The following supplements accompany the article

Batch spawning decreases competition among early life stages in coastal fishes: a simulation study using red drum *Sciaenops ocellatus*

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Supplement 1. Prey search rate and handling time

Prey search rate (ml s^{-1}) and handling time (s) of red drum larvae were estimated in the laboratory (see Nakayama & Fuiman 2010 for the rearing and experiment protocols). One individual was put into a 15 l glass tank (50 × 20 cm, 15 cm high). After 10 min of acclimation, prey (*Artemia* nauplii) were introduced in the tank. Time was recorded from the introduction of prey to the consumption of the 10th prey, and the average prey capture rate (prey s^{-1}) of the individual was calculated (N = 76, 6.1 to 25.7 mm standard length). After 10 prey captures, the larva was put back to an isolated 1 l plastic container without food, and this procedure was repeated for the same individual with 6 different prey densities (3, 4, 6, 10, 40, 80 prey l^{-1}) at 1 h intervals in a randomized order. Prey search rate and handling time were estimated for each of 76 individual larvae by fitting prey capture rates of 6 prey densities to Holling's disc equation:

$$E = \frac{aN}{1 + ahN} \qquad \text{(S1)}$$

where a is prey search rate (ml s^{-1}), h is handling time (s $prey^{-1}$), E is prey capture rate (prey s^{-1}) and N is prey density (prey ml^{-1}). Using nonlinear least-squares estimation, we obtained the relationship between body length and search volume as $a = 5.72e^{0.618L}$ (Fig. S1). Considering a wide variation of R^2 (0.52 to 0.99), each data point was weighed by its coefficient of determination (R^2) of the disc equation. The relationship between body length and handling time was estimated in the same manner by fitting $h = 1.02e^{7.63r}$ (Fig. S1), where r is the ratio of prey width to the gape width of fish (Kislalioglu & Gibson 1976). The width of *Artemia* nauplii was set at 0.23 mm (the average width of 20 individuals, S. Nakayama unpubl. data), and the gape width of red drum larvae (L_{gape}, mm) was estimated as $L_{gape} = 0.10L + 0.12$ (Krebs & Turingan 2003). All parameters in the models were significant ($p < 0.05$). Nonlinear least-squares estimations were performed using the 'nls' package in R version 2.10.1 (R Development Core Team 2009).

