The following supplement accompanies the article

Weak synchrony in the timing of larval release in upwelling regimes

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SUPPLEMENTARY MATERIAL

Model selection details and supplemental results

The influence of environmental factors on the synchrony and timing of larval release by *Hemigrapsus oregonensis* and *Petrolisthes cinctipes* from Bodega Bay was examined with a time series analysis and Akaike's information criterion (AIC) to compare the temporal pattern of hatching to daily records of sea surface temperature (SST), tidal amplitude and air temperature from the same time period. Models were fitted with generalized least squares (GLS) with an error covariance matrix that accounted for potential autocorrelation in the hatching time (Pinheiro & Bates 2004). To avoid having to evaluate the extremely large number of potential models possible given 6 different predictor variables, we pursued a staggered model selection procedure. We first considered only models with each of the 6 potential predictors alone to identify the variables that exhibited significant univariate relationships with hatching (at a nonconservative $\alpha = 0.1$ level). We then discarded the variables that did not exhibit a significant univariate relationship and evaluated models with all possible combinations and higher-order interactions among the remaining variables. The rationale for this somewhat ad hoc process was that it is generally undesirable to compare large numbers of candidate models unless relationships that are spurious and not biologically meaningful (Johnson & Omland 2004) are identified, and we believed it was reasonable to expect that each of the predictors in the best model would have at least moderate predictive power on their own. To ensure that we did not overlook meaningful models using this process, we also considered several models including all

6 of the predictors and their interactions, but such models were not more parsimonious than simpler alternatives.

Linear models were fitted by means of GLS with an error covariance matrix that accounted for potential autocorrelation in the hatching time series (Pinheiro & Bates 2004). Hatching proportions were arcsine-square-root transformed before analysis; examination of residuals from fitted models did not reveal substantial deviations from normality. GLS models were implemented with the GLS function in the statistical package for R v. 2.9.1 (R Development Core Team 2009). To determine the correct autoregressive error structure, we used the R function AR to compare alternative autoregression models using AIC. Based on that preliminary analysis, we used an AR(3) error structure for *Petrolisthes cinctipes* and AR(1) for *Hemigrapsus oregonensis.* We also examined the autocorrelation structure of single-differenced time series for each species to ensure that there was no overall trend in the data, but none was evident so we present the analysis of nondifferenced data only. AIC statistics were calculated with the R package BBMLE provided by Bolker (2008).

Several gaps of less than a few days occurred in SST and air temperature time series, and 2 long gaps of up to 20 d occurred in the SST data at the beginning of the time series for *Hemigrapsus oregonensis*. These missing values complicated the calculation of running averages and the covariance structure for the time series analysis, so we linearly interpolated the time series to fill the gaps. This procedure allowed us to include more of the hatching time series in the analysis and improved statistical power. An identical analysis using noninterpolated SST and air temperature time series produced results that were qualitatively identical but less statistically powerful, so the interpolation procedure did not produce spurious results.

For *Petrolisthes cinctipes*, the lagged mean tidal amplitude and air temperature were the only factors with coefficients that were significantly different from 0 in univariate GLS models (the other 4 predictors had $p > 0.25$; Fig. S2, Table S2). Of the set of models including interactions between those 2 variables (Table S2), the most parsimonious model only had a constant intercept term. This model had an AIC weight of 0.74; the next best model included a term for mean air temperature and had ΔAIC = 3.6 (ΔAIC is the difference in AIC score between a particular model and the model with the lowest AIC score) and AIC weight of 0.12. The latter model described a positive relationship between air temperature and hatching (Fig. S3, Table S2), but it explained only 1.4% of the variance in the data set, and overall there was little evidence that any of the environmental factors explained the temporal pattern in *P. cinctipes* hatching. This may be related to the long-term periodicity in the hatching time series, and the short-term periodicity detected by spectral analysis was again evident (Fig. S2).

