ICES CM 2014/3524 M:15

Differential effects of temperature on growth and maturity may contribute to reduced body size in the ectotherm *Haliotis rubra.*

Fay Helidoniotis[a,b], Malcolm Haddon[a], Farhan Rizwi[a]
[a]*Commonwealth Scientific and Industrial Research Organisation (CSIRO),*
[b]*Institute for Marine and Antarctic Studies, University of Tasmania (IMAS)*
Fay.Helidoniotis@csiro.au

Summary

A reduction in body size in warmer temperatures is considered to be a universal response to global warming. Among ectotherms, reaction norms between body size, growth rate and temperature exhibit faster growth rates but smaller adult body size as temperatures increase. Wild populations of an abalone species in Tasmania were studied under varying temperatures. Growth rate was measured in 30 populations where mean annual water temperatures ranged between 11.8 - 15.5 ^{0}C. The size at the onset of maturity was estimated for 233 populations where mean annual temperatures ranged between 9.2 - 15.5 ^{0}C. Consistent with the universal response in global warming, the mean body size of abalone was smaller in warmer temperatures despite the mean growth rate of juveniles being slightly higher in warmer waters. The size at onset of maturity decreased with increasing temperature, which in turn slowed down growth rate sufficiently to attenuate final adult size. There were differential effects of temperature on growth and maturity. The onset of maturity was more thermally sensitive than growth rate, and may have implications for fisheries productivity even within the thermal tolerance of the species.

Introduction

Ectotherms make up 99.9% of species worldwide (Atkinson and Sibly, 1997) and are a fundamental part of the world's fisheries. Therefore studying the effects of warming on ectotherms is ecologically and economically important. Temperatures are likely to remain within the thermal tolerance for many populations over the next few decades, even with predicted temperature increases. Abalone is a useful indicator species for studying the proposed theoretical effects of warming temperatures. Being a poikilothermic and relatively sessile species, ambient temperature is integrated into its population biology. However many studies focus on the effect of temperature on growth rates and final body size with less focus on any effects on the onset of maturity and final size under warming temperatures.

Materials and Methods

Growth for 30 populations was determined from tag-recapture data collected from abalone left for one year at-liberty and fitted with an inverse logistic growth model. Maturity for 233 populations was determined by visual examination of gonad colour and size (Branden and Shepherd, 1983). Satellite sea-surface temperatures were ground-truthed against in situ temperature data loggers at depths where abalone were found The mean monthly satellite SST temperatures were strongly correlated with in-situ measurements ($r = 0.942$, $R^2 = 0.8874$).

Results and Discussion

Empirical data on wild populations are considered to be a requirement in assessing the validity of proposed theoretical effects of reaction norms in growth and maturity (Angilletta and Dunham, 2003). Observations of the population biology within the thermal tolerance of the species were consistent with Atkinson and Sibly (1997): smaller abalone occurred in warmer waters (Fig 1a) despite the slightly higher initial growth rate of juveniles in warmer temperatures (Fig 1b), and the size at maturity decreased in warmer temperatures (Fig 1c). Similar results were also found in a wild abalone species (*Haliotis iris*) in New Zealand (Naylor et al., 2006).

Recent studies currently address the differential effects of temperature on growth and maturity (Forster et al., 2011). Our study demonstrated that the correlation between maturity and temperature was more significant (R^2 = 0.241) than the correlation between growth rate and temperature (R^2 = 0.011). This is consistent with results from recent controlled experiments where developmental rates, such as the onset of maturity were more thermally sensitive that growth rate (Forster et al., 2011). As maturity is approached earlier in warmer waters, and energy is partitioned away from somatic growth toward reproductive growth, (Figure 1d, Lester et al., 2004), the smaller maximum shell length in warmer waters may be mediated by the onset of maturity. One of the central concerns in fisheries management is the level of productivity and biomass of the mature spawning population; factors that may be influenced by varying maturity schedules under temperature gradients.

