Metapopulations: Part II

EFB 370: Population Ecology

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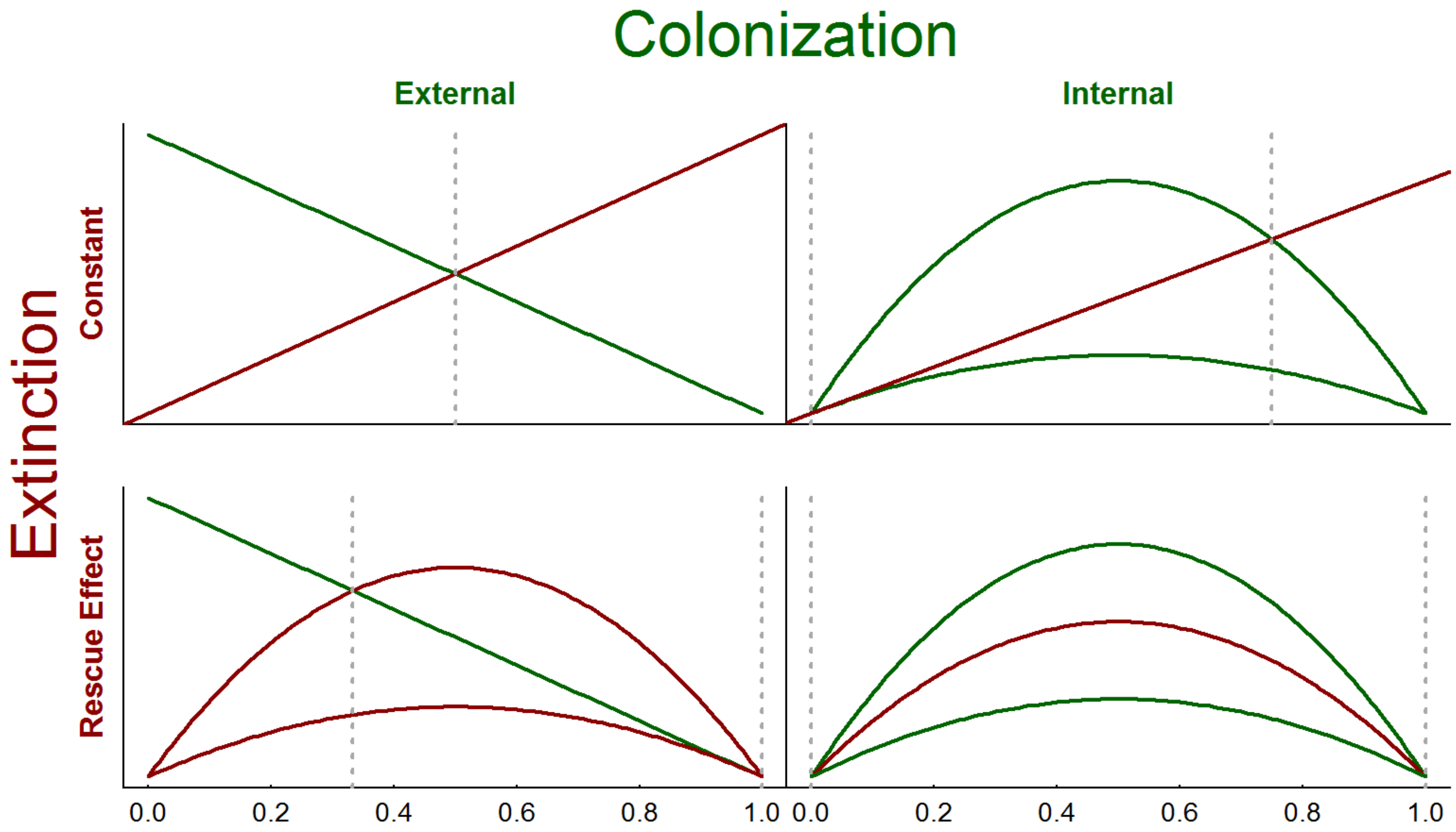
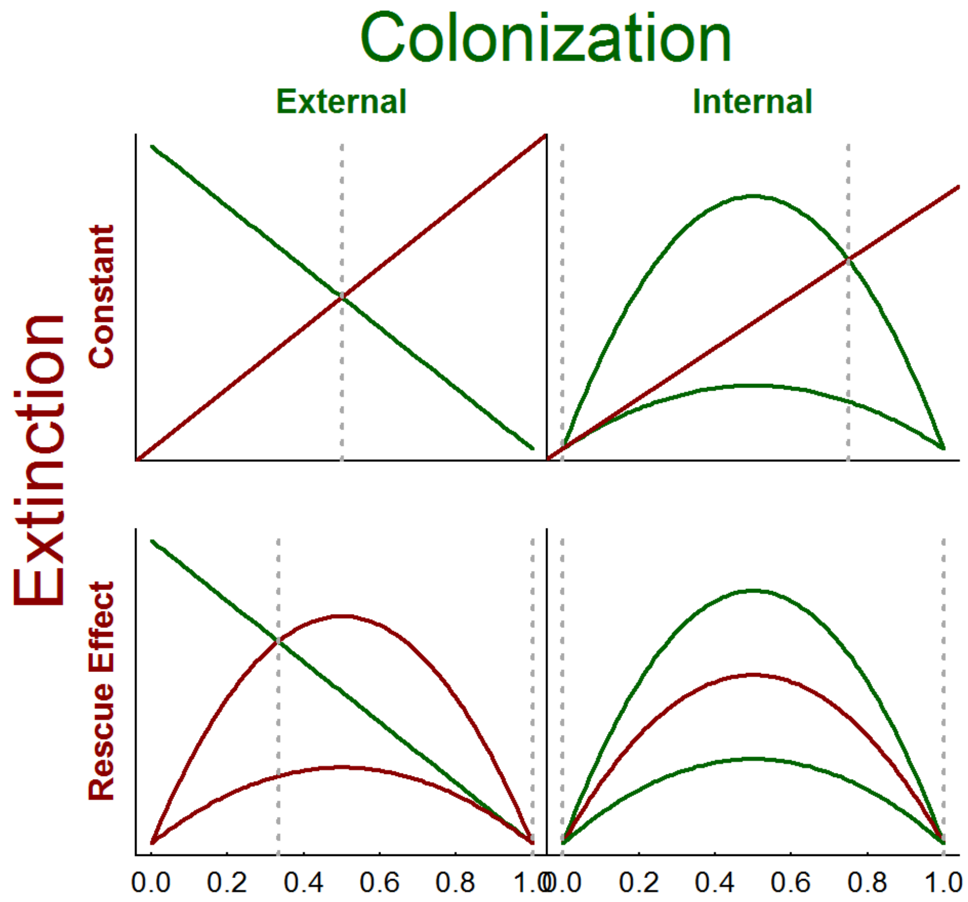
March 20, 2023