Bolker BM (2008) Ecological models and data. Princeton University Press, Princeton, NJ

Johnson JB, Omland KS (2004) Model selection in ecology and evolution. Trends Ecol Evol 19:101–108

Pinheiro JC, Bates DM (2004) Mixed-effects models in S and S-PLUS. Springer Science and Business Media, New York, NY

R Development Core Team (2009) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Available at: www.R-project.org

Table S1. *Hemigrapsus oregonensis*. Summary of (a) model selection and (b) most parsimonious model for larvae collected near Bodega Bay from 11 December 2000 to 21 May 2001. For each model, we indicate the AIC-based ranking (*R* no.), the number of parameters (*k*), difference between AIC score and the lowest observed AIC score (ΔAIC), and the Akaike weight (w_i). Model terms are abbreviated as the mean (m) or rate of change (r) in tidal amplitude (T), sea surface temperature (S) or air temperature (A). All models included an intercept (Int); interaction terms indicated by ×. The most parsimonious model is shown in **bold** text in (a). Note: All models use an AR(1) correlation structure with autoregression coefficient $\phi = 0.1608$

(a) Model selection

Model	*R* no.	*k*	ΔAIC	w_i
Int	0	3	11.1	0.003
Int + mT	1	4	11.5	0.003
Int + mS	2	4	19.0	<0.001
Int + mA	3	4	19.8	<0.001
Int + rT	4	4	9.6	0.007
Int + rS	5	4	10.8	0.004
Int + rA	6	4	17.0	<0.001
Int + mT + rT	7	5	14.4	<0.001
Int + mT + rT + mT × rT	8	6	19.6	<0.001
Int + mT + rS	11	5	11.8	0.002
Int + mT + rS + mT × rS	12	6	13.4	0.001
Int + rT + rS	9	5	8.9	0.011
Int + rT + rS + rT × rS	**10**	**6**	**0**	**0.889**
Int + mT + rT + rS	16	6	14.2	<0.001
Int + mT + rT + rS + mT × rT	17	7	19.5	<0.001
Int + mT + rT + rS + mT × rS	18	7	14.9	<0.001
Int + mT + rT + rS + rT × rS	13	7	5.4	0.059
Int + mT + rT + rS + mT × rT + mT × rS	19	8	20.6	<0.001
Int + mT + rT + rS + mT ×rT + rT × rS	15	8	11.2	0.003
Int + mT + rT + rS + mT × rS + rT × rS	21	8	8.3	0.014
Int + mT + rT + rS + mT × rT + mT × rS + rT × rS	20	9	14.1	<0.001
Int + mT + rT + rS + mT × rT + mT × rS + rT × rS + mT × rT × rS	14	10	13.8	<0.001

(b) Most parsimonious model

Term	Value	SE	*t*-value	p
Int	0.0940	0.0116	8.075	<0.0001
rT	0.0499	0.0138	3.633	0.0004
rS	0.3966	0.1758	2.256	0.0255
rT × rS	–0.8852	0.2829	–3.129	0.0021

Table S2. *Petrolisthes cinctipes*. Summary of (a) model selection and (b) most parsimonious model for larvae collected near Bodega Bay from 6 March to 8 August 2001. The most parsimonious model is shown in **bold** text in (a). See Table S1 for symbols and abbreviations

(a) Model selection

Model	*R* no.	*k*	ΔAIC	w_i
Int	**0**	**3**	**0**	**0.741**
Int + mT	1	4	4.7	0.069
Int + mS	2	4	6.8	0.025
Int + mA	3	4	3.6	0.120
Int + rT	4	4	7.5	0.017
Int + rS	5	4	8.8	0.009
Int + rA	6	4	8.6	0.010
Int + mT + mA	7	5	9.1	0.008
Int + mT + mA + mT × mA	8	6	16.9	<0.001

(b) Most parsimonious model

Term	Value	SE	*t*-value	p
Model 1[a]				
Int	0.1727	0.0405	4.262	<0.0001
Model 2[b]				
Int	–0.3107	0.2368	–1.312	0.1915
mA	0.0442	0.0213	2.074	0.0398

[a] ΔAIC = 0; AR(3) correlation structure; autocorrelation coefficients $\phi_1 = 0.2810$, $\phi_2 = 0.1633$, $\phi_3 = 0.2941$

