Alternative reproductive tactics in cichlid fish

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Sexual selection – characteristics that maximize reproductive success

sexualselection.edublogs.org

www.remybumppofieldguide.org

www.perlgurl.org

blogs.scientificamerican.com

- Intimidating/defeating opponents of the **same sex** (size dimorphism, secondary sex characteristics)
- Attraction of the **opposite sex** (ornaments)

cichlids

- Family of freshwater fish (Asia, Africa and South America)
- Remarkable dimorphism (size, color, ornaments)

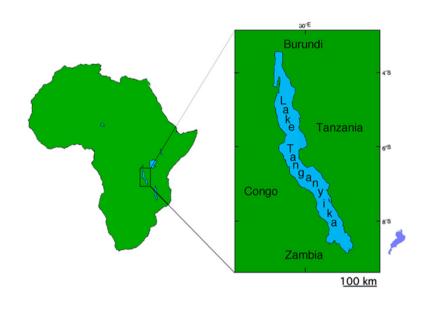*Apistogramma cacatuoides.* Amazon Basin, South America

my-fish.org

Aulonocara jacobfreibergi. Lake Malawi, Africa

- External fertilization in fish (allowing the selection of **parasitic** tactics)

Taborsky. 2001. The Journal of heredity.

3

Alternative Reproductive Tactics
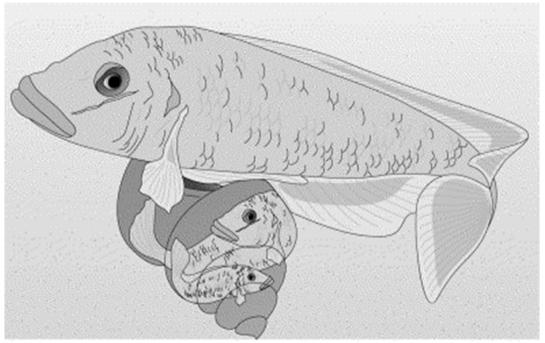

Foto: © Henrik Malchau

cichlidlovers.com

- *Lamprologus callipterus*
- Strong size dimorphism (competition between large males)
- Males collect and guard shells (nests)
- Females shelter and spawn in shells

Taborsky. 2001. The Journal of heredity.

- Very small males are able to enter inside guarded shells and breed with females during the reproductive period (**parasitic tactic**)
  - Small males go to innermost part of the shell

- Tactics are hereditary (size of male offspring is related to the size of the father)
  - Sizes between males tactics are disproportional (bimodal selection of male size)

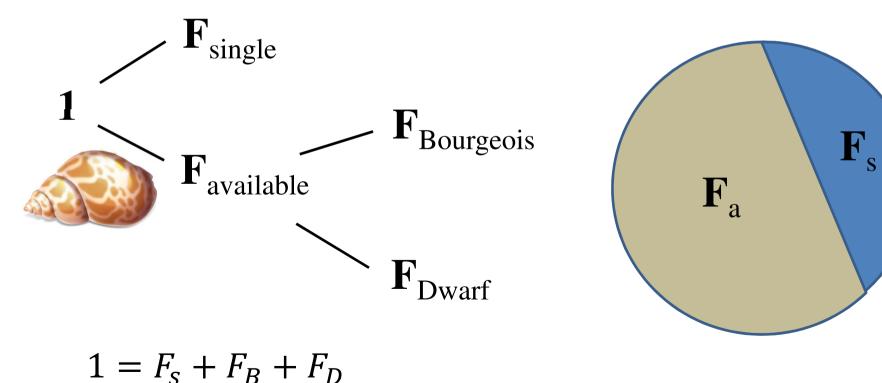Wirtz-Ocana et al. 2013. Ecology and Evolution.

Strategies

- **Bourgeois**
  - Nesting
  - Large sized
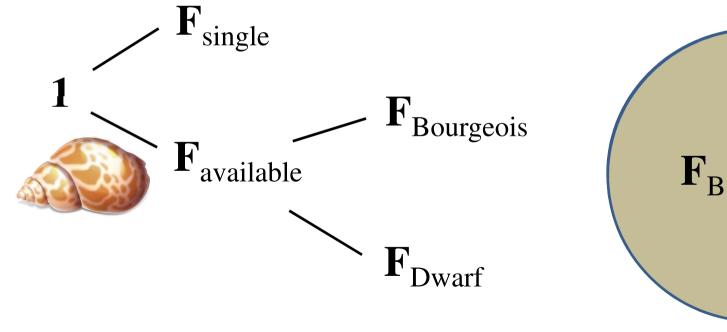
- **Dwarf**
  - Small sized
  - Cryptic (detection)

Taborsky. 2001. The Journal of heredity.