Four metapopulation models



With very different predictions! (Nice synthesis - mainly due to Gotelli.)

Model predictions:



	External Colonization	Internal Colonization
Constant Extinction	$\frac{p_c}{p_c+p_e}$	0 or $1 - p_e/p_c$
Rescue Effect	$\frac{p_c}{p_e}$ or 1	0 or 1

So … **are metapopulations stable or not!?**

Theory vs. Reality

Assumptions

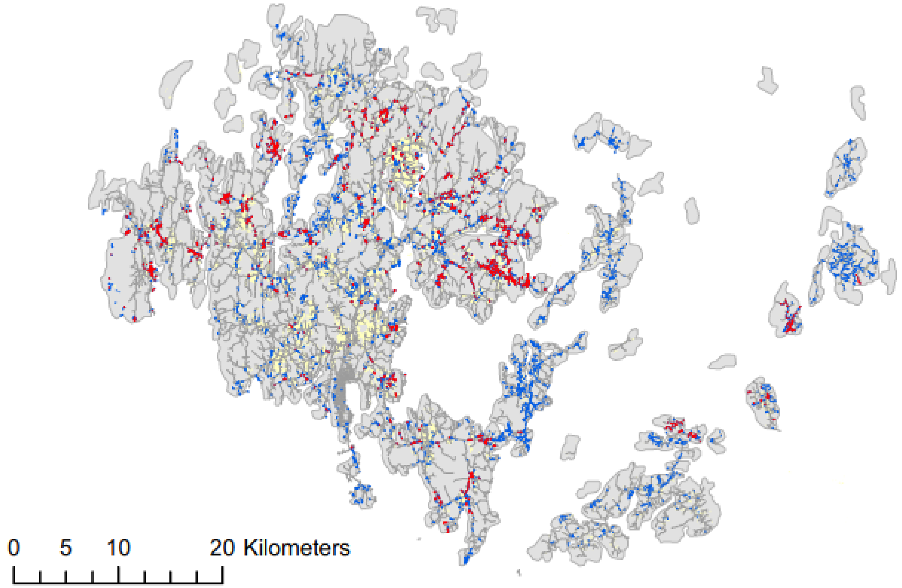
- "Instantaneous" (binary) population growth - straight to K
- Homogeneous patch quality
- Homogeneous growth process
- Implicit spatial structure - (all patches affect all others equally)
- Deterministic process

