# Tracking indices as measures of synchronization of isotopic temperature of NZ abalone shells with ambient water temperature

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## ABSTRACT

Synchrony, synchronistic occurrence, has been studied in population dynamics, health science and in phenology. Moran (1953) first introduced the concept of synchrony between population dynamics and concomitant weather conditions using Canadian lynx data showing that the degree of synchrony decreases with increasing distance and since then, it has been studied in various areas of research. Although spatial synchrony, which considers similarity across locations and species, has been studied widely, temporal synchrony, which considers timing of events, has been studied mostly in phenology.

In a recent study, Naylor et al. (2007) suggested the possible use of variations in the ratios of oxygen and carbon isotopes to determine age, growth and reproductive patterns in shells of *Haliotis iris*. They suggested that oxygen isotope profiles within shells reflected ambient water temperature at the time of shell precipitation, and that these ($\delta^{18}$O and $\delta^{13}$C) profiles could be used to determine age and growth patterns. Naylor et al. (2007) used two temperature series, ambient water temperature and isotopic temperature from shells. Their preliminary work indicated that two types of growth model, the von-Berterlanffy (VB) or the Gompertz (G) growth model were equally good in “mirroring” isotopic temperature. However, the G model was preferred to the VB model as it fitted better to tagging information data (Naylor et al. 2007).

In this study, we look at the tracking indices of two temperature series, ambient water temperature and isotopic temperature of Naylor et al. (2007) to measure synchronicity. We show that temperature estimated from abalone shells using oxygen isotope profiles statistically track and/or synchronize with ambient water temperature. In terms of fitting isotopic temperature with ambient water temperature, one growth model, namely the von Berterlanffy (VB), fits significantly better than the G model. This is established using a block bootstrapping method to calculate the confidence interval of so the so-called tracking indices, that mirror synchrony.

This work represents an improvement because the VB model and the G model, by their definition, give different biomass estimation for the future in terms of time and amount. The VB model will estimate smaller biomass than the G model, although the G model will take longer to build the available biomass, since it reaches the minimum legal size 2-6 years later than the VB model. By choosing the VB model over the G model, we are selecting a model where in a shell reaches the minimum legal size faster, although the biomass of the shell is not as heavy as the amount calculated via the G model. The impact on total biomass, in the future, via the VB and the G models was not examined in this study, and is future work.

Tracking indices between two temperature series (isotopic - estimated shell temperature and ambient water temperature) were obtained for four shells: (a) between the two temperature series as they are, (b) between ambient water temperature and the kernel smoothed isotopic temperature; and (c) on the moving block bootstrapped series of isotopic temperature and ambient water temperature.

The local bandwidth choice in Kernel regression showed the largest bandwidth of shell 3, which can be related to the smallest asymptotic length ($L_\infty$=136.32 with VB) and slower growth rate (large $K$, $K$=0.38 with VB) and the smallest bandwidth of shell 2, which can be related to the largest asymptotic length ($L_\infty$=181.84 with VB) and its fast growth rate to the minimum legal size (Naylor et al. 2007). At the minimum legal size, shell 3 will be 6.6 years old whereas shell 2 will only be 4.4 years old.

Tracking indices showed that the shell and water temperature series are synchronizing and parallel; and that the VB growth model synchronizes significantly better for shells 1, 3, and 4. The G growth model synchronizes significantly better for shell 2 only.

