Population Ecology III: Some Of All The Rest

EFB 390: Wildlife Ecology and Management

Dr. Elie Gurarie

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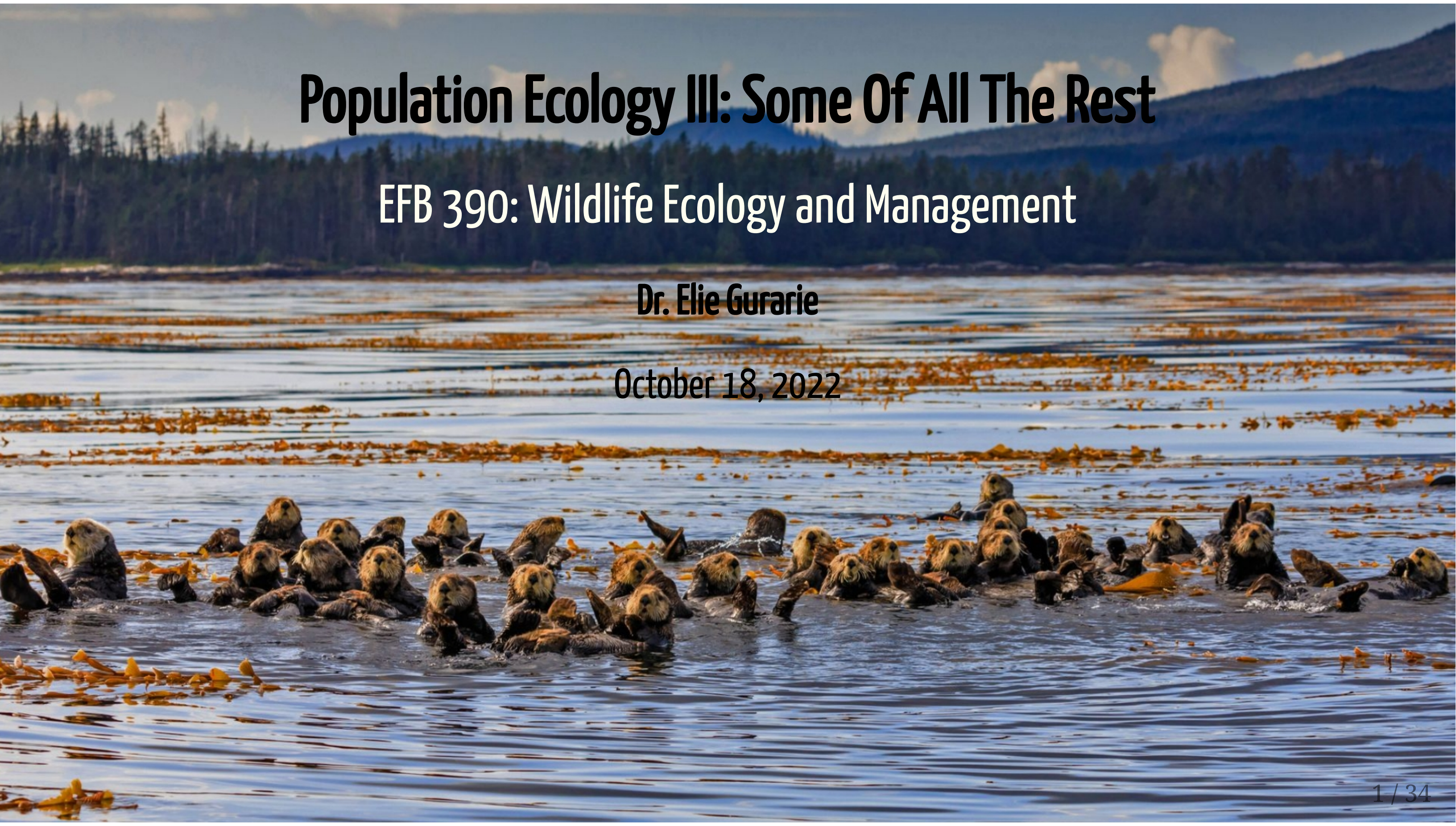


So far ...

We've studied this equation: $N_t = N_{t-1} + B_t - D_t$

with two assumptions:

Exponential Growth

Births and **Deaths proportional** to **N**

Logistic Growth

Births decrease and/or **Deaths** decrease (linearly?) with **N**

More complex topics in population ecology

Blowing up:

$$N_t$$

into:

sex / age classes:	**structured populations**
multiple sub-populations:	**meta-populations**
multiple species:	**competitors / predator-prey**
infected, susceptible, recovered:	**disease dynamics**