Question

- In which conditions there is long-term coexistence of both strategies in a population?

Assumptions

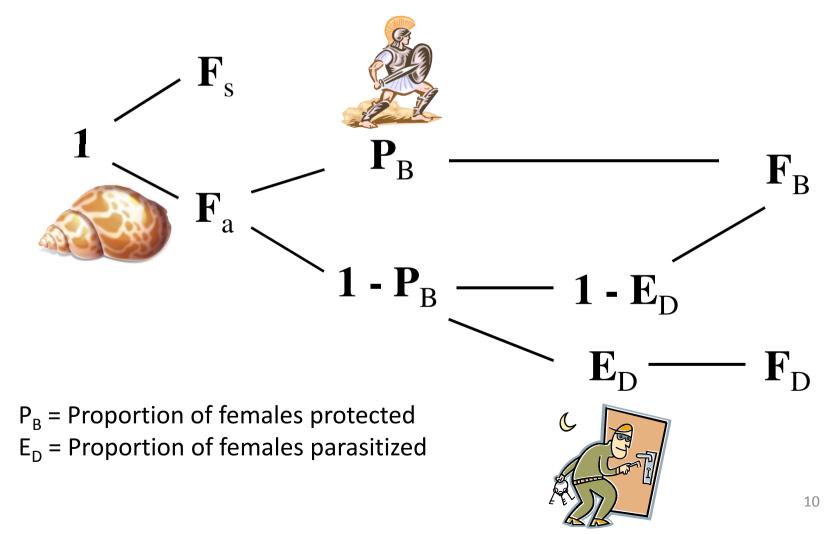- Total females are constant in time (simplify)
- Proportion of females

$\mathbf{F}_{\text{single}}$

$\mathbf{1}$

$\mathbf{F}_{\text{available}}$

$\mathbf{F}_{\text{Bourgeois}}$

$\mathbf{F}_{\text{Dwarf}}$

$\mathbf{F}_{\text{s}}$

$\mathbf{F}_{\text{a}}$

$$1 = F_S + F_B + F_D$$

Assumptions

- Total females are constant in time (simplify)
- Proportion of females

$$\mathbf{F}_{single}$$

$$\mathbf{1}$$

$$\mathbf{F}_{available}$$

$$\mathbf{F}_{Bourgeois}$$

$$\mathbf{F}_{Dwarf}$$

$$1 = F_S + F_B + F_D$$

Assumptions

- Available females could be protected or not
- Non protected females can mate with dwarf or bourgeois

$$F_s$$

$$1$$

$$F_a$$

$$P_B \qquad\qquad F_B$$

$$1 - P_B \quad\text{—}\quad 1 - E_D$$

$$E_D \quad\text{—}\quad F_D$$

P_B = Proportion of females protected
E_D = Proportion of females parasitized

Assumptions

- Bourgeois are essential for the reproduction of the species (nesting)

Foto: © Henrik Malchau

$$F_s = \frac{1}{1 + e\,B/F}$$

F_s = Proportion of single females
e = Efficiency of building nests
B = Bourgeois
F = Number of females (fixed)

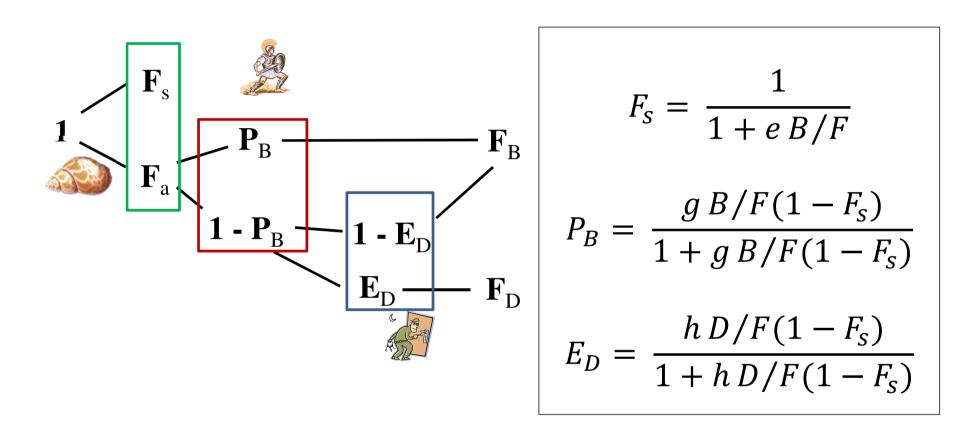# Differential equations

$$
\left\{
\begin{array}{l}
\dfrac{dB}{dt} = aF_B F - bB \\[3em]
\dfrac{dD}{dt} = cF_D F - dD
\end{array}
\right.
$$

