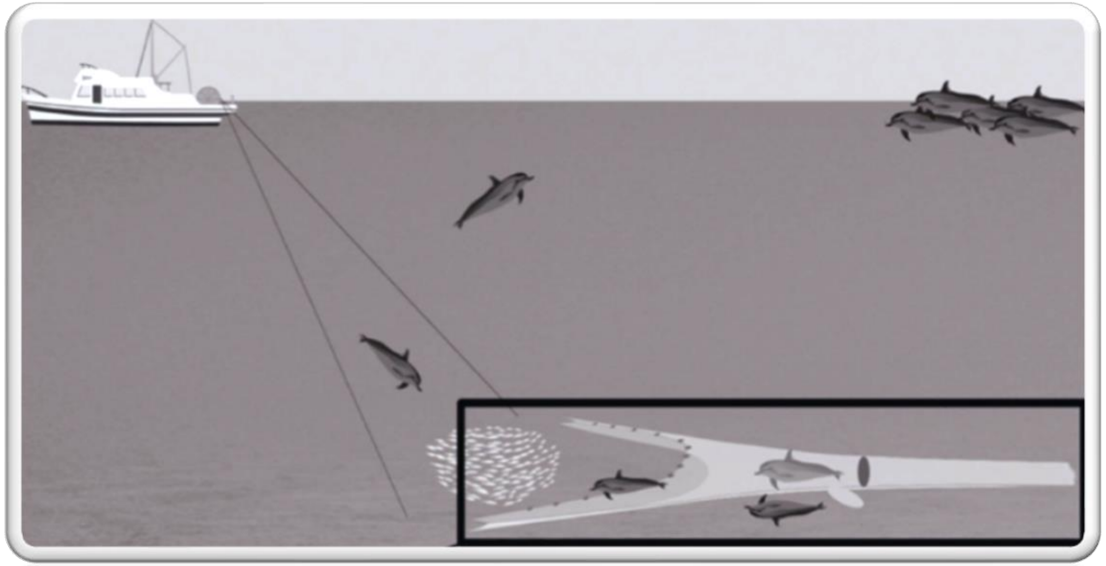
***SAMSE*:**
A Stochastic Model to Set Sustainable Limits to Wildlife Mortality in a Changing World

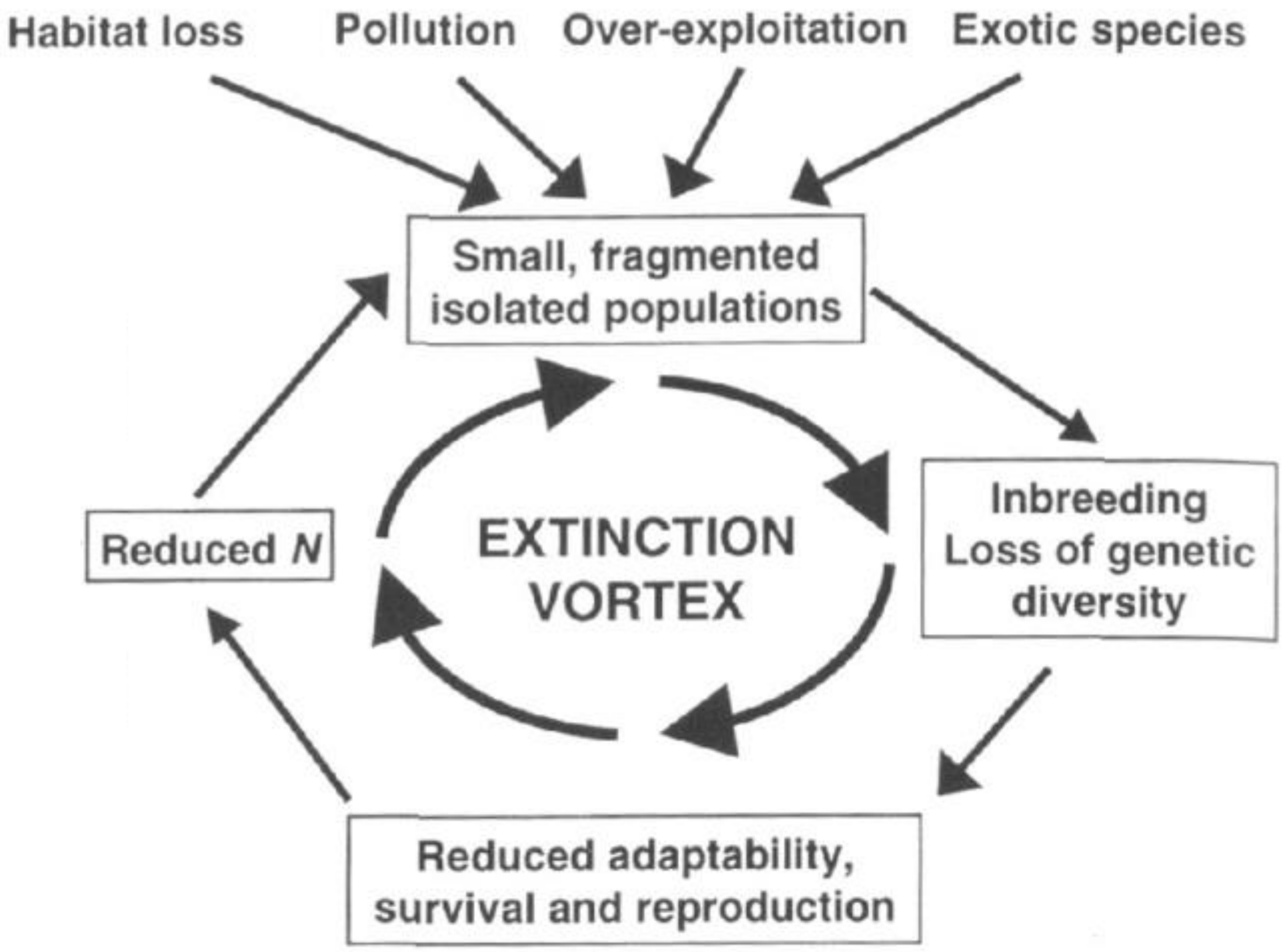
Oliver Manlik, Robert C. Lacy,
William B. Sherwin, Hugh Finn,
Neil R. Loneragan, Simon J. Allen