Drilling into structure of Birth and Death

$$N_t = N_{t-1} + B_t - D_t$$

B = Births

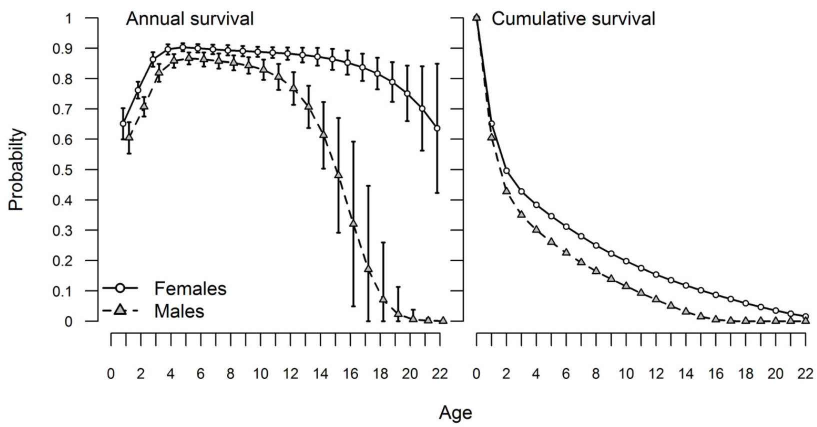
- **Fecundity** = # births / female / unit time

(*unit time* can be any unit of time, but is usually year)

D = Deaths

- **Mortality (rate)** = probability of death / unit time
- **Survival (rate)** = 1 - Mortality rate

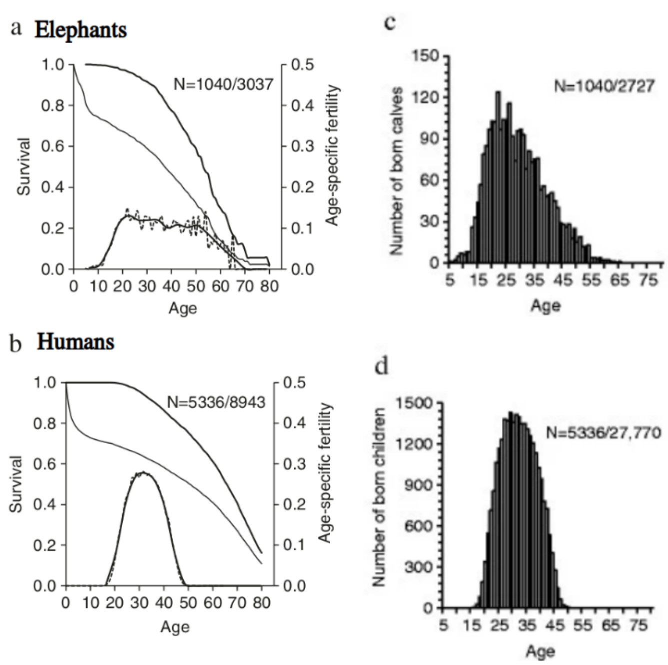
Basic fact of life I: Survival varies with age!

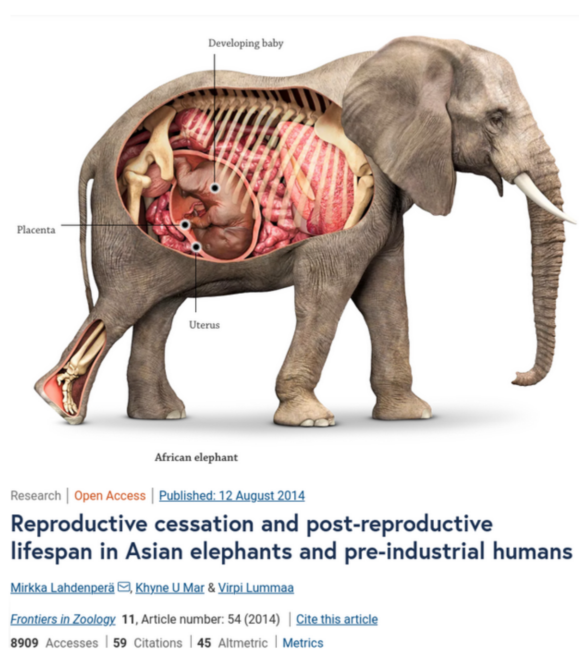


- **Survival Probability** ($S_0, S_1, S_2, ...$) always between 0 and 1.
- **Cumulative Survival** ($1, S_0, S_0S_1, S_0S_1S_2, ...$) always starts at 1 and goes to 0