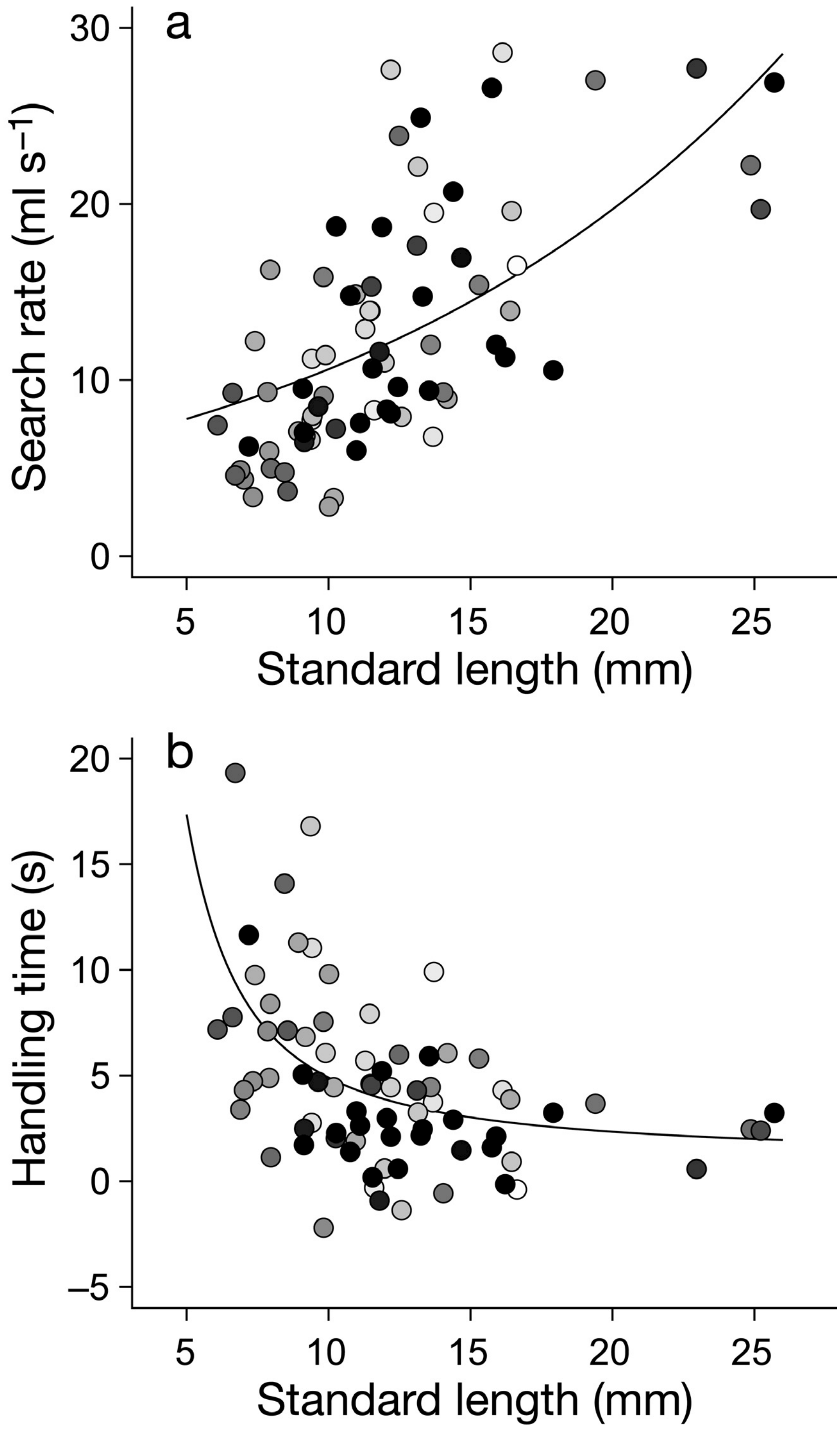

Fig. S1. *Sciaenops ocellatus.* Relationship between body lengths of red drum larvae (mm) and (a) prey search rate (ml s^{-1}) and (b) handling time (s). Lines indicate the predicted values, and points indicate the data estimated from Holling's disc equation. The fill intensity of the data points represents the value of R^2, ranging from (○) 0.5 to (●) 1

Supplement 2. Prey capture success and profitability

The capture success on copepods and mysids was measured in the laboratory experiments. For copepods, a red drum larva (4.5 to 29.5 mm SL) was put in a plastic chamber (10 × 10 × 10 cm) filled with sea water (about 27ºC, 27 ppt). After 10 min of acclimation, 30 adult calanoid copepods (*Acartia* spp., about 0.6 mm in length) were gently introduced in the chamber using a pipette. After exhibiting 10 feeding bouts, the larva was removed from the chamber with a dip net and euthanized with MS-222, and the number of copepods in its gut was counted. For mysids, 12 adult mysids (*Neomysis* spp., about 6.1 mm in length) were introduced in the chamber with a larva, and the capture success on mysids was directly observed over 10 attacks. When a larva did not conduct 10 attacks in 10 min, we stopped the observation and calculated the capture success from the number of attacks observed in 10 min. Red drum larvae were not fed for 15 to 18 h before the experiment. In total, 37 and 25 individuals were tested for copepods and mysids, respectively. The proportion of successful attacks (P_1 for copepod, P_2 for mysid) was estimated as a function of dry weight of the fish (W, mg) using a nonlinear least-squares regression (Fig. S2):

$$P_1 = \frac{0.62W^2}{2.21+W^2} \tag{S2}$$

$$P_2 = \frac{0.70W^2}{235.83+W^2} \tag{S3}$$

In the model, a larva was assigned to feed on either copepods or mysids or both so that it maximized energy gain per unit time. Following Letcher et al. (1996), each individual first evaluates the energy gain, $C_i P_i / h_i$, where C_i is the energy content of prey i (i = 1 for copepods, 2 for mysids). We used $C_1 = 0.0195$ cal (Morris & Hopkins 1983) and $C_2 = 1.3686$ cal (Donnelly et al. 1993). Then, an individual evaluates the profitability (f, energy gain per unit feeding time, cal s^{-1}):

$$f = \frac{\Sigma C_i E'_i P_i}{1+\Sigma E'_i h_i} \tag{S4}$$

by adding the prey item from the one with higher energy gain ($C_i P_i / h_i$) until the profitability starts to decrease. E'_i denotes encounter rate to prey i by taking into account interference competition (see Eq. 3 in the main article). Individuals were assigned to adopt prey habits that maximize the profitability. Multiplying f by 3600 gives the hourly energy gain of an individual. Nonlinear least-squares estimations were performed using the 'nls' package in R version 2.10.1 (R Development Core Team 2009).