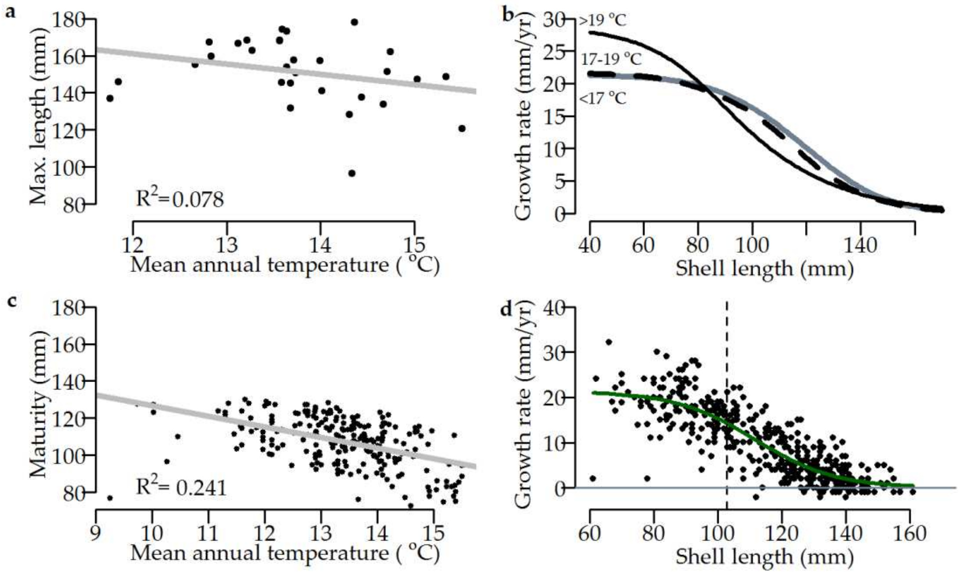

Figure 1. Effect of temperature on maximum shell length, growth rate and maturity on *Haliotis rubra*. a, Maximum shell size decreases with increasing temperature, (n = 30 populations). b, Initial growth rate generally increased with increasing temperature (n = 30 populations total, n=15 populations for <17 ^{0}C, n=12 for 17 - 19^{0}C, n=3 for >19^{0}C. Mean maximum (February) temperatures were used because summer temperatures were found to have an observed effect upon growth rate in cultured adult abalone (Gilroy and Edwards, 1998). Growth rate is measured using the MaxΔL parameter of the inverse logistic model (Haddon et al., 2008). c, Size at maturity decreased with increasing temperature (n =233 populations) d, An example of the relationship between size at maturity (represented by the dotted vertical line) and the mean population growth rate.

References

Angilletta, M.J., Jr. and Dunham, A.E. 2003. The Temperature-Size Rule in Ectotherms: Simple Evolutionary Explanations May Not Be General. The American Naturalist, 162: 332-342.

Atkinson, D. and Sibly, R.M. 1997. Why are organisms usually bigger in colder environments? Making sense of a life history puzzle. Trends in Ecology & Evolution, 12: 5.

Branden, K.L. and Shepherd, S.A. 1983 A survey of stocks of the abalone Haliotis roei Gray on the western coast of Spencer Gulf, South Australia. Parts 1 and 2, Department of Fisheries South Australia, Adelaide.

Forster, J., Hirst, Andrew G. and Woodward, G.D.-. 2011. Growth and Development Rates Have Different Thermal Responses. The American Naturalist, 178: 668-678.

Gilroy, A. and Edwards, S.J. 1998. Optimum temperature for growth of Australian abalone: preferred temperature and critical thermal maximum for blacklip abalone, Haliotis rubra (Leach), and greenlip abalone, Haliotis laevigata (Leach). Aquaculture Research, 29: 481-485.

Haddon, M., Mundy, C. and Tarbath, D. 2008. Using an inverse-logistic model to describe growth increments of blacklip abalone (*Haliotis rubra*) in Tasmania. Fishery Bulletin, 106: 58-71.

Lester, N.P., Shuter, B.J. and Abrams, P.A. 2004. Interpreting the von Bertalanffy model of somatic growth in fishes: the cost of reproduction. Proceedings of the Royal Society B: Biological Sciences, 271: 1625-1631.

Naylor, J.R., Andrew, N.L. and Kim, S.W. 2006. Demographic variation in the New Zealand abalone Haliotis iris. Marine and Freshwater Research, 57: 215-224.