The Effect of Localized Oil Spills on the Atlantic Loggerhead Turtle Population Dynamics

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Research Question

- How will a localized, offshore oil spill affect the populations of Atlantic loggerhead turtles?
- What implications do our findings have for conservation measures?

Introduction

Loggerhead turtles:

- Most studied of the six endangered Atlantic sea turtles
- Threats: habitat loss, predation, littering, climate change, fishing

Oil spills (1992–2001):

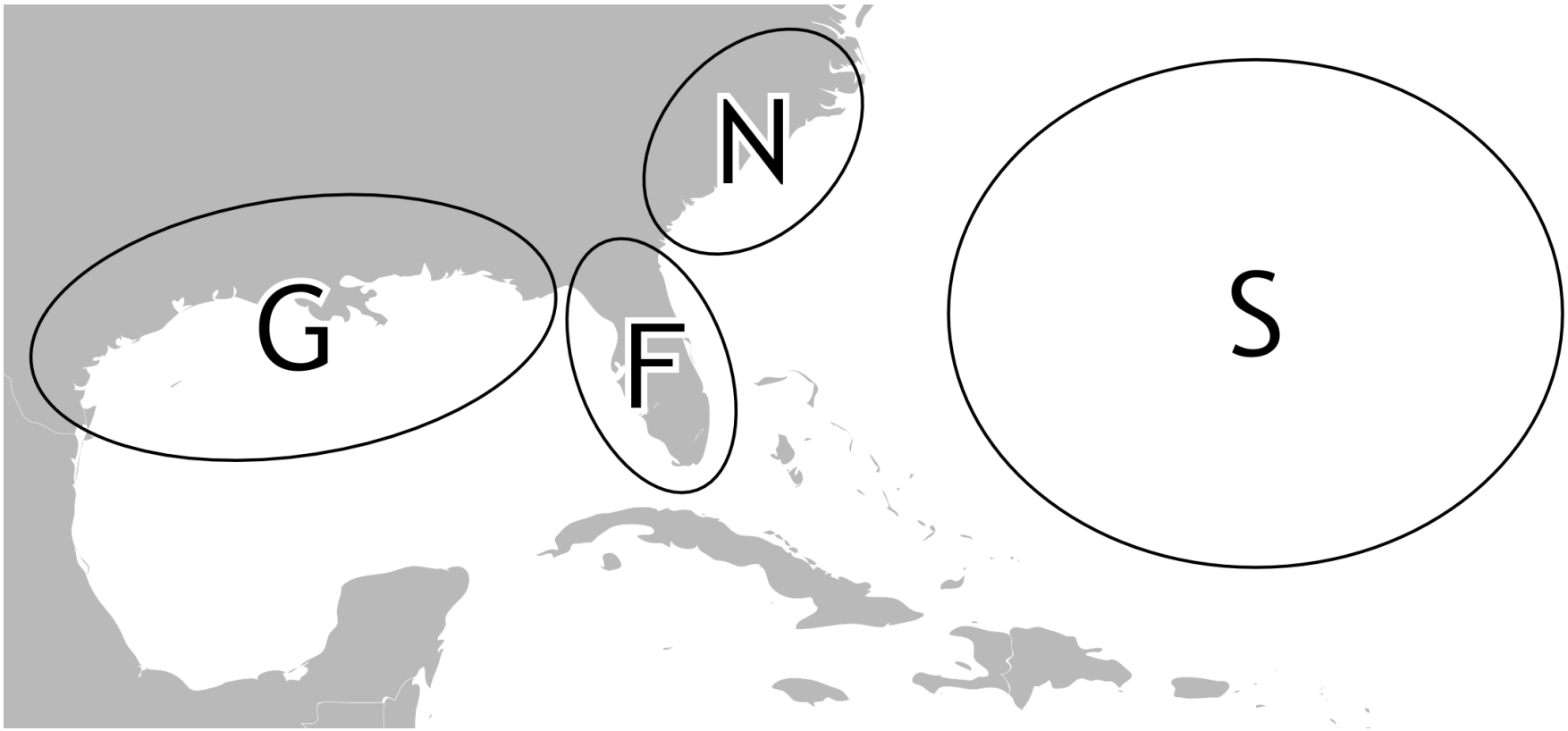
- 26 in the Gulf of Mexico
- 16 in Caribbean
- 9 off Florida peninsula
- 12 in coastal region north of Florida