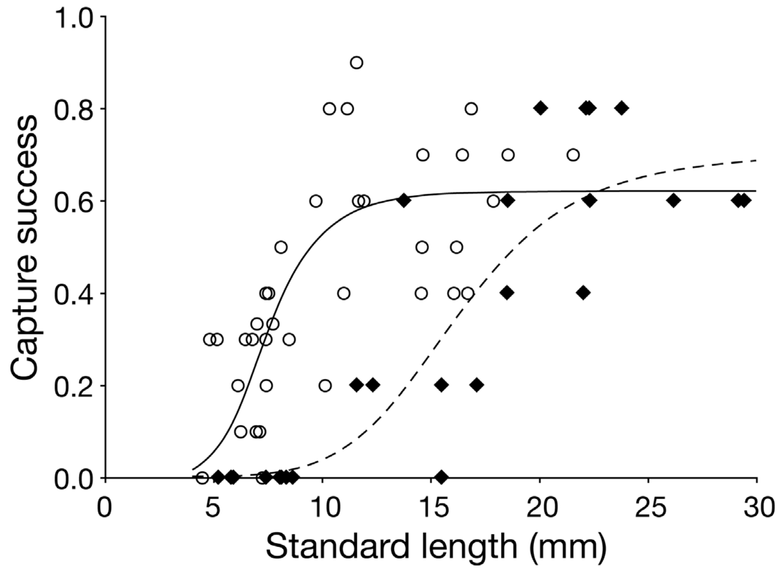

Fig. S2. *Sciaenops ocellatus.* Relationship between standard length (mm) of red drum and prey capture success. (○) observed capture success for copepods, (■) observed capture success for mysids, (———) predicted capture success for copepods. (– – – –) predicted capture success for mysids.

Supplement 3. Growth

The energy available for growth (ΔC) was calculated by subtracting resting metabolism (M_{res}, cal h^{-1}), active metabolism (M_{act}, cal h^{-1}), specific dynamic action (E_{SDA}, cal h^{-1}) and excretion (E_{excr}, cal h^{-1}) from the total energy consumed (C_{total}) adjusted by assimilation efficiency (A):

$$\Delta C = AC_{total} - (M_{res} + M_{act} + E_{SDA} + E_{excr}) \tag{S5}$$

Assimilation efficiency (A) was set as a function of dry weight of a larva (Peck & Daewel 2007):

$$A = 0.7[1 - 0.3e^{-0.003(W - 16.864)}] \tag{S6}$$

The relationship between resting metabolism (M_{res}, cal h^{-1}) and wet weight (W_{wet}, g) in red drum (Neill et al. 2004, measured at 18°C) was adjusted by temperature (Arrhenius effect; Gillooly et al. 2001) as:

$$M_{res} = 0.34 W_{wet}^{0.8} \exp\left[\frac{5020(T-18)}{(T+273.15)(18+273.15)}\right] \tag{S7}$$

where $w_{wet} = (W / 3.59^{1.04} \times 10^{-5}$ (S. Nakayama unpubl. data). Resting metabolism was applied for 24 h d^{-1} in the model. Active metabolism was set 2.5 times higher than resting metabolism (Letcher et al. 1996), and it was applied only while a larva was foraging (12 h d^{-1} or less if a larva achieved the maximum prey consumption). E_{SDA} and E_{excr} were set at 0.156 and 0.07 cal h^{-1}of total consumption, respectively (Houde & Zastrow 1993). ΔC was converted to dry weight (0.004 cal µg^{-1}; Fontaine et al 2007). Maximum consumption (C_{max}, cal d^{-1}) was calculated from the relationship between temperature and growth in the laboratory (from Pérez-Domínguez et al. 2006) as:

$$C_{max} = 86842W \times \exp\left(\frac{-5158.2}{T+273.15}\right) \tag{S8}$$

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