The following supplement accompanies the article

Trait-mediated ecosystem impacts: how morphology and size affect pumping rates of the Caribbean giant barrel sponge

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Supplement. Model of sponge morphology and flow used to explain the relationship between spongocoel morphology and excurrent flow.

MATERIALS AND METHODS

Results indicated that excurrent velocity distributions varied as a function of spongocoel morphology (Fig. 2). We therefore considered concomitant changes in sponge and spongocoel morphologies to explain the distribution of velocities across the osculum. For our model of sponge morphology and flow (Fig. S1), aquiferous canals were assumed to be organized in a manner that minimized the distance from incurrent ostia to excurrent apertures lining the spongocoel. The volume of each sponge (V_{sponge}), excluding the volume of the spongocoel, was then divided into wall (V_{wall}) and base (V_{base}) volumes that discharge seawater through excurrent canals terminating along the spongocoel wall and spongocoel base, respectively (Fig. S1). V_{base} was approximated as a frustum of a cone and V_{wall} was calculated as the difference between V_{sponge} and V_{base}. The ratio of V_{base} to V_{wall} was used as a measure of sponge morphology.

Based on our investigation of pumping and sponge size (see results), we assumed that volume flow scaled isometrically with sponge tissue volume such that the volumes of seawater discharged by excurrent canals terminating along the spongocoel wall and spongocoel base were proportional to V_{wall} and V_{base}, respectively. Flow through V_{base} was assumed to exit an area ($A_{oscbase}$) of the osculum equivalent to A_{sb} and flow through V_{wall} was assumed to exit an area ($A_{oscwall}$) of the osculum equivalent to the difference between A_{osc} and $A_{oscbase}$ (Fig. S1). The ratio of V_{wall} to $A_{oscwall}$ was used as a measure of the excurrent velocity of seawater at the osculum margin and the ratio of V_{base} to $A_{oscbase}$ was used as a measure of the excurrent velocity at the osculum centerline. The ratio of $(V_{wall} / A_{oscwall})/(V_{base} / A_{oscbase})$ is therefore a measure of the distribution of velocities across the osculum; plug flow results when the ratio of V_{wall} per $A_{oscwall}$ is equivalent to V_{base} per $A_{oscbase}$, and near-parabolic flow occurs when V_{wall} per $A_{oscwall}$ is less than V_{base} per $A_{oscbase}$. Given this model of sponge morphology and flow, the relationship between sponge and spongocoel morphology was investigated by performing OLS regression on the $\log_{10}$-transformed ratios of A_{osc} to A_{sb} and V_{base} to V_{wall}. To investigate how changes in sponge and spongocoel morphology may affect osculum velocity profiles, OLS regression was performed on $\log_{10}$-transformed ratios of $(V_{wall} / A_{oscwall})/(V_{base} / A_{oscbase})$ and A_{osc} to A_{sb}.

RESULTS

The majority of all sponges measured (94%) were found to have proportionally more tissue volume distributed around walls (V_{wall}) than at the base (V_{base}). Ratios of A_{osc} to A_{sb} varied independently of V_{sponge} (OLS regression; $P = 0.29$) and ranged from 1.5 to 484. Sponges with larger ratios of A_{osc} to A_{sb} were found to generally have a greater proportion of tissue volume distributed as V_{wall} than V_{base} ($V_{base} / V_{wall} = 0.79(A_{osc} / A_{sb})^{-0.41}$; $n = 235$, $r^2 = 0.28$, $p < 0.001$) (Fig. S2A). Excurrent velocity distributions varied as a function of concomitant changes in sponge and spongocoel morphology. Ratios of $(V_{wall} / A_{oscwall})/(V_{base} / A_{oscbase})$ were found to allometrically decrease with increasing ratios of A_{osc} to A_{sb} ($n = 235$, $r^2 = 0.53$, $p < 0.001$) (Fig. S2B) according to the equation:

$$\frac{V_{wall}}{A_{oscwall}} / \frac{V_{base}}{A_{oscbase}} = 1.92\left(\frac{A_{osc}}{A_{sb}}\right)^{-0.70} \qquad \text{(S1)}$$

Given the relationship described by Eq. S1, near-parabolic flow occurs when A_{osc} is greater than 2.54 times A_{sb}.