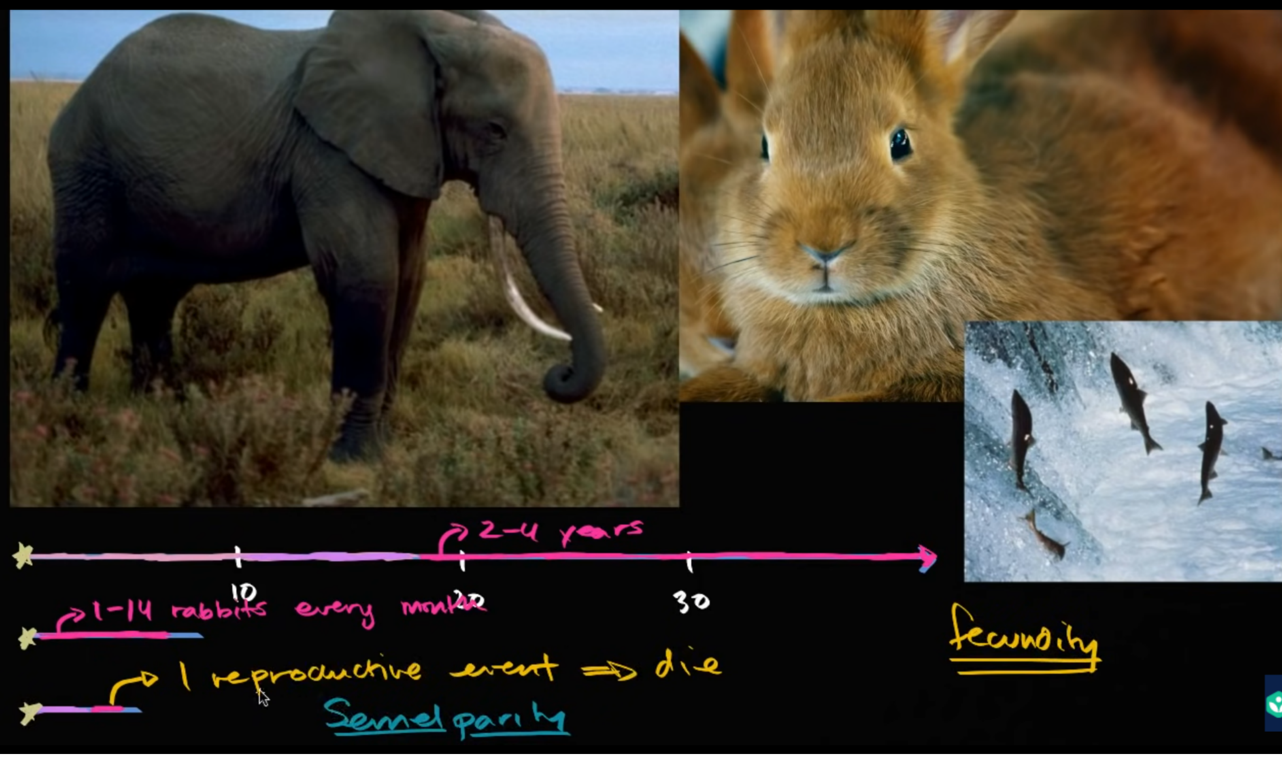
(Altukhov et al. 2015)

Basic fact of life II: Fecundity varies with age!





Life History is the reproduction / mortality pattern



Survival curves

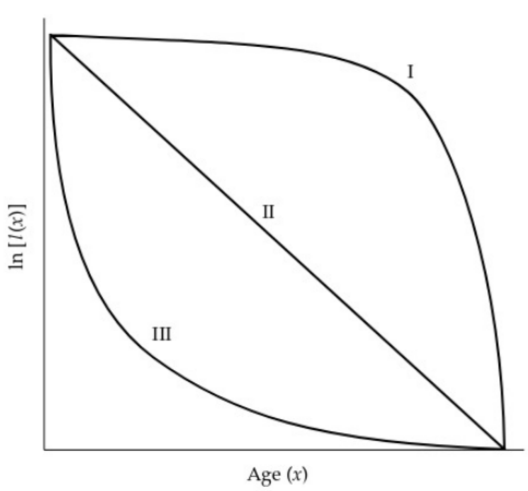
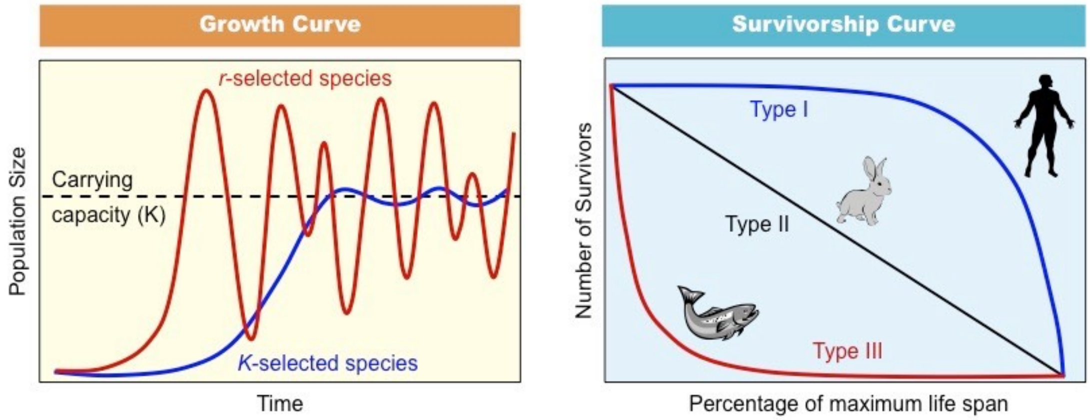


Figure 3.2 Type I, II, and III survivorship curves. Note the logarithmic transformation of the y axis.

