Fidelity of parent-offspring transmission and the evolution of social behavior in subdivided populations.

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Expected frequency of altruists in the population

$$\mathbb{E}[\bar{X}] = \nu + \delta\, \nu(1-\nu)\, \frac{1-\mu}{\mu}\, (1 - Q_{\text{out}})\, \times$$

$$\left(-c - (b-c)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n\,(N_d - 1)}\right)\right.$$

$$\left. + \frac{Q_{\text{in}} - Q_{\text{out}}}{1 - Q_{\text{out}}}\left[b - (b-c)\,(n-1)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n\,(N_d - 1)}\right)\right]\right)$$

Expected frequency of altruists in the population

Mutation-drift equilibrium

$$\mathbb{E}[\bar{X}] = \nu + \delta \; \nu(1-\nu) \; \frac{1-\mu}{\mu} \; (1-Q_{\text{out}}) \times$$

$$\left(-c \; - (b-c) \left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d-1)} \right) \right.$$

$$\left. + \frac{Q_{\text{in}} - Q_{\text{out}}}{1 - Q_{\text{out}}} \left[b - (b-c)(n-1) \left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d-1)} \right) \right] \right)$$

Expected frequency of altruists in the population

Mutation-drift equilibrium

Selection strength

$$\mathbb{E}[\bar{X}] = \nu + \delta\, \nu(1-\nu)\, \frac{1-\mu}{\mu}\, (1 - Q_{\text{out}})\, \times$$

$$\left(-c - (b-c)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d-1)}\right) \right.$$

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Expected frequency of altruists in the population

Mutation-drift equilibrium

Selection strength

~~Population variance~~
Variance in the state of one site

$$\mathbb{E}[\overline{X}] = \nu + \delta \; \nu(1-\nu) \; \frac{1-\mu}{\mu} \; (1 - Q_{\text{out}}) \; \times$$

$$\left(-c - (b-c) \left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d-1)} \right) \right.$$

$$\left. + \frac{Q_{\text{in}} - Q_{\text{out}}}{1 - Q_{\text{out}}} \left[b - (b-c)(n-1) \left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d-1)} \right) \right] \right)$$

Expected frequency of altruists in the population

Mutation-drift equilibrium — Selection strength — Population variance / Variance in the state of one site

$$\mathbb{E}[\overline{X}] = \nu + \delta \; \nu(1-\nu) \; \frac{1-\mu}{\mu} \; (1 - Q_{\text{out}}) \; \times$$

$$\left(-c - (b-c) \left(\frac{(1-m)^2}{n} + \frac{m^2}{n\,(N_d - 1)} \right) - \mathcal{C} \right.$$

$$\left. + \frac{Q_{\text{in}} - Q_{\text{out}}}{1 - Q_{\text{out}}} \left[b - (b-c)\,(n-1) \left(\frac{(1-m)^2}{n} + \frac{m^2}{n\,(N_d - 1)} \right) \right] \right)$$

Expected frequency of altruists in the population

Mutation-drift equilibrium

Selection strength
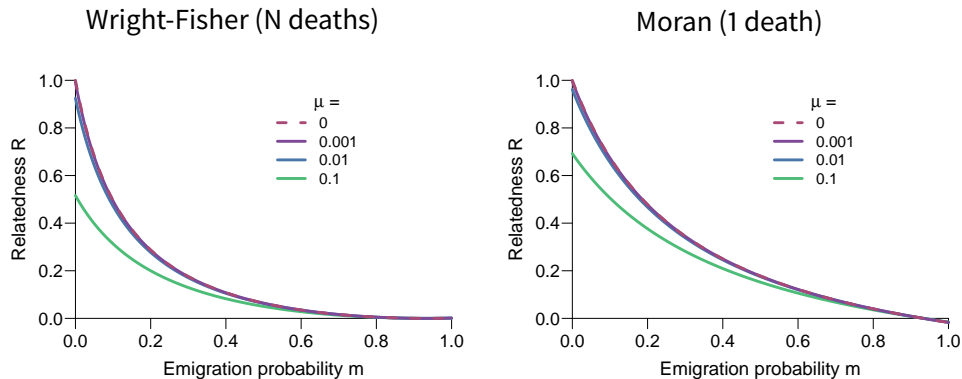
~~Population variance~~ Variance in the state of one site

$$\mathbb{E}[\overline{X}] = \nu + \delta \; \nu(1-\nu) \; \frac{1-\mu}{\mu} \; (1 - Q_{\text{out}}) \times$$