Complications

- You can have **none**, **some**, or **lots** in a patch
- Unique - K_i
- Unique r_i
- Neighboring patches are more locally important, some patches are very connected, some are very distant
- Stochasticity is very important, esp. for extinction probabilities

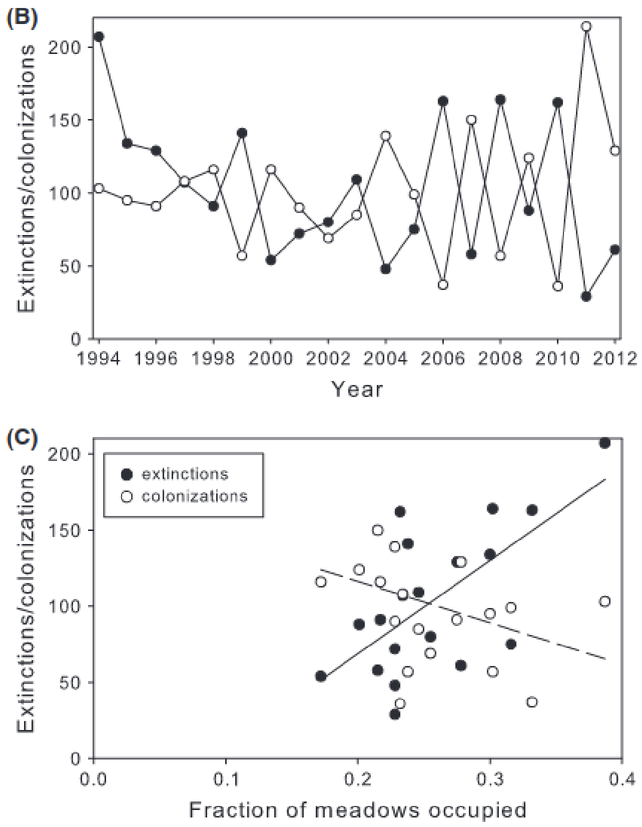
Which is it!?

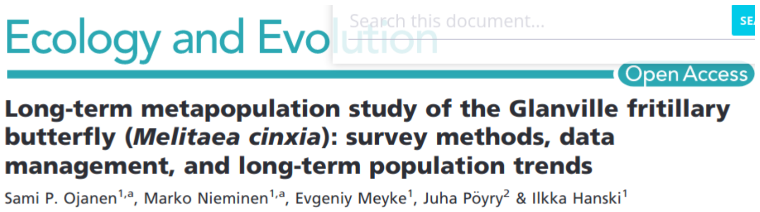
It's hard to do metapopulation studies!



The longest-term, most data-rich study ever …

leads to somewhat *meh* results





Ecology and Evolution

Open Access

Long-term metapopulation study of the Glanville fritillary butterfly (*Melitaea cinxia*): survey methods, data management, and long-term population trends

Sami P. Ojanen[1,a], Marko Nieminen[1,a], Evgeniy Meyke[1], Juha Pöyry[2] & Ilkka Hanski[1]

General principles of metapopulation management

1. Can be challenging because **equilibrium** may or may not exist!
2. Metapopulation will surely become extinct if patches are removed …
3. … but **facilitating recolonization** and maintaining **large patches** can help.
4. As many fragments as possible should be preserved…
5. … but distances can't be too large, or no recolonization or rescue effect.
6. Properties of the matrix are important: **corridors** and **stepping stones**.
7. Recolonization has to be observed within a few generations for metapopulations to have a chance.
8. Sizes of patches is important to hedge against demographic stochasticity.