DISCUSSION

Our model of sponge morphology and flow closely approximated the relationship observed between spongocoel morphology and velocity distributions and suggests that the partitioning of sponge biomass relative to the spongocoel influences excurrent water flow. The scaling exponent of the model (-0.70; Eq. S1) was similar to that for the empirical relationship between velocity distributions and spongocoel morphology (-0.52; Eq. 3), and described velocity distributions that become increasingly parabolic as A_{osc} increases relative to A_{sb}. Unlike *M. laxissima* (Reiswig 1974), osculum area was greater than spongocoel base area for all *X. muta* measured (i.e. A_{osc} / A_{sb} was always greater than 1). Additionally, velocity distributions for *M. laxissima* approached plug flow when the ratio of osculum diameter to spongocoel base diameter was less than 1, whereas the empirical relationship between velocity distributions and spongocoel morphology of *X. muta* indicates that plug flow results when the ratio of A_{osc} to A_{sb} is 2.87. This is explained by a greater partitioning of biomass as V_{wall} relative to V_{sponge} for the majority (96%) of sponges measured. This is also supported by the model, as plug flow was found to occur when the ratio of A_{osc} to A_{sb} is 2.54. Approximately 9% of sponges, however, were predicted by the model to have reverse-parabolic excurrent velocity distributions (ratios of V_{wall} per $A_{oscwall}$ to V_{base} per $A_{oscbase}$ > 1) (Fig. S2B). While possible, reverse parabolic velocity distributions were not found to occur among sponges measured and this is likely an artifact of the simplified approximation of velocity distributions used by the model that does not consider the nonlinear nature of velocity profiles.

LITERATURE CITED

Reiswig HM (1974) Water transport, respiration and energetics of three tropical marine sponges. J Exp Mar Biol Ecol 14:231–249

Fig. S1. Schematic of the conceptual model of *Xestospongia muta* used to examine the relationship between spongocoel morphology and flow (Fig.2). Seawater entering the *spongocoel* through the $spongocoel_{base}$ is proportional to the tissue volume of sponge *base* and exits the osculum through the area of osc_{base}. A volume of seawater proportional to the tissue volume of sponge *wall* drains into the *spongocoel* at the $spongocoel_{wall}$ and exits the osculum through osc_{wall}.

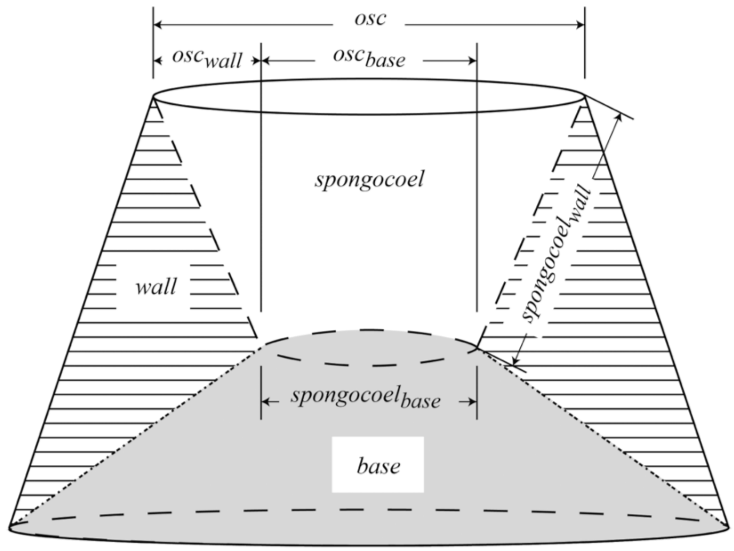

Fig. S2. Scatterplots of (A) the ratio of base volume (V_{base}) to wall volume (V_{wall}), a measure of sponge morphology, and (B) the ratio of V_{wall} per osculum peripheral area ($A_{oscwall}$) to V_{base} per osculum center area ($A_{oscbase}$), a measure of the distribution of velocities across the osculum, vs. the ratio of sponge osculum area (A_{osc}) to spongocoel base area (A_{sb}), a measure of spongocoel morphology. Variables were calculated based on the conceptual model of sponge morphology and flow (Fig. S1).