The following supplement accompanies the article

Fish predation after weakly synchronized larval release in a coastal upwelling system

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Supplement. Tables present summaries of plankton and fish concentrations in the marsh as well as electivities of fishes for each prey item. Figures show the zoeae from this study, amphipod abundance as an indicator of background zooplankton abundance, and larval release data prior to the removal of zero data

Table S1. Mean (±SE) concentrations of zooplankters during 9 trips to 2 marshes in northern California from 2 June to 22 July 2006. Taxa in **bold** were targeted for possible synchronous release

Species	Concentration (no. m^{-3})	Percent of total
***Pachygrapsus crassipes* larvae I**	11210.45 ± 2744.84	28.94
***Hemigrapsus oregonensis* larvae I**	7821.05 ± 2063.64	20.19
Amphipods	6142.30 ± 957.87	15.86
Ostracods	3526.33 ± 1294.52	9.10
Cumaceans	2650.74 ± 715.80	6.84
***Neotrypaea californiensis* larvae I**	2142.38 ± 747.79	5.53
Calanoid copepods	1413.11 ± 190.11	3.65
Harpacticoid copepods	1280.50 ± 370.71	3.31
Bivalves	845.95 ± 225.34	2.18
***Scleroplax granulata* larvae I**	360.21 ± 67.17	0.93
***Pinnixa tubicola* larvae I**	222.55 ± 37.17	0.57
Terrestrial insect larvae	166.47 ± 42.55	0.43
Terrestrial insects	122.81 ± 47.24	0.63
Tanaids	102.25 ± 54.34	0.26
Pinnotherid A larvae I	96.28 ± 18.66	0.25
Gastropods	70.29 ± 19.03	0.18
Polychaetes	58.87 ± 20.75	0.15
Foraminferans	56.27 ± 15.21	0.15
Nematodes	53.36 ± 13.63	0.14
Carcinus maenas larvae I	39.20 ± 13.51	0.10
Caridean larvae	35.44 ± 10.95	0.09
Hemigrapsus nudus larvae I	32.14 ± 23.39	0.08
Water mites	30.62 ± 11.08	0.08
Pachygrapsus crassipes prezoeae	29.92 ± 20.14	0.08
Anemones	29.92 ± 9.88	0.08
Isopods	25.32 ± 7.93	0.07
Ctenophores	9.54 ± 6.65	0.02
Barnacle cyprids	7.88 ± 1.94	0.02
Lophopanopeus bellus bellus larvae I	6.92 ± 2.19	0.02
Barnacle nauplii	5.48 ± 4.08	0.01
Pinnotherid B larvae I	4.61 ± 2.75	0.01
Mysids	3.74 ± 2.57	0.01
Oligochaetes	2.69 ± 1.35	0.01
Pugettia producta larvae I	2.37 ± 1.53	0.01
Emerita analoga larvae I	2.30 ± 1.13	0.01
Pagurus spp. larvae I	1.56 ± 0.78	<0.01
Cladocerans	0.98 ± 0.44	<0.01
Sipunculid larvae	0.30 ± 0.30	<0.01
Phoronid larvae	0.15 ± 0.15	<0.01

Table S2. Mean number (±1 SE) of fishes collected during 9 trips to 2 marshes in Tomales Bay, California, from 2 June to 22 July 2006

Species	Family	Common name	Mean	SE	Percent of total
Atherinops affinis	Atheriniformes	Topsmelt	243.00	74.30	46.79
Engraulis mordax	Engraulidae	Northern anchovy	137.64	68.77	26.50
Gasterosteus aculeatus	Gasterosteidae	Three-spined stickleback	47.29	11.12	9.10
Cymatogaster aggregata	Embiotocidae	Shiner perch	45.86	38.48	8.83
Clevlandia ios	Gobiidae	Arrow goby	32.07	15.11	6.18
Hyperprosopon argenteum	Embiotocidae	Walleye surfperch	3.11	1.38	1.20
Leptocottus armatus	Cottidae	Staghorn sculpin	2.57	1.38	0.50
Syngnathus leptorhynchus	Syngnathidae	Bay pipefish	1.64	0.77	0.30
Gillichthys mirabilis	Gobiidae	Longjawed mudsucker	1.43	0.73	0.28
Triakis semifasciata	Triakidae	Leopard shark	0.86	0.58	0.17
Hypomesus pretiosus	Osmeridae	Surfsmelt	0.50	0.34	0.10
Clupea pallasi	Clupeidae	Pacific herring	0.21	0.21	0.04
Pleuronichthys coenosus	Pleuronectidae	C-O sole	0.07	0.07	0.01