(*Hanski, I. 1997. Metapopulation biology. Pp. 69-91. San Diego, USA, Academic Press.*)

Question: How is **poaching** affecting recovery of Pinto Abalone?

- important cultural / subsistence item for Indigeneous communities on Pacific coast.
- overharvested commercially to **near extinction**
- commercial harvest **banned** in 1990
- recovering very slowly … or not at all

Haliotis kamtschatkana

VANCOUVER SUN

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Rare B.C. abalone easy pickings for unscrupulous poachers

The rarest and most expensive B.C. seafood is easy pickings for unscrupulous poachers, who, with a little local knowledge and scuba gear, can decimate a patch of abalone in a matter of hours or days.

Larry Pynn

Published Oct 29, 2009 • Last updated Nov 01, 2009 • 11 minute read

Dm sibilhaa'nm da laxyuubm Gitxaała: Picking Abalone in Gitxaała Territory

Charles R. Menzies

In the face of aggressive overfishing of *bilhaa* (abalone) by non-Indigenous commercial fishermen, the Canadian Department of Fisheries and Oceans closed all forms of harve
harvesting practices of Gitxaała, an indigenous
antiquity of Gitxaała fisheries practices. The pa

Key words: abalone, indigenous fisheries, nort

Bilhaa—Harvest, Processing, and Use

The Gitxaała approach to bilhaa harvesting is and has been explicitly organized to ensure the continuation of the biological stock. Gitxaała harvesting practices reflect the cultural keystone role of bilhaa as a treasured entity, a social being with whom we share relations, and as an important cultural marker of being a ranked member of Gitxaała society.

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British Columbia

Richmond fish broker fined $77,500 for selling endangered abalone

DFO says shellfish was concealed in a warehouse room

Question: How is **poaching** affecting recovery of Pinto Abalone?

Solution: **lots of modeling!**

NRC Research Press
ARTICLE

Modelling the impact of poaching on metapopulation viability for data-limited species

Abbey E. Camaclang, Janelle M.R. Curtis, Ilona Naujokaitis-Lewis, Mark S. Poesch, and Marten A. Koops

Published by NRC Research Press

Submodel	Parameter	Description	Baseline values used for initializing simulations	Reference or source	Range of values used for sensitivity analysis
Habitat suitability model	Habitat suitability (HS)	Where HS = 0, denotes poor suitability of habitat attributes[a]; where HS = 4, denotes high suitability of habitat attributes	0–4	Jamieson et al. 2004	Sampled from normal distribution, with mean = mean (HS); SD = SD (HS); min = HS threshold
	Habitat suitability threshold	Minimum HS value where habitat is highly suitable in three of four attributes	3	J. Lessard, personal communication	Sampled from normal distribution, with mean = HS threshold, CV[b] = 10%
	Neighbourhood distance (NghbdDistance)	Based on movement patterns of tagged abalone	230 m	J. Lessard, personal communication	Sampled from normal distribution, with mean = NghbdDistance, CV = 10%
Population model	Maximum growth rate, R_{max}	Based on maximum recruitment in highly suitable habitats	1.6	Zhang et al. 2007; Chadès et al. 2012	Sampled from normal distribution, with mean = mean (R_{max}), SD = SD (R_{max}), or CV = 10%
	Carrying capacity, k	Applies to all stages, where ths = total patch habitat suitability	k = 6500·ths	Chadès et al. 2012	Sampled from normal distribution, with mean = k, CV = 10%
	Density dependence function	Ricker function[c], based on abundance of all stages	$R(t) = R_{max} \cdot e^{\frac{-\ln(R_{max}) \cdot N(t)}{K}}$	Zhang et al. 2007	Ricker, Beverton–Holt: $R(t) = \frac{R_{max} \cdot K}{R_{max} \cdot N(t) - N(t) + K}$, Ceiling
	Survival rate	Based on survey estimates of age-specific densities	0.818 for all stages	Chadès et al. 2012	Sampled from lognormal distribution, with mean = survival rate, CV = 10%
	Fecundities	Based on estimates of age-specific densities and masses from survey data	Age 4 = 0.074 Age 5 = 0.1409 Age 6 = 0.2057 Age 7 = 0.2655 Age 8 = 0.3207 Age 9 = 0.3695 Age 10 = 0.4031 Age 11 = 0.4299 Age 12 = 0.4519 Age 13+ = 0.6306	Chadès et al. 2012	Sampled from lognormal distribution, mean = mean (fecundities), CV = 10%
	Initial abundances, N_0	Abalone abundance in patch i at time 0; assuming population abundance is at 15% of historical abundance (just above percent declines since 1978)	N_0 = 975·ths	Lessard et al. 2007	San
Dispersal model	Dispersal distance function, m_{ij}	Proportion of individuals dispersing from patch i to patch j, located x units apart	For x ≤ 23.8 km, m_{ij} = 0.1258 $e^{-0.2148x}$; for x > 23.8 km, m_{ij} = 0	Jamieson et al. 2004[d]	Not
	Dispersal survival	Proportion of dispersers that survive movement from patch i to patch j	1	No data available	San
	Correlation distance function	Correlation in survival and fecundity among populations	0	No data available	Bas

