Appendices to: Circulation constrains the evolution of larval development modes and life histories in the coastal ocean

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Appendix D: Details of comparison of theory to observed life-history distribution: Marshall et al. (2012) (hereafter DM) gathered life-history data from a large number of marine invertebrates distributed globally to understand the environmental variables that constrain life-history strategies in these organisms; we constrain our analysis to their records that are within 50km of continental coastlines. As documented in DM's supplementary materiel, they gathered life-history from the published literature (supplemented with some personal data from DM) on marine invertebrates from 5 phyla: cnidarians, annelids, molluscs, echinoderms and chordates (ascidians only). Each species was categorized as having feeding versus non-feeding larvae, and dispersing versus non-dispersing larvae; for the purposes of this work, a species was determined to be planktotrophic if it had a planktonic larval stage that must feed in the plankton to complete development.

Circulation and sea-surface data from surface drifters compiled by Lumpkin & Garraffo (2005) (hearafter L&G) are used to calculate the circulation components of Π_2; The mean currents U, the standard deviation of the currents from that mean, σ, and the integral timescale over which those fluctuations de-correlate $\tau_{L.}$ They include all surface drifter data recorded within NOAA's Global Drifter Program through December 2010, and calculate monthly mean surface currents and temperature, the variability of these with respect to the monthly means, and the timescale of their variability at 1 degree resolution. Following DM, annual averages formed from the monthly data are used.

Π_2 is a composite of physical parameters controlling the mean and stochastic components of transport (U an $\sigma^2\tau$, respectively) and the biological parameter growth less mortality (*g*-*m*). This latter term is poorly constrained. We shall assume that its spatial variation is dominated by temperature. The variation in growth with temperature amongst a broad range of species is assumed to vary as described for within-species variation by O'Connor et al. (2007). While there is some evidence for temperature compensation, there is a strong tendency for the species in colder water to grow more slowly (Hoegh-Guldberg and Pearse 1995). We do not attempt to estimate the absolute magnitude of growth across many species in many places, but only how it varies with temperature (details in appendix E). Firm data on the dependence of mortality *m* on temperature is scarce. We shall assume that mortality is dominated by predation, and the metabolism of predators, and thus the rate of predation, scales as growth does (e.g. Houde 1989, Pepin 1991, both for fish larvae). These assumptions are hard to formally justify, but no better choice is apparent (see Rumrill 1990). Given these assumptions, we can estimate how (*g*-*m*) varies with temperature, but not its absolute value.

To cope with this uncertainty we make multiple logistic regressions, each within a narrow temperature range, for the presence of a planktotrophic larval stage against the log of U^2, $\sigma^2\tau$ and Π_2 (Table 1; the log transform enhance normality and makes Π_2 an additive function of the log of its components; otherwise the analysis is as in DM). Temperature ranges are chosen so that the fractional change in growth rate expected from the relationship of O'Connor et al. (2007) is the same over each temperature range.

A logistic regression fits a *tanh* curve representing the probability of a given variable (here the presence or absence of planktotrophy) to an independent variable (here the log of U^2,

$\sigma^2\tau$ and Π_2). The resulting probability curves are by definition smooth; to illustrate the degree of fit to the data, the spatial distribution of planktotrophy with respect to $\log(U^2)$ are shown in figure D1, and tables showing the fitting coefficients, their 95% confidence intervals, and McFadden's ρ^2 are shown for all variables in tables D1 through D3. Analysis was preformed with Systat version 13.

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TABLE D1. Logistic regression statistics for $\log(U^2)$; values in brackets are 95% confidence range.

Temperature Range	Coefficient for $\log(U^2)$	*P* value for $\log(U^2)$	Coefficient for constant	*P* value for constant	McFadden's ρ^2
7.5° to 11°	-1.245 [-2.363,-0.128]	0.029	-4.115 [-7.414,-0.817]	0.014	0.127
11° to 15°	-1.398 [-1.871,-0.925]	0.003	-3.592 [-4.764,-2.42]	0.002	0.063
15° to 20°	-1.699 [-2.993,-0.405]	0.010	-3.681 [-6.667,-0.695]	0.016	0.077
20° to 27°	0.465 [0.024,0.906]	0.039	1.483 [0.890,2.076]	<0.001	0.033

TABLE D2. Regression statistics for $\log(\sigma^2\tau_L)$; values in brackets are 95% confidence range.

Temperature Range	Coefficient for $\log(\sigma^2\tau_L)$	*P* value for $\log(\sigma^2\tau_L)$	Coefficient for constant	*P* value for constant	McFadden's ρ^2
7.5° to 11°	-3.934 [-7.141,-0.727]	0.016	-8.302 [-14.646,-1.959]	0.010	0.171
11° to 15°	1.560 [-0.485,3.606]	0.135	2.338 [-0.956,5.631]	0.164	0.016
15° to 20°	-1.050 [-3.872,1.772]	0.466	-1.566 [-6.399,3.266]	0.525	0.006
20° to 27°	0.486 [-0.521,1.494]	0.344	1.423 [0.467,2.379]	0.004	0.005

TABLE D3. Regression statistics for $\log(\Pi^2)$; values in brackets are 95% confidence range.