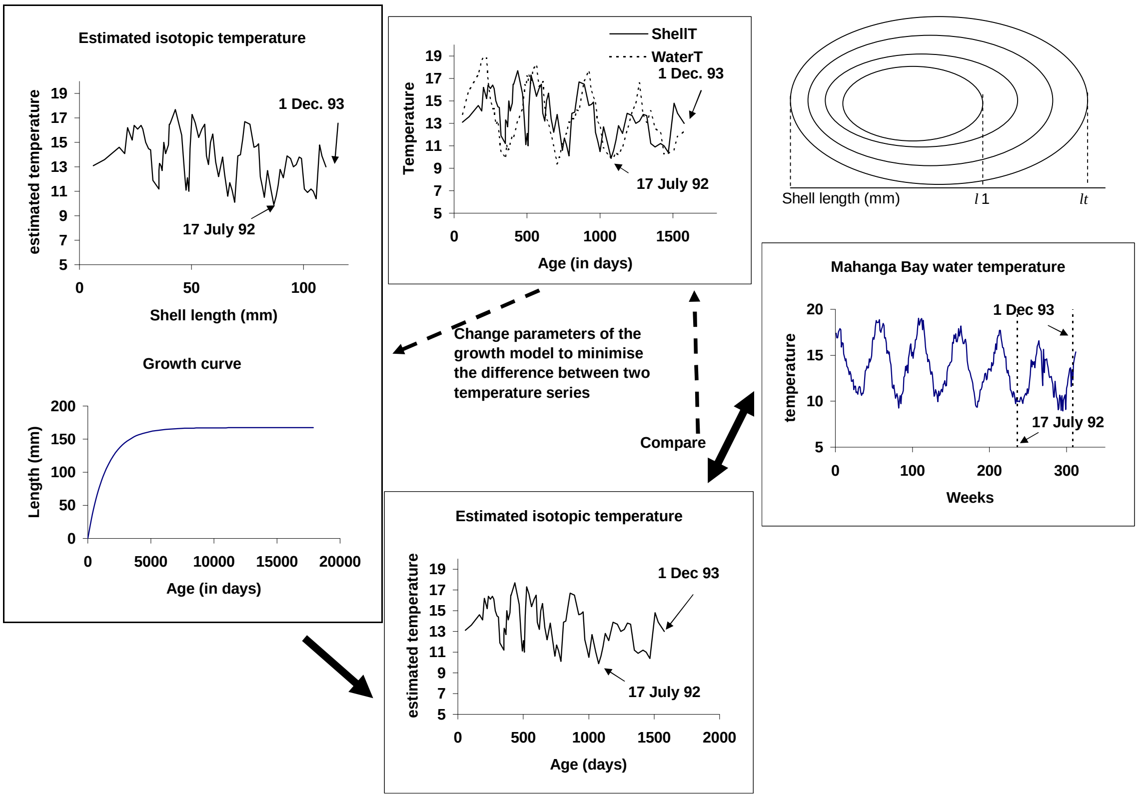


**Figure 1.** Schema of modelling and estimation.

## 1 INTRODUCTION

Synchrony has been studied in population dynamics (Moran 1953, Ranta et al. 1995a, 1995b, 1997, Bjørnstad 2000, Bjørnstad et al. 1999a, 1999b, Økland and Bjørnstad 2003, Koenig 2002, Liebhold et al. 2004, Raimondo et al. 2004), health science (Cummings et al. 2004, Basarsky et al. 1998) and in phenology (Augspurger 1983, Keatley et al. 2004, Hudson et al. 2006). Moran (1953) first introduced the concept of synchrony between population dynamics and concomitant weather conditions using the Canadian lynx data. He showed that the degree of synchrony decreases with increasing distance (i.e. the lynx cycle was less synchronous with temperature from areas which are more distant). Since then, synchronicity between population dynamics and weather is known as the "Moran effect". Although spatial synchrony, which considers similarity across locations and species, has been studied widely (Ranta et al. 1995b, Bjørnstad 2000, Bjørnstad et al. 1999a, 1999b, Økland and Bjørnstad 2003, Koenig 2002, Liebhold et al. 2004, Raimondo et al. 2004), temporal synchrony, which considers timing of events, has been studied mostly in phenology (Keatley et al. 2004, Augspurger 1983, Hudson et al. 2006).

In a recent study, Naylor et al. (2007) suggested the possible use of variations in the ratios of oxygen and carbon isotopes to determine age, growth and reproductive patterns in shells of *Haliotis iris*. They suggested that oxygen isotope profiles within shells reflected ambient water temperature at the time of shell precipitation, and that these ($\delta^{18}$O and $\delta^{13}$C) profiles could be used to determine age and growth patterns. Naylor et al. (2007) used two temperature series, ambient water temperature and isotopic temperature from shells. To match these two temperature series, an age at each shell incremental length was estimated using the two growth models, VB and G, and the tagging information, shell lengths at the time of tagging and recapturing (Figure 1). The approach adopted here is to match estimated shell temperature at length ($L$) with ambient water temperature at chronological time - essentially, matching two different time metameters and two different functionals. Naylor et al.'s (2007) preliminary work indicated that two types of growth model, the von-Berterlanffy (VB) or the Gompertz (G) growth model were equally good in "mirroring" isotopic temperature. However, the G model was preferred to the VB model because it fitted better to fisheries tagging information data.

In this study, we use synchronicity as a measure of goodness of fit. We look at the tracking indices of two temperature series, ambient water temperature and isotopic temperature of Naylor et al. (2007) to assess synchronicity.

