* grew very slowly in the laboratory relative to the field, and the growth trajectory was approximately linear. While the majority of *R. tapirina* larvae survived, very few *A. rostratus* larvae survived (Crawford 1984). This suggests once again that exponential growth in this species is indicative of good condition while linear growth is indicative of poor condition. These results also suggest that field-collected larvae were not strongly food limited. Larvae of jack mackerel collected off the east coast of Tasmania in 1989 were also apparently not food limited (A. Jordan, pers. comm.), and once again growth was exponential (Figure 3). Exponential growth trajectories may be accentuated in areas with high predation such that slow growing larvae are rapidly removed.

Overseas research supports the contention that larval growth is typically exponential (eg. Bolz and Lough 1983; Fives *et al.* 1986; Fukuhara 1986; Comyns *et al.* 1989; Palomera *et al.* 1988) probably because mobility and ability to capture prey increases rapidly in the early larval stage (Hunter 1981). In fact growth from the early larval stage is typically best described by a Gompertz curve because larval growth is exponential (Zweifel and Lasker 1976). Where linear models have been fitted to growth data, the variability in the data is usually such that the true shape of the growth trajectory would be impossible to determine (eg. Cowan 1988). It is likely that only in extreme cases of food limitation in the laboratory or the field will true linear growth be detected. Where food limitation is present, but not extreme, it will be expressed as temporal or spatial variation in the rate of exponential growth. Detecting this variation will require relatively large sample sizes for sufficient statistical power. However, simply by examining the backcalculated growth trajectories of a few larvae, the shape of the growth trajectory (ie linear vs exponential) may indicate whether severe food limitation is occurring.

Linear, rather than exponential growth trajectories may also occur when larvae experience low water temperatures relative to the

normal range. For example, Methot and Kramer (1979) determined growth trajectories of northern anchovy, *Engraulis mordax*, larvae from the field and laboratory, and growth trajectories ranged from linear at the lowest temperatures to moderately exponential at higher temperatures. Temperature effects will have to be taken into account if growth trajectory is to be used as a measure of condition. In the case of southern bluefin tuna larvae, temperature conditions were relatively constant over all samples (Jenkins *et al.* 1991)

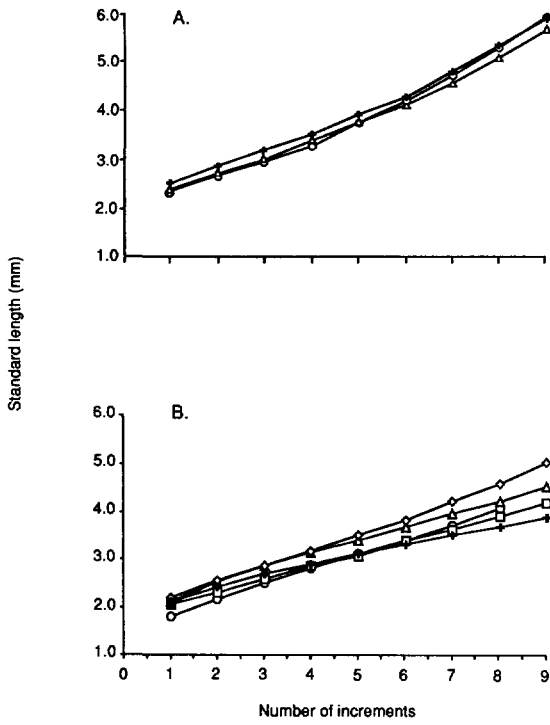
The importance of growth rate to survival of larvae is still under question. While early growth in most larvae appears to increase exponentially, in a number of larvae there is a marked reduction in growth at the end of the larval stage. For example, King George whiting, *Sillaginodes punctatus*, larvae show an exponential increase in daily increment width, which would be proportional to growth rate (B. Bruce, personal communication; B.D. Stewart, unpublished data), in early stages (Figure 4). However there is a marked decrease in growth at the end of the larval stage before a rapid exponential increase upon settlement (Figure 5). This pattern has also been observed in a number of labrid species (Victor 1986; Cowan 1991). It is possible that high growth rate is particularly important in the youngest stages due to vulnerability to size-selective predation. For example, Brothers *et al.* (1983) found that young juvenile bluefin tuna, *Thunnus thynnus*, were derived from the fastest growing fraction of larvae. However, particularly in benthic fishes, factors relating to successful settlement may become more important in later stages, i.e. the flexibility to remain in the plankton at the optimal size and stage of development for settlement until a suitable juvenile habitat is found.