[b] ΔAIC = 3.6; AR(3) correlation structure; autocorrelation coefficients $\phi_1 = 0.2669$, $\phi_2 = 0.1698$, $\phi_3 = 0.3070$

Fig. S1. *Hemigrapsus oregonensis*. Time series of environmental variables and larval release near Bodega Bay from 11 December 2000 to 21 May 2001: (a) tidal amplitude, (b) sea surface temperature (SST), (c) air temperature, (d) total number of ovigerous females (dashed line) and proportion of total hatching (solid line). In (b) and (c), dashed-line segments indicate missing values that were interpolated

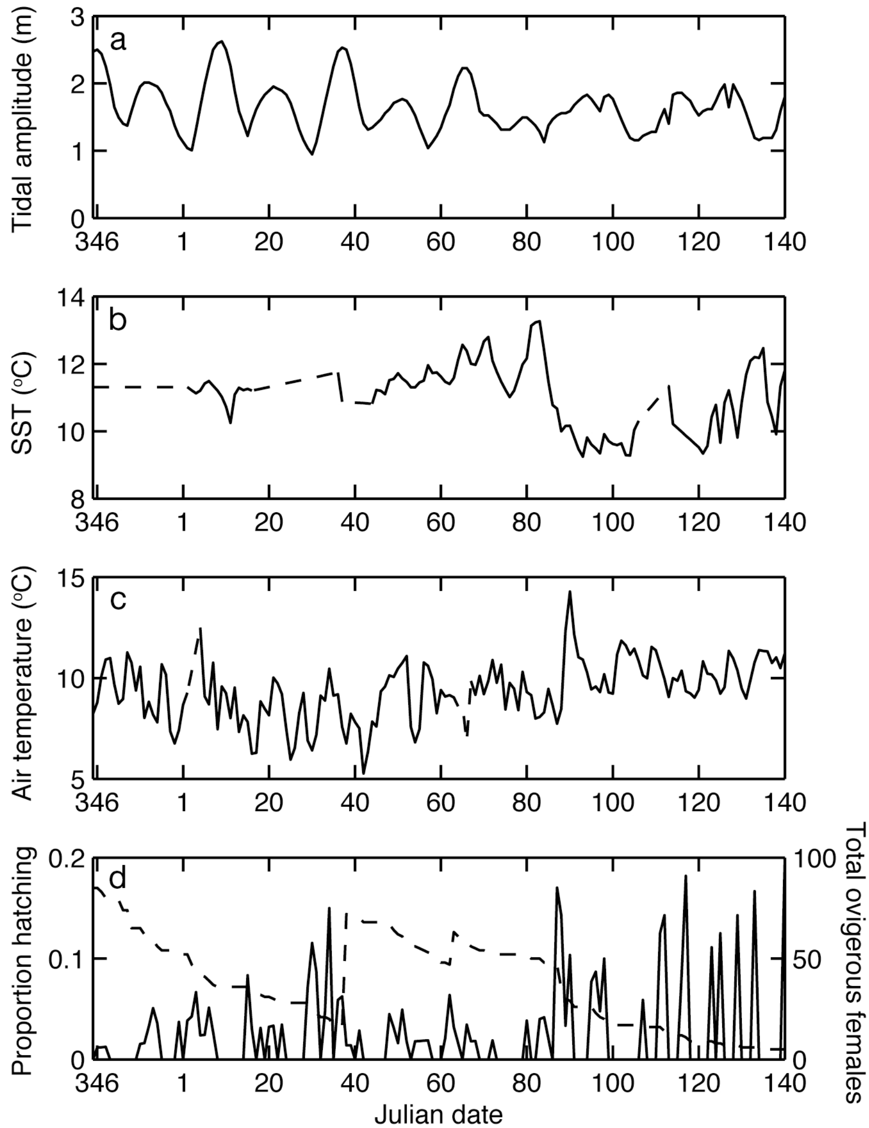

Fig. S2. *Petrolisthes cinctipes* . Time series of environmental variables and larval release near Bodega Bay from 6 March to 8 August 2001: (a) tidal amplitude, (b) sea surface temperature (SST), (c) air temperature, (d) total number of ovigerous females (dashed line) and proportion of total hatching (solid line). In (b) and (c), dashed-line segments indicate missing values that were interpolated