UNEP ASCOBANS
30 YEARS 1992-2022



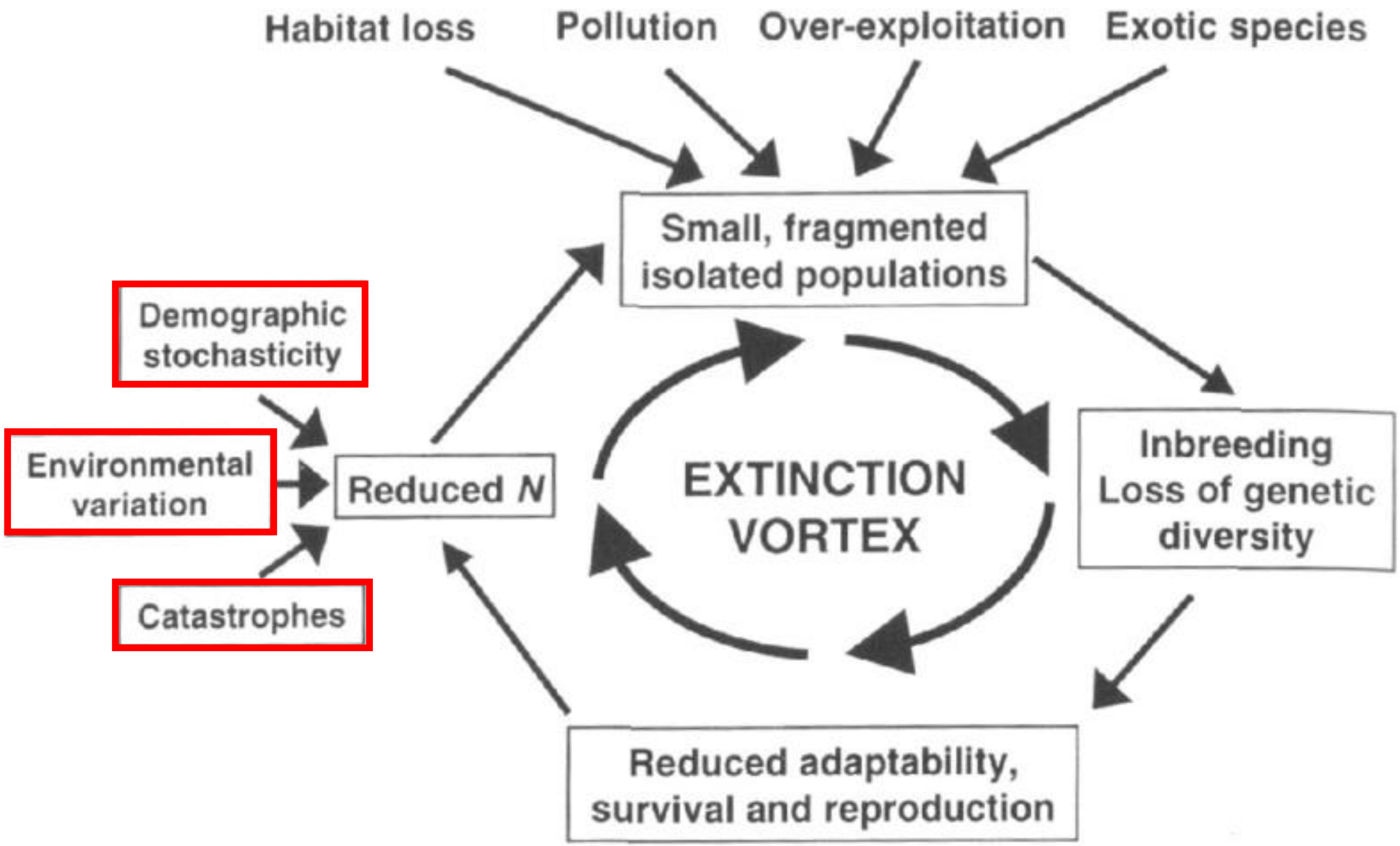
UAEU
جامعة الإمارات العربية المتحدة
United Arab Emirates University

Extinction Vortex



Frankham et al. 2002

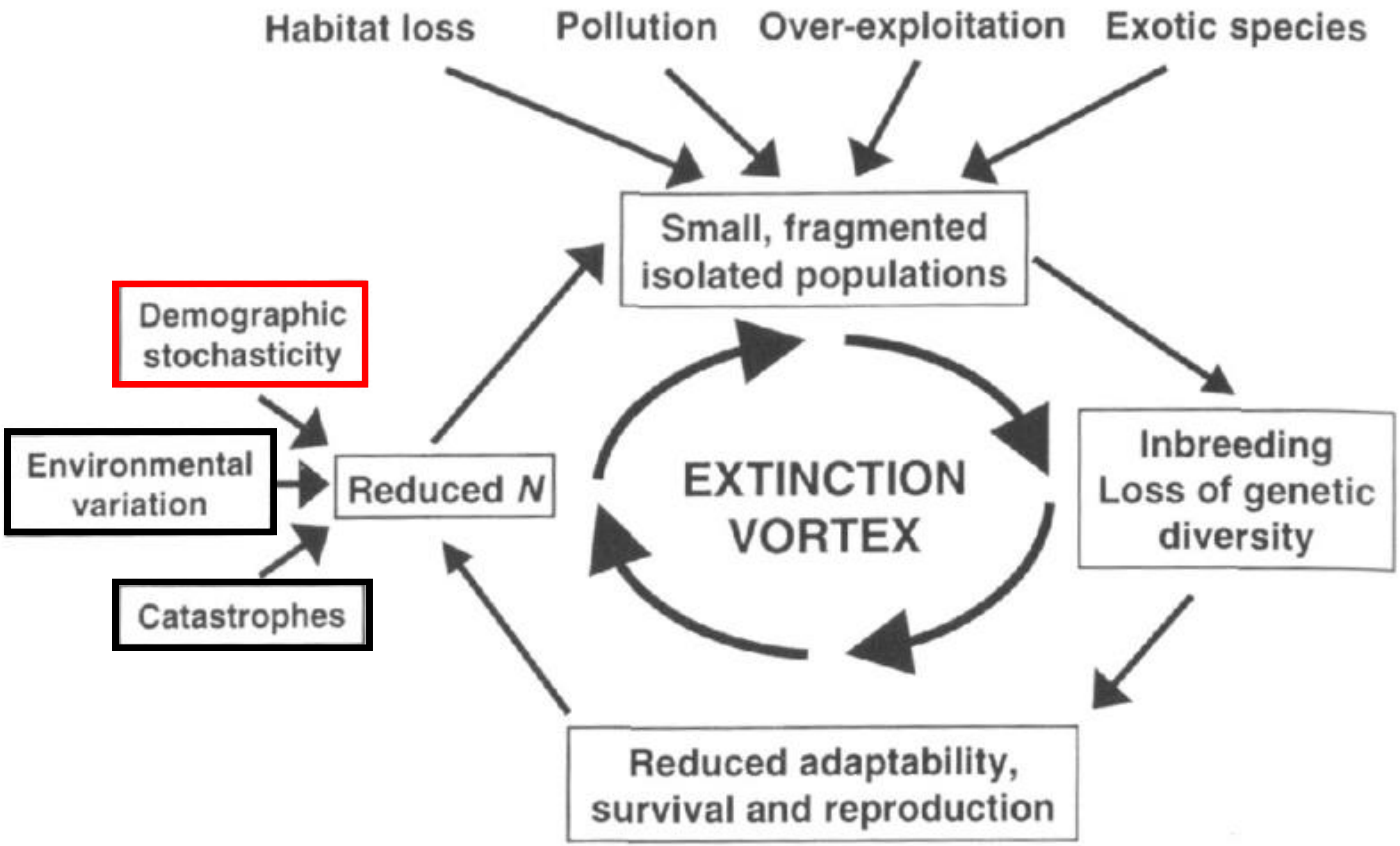
Stochastic Events Accelerate Extinction Vortex



Stochastic Events: **Random (chance) events** that can affect population dynamics