- **TYPE I:** high survivorship for juveniles; most mortality late in life
- **TYPE II:** survivorship (or mortality) is relatively constant throughout life
- **TYPE III:** low survivorship for juveniles; survivorship high once older ages are reached

Life history strategies: *r*-selected, vs. *K*-selected species

For a long time a popular **paradigm** (conceptual model purporting to explain a wide range of phenomenon) for understanding evolutionary drivers of life-history variation. Still popularly taught:



r-selected species

strategy:

- lots of offspring
- little or no parental investment
- semelparous
- early maturity
- Type III survivorship
- low survivorship
- short life-expectancy

drivers:

- small size
- unstable / unpredictable environments

consequence

- highly fluctuating populations

K-selected species

strategy:

- few offspring
- lots of parental investment
- high survivorship
- late maturity
- iteroparous
- long life-expectancy
- Type I survivorship schedule

drivers:

- stable environments
- large

consequence

- more stable / slowly-fluctuating populations

Nice theory you've got there, but lots of counter-examples

- What about **trees**? They're big, they're long-lived (very **K**), but they produce and disperse a **heckload** of seeds (very, very **r**).
- What about **iteroparous** species (**K**) that are hedging their bets against high inter-annual variation in environmental conditions (very **r**)?

> The r- and K-selection paradigm was focussed on **density-dependent selection**. This paradigm was challenged as it became clear that ... **age-specific mortality** provide[s] a more mechanistic link between an environment and an **optimal life history** ...
>
> (Reznick et al. (2002) Ecology)

Salmonid (counter)-example

Semelparous species

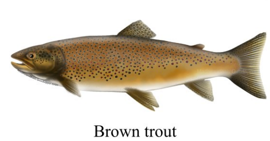
Much bigger eggs (189 > 86 mg).

Also nest building and guarding behavior, before dying,

i.e. greater investment in **Juvenile Survival** over **Adult Survival**.

The iteros just keep staying alive and trying to

breed again and again.



> Inconsistent with **r-K** paradigm!

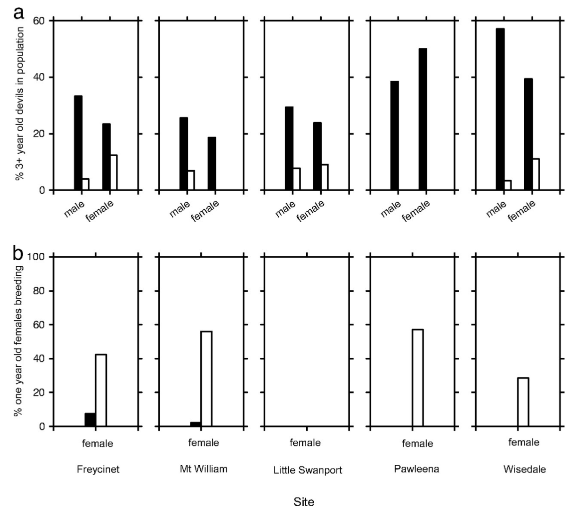
Tasmanian devil (*Sarcophilus harrisii*)

Only marsupial carnivore | range restricted to Tasmania

Dying of *facial tumor disease*; an infectious cancer (!) which kills nearly all adults > 3 years

Switch to Semelparity

Previously: Longer-lived, and iteroparous, with later birth (over 1 year old)



Now: Semelparous, one-shot, younger mothers (almost NO 2-3 year old animals!) (Jones et al. (2013))

Monoceros academicus: Three Life Stages

.	Larva	Sophomore	Emeritus
.			
Survival	0.5	1	0
Fecundity	0	1.5	0.5

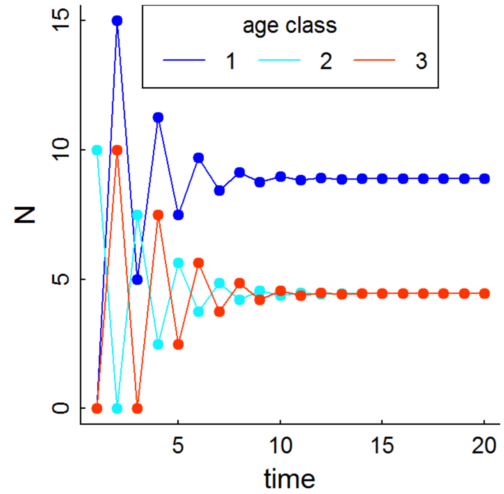
- **Survival** is a **probability** (unitless)
- **Fecundity** is an **expected number** of offspring (n. ind.).

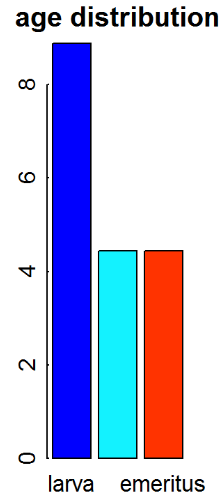
Human experiment: 8 volunteers please.