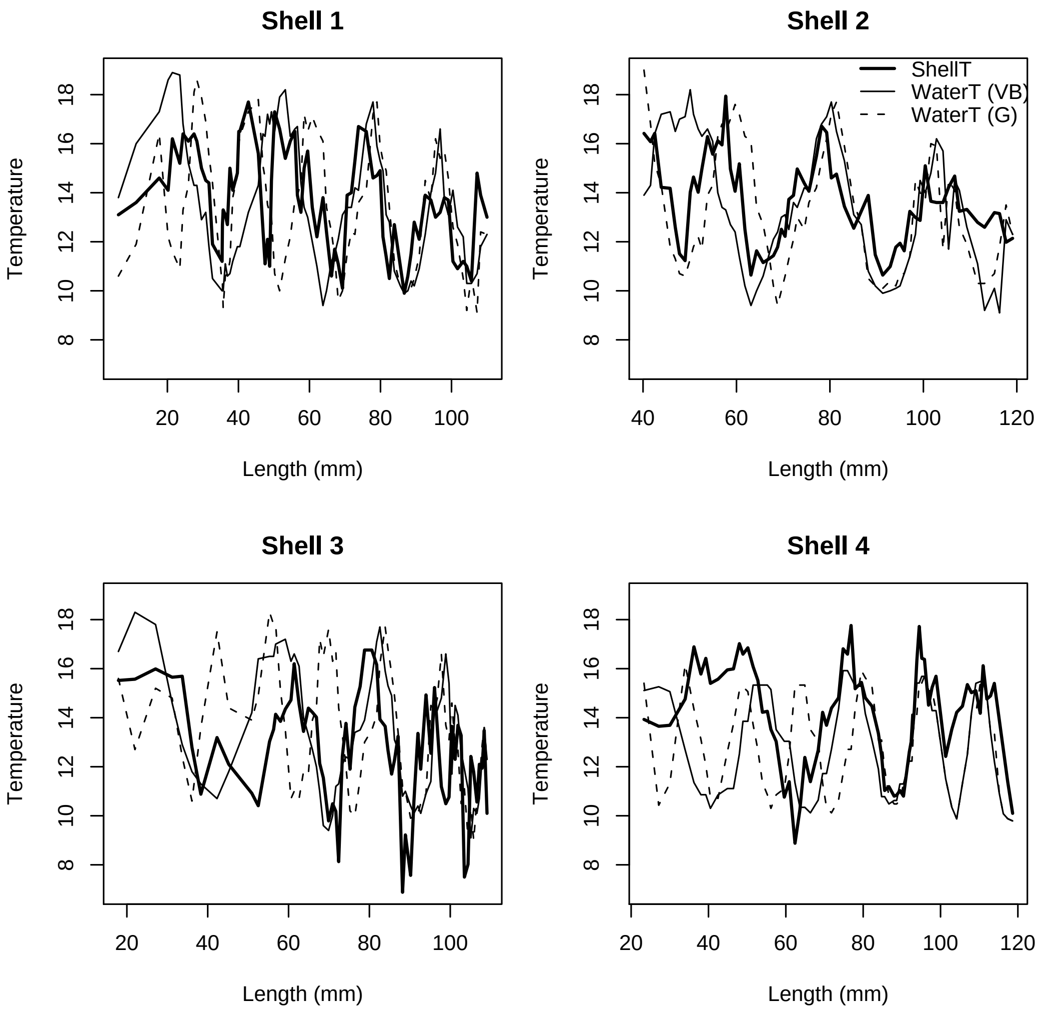


**Figure 2.** Fitted ambient water temperature via the von Berterlanffy (WaterT (VB), thin solid line) and the Gompertz (WaterT (G), dashed line) model and isotopic temperature (ShellT, think solid line) for each shell. This shell was tagged on 17th July 1992 and recaptured on 1st December 1993.

## 2 DATA AND MODELS

Temperature series from two sources, ambient water temperature (mean weakly temperature records from Mahanga Bay and for Cape Campbell (Naylor et al. 2007) and mean monthly ambient water temperatures estimates NIWA SST Archive (Uddstrom and Oien 1999)) estimated isotopic temperature from four shells were used for this study. Four shells from two localities in New Zealand were used; three shells from Mahanga Bay and one (shell 4) from Cape Campbell (Naylor et al. 2007). Ambient water temperature has been fitted to the estimated isotopic temperature series using two growth models: von Berterlanffy (VB) and Gompertz (G) (Naylor et al. 2007). The data used for this study, fitted ambient water temperature via the Von Beterlanffy and the Gompertz growth model. This with isotopic temperature are shown in Figure 2 for the four shells.

For the age-based von Berterlanffy growth model, with three parameters, asymptotic length, $L_\infty$, rate parameter, $K$, and initial time parameter, $t_0$. The expected length at day $t$, $l_t$, is calculated as:

$$l_t = L_\infty \left(1 - e^{-\frac{K(t-t_0)}{365}}\right). \quad (1)$$

Equation (1) can be rearranged to obtain the expected age in days, $\hat{t}_{l_i}$, of abalone of length $l_i$, where:

$$\hat{t}_{l_i} = t_0 - \frac{365}{K} \ln\left(1 - \frac{l_i}{L_\infty}\right), \quad (2)$$

the expected growth increment $\hat{d}$, $n$ days after tagging at $l_1$ is:

$$\hat{d} = (L_\infty - l_1)\left(1 - e^{-\frac{nK}{365}}\right). \quad (3)$$

Note that under the von-Berterlanffy growth model, a shell grows fast when it is small, but slows down its growth rate as it becomes larger (Figure 3).

For the age-based Gompertz growth model, with three parameters, asymptotic length, $L'_\infty$, rate parameter,