Frankham et al. 2002

Stochastic Events Accelerate Extinction Vortex



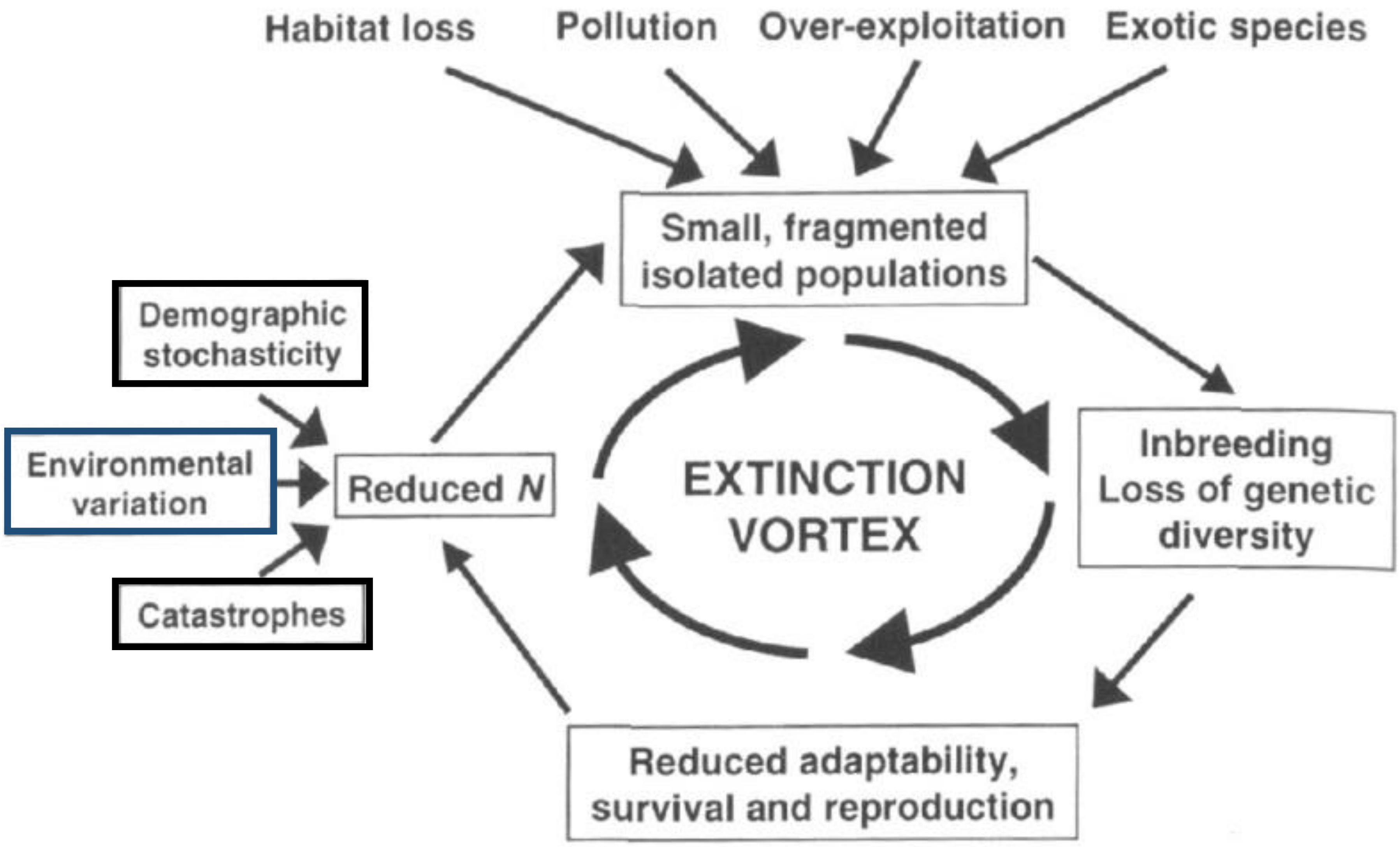
Stochastic Events:

Random (chance) events that can affect population dynamics

- **Demographic stochasticity** random fluctuation in obs. birth rate, death rate & sex ratio resulting from stochastic sampling processes

Frankham et al. 2002

Stochastic Events Accelerate Extinction Vortex



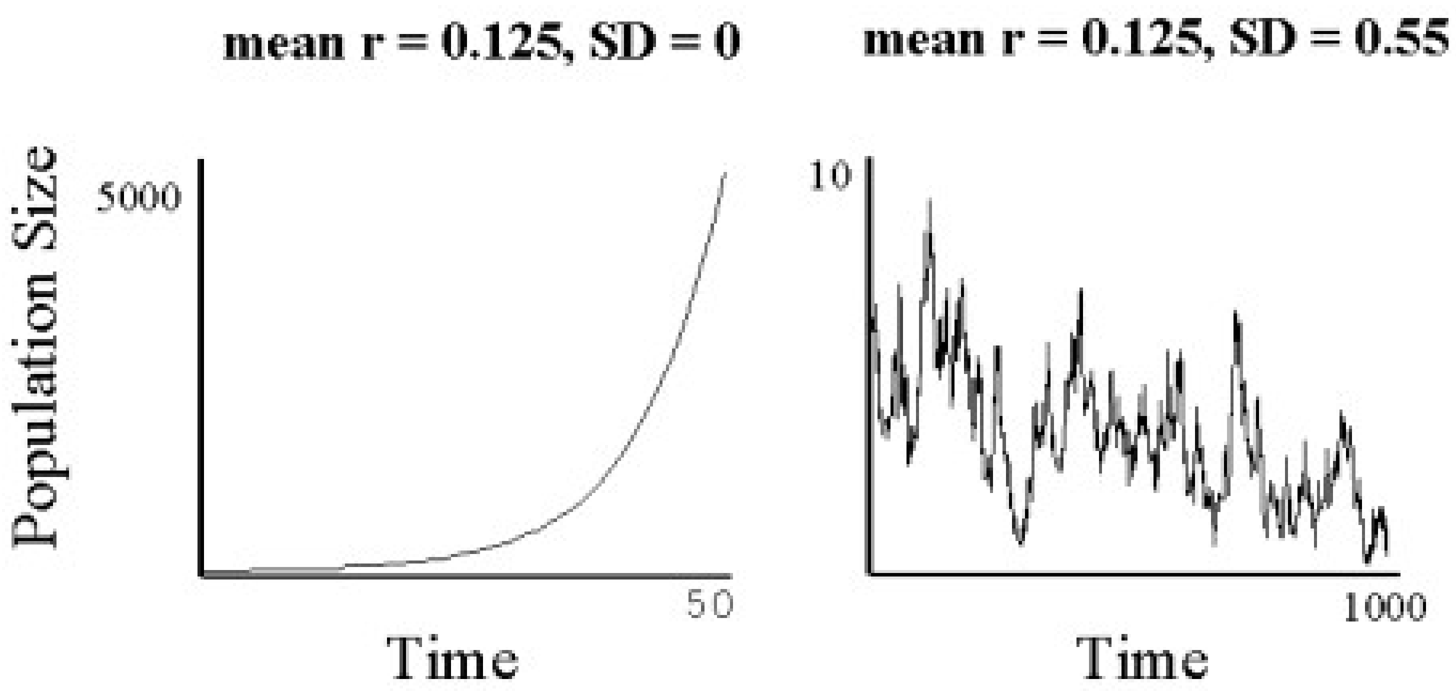
Frankham et al. 2002

Stochastic Events:
Random (chance) events that can affect population dynamics

- Demographic stochasticity
- **Environmental stochasticity:** fluctuation in probabilities of birth and death due to random fluctuations in the environment

Stochastic Events can affect Population growth (*r*)

Long-term growth rates can be negative even with average positive *r*, if variation in growth rate is high



Deterministic
(no stochasticity)

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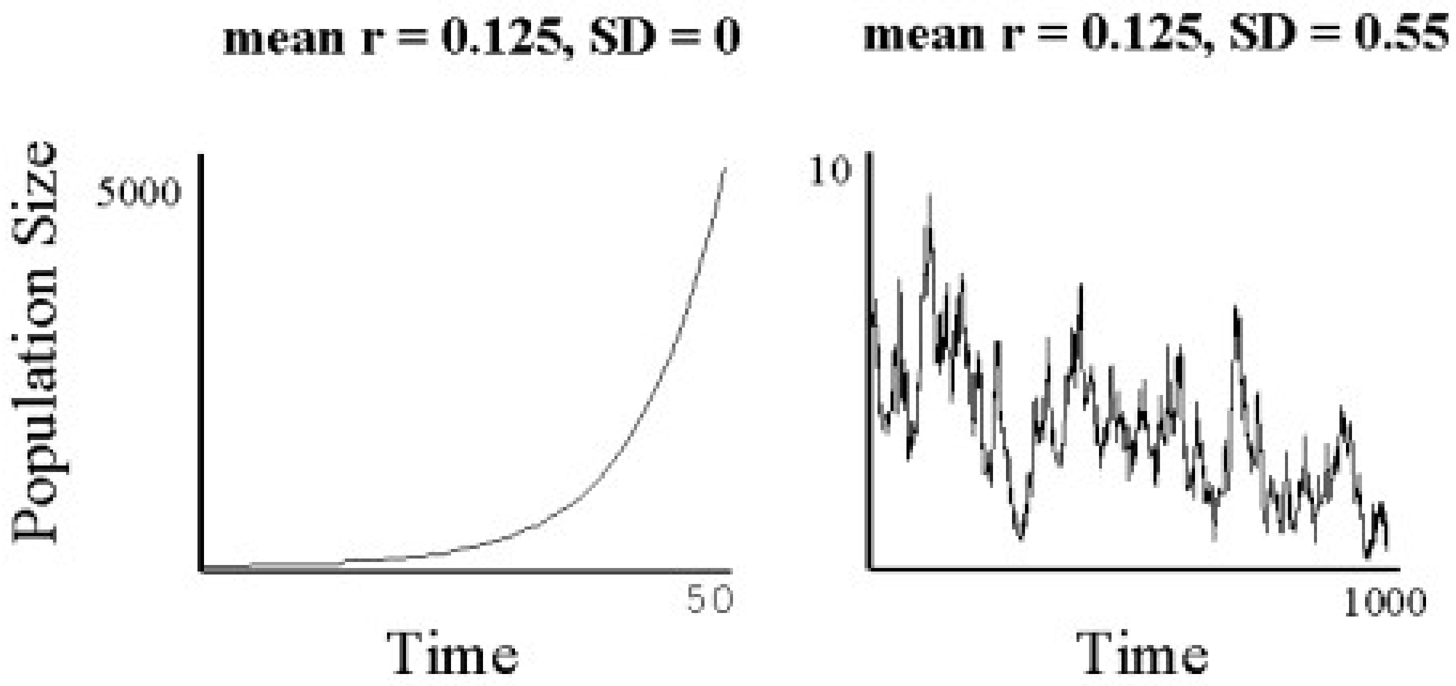