Ixtoc I (1979): 3 million barrels

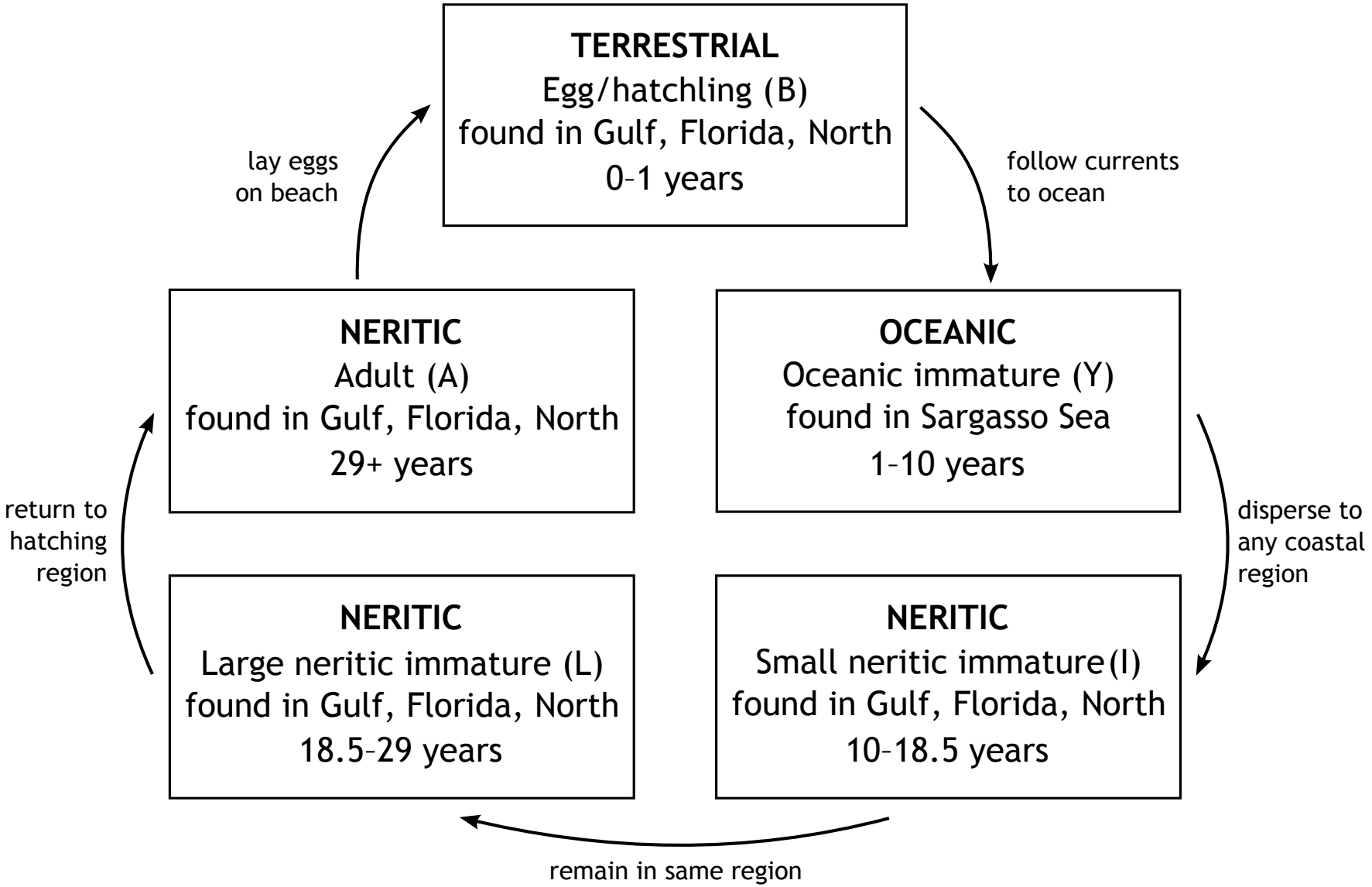
Deepwater Horizon (2010): up to 4.9 million barrels