[a]Habitat attributes include depth, currents, kelp abundance, and physical structure.
[b]Coefficient of variation.
[c]Zhang et al. (2007) reported similar statistical support for Ricker and Beverton–Holt models.
[d]Function fit to simulated data generated by the oceanographic circulation model.

Two full pages just to list the parameters!

Table 2. List of input parameters used to model poaching of northern abalone in Barkley Sound.

Parameter	Description	Estimated value or units	Range of values used for sensitivity analysis	Reference or source
Poaching extent	Total number of populations poached for each event	No data available	1–10	NA
Poaching location	Preferred poaching locations relative to access points	No data available	Random = no preference Far = remote locations preferred Near = accessible locations preferred	Raemaekers and Britz 2009; Tailby and Gant 2002
Spatial correlation	Presence of spatial correlation in poaching	No data available	Random = each population poached independently Correlated = nearby populations are poached first	NA
Poaching frequency	Frequency of poaching events	0.24–0.48 per year	0.24–0.48	COSEWIC 2009
Poaching intensity	Mortality rate of abalone from each poaching event	0.7–0.9	0.05–0.95	J. Lessard, personal communication

Habitat submodel

Patchy locations … looks like **metapopulation**

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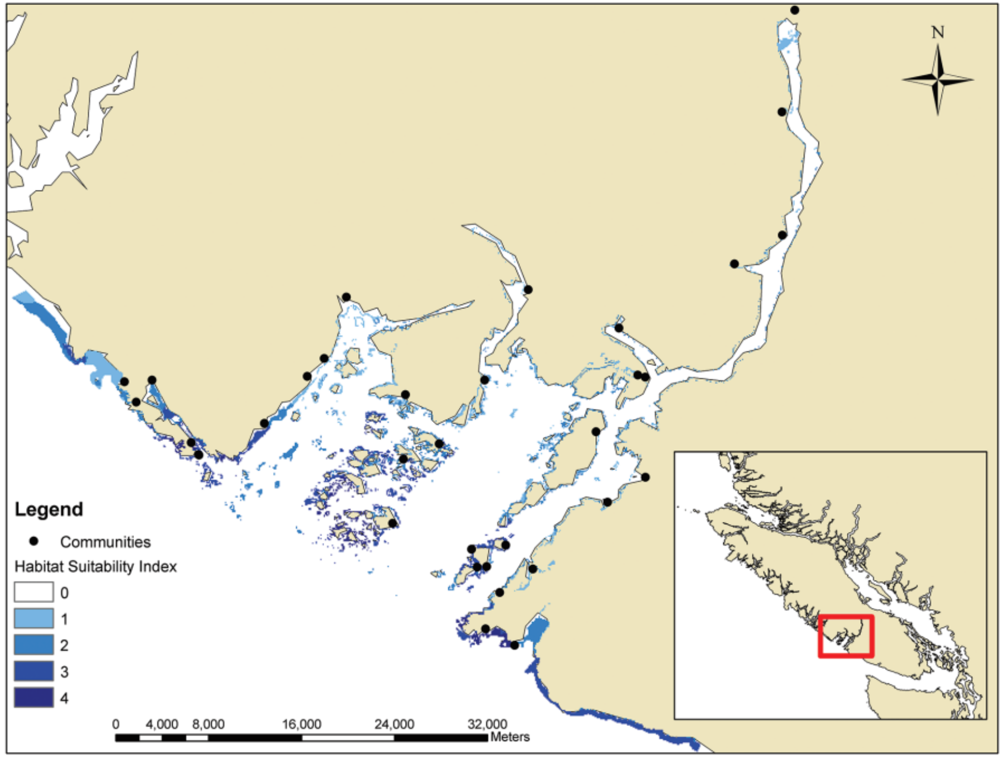