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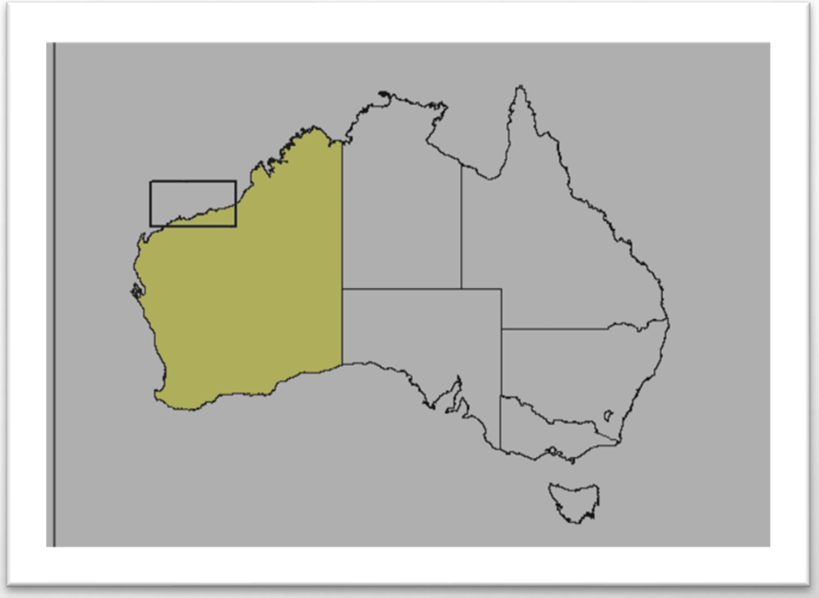
But **stochasticity is often ignored** in simple population models (e.g. Leslie matrix), especially when determining sustainable limits to wildlife mortality

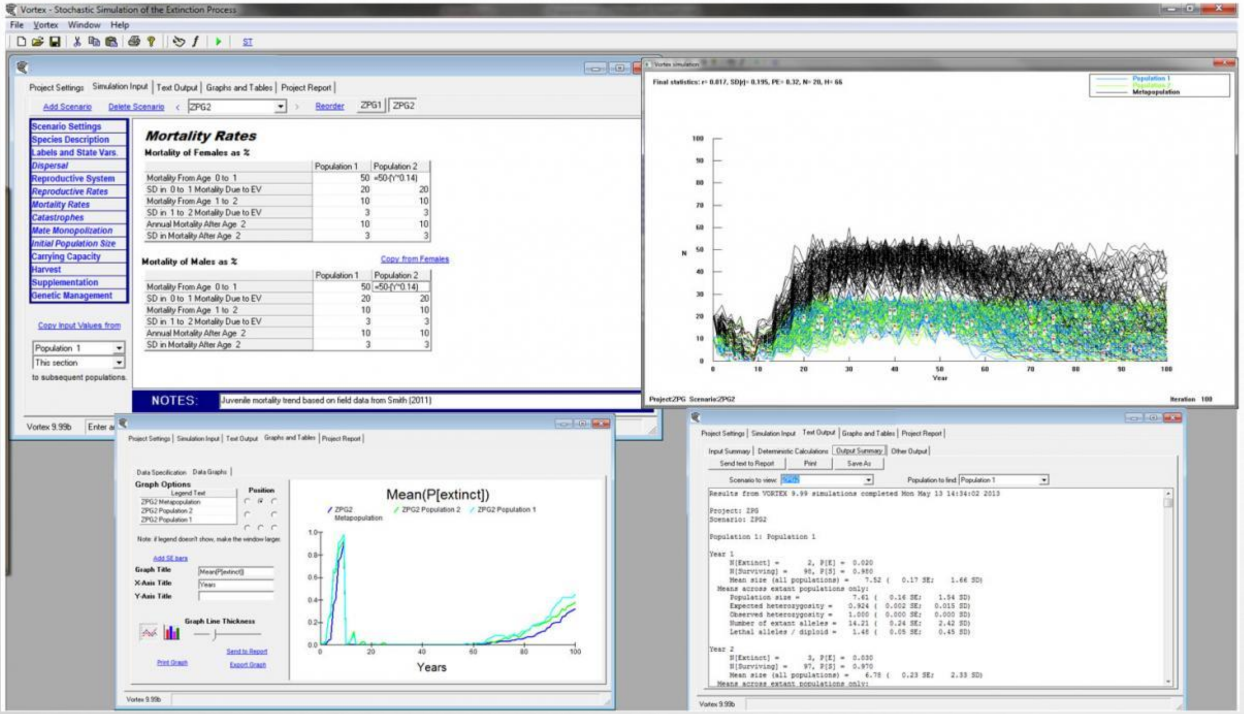
PILBARA FISH TRAWL FISHERY: BYCATCH OF BOTTLENOSE DOLPHINS

- **Pilbara Fish Trawl Fishery** (northern Western Australia) targets variety of scalefish species
- But also captures protected and threatened species, including **bottlenose dolphins** (*Tursiops truncatus*)



- **Bycatch rates of bottlenose dolphins:**
  - **Skippers' logbooks** (2012-2017): **24.5/yr** (mean) (73.5/3-yr)
  - **Independent Observers** (2002; 2006-2009): **50/yr** (150/3-yr)
  - **Western Australian Department of Fisheries**: **75/yr** (225/3-yr)
    "number of dolphins caught by the fishery should be < 75/yr"