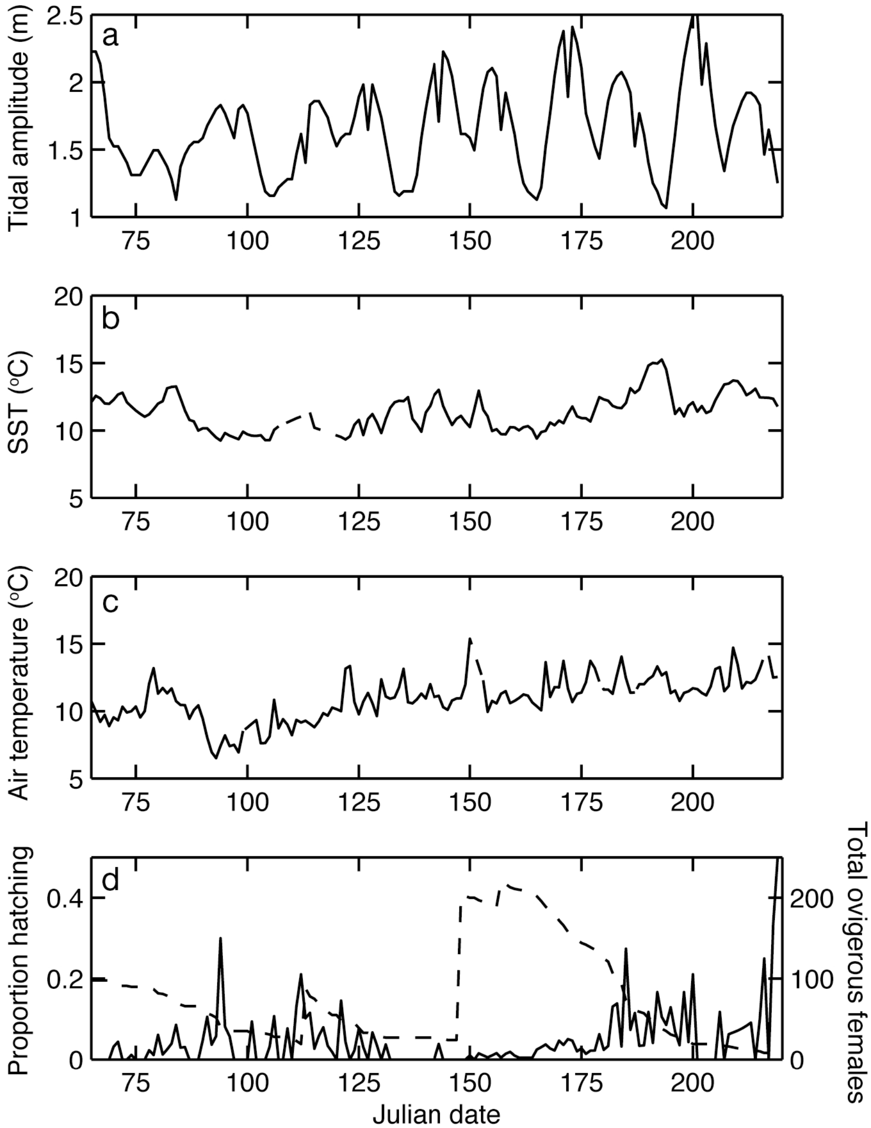

Fig. S3. *Petrolisthes cinctipes* . Best-fit GLS models for the time series near Bodega Bay from 6 March to 8 August 2001. Panels show the rates of change in (a) running mean of air temperature for 1 wk before hatching and (b) proportion of ovigerous females hatching (dashed line) relative to the two most parsimonious model fits (solid lines); the horizontal line was in the intercept-only model and the other line is a model including the effect of the running mean of air temperature