Population submodel

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	Initial abundances, N_0	Abalone abundance in patch i at time 0; assuming population abundance is at 15% of historical abundance (just above percent declines since 1978)	N_0 = 975·ths

all our friends represented:

- Growth rate - R_{max}
- Carrying capacity - k
- Age-structured fecundity
- Survival
- N_0

Dispersal submodel

Submodel	Parameter	Description	Baseline values used for initializing simulations
Dispersal model	Dispersal distance function, m_{ij}	Proportion of individuals dispersing from patch i to patch j, located x units apart	For $x \leq 23.8$ km, $m_{ij} = 0.1258\ e^{-0.2148x}$; for $x > 23.8$ km, $m_{ij} = 0$
	Dispersal survival	Proportion of dispersers that survive movement from patch i to patch j	1
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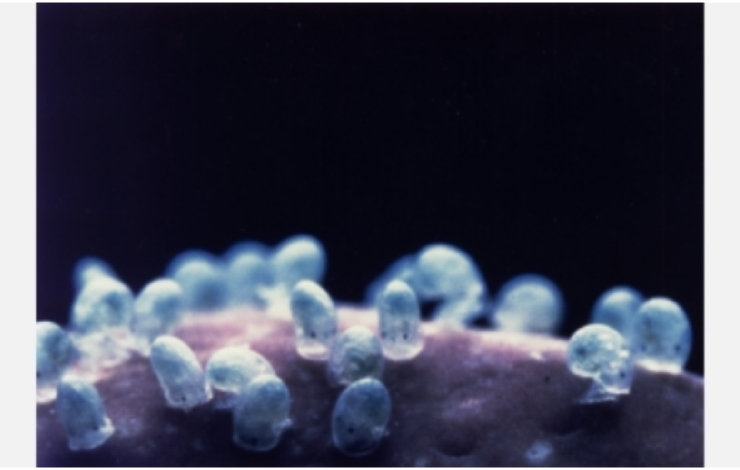
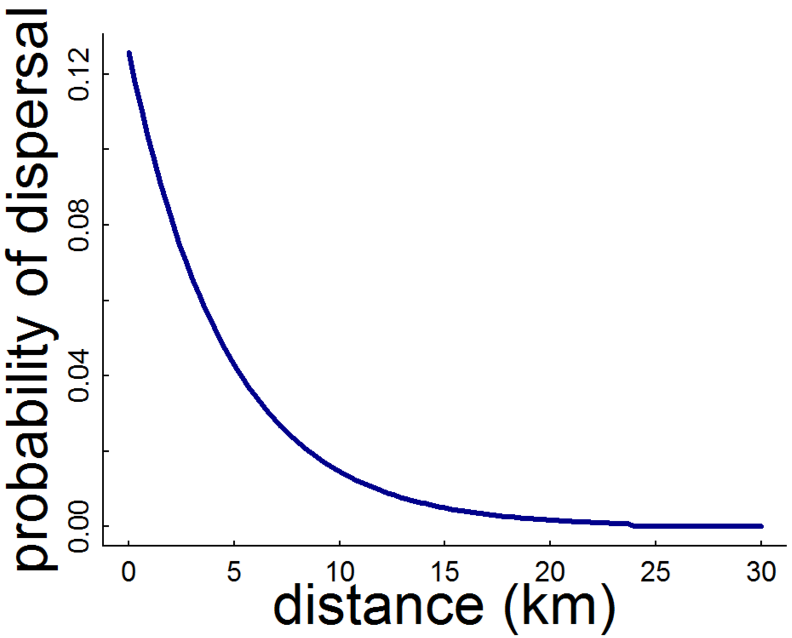


Very typical dispersal **kernel**:

$$Pr(A\,to\,B) = \alpha\, e^{-\beta\, d_{AB}}$$

where d_{AB} is distance between A and B.