Table S3. Feeding electivity of fishes collected in 2 marshes in Tomales Bay during high tides from 2 June to 22 July 2006. Prey items with the same superscript did not differ significantly according to a Tukey's post-hoc test

Prey	All species	*Engraulis mordax*	*Clevlandia ios*	*Gillichthys mirabilis*
Amphipod	0.377^{a}	0.492^{a}	0.451^{a}	0.583^{a}
Annelida	-0.866^{d}	-1^{b}	-0.680^{b}	-1^{b}
Cumacean	-0.920^{d}	-0.627^{b}	-1^{b}	-0.545^{b}
Harpacticoid	0.099^{b}	-0.438^{b}	0.351^{a}	-1^{b}
Hemigrapsus spp.	-0.949^{d}	-1^{b}	-1^{b}	-1^{b}
Neotrypaea californiensis	-0.878^{d}	-0.547^{b}	-1^{b}	-1^{b}
Ostracod	-0.125^{c}	-0.332^{b}	-0.507^{b}	-0.999^{b}
Pachygrapsus crassipes	-0.870^{d}	-0.999^{b}	-1^{b}	-1^{b}
Tanaid	-0.887^{d}	-1^{b}	-0.606^{b}	-1^{b}

Prey	*Cymatogaster aggregata*	*Leptocottus armatus*	*Gasterosteus aculeatus*	*Hypomesus pretiosus*
Amphipod	0.411^{a}	0.650^{a}	0.345^{a}	-0.972^{b}
Annelida	-1^{c}	-1^{b}	-0.594^{c}	-1^{b}
Cumacean	-1^{c}	-1^{b}	-0.967^{c}	-1^{b}
Harpacticoid	$-0.259^{b,c}$	-0.520^{b}	$0.083^{a,b}$	0.776^{a}
Hemigrapsus spp.	-1^{c}	-1^{b}	-1^{c}	-1^{b}
N. californiensis	-1^{c}	-1^{b}	-0.901^{c}	-1^{b}
Ostracod	$0.336^{a,b}$	-1^{b}	-0.027^{b}	-1^{b}
P. crassipes	-1^{c}	-1^{b}	-1^{c}	-0.999^{b}
Tanaid	-1^{c}	-1^{b}	-0.766^{c}	-1^{b}

Prey	*Atherinops affinis* (7–39mm)	*Atherinops affinis* (40–79mm)	*Atherinops affinis* (80–150mm)	*Hypomesus argenteum*
Amphipod	0.086^{a}	0.017^{a}	0.172^{a}	0.833^{a}
Annelida	-1^{b}	-1^{c}	-1^{b}	-1^{b}
Cumacean	-1^{b}	-1^{c}	-1^{b}	-0.816^{b}
Harpacticoid	0.387^{a}	$-0.376^{b,c}$	-0.149^{b}	-0.933^{b}
Hemigrapsus spp.	-1^{b}	$-0.571^{b,c}$	-1^{b}	-1^{b}
N. californiensis	-0.858^{b}	-0.858^{c}	-1^{b}	-1^{b}
Ostracod	-0.804^{b}	$0.116^{a,b,c}$	0.702^{a}	-0.731^{b}
P. crassipes	-1^{b}	$-0.134^{a,b}$	-0.999^{b}	-1^{b}
Tanaid	-1^{b}	-1^{c}	-1^{b}	-1^{2b}