B = Number of Bourgeois
D = Number of Dwarfs
F = Total number of females (fixed)
F_B = Proportion of females that mate with B
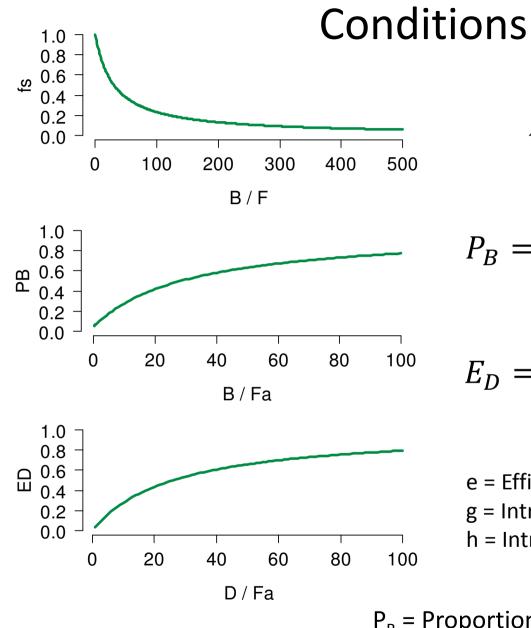F_D = Proportion of females that mate with D

a = Intrinsic reproductive rate of B
b = Death rate of B
c = Intrinsic reproductive rate of D
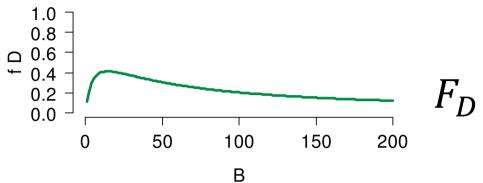d = Death rate of D

Conditions

$$F_S = \frac{1}{1 + e\,B/F}$$

$$P_B = \frac{g\,B/F(1 - F_S)}{1 + g\,B/F(1 - F_S)}$$

$$E_D = \frac{h\,D/F(1 - F_S)}{1 + h\,D/F(1 - F_S)}$$

e = Efficiency of nesting
g = Intrinsic capacity to protect females
h = Intrinsic capacity of cheating

Conditions

$$F_S = \frac{1}{1 + e\,B/F}$$

$$P_B = \frac{g\,B/F(1 - F_S)}{1 + g\,B/F(1 - F_S)}$$

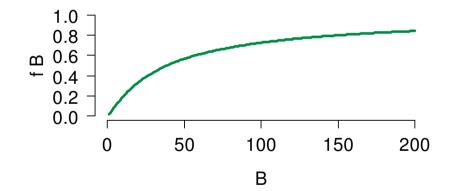$$E_D = \frac{h\,D/F(1 - F_S)}{1 + h\,D/F(1 - F_S)}$$