Poaching submodel

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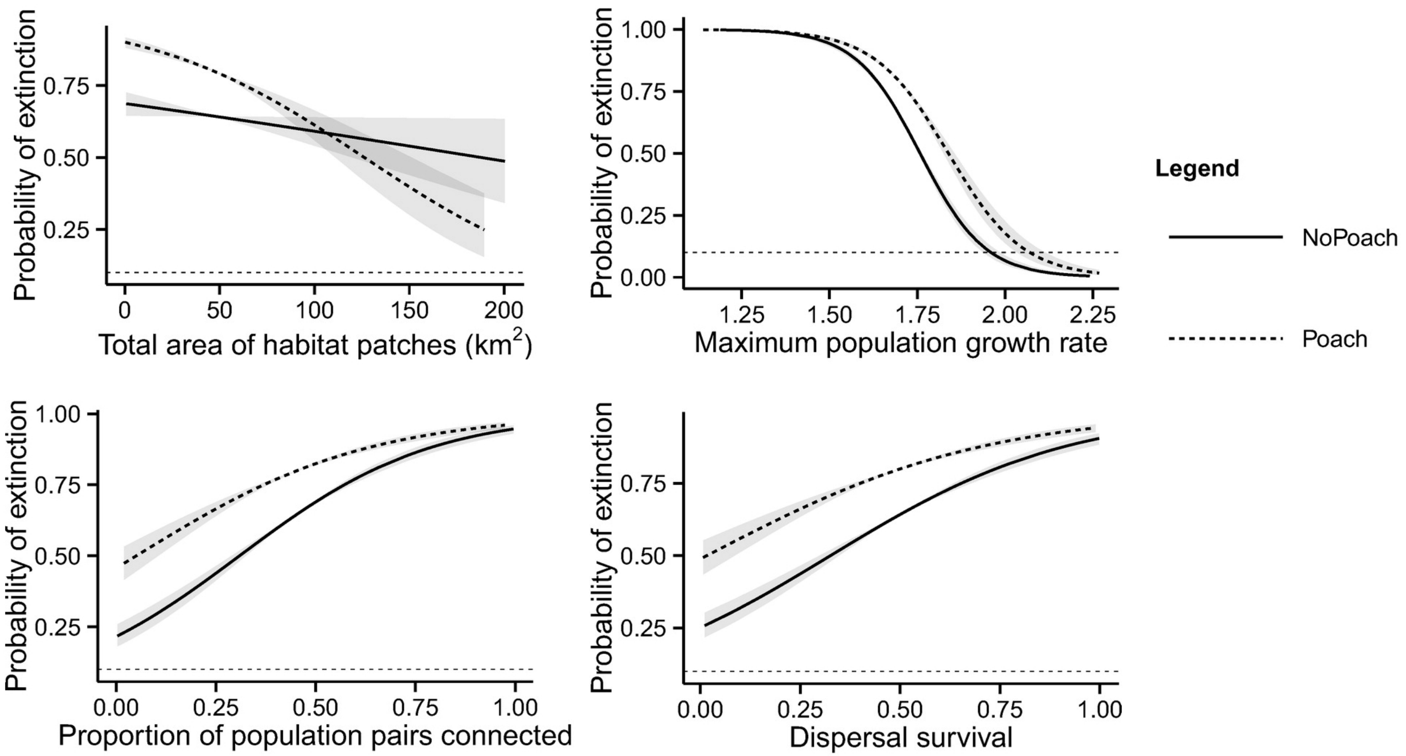
Heavy use of **sensitivity analysis** for unknown or difficult to know parameters,

Abalone results

Used: metapopulation **probability of extinction = 0.1** as threshold, (corresponding to IUCN definition of **vulnerable**).



Determined that **yes** in nearly ALL modeled scenarios, reasonable estimates of poaching lead to a higher **risk of extinction** for the metapopulation.

Pop Quiz: **Who Else Loves Abalone?**

our old friends!

NEXT TOPIC: Species Interactions!

For a fascinating deep dive in the interactions & conflicts among **abalone**, **sea otters**, **conservation laws**, and **First Nation stewardship** check out **this podcast:**