STOCHASTIC POPULATION MODEL USING VORTEX



https://www.cpsg.org/vortex-more-detail

- Used **VORTEX** for population modeling
- Set up standard 3-yr model of a <u>stable bottlenose dolphin population without bycatch</u>:
  - Population size estimate from impacted Pilbara population
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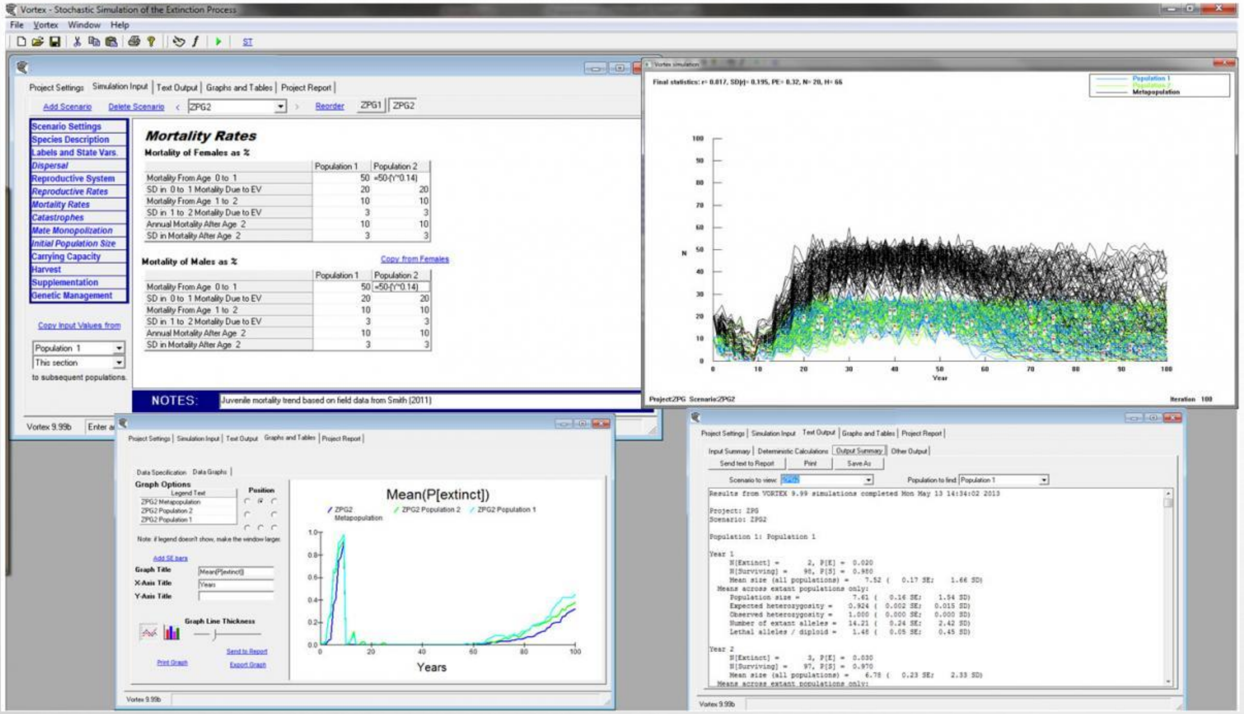

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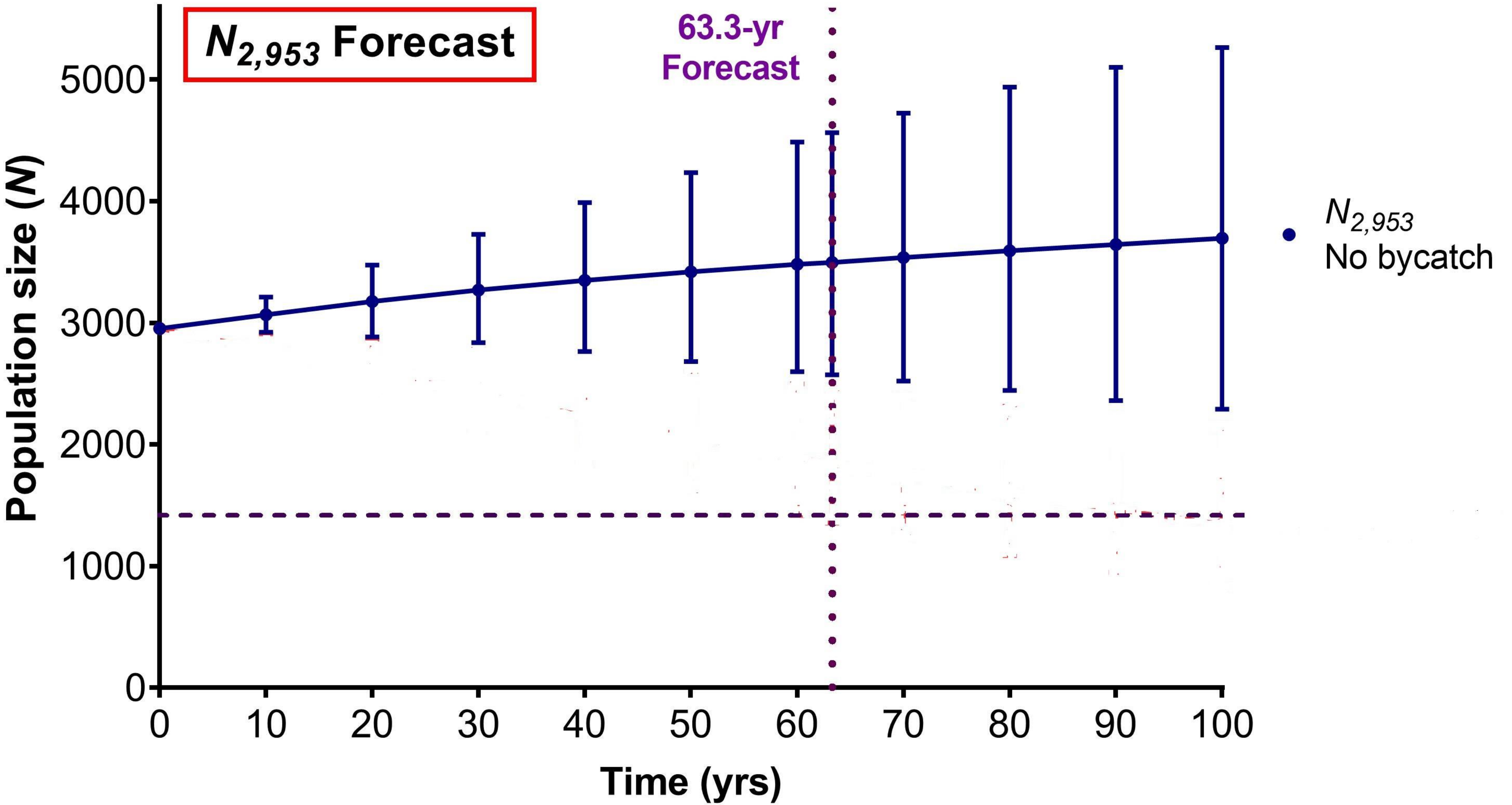
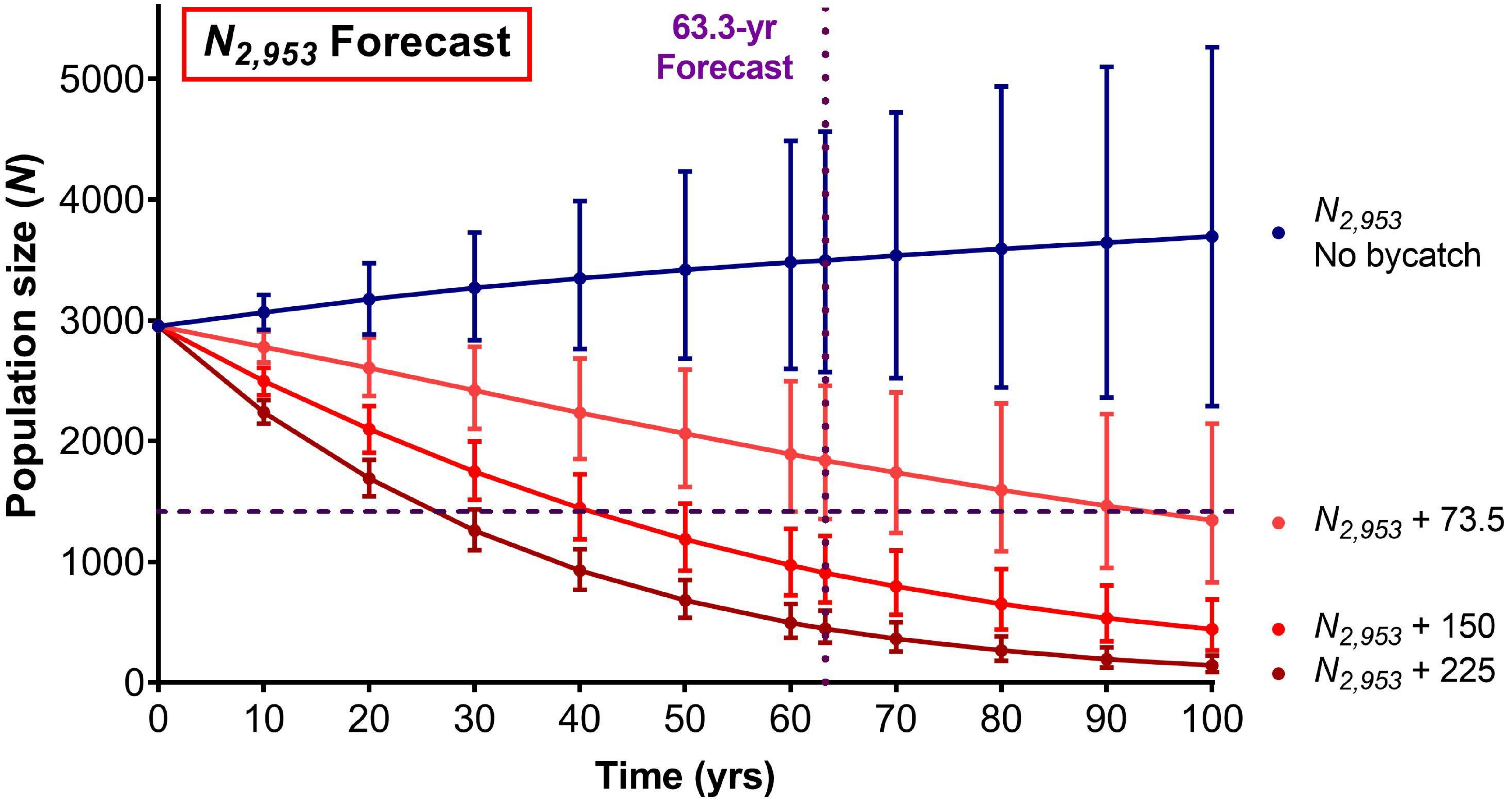
Set up **bycatch scenarios** based on estimated & reported bycatch rates, PBR:

- **73.5/3-yr**
- **150/3-yr**
- **225/3-yr**
- **PBR: 48.57/3-yr** (16.19/yr)



$N_{2,953}$ Forecast
63.3-yr
Forecast
Population size (N)
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
70
80
90
100
Time (yrs)
$N_{2,953}$
No bycatch



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$N_{2,953}$ + 73.5
$N_{2,953}$ + 150
$N_{2,953}$ + 225

INTRODUCING *SAMSE*:
SUSTAINABLE ANTHROPOGENIC MORTALITY IN STOCHASTIC ENVIRONMENTS

HOW DID WE APPLY *SAMSE*?

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  - **Environmental stochasticity**:

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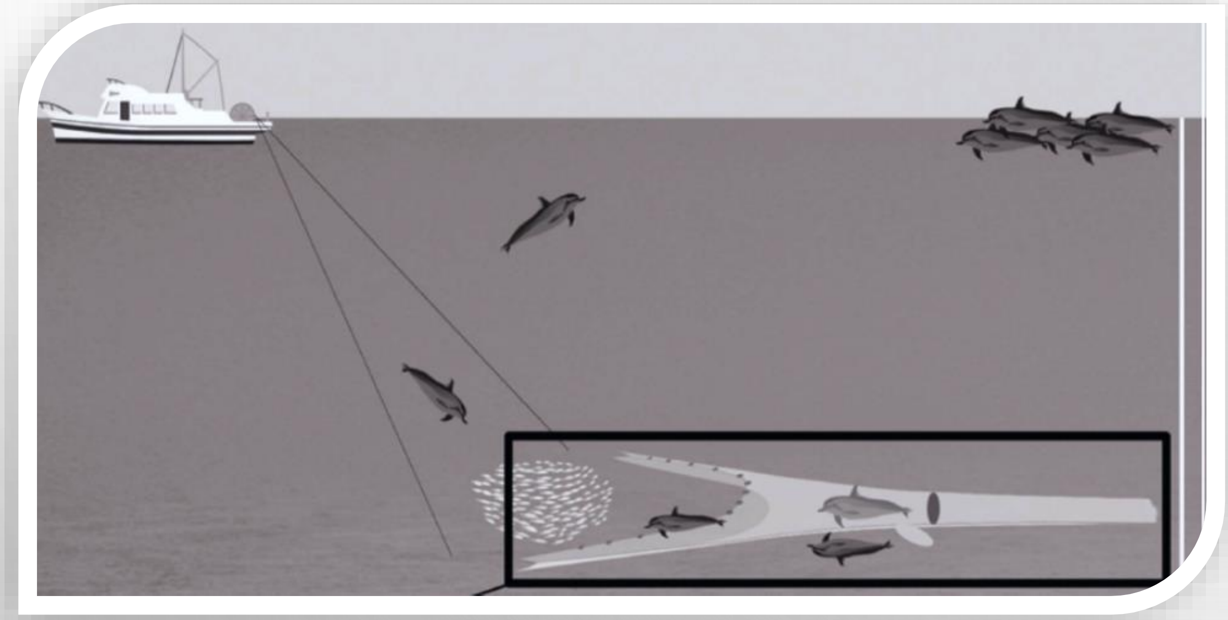
- Ran trial scenarios that included the removal of a set number of individuals until we reached forecasts that produced non-negative stochastic growth rates, i.e. the ***SAMSE* limit**

SAMSE RESULTS



N_0	*SAMSE*	r_{det}	r_{stoch}
1,619	**2.33**	0.0004	**0.0001**
2,953	**4.33**	0.0003	**0.0001**
5,473	**8**	0.0003	**0.0001**

N_0	***SAMSE* +1**	r_{det}	r_{stoch}
1,619	**2.67**	-0.0003	**-0.0007**
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SAMSE ≈ **2-8** removals/year

(7-24 per 3-yrs)

PBR vs **SAMSE**

PBR (Wade,1998)

N_{MIN} $(R_{MAX}/2)$ F_R

N_{MIN} = 1,619

R_{MAX} = 0.04 (default for cetaceans)

F_R = 0.5 (Wade, 1998)

THUS PBR =

1,619 x (0.04/2) x 0.5 = 16.19

PBR* ≈ **16** removals/year

(48-49 per 3-yrs)

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*__Potential Biological Removal__
(conventional method without stochasticity)

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TO REACH OR MAINTAIN
POPULATION STABILITY IN STOCHASTIC ENVIRONMENT

SAMSE

Impacted Population

Parameters may include:

- Abundance estimates
- Carrying capacity
- Fishery bycatch rates

Stable Reference Population

Parameters may include:

- Mortality rates
- Reproductive rates
- Age class distribution

(a) Demographic Stochasticity:

Emerges from simulated occurrence of events based on specified probabilities

Stochastic Model

Trials to determine *SAMSE*:

Increase mortality until threshold of +/- r_{stoch} is reached

(b) Environmental Stochasticity:

Incorporate vital rate SD_{EV}:

$$SD_{EV} = \sqrt{\sigma^2{}_{Tot} - \sigma^2{}_{Samp}}$$

Use binomial (or beta) distributions to sample annual value from mean and SD_{EV}

***SAMSE*:**

$r_{stoch} \geq 0$

***SAMSE + 1*:**

$r_{stoch} < 0$

Steps to follow:

1.) Setting up stochastic model based on parameters from impacted population and stable reference population