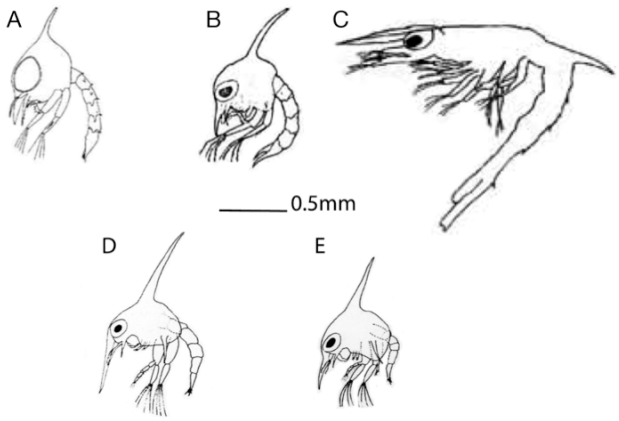

Fig. S1. Larvae of (A) *Pachygrapsus crassipes* (Stage 1), (B) *Hemigrapsus oregonensis* (Stage 1), (C) *Neotrypaea californiensis* (Stage 2), (D) *Scleroplax granulata* (Stage 1) and (E) *Pinnixa tubicola* (Stage 1). These crab larvae possess spines for defense, and their brown-black chromatophores affect the visibility of these otherwise transparent larvae to fishes; in contrast, shrimp larvae (*N. californiensis*) rely on evasive maneuvers and a pair of spines for defense, and they possess red chromatophores (Morgan 1987, 1989, 1990, Morgan & Christy 1996). Illustration authors: *P. crassipes* adapted from Schlotterbeck (1976), *H. oregonensis* adapted from Hart (1935), *N. californiensis* adapted from McCrow (1972) and both pinnotherids by L. Parsons (unpubl. data)

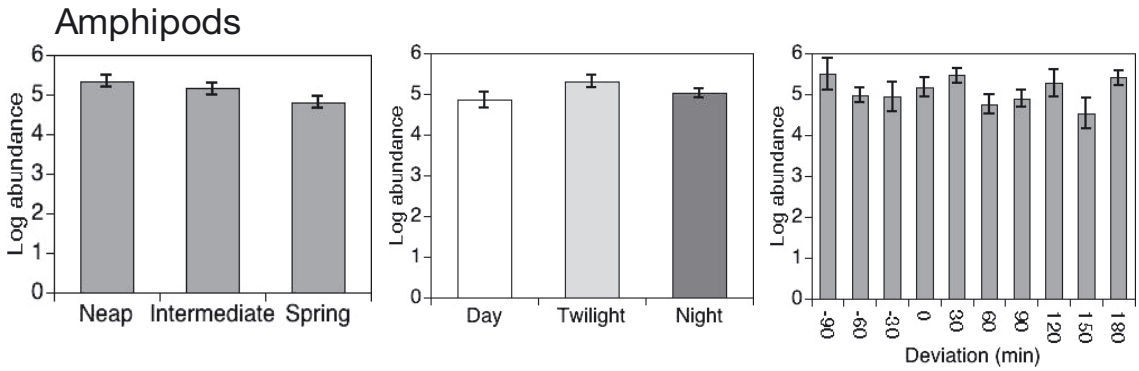

Fig. S2. Mean (±1 SE) log abundance of amphipods relative to tidal amplitude, light level and high tide. The zero on the x-axis of the plot in the third panel represents the time of high slack tide. Plots include tows with zero counts