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P_B = Proportion of females protected
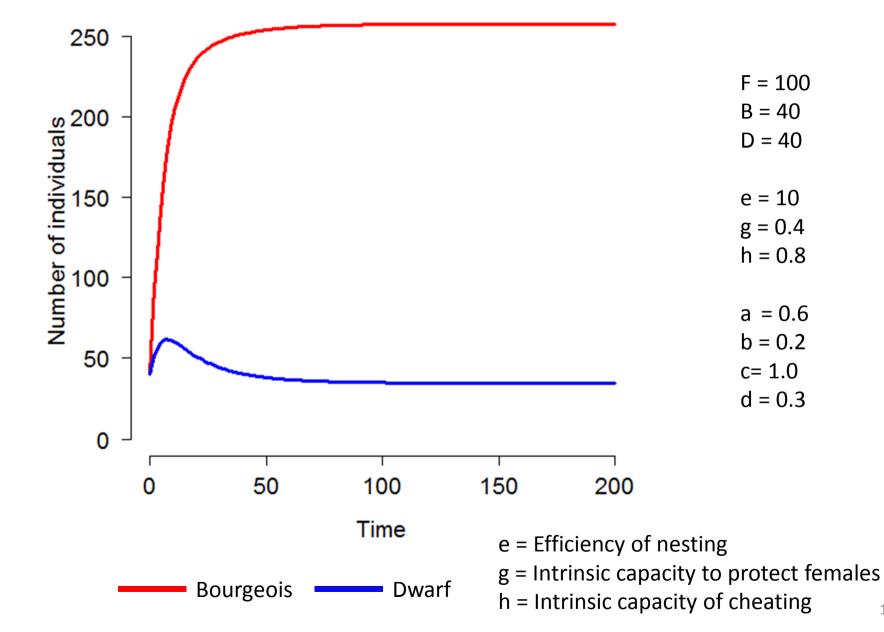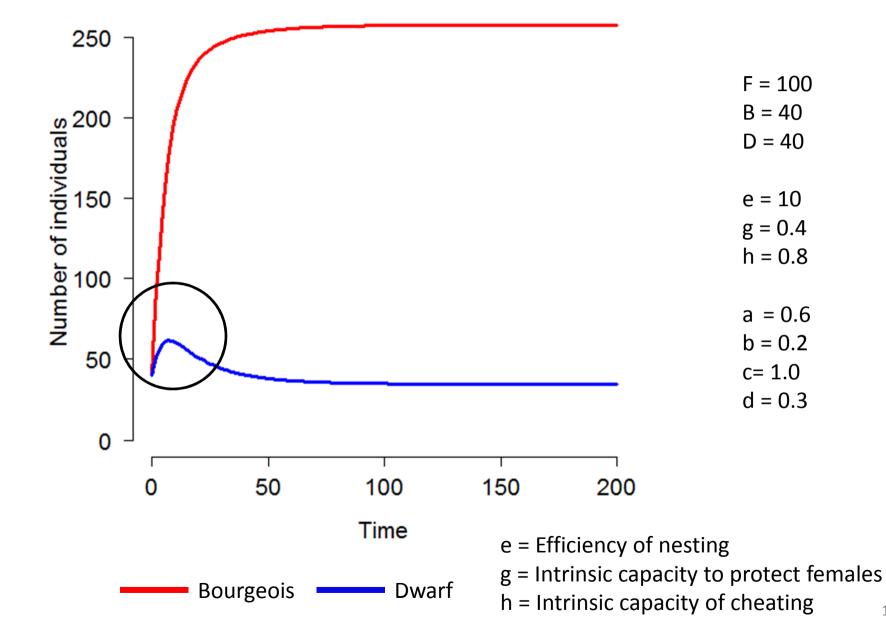E_D = Proportion of females parasitized