Experiment: results

Stage	Survival	Fecundity
1. larvae	0.5	0
2. sophomore	1	1
3. emeritus	0	.5

See numerical experiment:
https://egurarie.shinyapps.io/AgeStructuredG

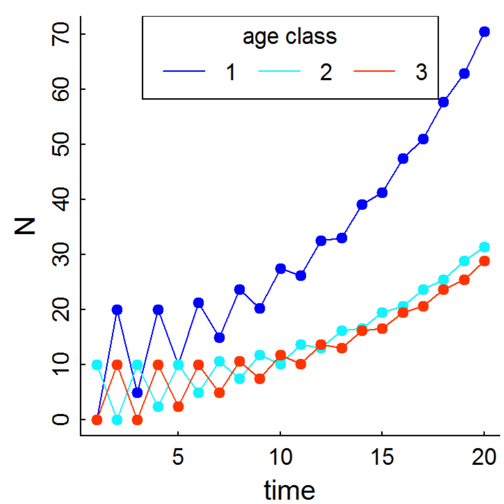


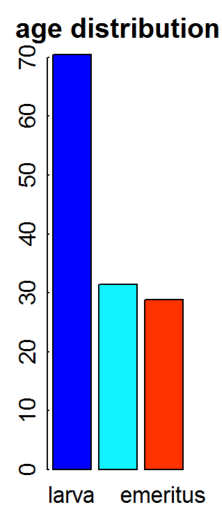


- Overall growth: $\lambda = 1$
- Stable age distribution: 50%, 25%, 25%

Change one value ....

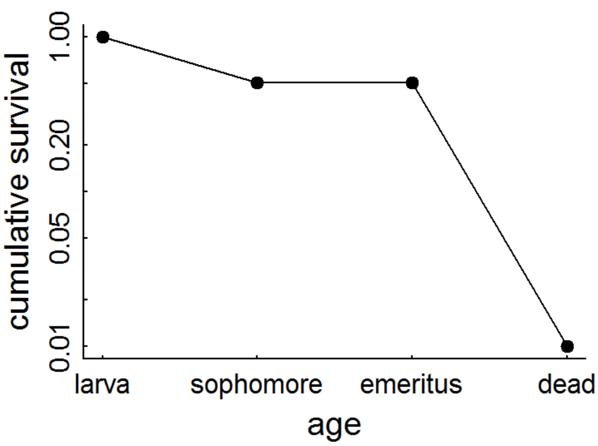
Stage	Survival	Fecundity
1. larvae	0.5	0
2. sophomore	1	2
3. emeritus	0	.5





- Overall growth: $\lambda = 1.11$
- Stable distribution: 54%, 24% 22%

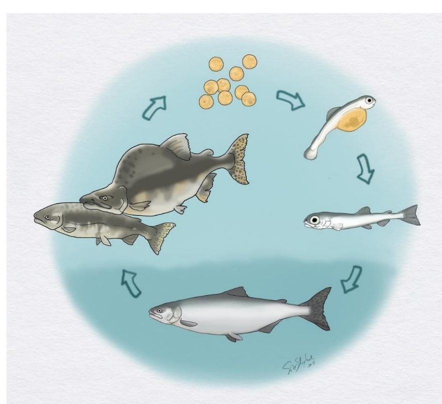
Monoceros academicus: Type I



- **TYPE I:** high survivorship for juveniles; most mortality late in life. Investment in young and survival. Typical of long-lived species.

Stage	Survival	Fecundity
1. larvae	0.5	0
2. sophomore	1	1.5
3. emeritus	0	.5

Pink Salmon (*Onchorrhynchus gorbusha*)



Strict 2-year life cycle

Year 0:

- Spawn in late-summer
- Hatch in winter
- Emerge in spring

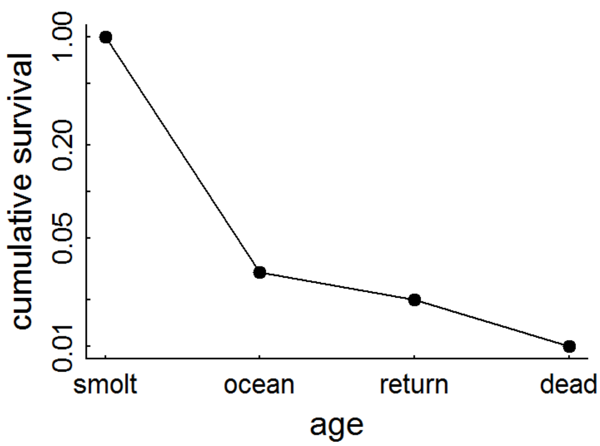
Year 1:

- Ocean phase

Year 2.

- Enter freshwater late spring
- Spawn
- Die

Pink Salmon (*Onchorrhynchus gorbusha*): Type III



- **TYPE III:** low survivorship for juveniles; survivorship high once older ages are reached. Basically - produce a whole boatload of offspring and hope for the best. Typically short-lived species.