$$\left(-c - (b-c)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d - 1)}\right) \; -\mathcal{C} \right.$$

$$\left. + \; \frac{Q_{\text{in}} - Q_{\text{out}}}{1 - Q_{\text{out}}} \left[b - (b-c)(n-1)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d - 1)}\right) \right] \right)$$

$$\mathcal{B}$$

Expected frequency of altruists in the population

Mutation-drift equilibrium

Selection strength

~~Population variance~~ Variance in the state of one site

$$\mathbb{E}[\overline{X}] = \nu + \delta \; \nu(1-\nu) \; \frac{1-\mu}{\mu} \; (1-Q_{\text{out}}) \; \times$$

$$\left(-c - (b-c)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n\,(N_d-1)}\right) \quad -\mathcal{C} \right.$$

$$\left. + \frac{Q_{\text{in}} - Q_{\text{out}}}{1 - Q_{\text{out}}} \left[b - (b-c)\,(n-1)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n\,(N_d-1)}\right) \right] \right)$$

R

$\mathcal{B}$

Expected frequency of altruists in the population

Mutation-drift equilibrium

Selection strength

~~Population variance~~ Variance in the state of one site

$$\mathbb{E}[\overline{X}] = \nu + \delta \; \nu(1-\nu) \; \frac{1-\mu}{\mu} \; (1-Q_{\text{out}}) \; \times$$

$$\left(-c - (b-c)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d-1)}\right) -\mathcal{C} \right.$$

$$\left. + \frac{Q_{\text{in}} - Q_{\text{out}}}{1-Q_{\text{out}}} \left[b - (b-c)(n-1)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d-1)}\right) \right] \right)$$

R

$\mathcal{B}$

How does relatedness R change with the emigration probability m?

How does relatedness *R* change with the emigration probability *m*?

Wright-Fisher (N deaths)   Moran (1 death)

$(n = 4, N_d = 15)$

Expected frequency of altruists in the population

Mutation-drift
equilibrium   Selection
strength   ~~Population variance~~
Variance in the state of one site

$$\mathbb{E}[\overline{X}] = \nu + \delta \, \nu(1-\nu) \, \frac{1-\mu}{\mu} \, (1 - Q_{\text{out}}) \, \times$$

$$\left(\underbrace{-c - (b-c)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n\,(N_d-1)}\right)}_{-\mathcal{C}} \right.$$

$$\left. + \underbrace{\frac{Q_{\text{in}} - Q_{\text{out}}}{1 - Q_{\text{out}}}}_{R \searrow} \left[\underbrace{b - (b-c)(n-1)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n\,(N_d-1)}\right)}_{\mathcal{B}} \right] \right)$$

Expected frequency of altruists in the population

Mutation-drift equilibrium

Selection strength

~~Population variance~~
Variance in the state of one site

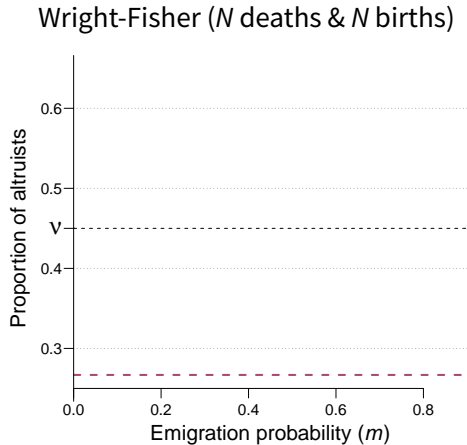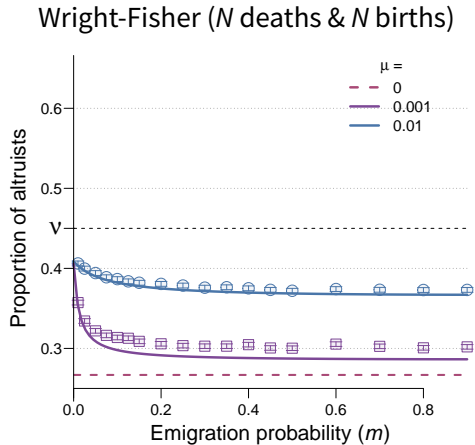$$\mathbb{E}[\overline{X}] = \nu + \delta\ \nu(1-\nu)\ \frac{1-\mu}{\mu}\ (1-Q_{\text{out}})\ \times$$

$$\left(-c - (b-c)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n\,(N_d-1)}\right) \ -\mathcal{C} \right.$$

$$\left. + \frac{Q_{\text{in}} - Q_{\text{out}}}{1-Q_{\text{out}}} \left[b - (b-c)\,(n-1)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n\,(N_d-1)}\right) \right] \right)$$