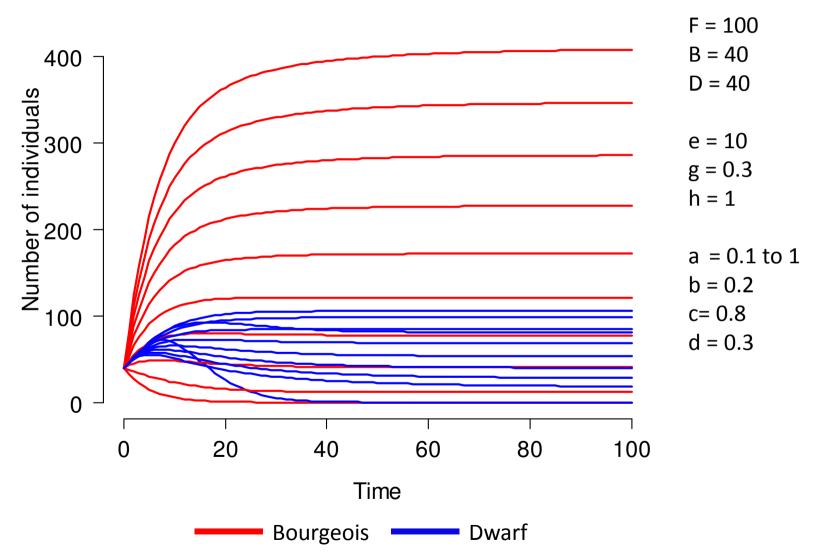# Conditions

$$F_D = (1 - F_s)(1 - P_B)E_D$$
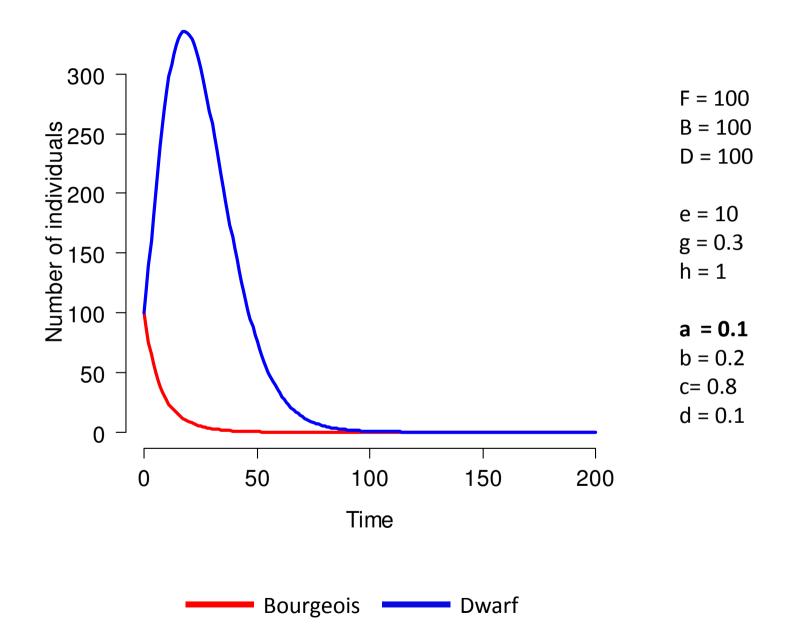
$$F_B = (1 - F_s) - F_D$$

P_B = Proportion of females protected
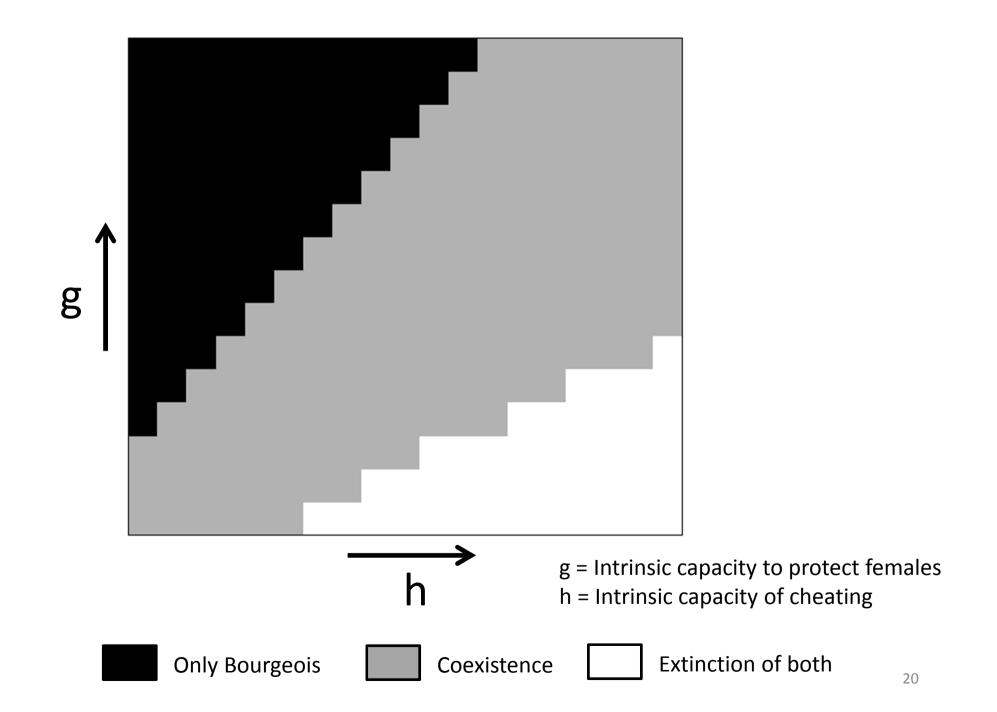E_D = Proportion of females parasitized

F = 100
B = 40
D = 40

e = 10
g = 0.4
h = 0.8

a = 0.6
b = 0.2
c = 1.0
d = 0.3

Bourgeois ― Dwarf ―

e = Efficiency of nesting
g = Intrinsic capacity to protect females
h = Intrinsic capacity of cheating