Stage	Survival	Fecundity
1. smolt	0.05	0
2. ocean	0.9	0
3. return	0	21

Species Interactions

Can also limit population growth

- Competition
- Coexistence
- Predation

Competition

An interaction between organisms (intraspecific) or between species (interspecific) in which fitness of one is lowered by the presence of another.

*We've already talked about **intra**-specific competition!*

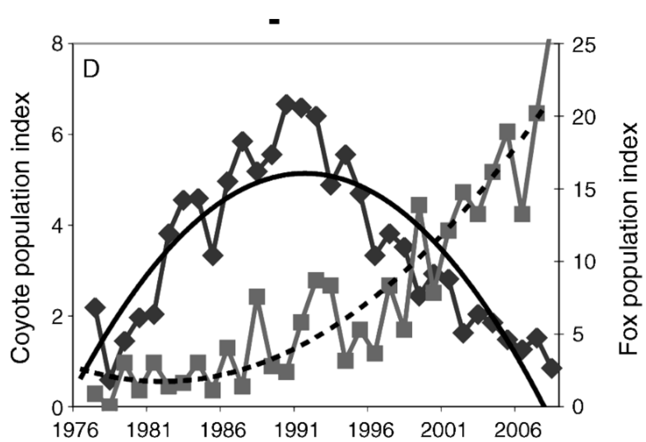
Fitness is Reproductive Success

- Combines **survival** and **reproduction**

Competitive Exclusion Principle

Two species **occupying the same niche** can NOT coexist

In *theory* Fox (*Vulpes vulpes*) and Coyote (*Canis latrans*) can't co-exist across southern Minnesota prairie / farmland



Levi and Wilmers (2021) *Ecology* 93(4)

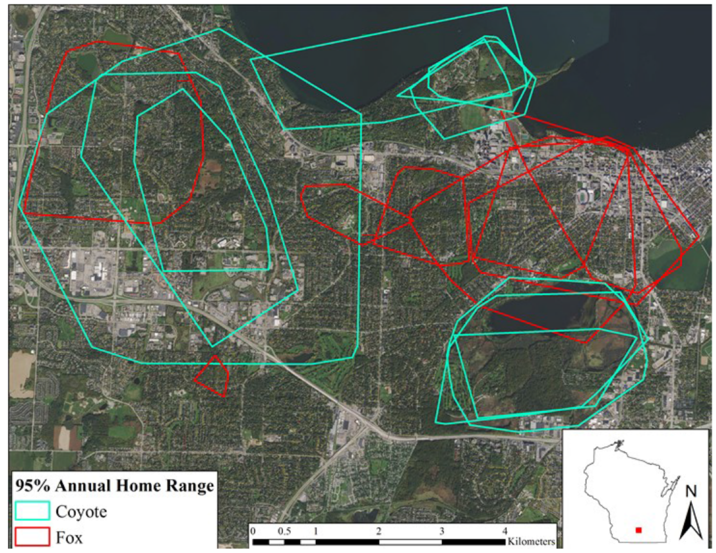
Except they often do! (via niche partitioning)

PLOS | ONE

RESEARCH ARTICLE

Coexistence of coyotes (*Canis latrans*) and red foxes (*Vulpes vulpes*) in an urban landscape

Marcus A. Mueller*, David Drake, Maximilian L. Allen



Madison, Wisconsin

Squirlicorn vs. Pegamunk

Limited space | Limited carrying capacity | Mutual animosity (periodic horn skewering and/or dropping on rocks) ….

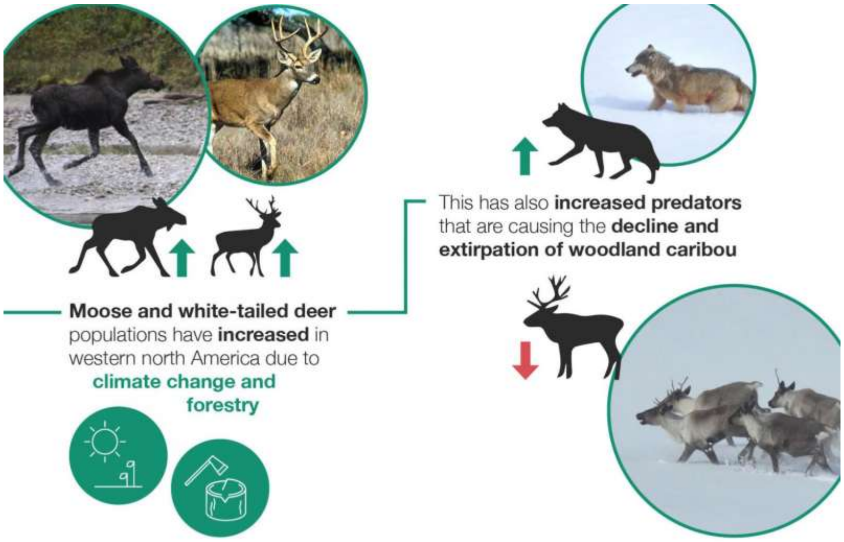
Can they get along!?

https://egurarie.shinyapps.io/SquirlicornVsPegamunk

Takeaway: If the interactinos are not *too* extreme relative to population growth rate, coexistence is possible.