Regions

- Nesting regions: Gulf (G), Florida (F), North (N)
- Oceanic region: Sargasso Sea (S)



Life Cycle


TERRESTRIAL
Egg/hatchling (B)
found in Gulf, Florida, North
0–1 years
lay eggs
on beach
follow currents
to ocean
NERITIC
Adult (A)
found in Gulf, Florida, North
29+ years
OCEANIC
Oceanic immature (Y)
found in Sargasso Sea
1–10 years
return to
hatching
region
disperse to
any coastal
region
NERITIC
Large neritic immature (L)
found in Gulf, Florida, North
18.5–29 years
NERITIC
Small neritic immature (I)
found in Gulf, Florida, North
10–18.5 years
remain in same region

Conceptual Model

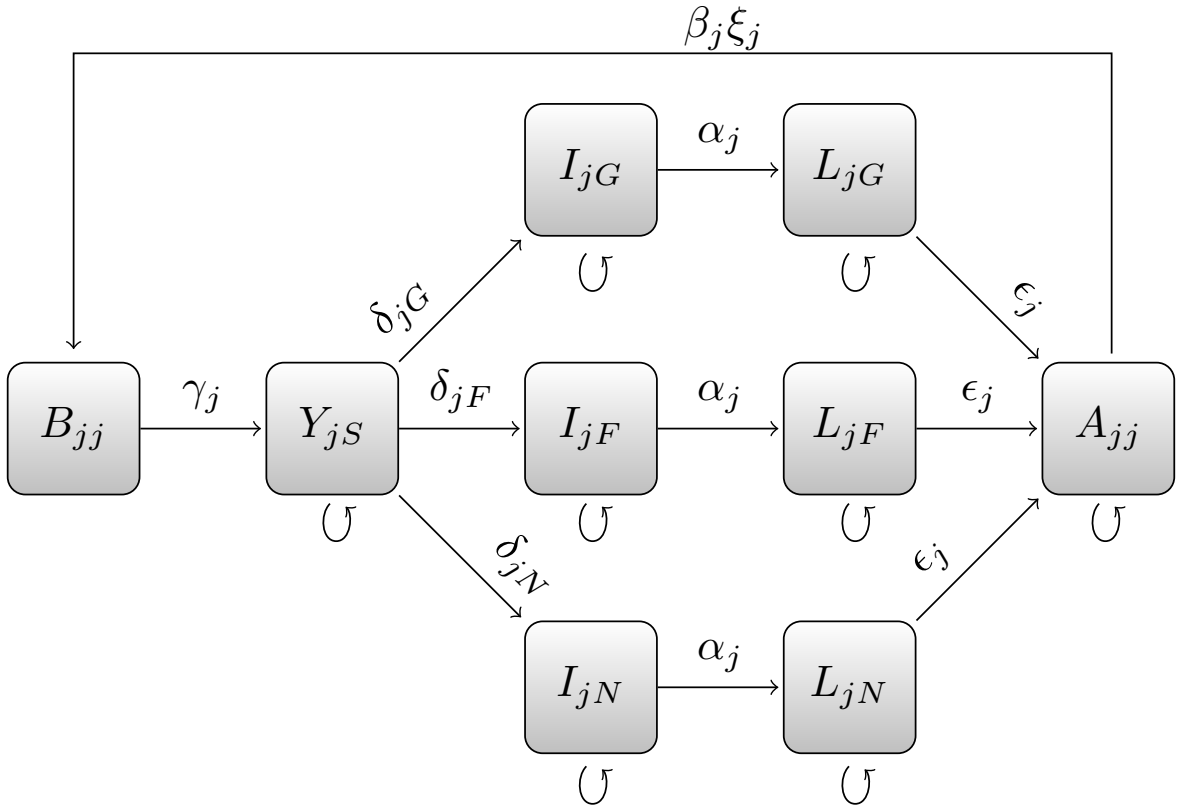
- Model for female population from region $j = G, F, N$
- First subscript: hatching region
- Second subscript: current location