Temperature Range	Coefficient for $\log(\Pi^2)$	*P* value for $\log(\Pi^2)$	Coefficient for constant	*P* value for constant	McFadden's ρ^2
7.5° to 11°	-2.441 [-4.460,-0.422]	0.018	-2.423 [-4.193,-0.653]	0.007	0.180
11° to 15°	-2.079 [-3.226,-0.932]	<0.001	-1.748 [-2.695, -0.800]	<0.001	0.107
15° to 20°	-1.866 [-3.284,-0.449]	0.010	-0.969 [-2.001,0.063]	0.066	0.087
20° to 27°	1.004 [0.232,1.776]	0.011	1.402 [0.904,1.900]	<0.001	0.039

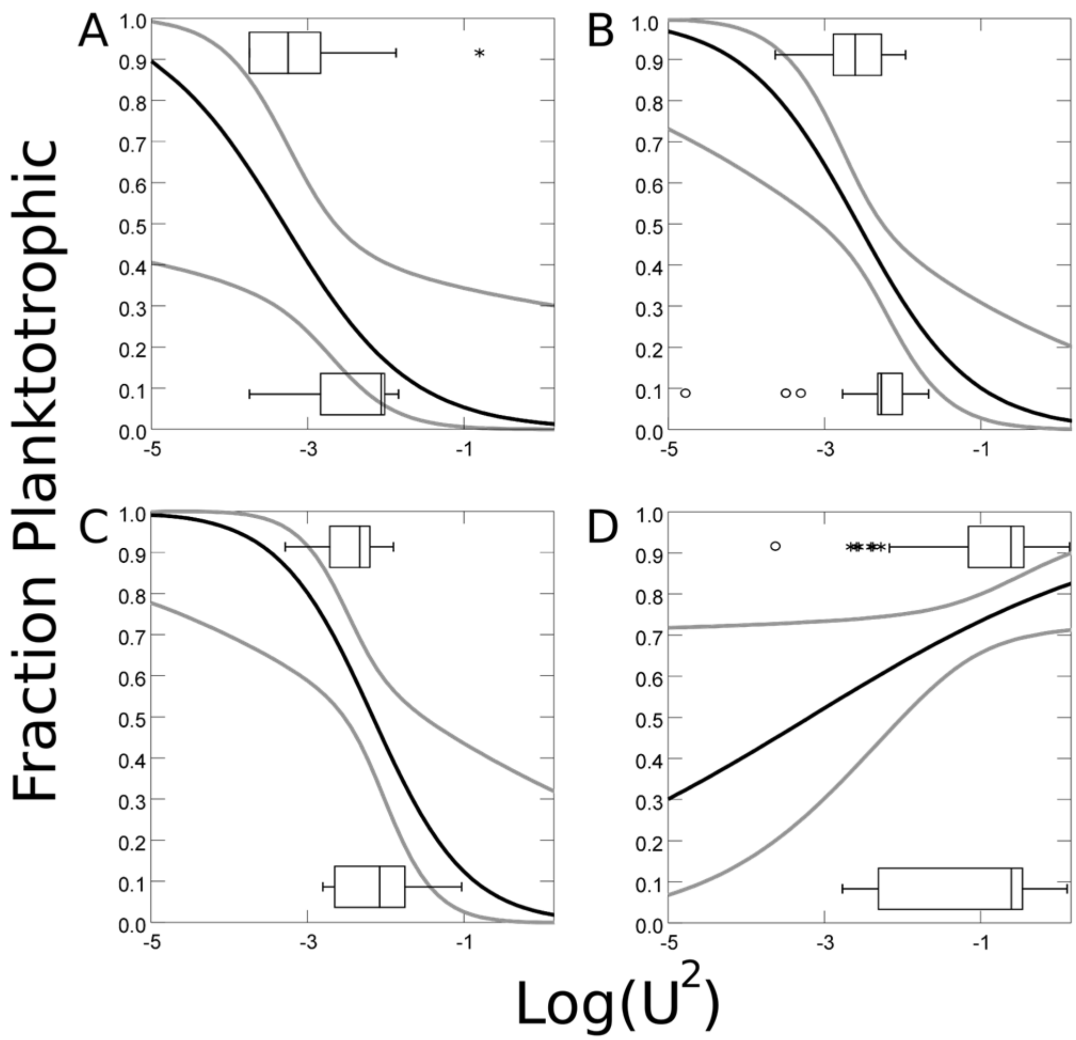

FIG. D1. The proportion of larval planktotrophy as a function of the mean ocean currents for the four temperature ranges given in Table 1, using life-history data from Marshall et al. (2012). Box plots on the upper portion of the plot shows the distribution of the planktotrophy in the data as a function of the currents, and those on the lower portion of the plots show the distribution of organisms with reproductive modes other than planktotrophy. Asterisks indicate points outside the interquartile range, and circles indicate points greatly outside of the interquartile range. Plot A is for organisms from locations where the annual mean temperature lies between 7.5^o to 11^o, B for those between 11^o to 15^o, C for 15^o to 20^o, and D for 20^o to 27^o.