16

F = 100
B = 40
D = 40

e = 10
g = 0.4
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a = 0.6
b = 0.2
c= 1.0
d = 0.3

e = Efficiency of nesting
g = Intrinsic capacity to protect females
h = Intrinsic capacity of cheating

17

Ranging a from 0.1 to 1

F = 100
B = 40
D = 40

e = 10
g = 0.3
h = 1

a = 0.1 to 1
b = 0.2
c= 0.8
d = 0.3

Number of individuals

Time

Bourgeois   Dwarf

F = 100
B = 100
D = 100

e = 10
g = 0.3
h = 1

a = 0.1
b = 0.2
c= 0.8
d = 0.1

Number of individuals

Time

Bourgeois   Dwarf

g = Intrinsic capacity to protect females
h = Intrinsic capacity of cheating

■ Only Bourgeois   ▨ Coexistence   □ Extinction of both

Conclusion

Coexistence will depend on growth and death rates of each strategy (a, b, c and d) – D depends on B

Coexistence (relation between g and h)

- Bourgeois competition (g)
  - Bourgeois is always busy (Protection is not perfect)

- Cryptic ability of dwarf (h)
  - Camouflage, mimic females… (threshold of low values of h for coexistence)
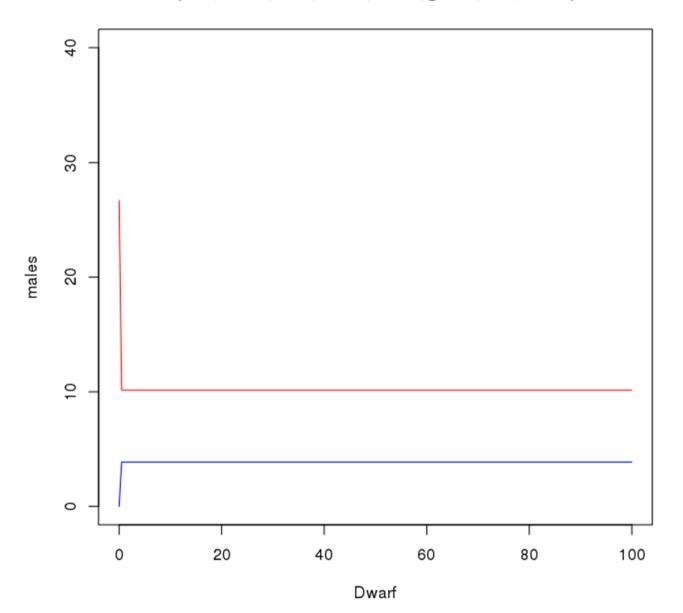 - High values of parasite efficiency extinct the species (threshold of high values)