Stage Classes:

B	eggs/hatchlings
Y	oceanic immatures
I	small neritic immatures
L	large neritic immatures
A	adults

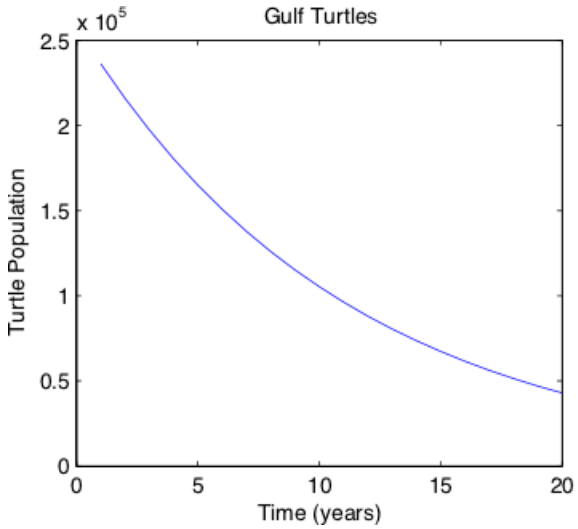
Regions:

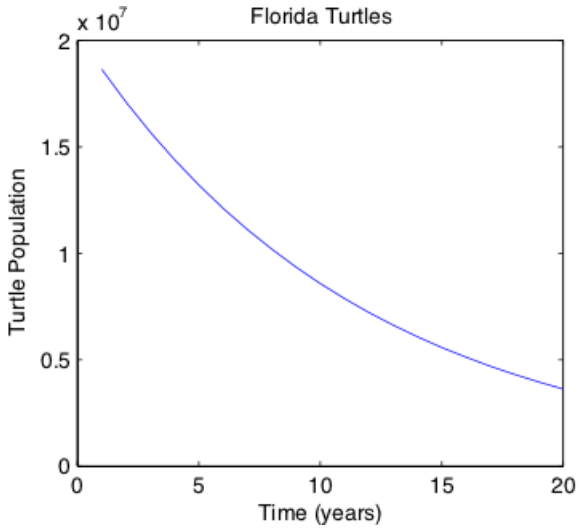
G	Gulf
F	Florida
N	North
S	Sargasso Sea

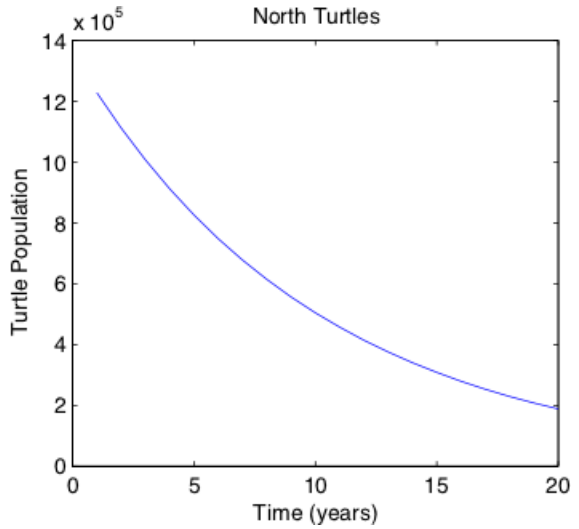


Population Model Simulation

Total populations over 20 years:







Annual survival:

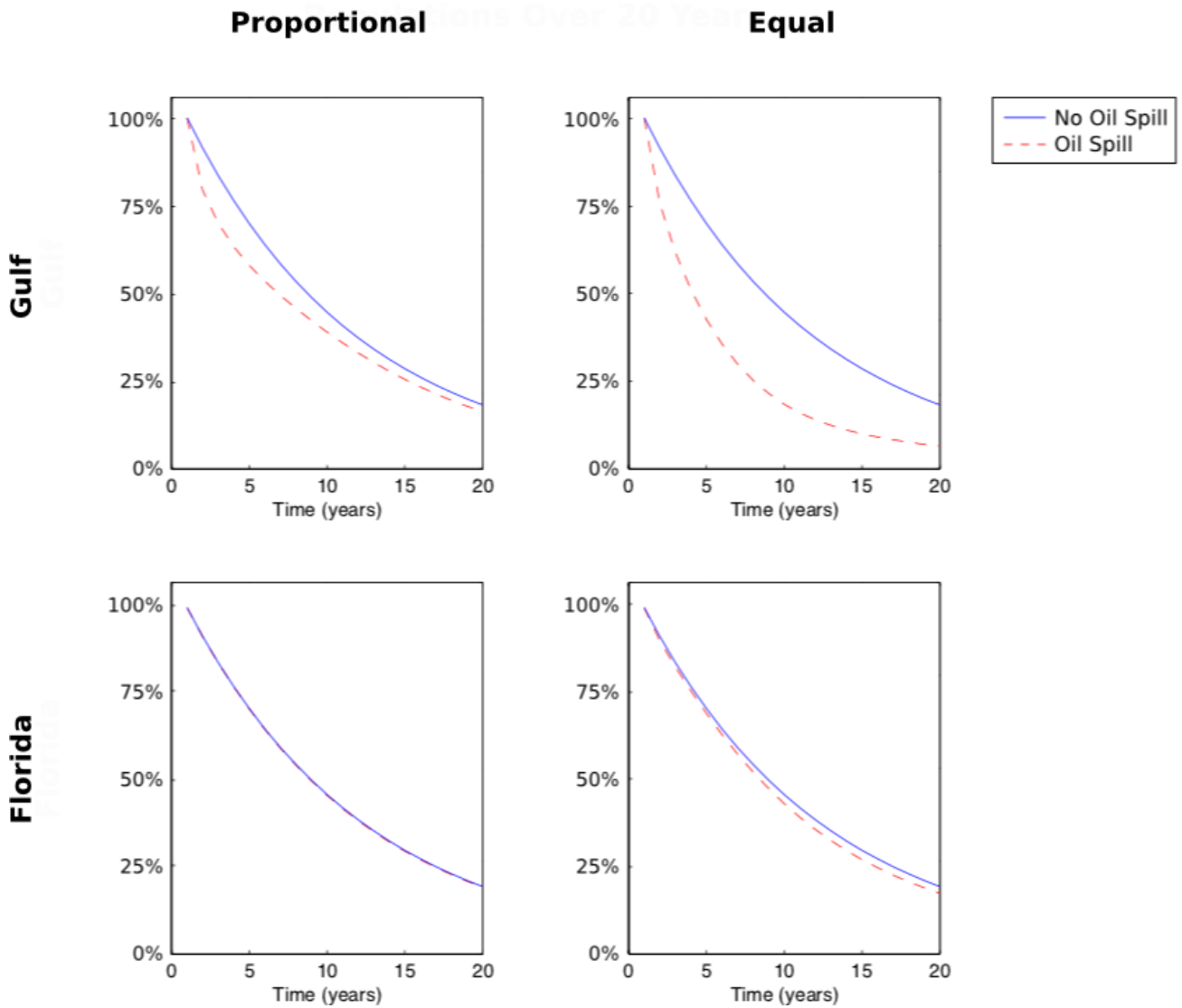
- Gulf: 91.42%
- Florida: 91.74%
- North: 90.64%

Introduction of Oil Spill

- Offshore, localized oil spill
- Initial toxicity $\theta = 25$, 50, 75 or 100% with half-life of one year
- Toxicity scenarios:
  - Proportional: toxicity divided by mean age in stage class
  - Equal: all stage classes affected equally
- Oceanic immatures unaffected