$R \searrow$ $\qquad\qquad\qquad \mathcal{B}$

Expected frequency of altruists in the population

Mutation-drift equilibrium

Selection strength

~~Population variance~~ Variance in the state of one site

$$\mathbb{E}[\overline{X}] = \nu + \delta \, \nu(1-\nu) \, \frac{1-\mu}{\mu} \, (1 - Q_{\text{out}}) \times$$

$$\left(-c - (b-c)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d - 1)}\right) \quad -\mathcal{C} \nearrow \right.$$

$$\left. + \frac{Q_{\text{in}} - Q_{\text{out}}}{1 - Q_{\text{out}}} \left[b - (b-c)(n-1)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d - 1)}\right) \right] \right)$$

$R \searrow$ $\mathcal{B} \nearrow$

Expected frequency of altruists in the population

Mutation-drift equilibrium

Selection strength

~~Population variance~~ Variance in the state of one site

$$\mathbb{E}[\overline{X}] = \nu + \delta \, \nu(1-\nu) \, \frac{1-\mu}{\mu} \, (1 - Q_{\text{out}}) \times$$

$$\left(-c - (b-c)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d - 1)}\right) \quad -\mathcal{C} \nearrow \right.$$

$$\left. + \frac{Q_{\text{in}} - Q_{\text{out}}}{1 - Q_{\text{out}}} \left[b - (b-c)(n-1)\left(\frac{(1-m)^2}{n} + \frac{m^2}{n(N_d - 1)}\right) \right] \right)$$

$R \searrow$ $\qquad$ $\mathcal{B} \nearrow$

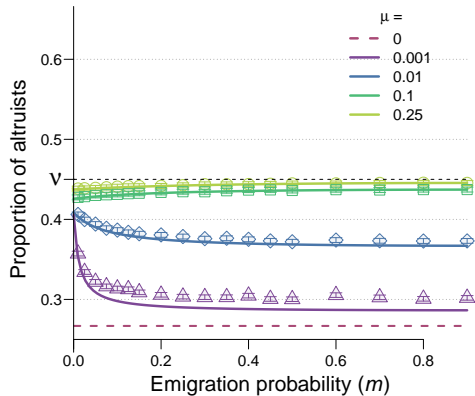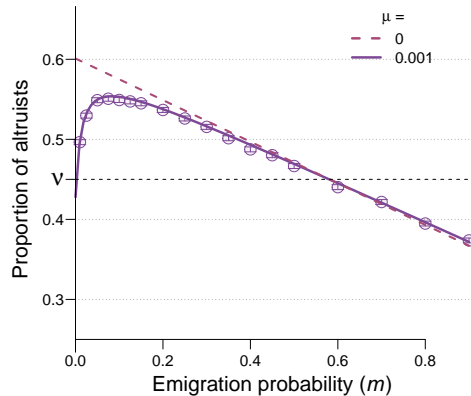# Effect of the emigration probability *m* on the expected proportion of altruists

Wright-Fisher (*N* deaths & *N* births)