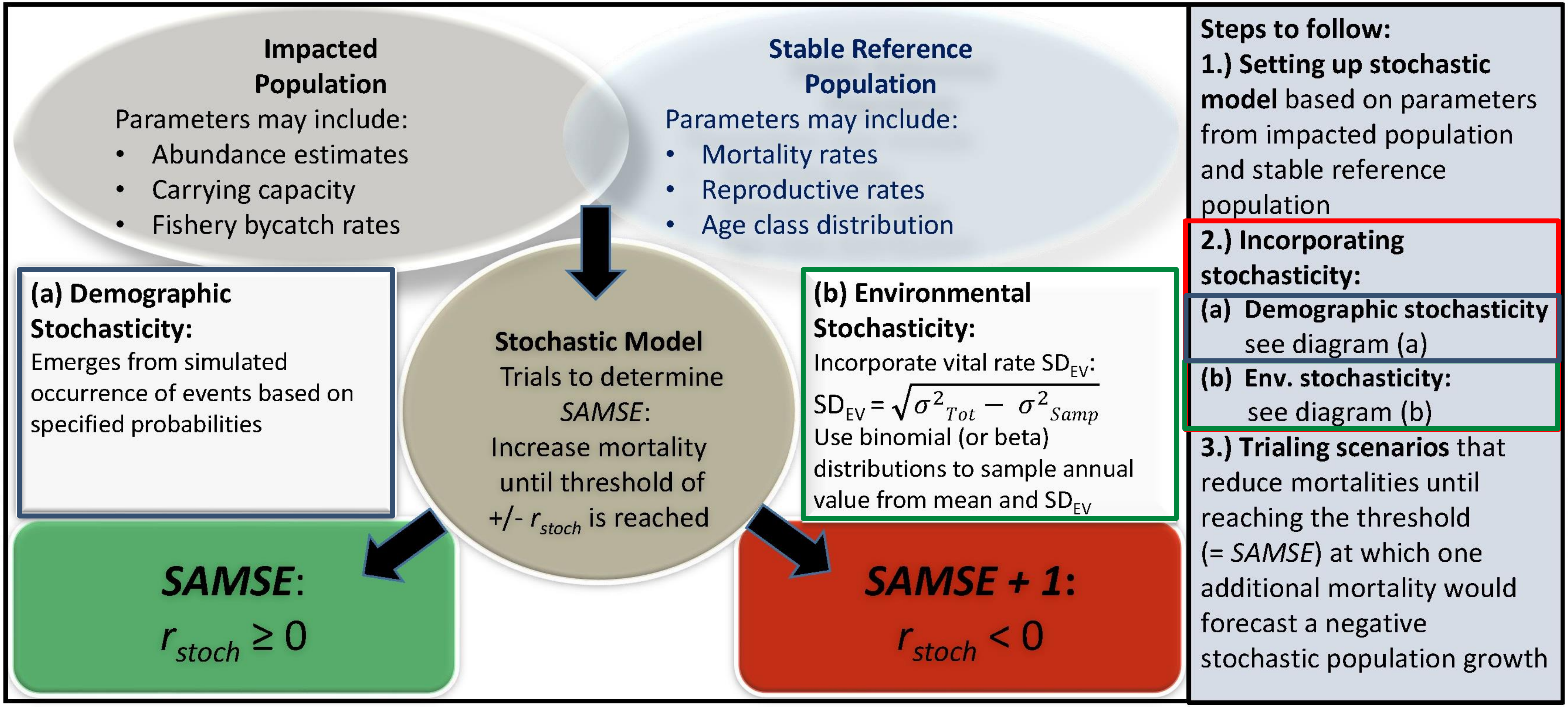
2.) Incorporating stochasticity:

(a) **Demographic stochasticity** see diagram (a)

(b) **Env. stochasticity:** see diagram (b)

3.) Trialing scenarios that reduce mortalities until reaching the threshold (= *SAMSE*) at which one additional mortality would forecast a negative stochastic population growth

SAMSE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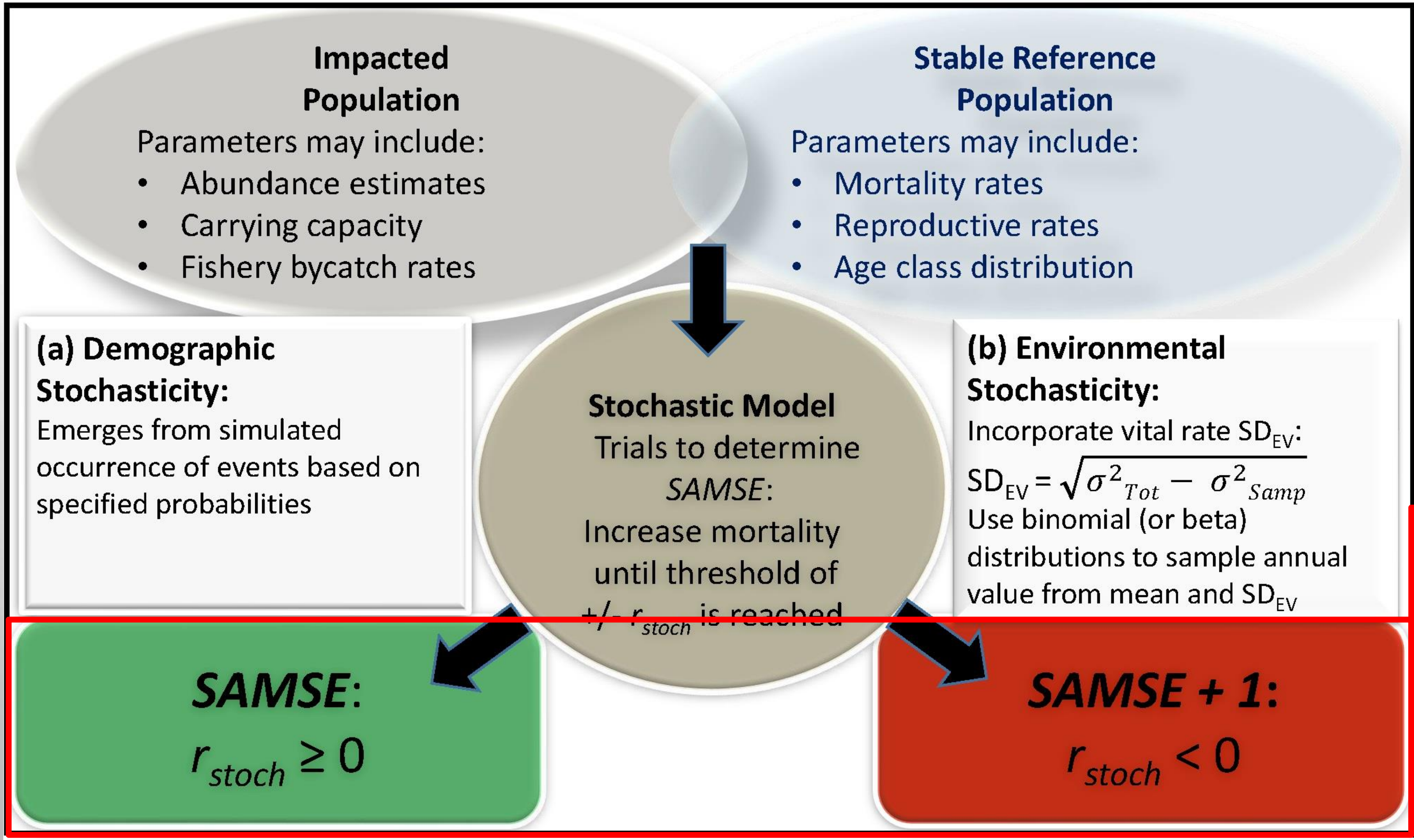

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WHAT IS *SAMSE*?