Thank you

- Assistants: Bernardo Niebuhr, Diogo Melo and Fernando Rossine, Renato Coutinho, Ayana Martins, Flávia...
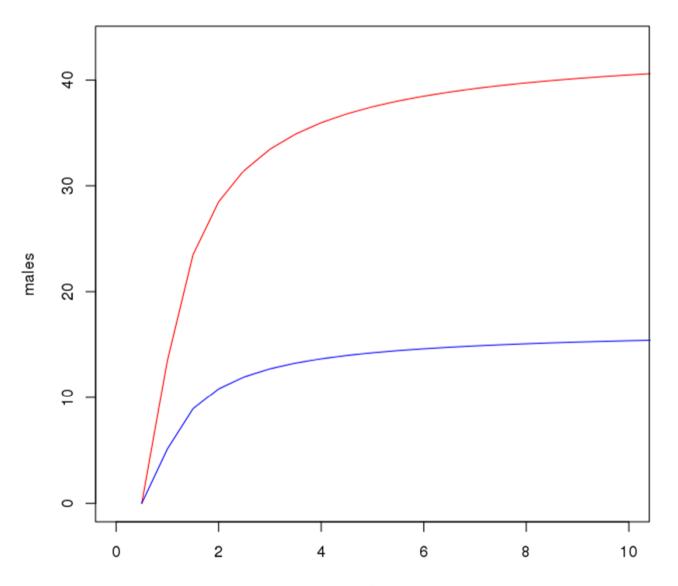
- Otso Ovaskainen and François Massol
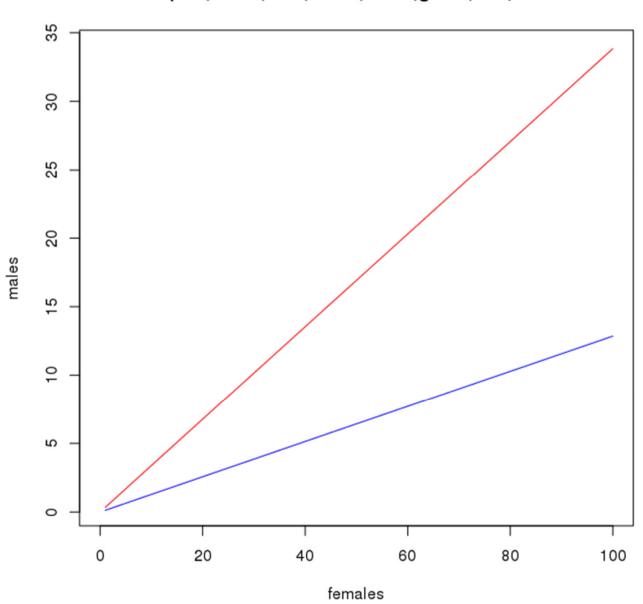
Southern-Summer School on Mathematical Biology
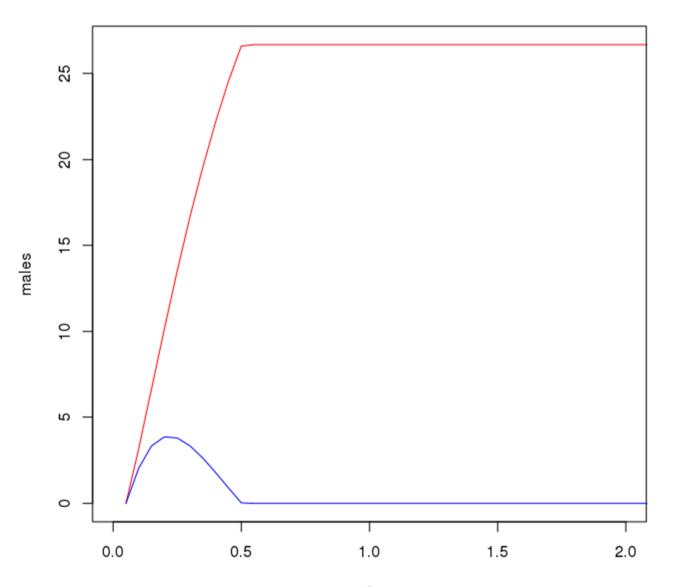
(a=1,b=0.5,ci=1,d=0.5,e=0.9,g=0.2,h=1,Fi=30)
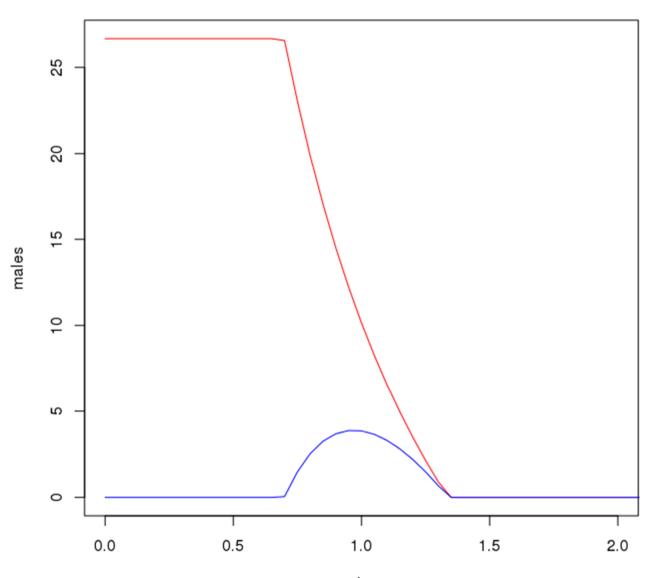
(a=1,b=0.5,ci=1,d=0.5,e=i,g=0.2,h=1,Fi=30)

(a=1,b=0.5,ci=1,d=0.5,e=0.9,g=0.2,h=1,Fi=i

(a=1,b=0.5,ci=1,d=0.5,e=0.9,g=0.2,h=i,Fi=30)

(a=1,b=0.5,ci=1,d=0.5,e=0.9,g=0.2,h=i,Fi=30)