In summary, we may not need to know the full range of potential growth rates to determine if larvae are severely food limited; simply determining the shape of the growth trajectory may tell us this. Such severe food limitation may be more likely in species such as southern bluefin tuna where larvae occur in concentrated patches

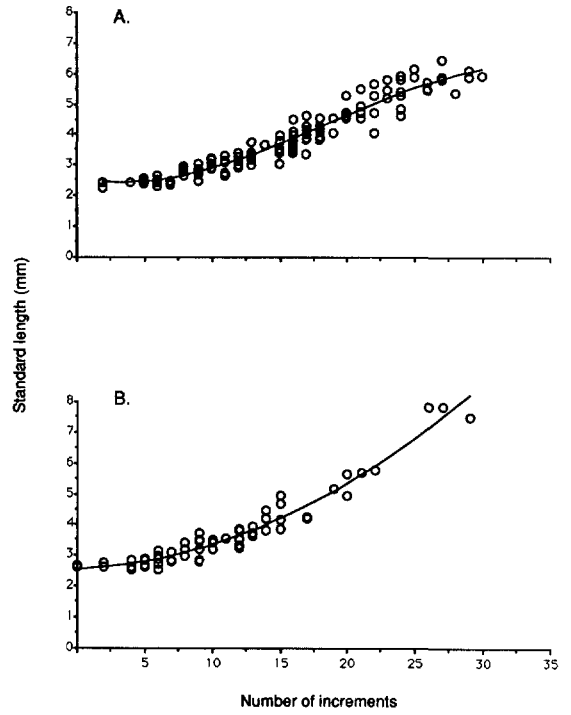
in oligotrophic/oceanic waters. Australian research on larval fish ecology has yet to detect such severe food limitation in coastal waters. Further research is needed into the relationship between growth rate and stage-specific survival so that knowledge of larval growth rate can be translated into probability of survival.

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**Figure 1.** Examples of individual growth trajectories of *Thunnus maccoyii* larvae, (A) Individuals from a station outside the larval patch, (B) individuals from a station inside the patch.



**Figure 2.** Populations based growth curves of (A) *Rhombosolea tapirina* and (B) *Ammotretis rostratus* larvae collected from Port Phillip Bay.

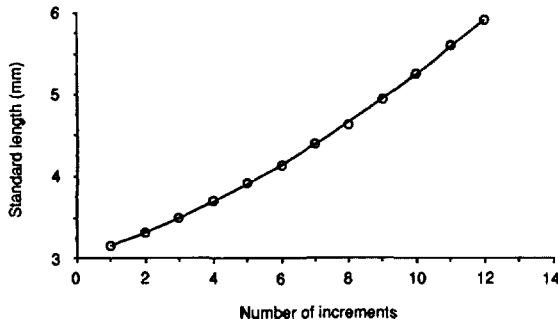


Figure 3. Backcalculated growth trajectory of an individual *Trachurus declivis* larva collected off the east coast of Tasmania.

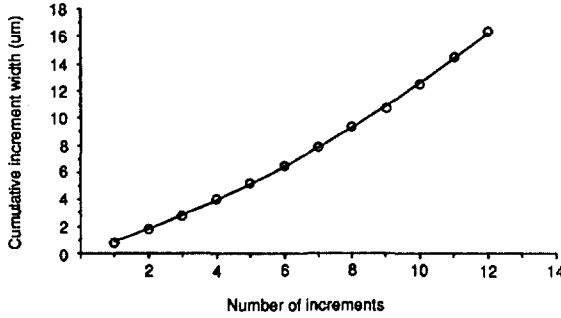


Figure 4. Relationship between cumulative increment width and number of daily increments in the early larval phase of an individual *Sillaginodes punctatus* collected from Port Phillip Bay.

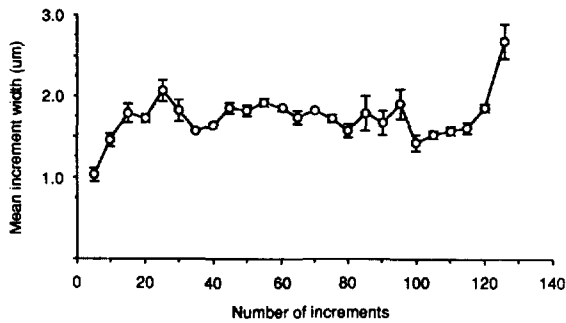


Figure 5. Relationship between mean ( $\pm 1$  s.d.) increment width and number of daily increments up to the settlement phase of a sample of early post-settlement *Sillaginodes punctatus* collected from Port Phillip Bay.