Mating group size and optimal sexual pattern in sedentary marine animals

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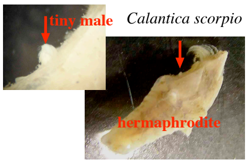
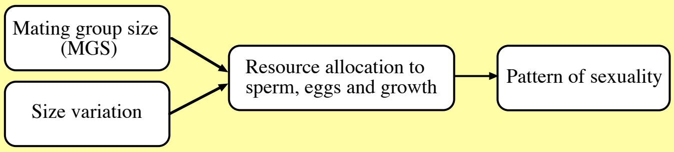
1. Introduction

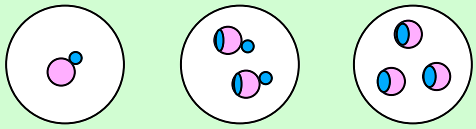
- In sedentary marine animals, such as barnacles and bivalves, their males are generally very small comparing with large individuals (simultaneous hermaphrodites or females).



- The pattern of sexuality
  A. Simultaneous hermaphroditism
  B. Androdioecy (large hermaphrodites & tiny males)
  C. Dioecy (large females & tiny males)
  D. Sex change (tiny males --> large females)



Empirical relation between MGS and the pattern of sexuality



Dioecy | Androdioecy | Simultaneous hermaphroditism

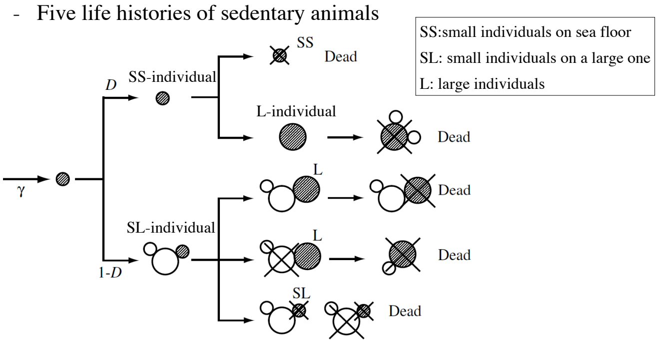
small MGS (MGS ~ 1) ←→ large MGS (MGS > 3)

- Two size classes: small individual (s_S) < large individuals (s_L)

- We define four sexual patterns by using the optimal resource allocation of small and large individuals, and consider the relation between MGS and sexual pattern.

2. Model

- Five life histories of sedentary animals



$g(t)$, $m(t)$, $f(t)$: resource allocation ratio to growth, male and female functions, respectively

	Resource allocation ratio	Reproductive success $\phi(t)$
SS-individual	$g_{SS}(t)=1$	0
SL-individual	$m_{SL}(t)+g_{SL}(t)=1$	$F\Delta t \times \frac{m_{SL}(t)r_S}{\Theta[K-1]\cdot\alpha\Delta t + NA\Delta t + m_{SL}(t)r_S}$
L-individual	$m_L(t)+f_L(t)=1$	$(K-1)[F\Delta t \times \frac{m_L(t)r_L}{K-1}\cdot((K-2)\cdot\frac{\alpha\Delta t}{K-1} + N_W A\Delta t + \frac{m_L(t)r_L}{K-1})^{-1}]$ + $f_L(t)r_L\Theta[\Theta[K-1]\alpha\Delta t + N_L A\Delta t]$

We calculate the optimal resource allocation ratio which maximize lifetime reproductive success by using dynamic programming.

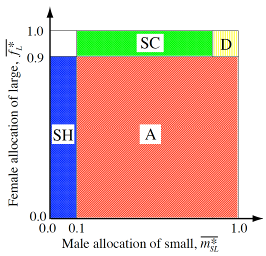
(Expected reproductive success after time *t*)= max [(Reproductive success at time *t*)
+(Expected reproductive success after time *t*+*Δ t*)]

$$R_{SS}(K,0,0;t) = \max_{0\le m_{SS}(t)\le 1}[\phi_{SS}(K,0,0;m_{SS}(t),t) + \sum_{\tilde{K}}\sum_{\tilde{i}} p_{i\tilde{i}}R_{\tilde{i}}(\tilde{K},0,0;t+\Delta t)]$$

$$R_{SL}(K,N,0;t) = \max_{0\le m_{SL}(t)\le 1}[\phi_{SL}(K,N,0;m_{SL}(t),t) + \sum_{\tilde{K}}\sum_{\tilde{N}}\sum_{\tilde{i}} p_{i\tilde{i}}R_{\tilde{i}}(\tilde{K},\tilde{N},0;t+\Delta t)]$$

$$R_{L}(K,0,N_L;t) = \max_{0\le m_{L}(t)\le 1}[\phi_{L}(K,0,N_L;m_{L}(t),t) + \sum_{\tilde{K}}\sum_{\tilde{N}_L}\sum_{\tilde{i}} p_{i\tilde{i}}R_{\tilde{i}}(\tilde{K},0,\tilde{N}_L;t+\Delta t)]$$