Effect of the emigration probability *m* on the expected proportion of altruists
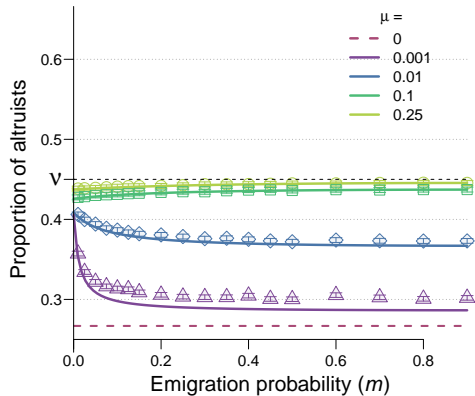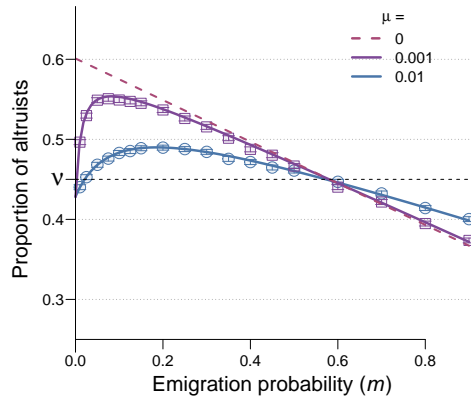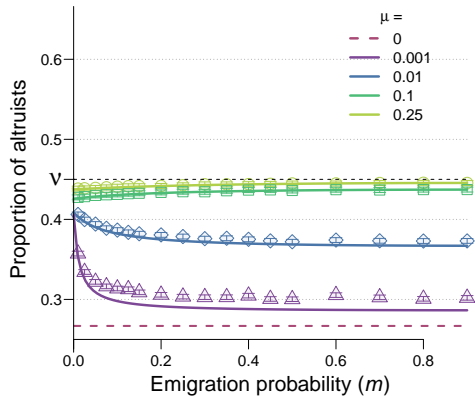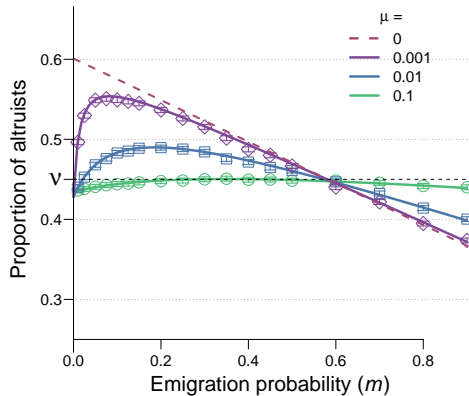

Wright-Fisher (*N* deaths & *N* births)

Effect of the emigration probability *m* on the expected proportion of altruists

Wright-Fisher (*N* deaths & *N* births)

Effect of the emigration probability *m* on the expected proportion of altruists
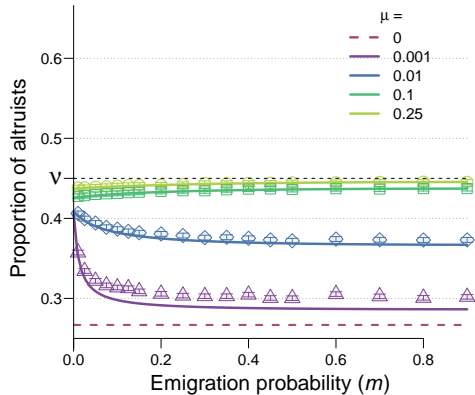

Wright-Fisher (*N* deaths & *N* births)

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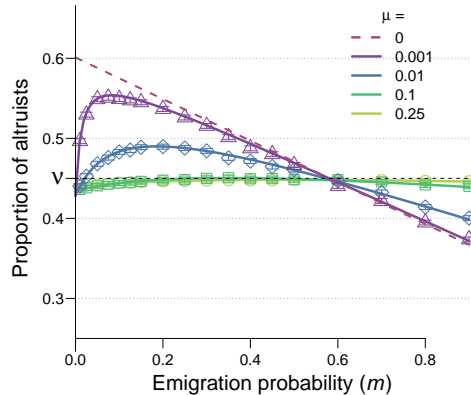

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Effect of the emigration probability *m* on the expected proportion of altruists

Wright-Fisher (*N* deaths & *N* births)
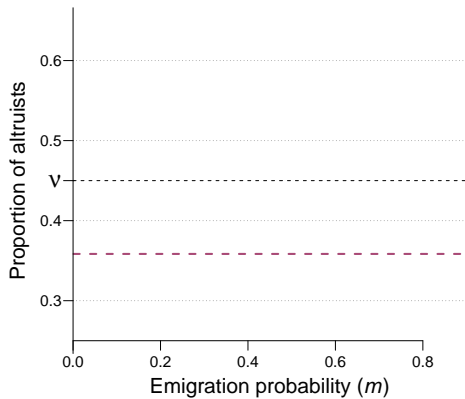
Moran Death-Birth (1 death & 1 birth)

Effect of the emigration probability *m* on the expected proportion of altruists

Wright-Fisher (*N* deaths & *N* births)

Moran Death-Birth (1 death & 1 birth)

Effect of the emigration probability *m* on the expected proportion of altruists

Wright-Fisher (*N* deaths & *N* births)

Moran Death-Birth (1 death & 1 birth)

Effect of the emigration probability *m* on the expected proportion of altruists

Wright-Fisher (*N* deaths & *N* births)

Moran Death-Birth (1 death & 1 birth)

Is the result robust?