- **S**ustainable **A**nthropogenic **M**ortality in **S**tochastic **E**nvironments
- ***SAMSE*** is a population modelling approach that incorporates stochasticity to estimate sustainable limits to human-caused mortality of wildlife (not only bycatch!)
- ***SAMSE*-limit**: The maximum number of individuals that can be removed by human activity, without resulting in negative stochastic growth rate forecasts
  - Removing one more individual per year would result in a population decline, i.e. a negative stochastic *r (= SAMSE +1)*
- ***SAMSE*** allows us to incorporate stochasticity in the following ways:
  - <u>Demographic stochasticity</u>
  - <u>Environmental stochasticity</u>
  - <u>Dependency of offspring</u> on fate of parent(s) (e.g. dolphin calves that are dependent on mothers)

ADVANTAGES & LIMITATIONS OF *SAMSE*

- ***SAMSE*** can incorporate **demographic stochasticity** & **environmental stochasticity**
- ***SAMSE*** can incorporate surrogate data from well-studied, stable reference populations, i.e. does not require lots of data from impacted population
- ***SAMSE*** is broadly applicable to a large range of taxa and situations (not only bycatch)
- ***SAMSE*** can be performed using various off-the-shelf modeling software that allows the incorporation of stochastic factors, e.g. **VORTEX***, RAMAS

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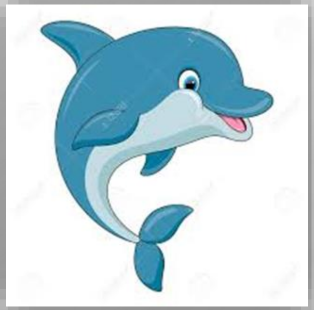

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- ***SAMSE*** can incorporate other threats (pollution, etc.); (akin to changing RMAX)
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***PLAN**:
- Incorporate module into **VORTEX** to report ***SAMSE*-limit**
- Create "**library**" of pre-configured baseline **VORTEX** models for various species

THANKS FOR YOUR INTEREST!

Oliver Manlik (UAEU), Robert C Lacy, William B Sherwin, Hugh Finn, Neil R Loneragan, Simon J Allen

Conservation Biology

CONTRIBUTED PAPERS | Open Access

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First published: 04 February 2022 | https://doi.org/10.1111/cobi.13897

IUCN Conservation Planning Specialist Group, Species Conservation Toolkit Initiative SCTI: *SAMSE* to be incorporated into VORTEX

THANKS FOR YOUR INTEREST!

Oliver Manlik (UAEU)

Opportunities for PhD at United Arab Emirates University:

- Population genomics fish (sardines, tuna)
- Gene expression in response to climate change (*Tigriopus*)

Contact me:
oliver.manlik@uaeu.ac.ae
Twitter: @Omanlik

ASCOBANS
30 YEARS 1992-2022

WHAT IS **EFFECT OF STOCHASTICITY** ON FORECASTS?

	With Stochasticity	**With Env Stochasticity**	**NO Stochasticity**
Growth rate (*r*)	− 0.0233 to − 0.0972	− 0.0199 to − 0.0860	− 0.0196 to − 0.0832
% Change	**− 17% to − 23%**	**− 2% to − 7%**	NA

- Incorporating **stochasticity** substantially lowers population growth (by 17 to 23%), depending on population size
- **Large effect of demographic stochasticity**, in particular calf-mother dependency

POTENTIAL BIOLOGICAL REMOVAL (PBR)

- ***PBR*** estimates maximum number of animals that may be removed from a "stock" while allowing that stock to reach or maintain its "optimum sustainable population"
- ***PBR*** is considered to provide a conservative limit for human-caused mortality
- **US Marine Mammal Protection Act** (MMPA, 1972) provides statutory framework for PBR concept

PBR (Wade,1998):

$\boldsymbol{N_{MIN}\ (R_{MAX}/2)\ F_R}$

N_{MIN} = Min N estimate

R_{MAX} = 0.04 (default for cetaceans)

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- ***PBR*** is considered to provide a conservative limit for human-caused mortality
- **US Marine Mammal Protection Act** (MMPA, 1972) provides statutory framework for PBR concept
- Original equation/model is deterministic—i.e. does not incorporate stochasticity

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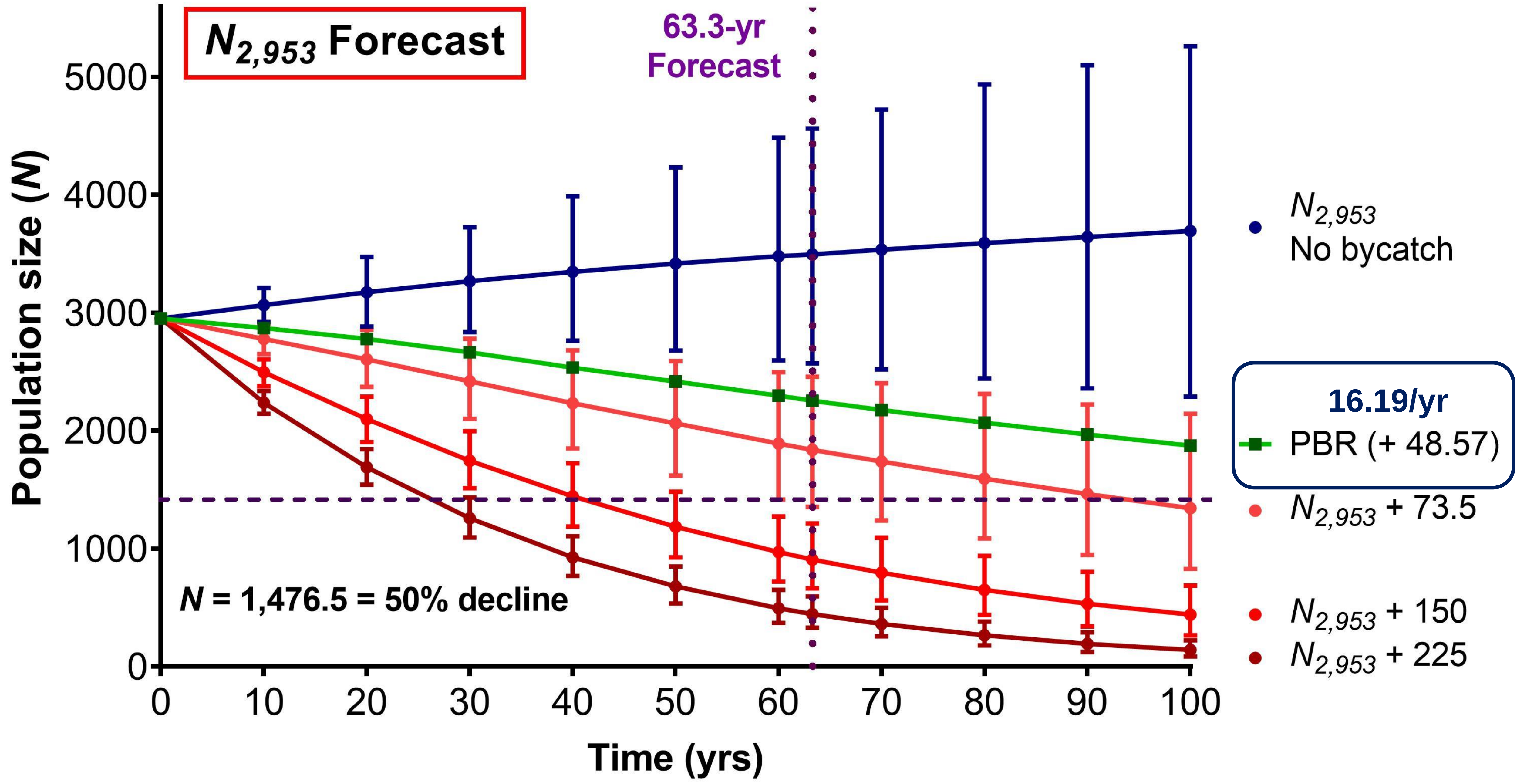
Photo: Claire Daniel



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POTENTIAL BIOLOGICAL REMOVAL (PBR)

PBR (Wade,1998):

"*The model used is deterministic rather than stochastic…*"

"*it would be useful to **investigate the effects of stochastic dynamics** through simulations which incorporated plausible levels of environmental variance*"

SAMSE

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