- Strategy range of four patterns of sexuality
  We define the patterns of sexuality by using the range of the average ESS allocation shedule:



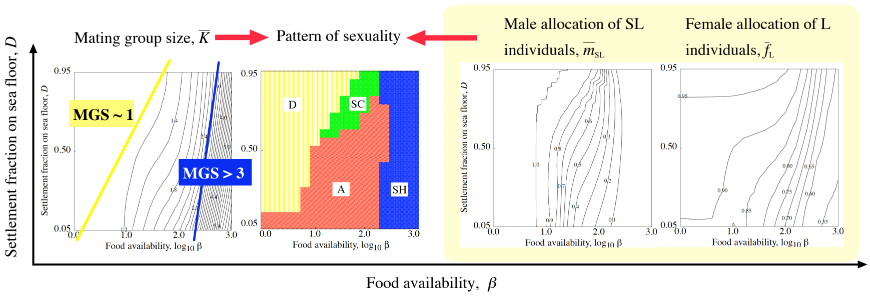
$$\overline{m^*_{SL}} = \frac{\sum_{K,N,t} q_{SL}(K,N,0;t)m^*_{SL}(K,N,0;t)}{\sum_{K,N,t} q_{SL}(K,N,0;t)}$$

$$\overline{f^*_{L}} = \frac{\sum_{K,N_L,t} q_{L}(K,0,N_L;t)f^*_{L}(K,0,N_L;t)}{\sum_{K,N_L,t} q_{L}(K,0,N_L;t)}$$

where $q_i(K,N,N_L;t)$ is the probability that the mutant's state is (K,N,N_L) at time *t*.

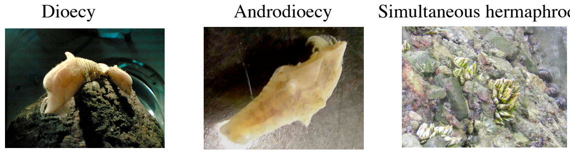
Sexual patterns	the range of $\overline{m^*_{SL}}$	the range of $\overline{f^*_L}$
Simultaneous hermaphroditism (SH)	$0 < \overline{m^*_{SL}} < 0.1$	$0 < \overline{f^*_L} < 0.9$
Androdioecy (A)	$0.1 < \overline{m^*_{SL}} < 1.0$	$0 < \overline{f^*_L} < 0.9$
Dioecy (D)	$0.9 < \overline{m^*_{SL}} < 1.0$	$0.9 < \overline{f^*_L} < 1.0$
Sex change (SC)	$0.1 < \overline{m^*_{SL}} < 0.9$	$0.9 < \overline{f^*_L} < 1.0$

3. Result & Summary

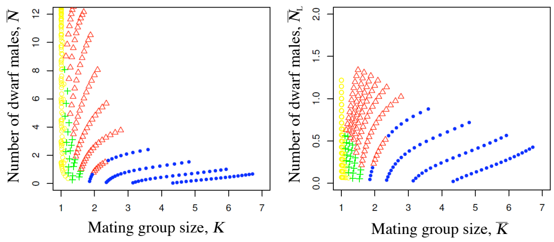


The patterns of sexuality in field

small MGS ←→ large MGS

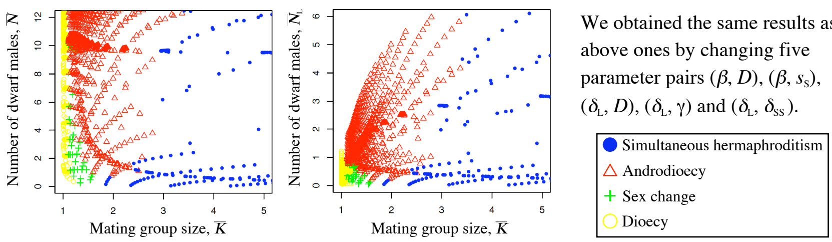


small β ←→ large β



- The pattern of sexuality changes in the order of the mating group size ($\overline{K}$).

- The effect of number of dwarf males ($\overline{N}$, $\overline{N}_L$) on the pattern of sexuality is small.



We obtained the same results as above ones by changing five parameter pairs (β, D), (β, s_S), (δ_L, D), (δ_L, γ) and (δ_L, δ_{SS}).

Why MGS affects the pattern of sexuality ?

MGS | **sexual pattern**

small MGS --> Sperm competition is weak for SL individuals. --> ***Dioecy***
SL individuals can obtain large reproductive success through male function.
Lack of female-role mating partner for large individuals
$\overline{m}^*_{SL} \sim 1$, $\overline{f}^*_L \sim 1$

Dioecy ↓ ***Sex change*** ↓ ***Androdioecy*** ↓

large MGS --> Sperm competition is severe. --> ***Simultaneous hermphroditism***
SL individuals allocate their resources to growth rather than male function.
Large individuals have both male and female partners.
$\overline{m}^*_{SL} \sim 0$, $\overline{f}^*_L \sim 0.5$