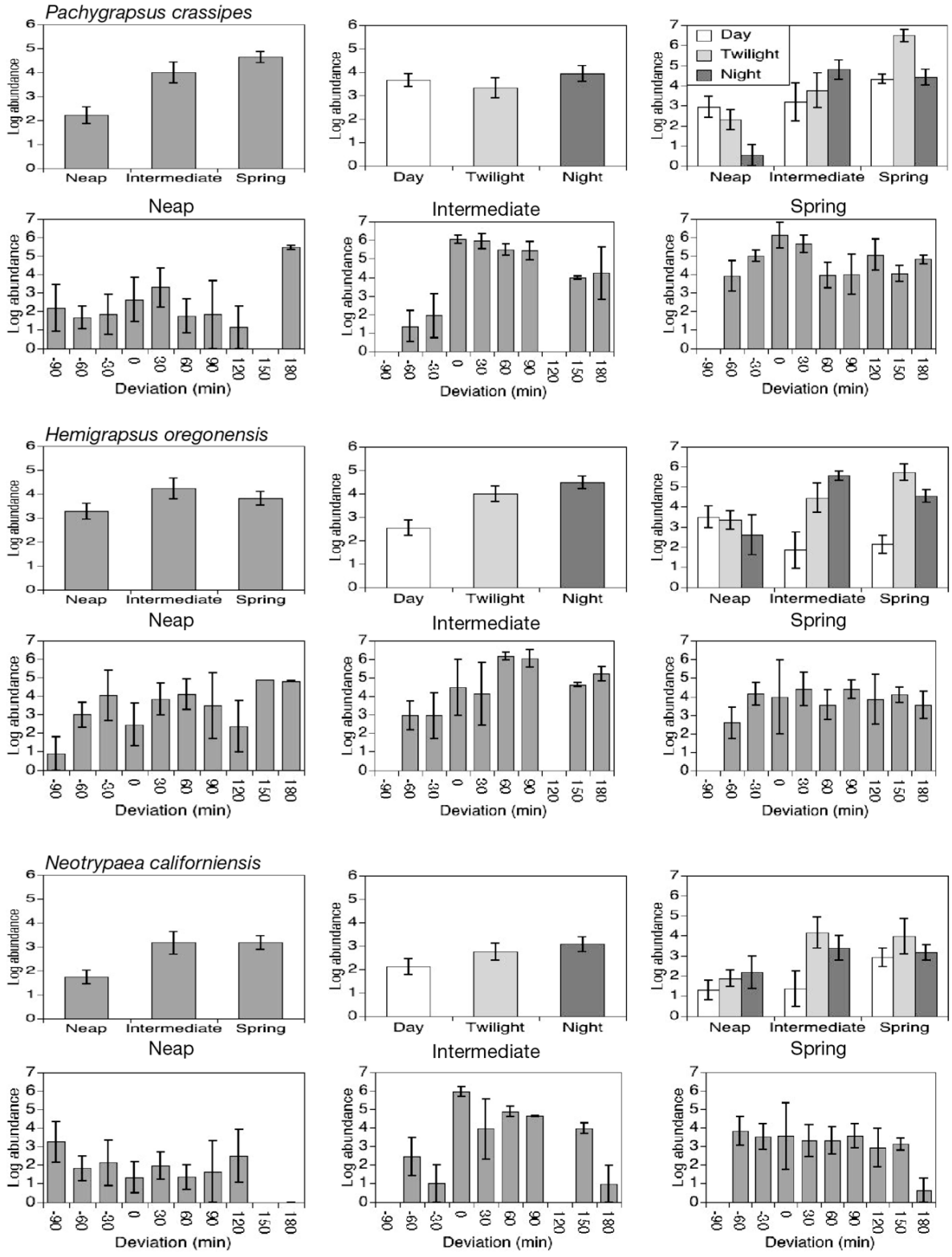

Fig. S3. *Pachygrapsus crassipes*, *Hemigrapsus oregonensis* and *Neotrypaea californiensis*. Mean (±1 SE) log abundance of larvae relative to tidal amplitude, light level, light level during neap, intermediate and spring tides and high tide relative to tidal amplitude. Plots include tows with zero counts