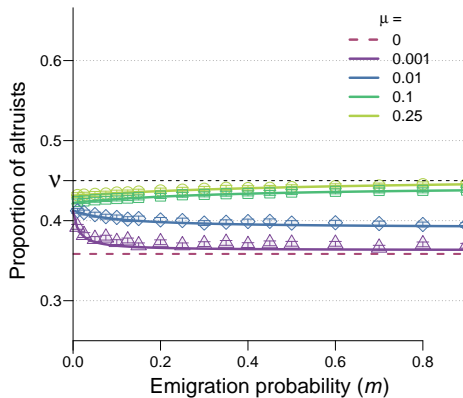# Another life-cycle

Moran Birth-Death (1 birth & 1 death)
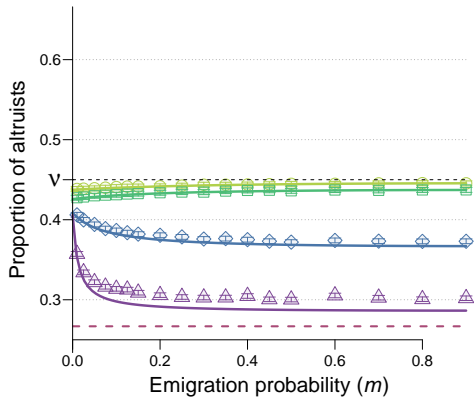
Another life-cycle

Moran Birth-Death (1 birth & 1 death)

Moran Birth-Death (1 birth & 1 death)

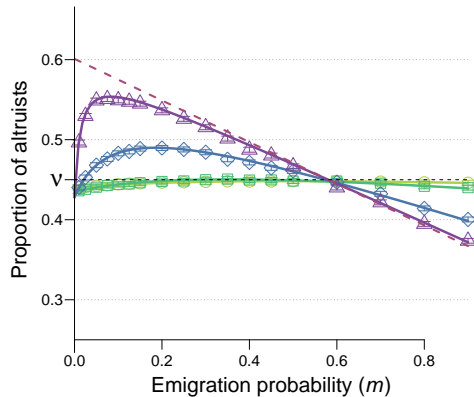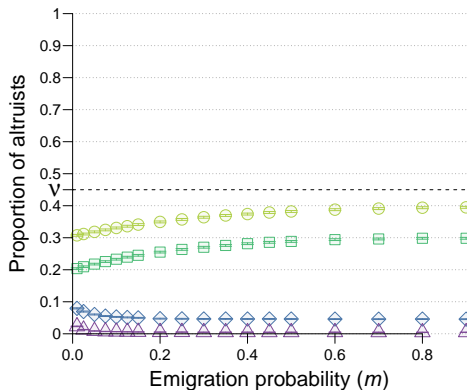Wright-Fisher, weak selection

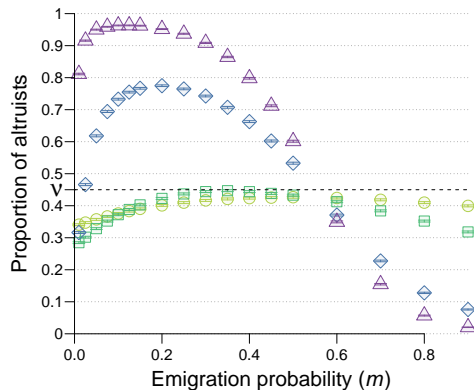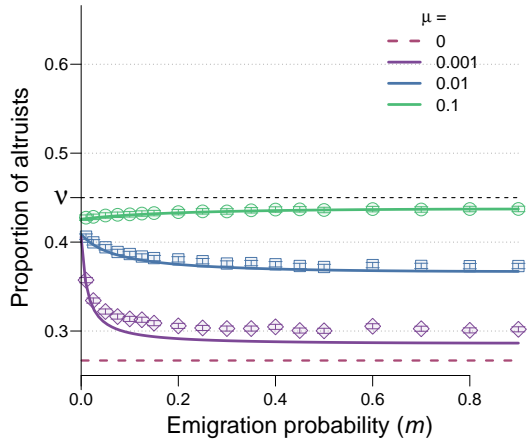Moran Death-Birth, weak selection

Strong selection

Wright-Fisher, strong selection

Moran Death-Birth, strong selection

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