Apparent competition

Species A eats Species B and C, if Species B increases, Species C is in trouble.



Major habitat fragmentation from oil-gas extraction.

Serrouya et al. (2017)

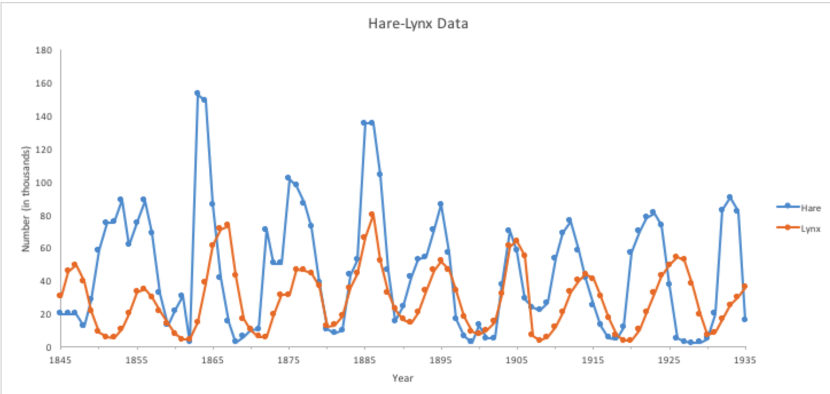
Predation

an ecological process where one organism (the predator) consumes another (the prey).

- Provides most of the principle route of energy flow through ecosystems
- Strong selective pressure
- **Chief source of density dependent effects** in regulation of many animal (and plant) populations

Predator-prey dynamics

Based (mainly) on fur sales from the Hudson Bay Company in Canada over 100 years. Roughly a 9 to 11 year, fairly synchronous, cycle.



Theory suggests the **predators** and **prey** cycle … but it turns out that is *probably* not the case.

Equations and models

Exponential model

$$\frac{dN}{dt} = rN$$

Basic assumption: Growth rate is proportional to population size

Equations and models

Exponential model

$\frac{dN}{dt} = rN$

Logistic model

$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$

Assumption growth rate goes to 0 at `(N=K)`

Competition model

$$\frac{dC}{dt} = r_c C \left(1 - \frac{C}{K_c} - \alpha \frac{F}{K_c}\right)$$

$$\frac{dF}{dt} = r_f F \left(1 - \frac{F}{K_f} - \beta \frac{C}{K_f}\right)$$

contains carrying capacities AND interactions

Predator-Prey Model

$\frac{dP}{dt} = -qP + \gamma VP$

$\frac{dV}{dt} = rV - \sigma VP$

Predator-Prey-Prey Model

Wolf equation $W(t)$:

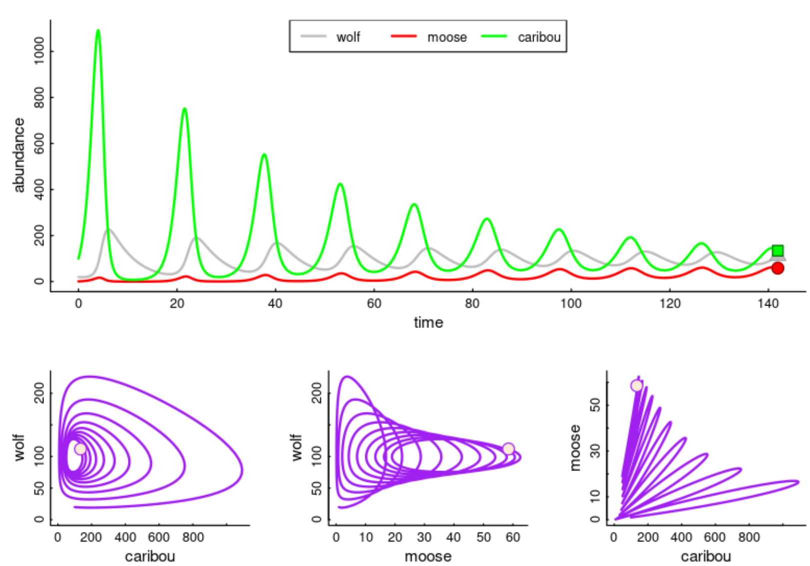
$$\frac{dW}{dt} = (\gamma_m M + \gamma_c C - \delta)W$$

Moose equation $M(t)$:

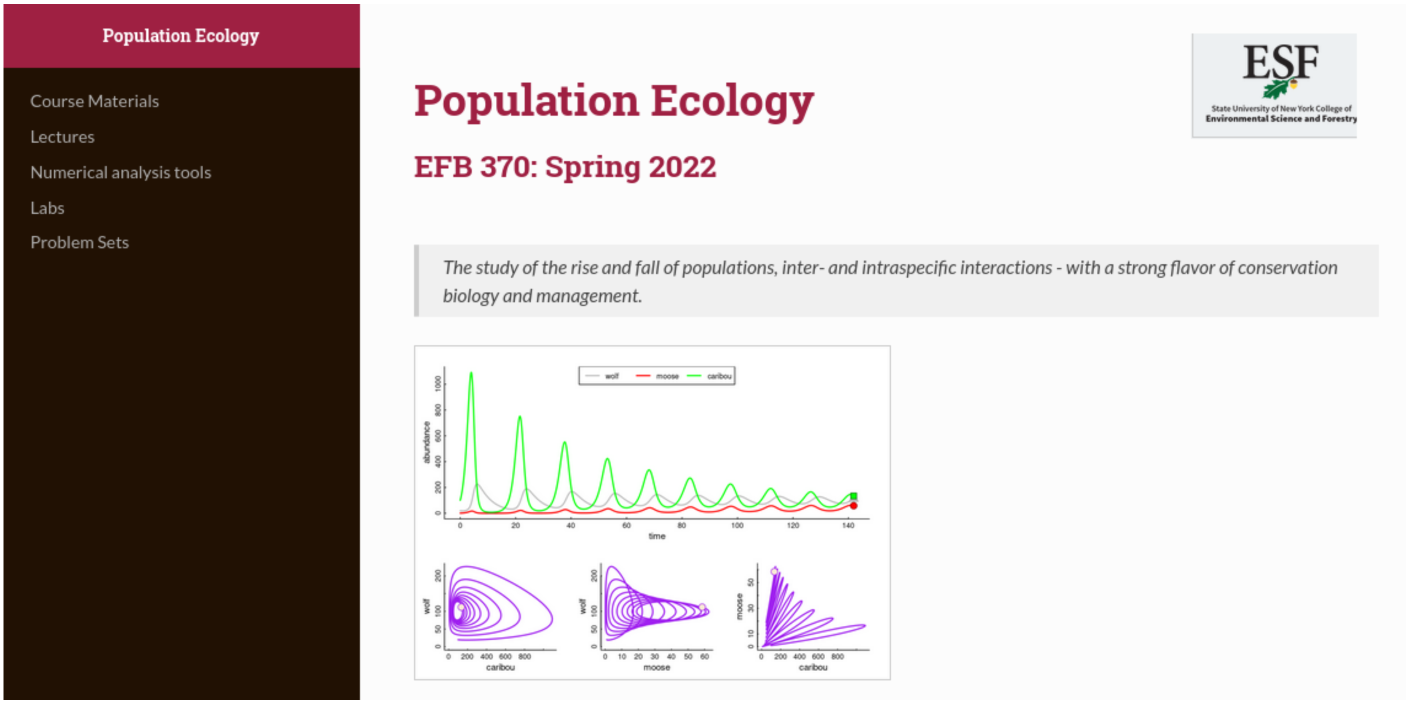
$$\frac{dM}{dt} = r_m M \left(1 - \frac{M}{K_m}\right) - \sigma_m MW$$

Woodland caribou equation $C(t)$:

$$\frac{dC}{dt} = r_c C \left(1 - \frac{C}{K_c}\right) - \sigma_c CW$$



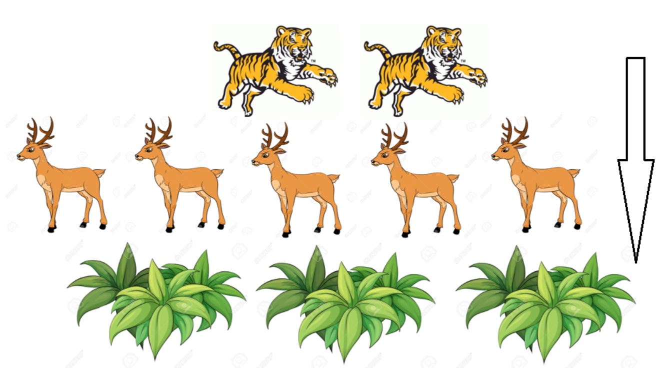
To learn more:



Take-aways ....

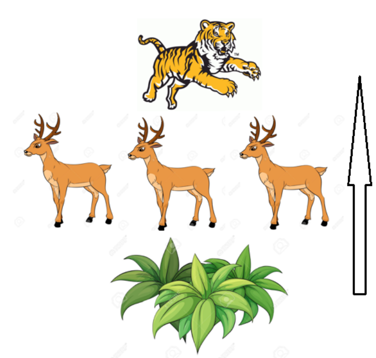
Top-down

Sometimes predation is extremely important at limiting growth of prey populations.



Bottom-up

Sometimes, predators are very much limited by the resources coming up the chain.



Resolving these questions is hard! (and interesting), and involves a combination of deep ecological research and modeling.