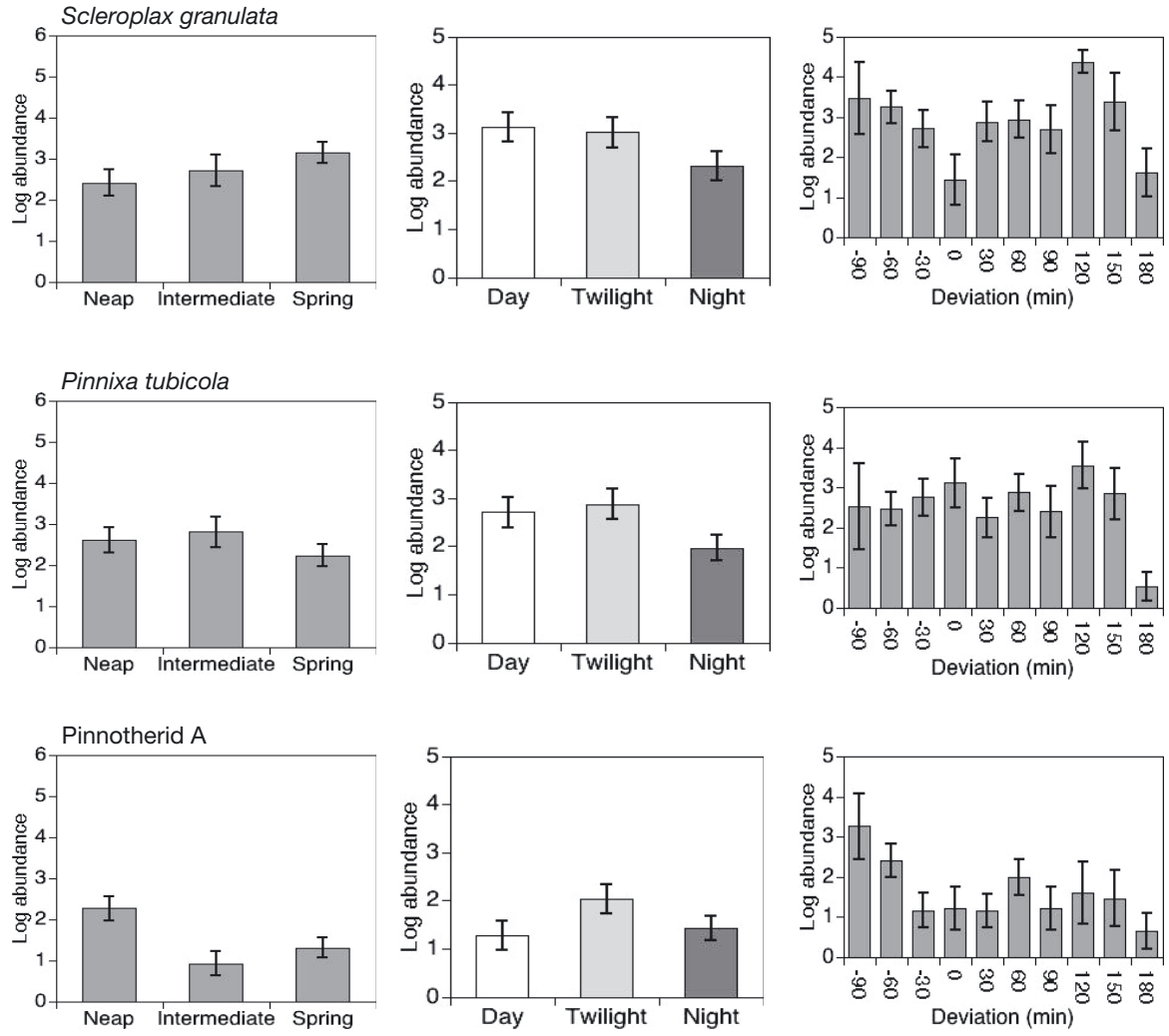

Fig. S4. *Scleroplax granulata, Pinnixa tubicola* and Pinnotherid A. Mean (±1 SE) log abundance of larvae relative to tidal amplitude, light level and high tide. Plots include tows with zero counts

LITERATURE CITED

Hart JFL (1935) The larval development of British Columbia Brachyura, I. Xanthidae, Pinnotheridae (in part) and Grapsidae. Can J Res 12:411–432

McCrow LT (1972) The ghost shrimp, *Callianassa californiensis*. MS thesis, Oregon State University, Corvallis, OR

Morgan SG (1987) Morphological and behavioral antipredatory adaptations of decapod zoeae. Oecologia 73:393–400

Morgan SG (1989) Adaptive significance of spination in estuarine crab zoeae. Ecology 70:464–482

Morgan SG (1990) Impact of planktivorous fishes on dispersal, hatching and morphology of estuarine crab larvae. Ecology 71:1639–1652

Morgan SG, Christy JH (1996) Survival of marine larvae under the countervailing selective pressures of photodamage and predation. Limnol Oceanogr 41:498–504

Schlotterbeck RE (1976) The larval development of the lined shore crab, *Pachygrapsus crassipes* Randall, 1840 (Decapoda Brachyura, Grapsidae) reared in the laboratory. Crustaceana 30:184–200