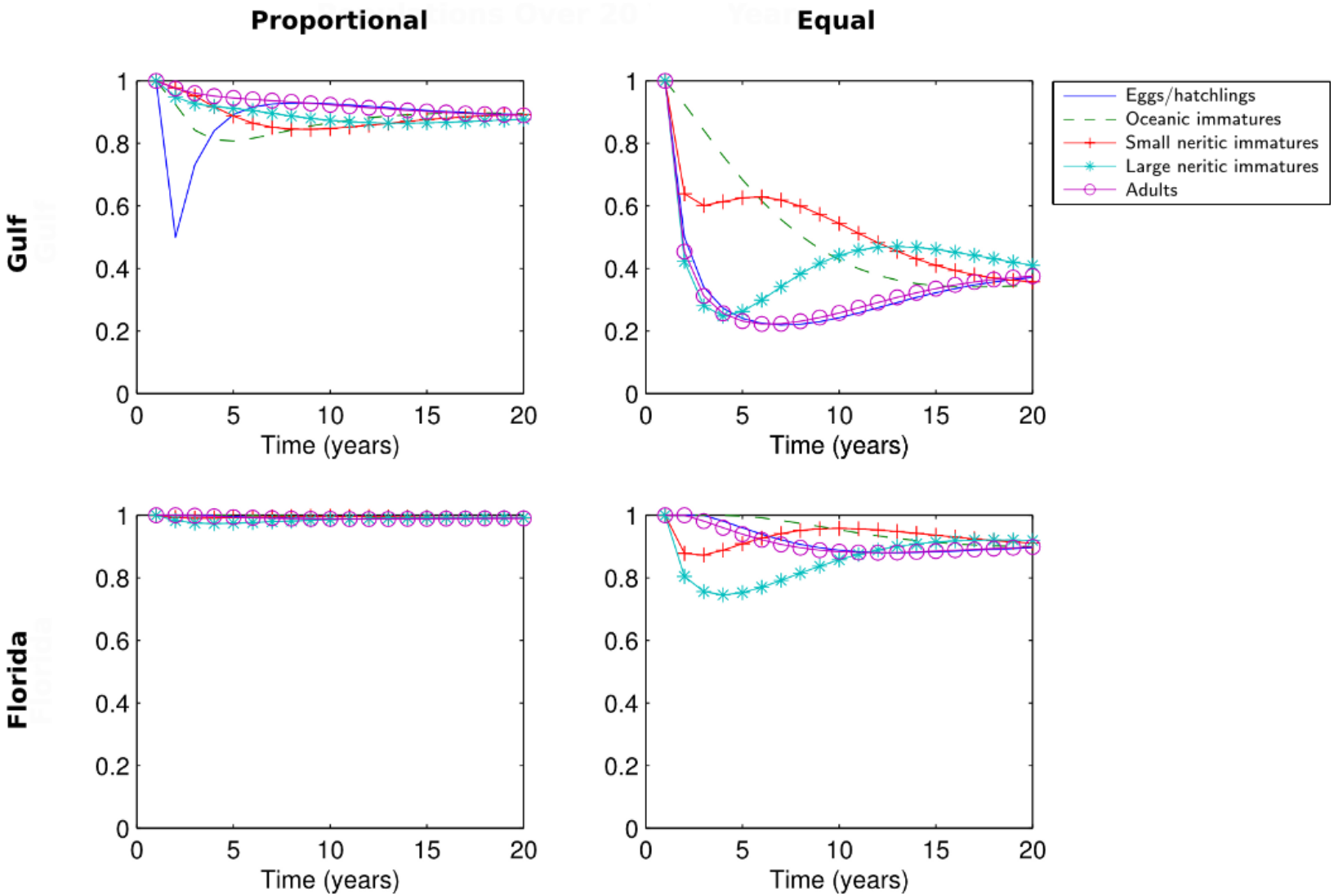
Simulation: Gulf Spill with 50% Toxicity

Percentage of initial populations:



Simulation: Gulf Spill with 50% Toxicity

Ratio of populations with spill to those without spill:



Oil Spill Simulations

Limitations:

- Simulations assume no human interference
- Which parameters most influence turtle populations?

Transient Sensitivity Indices

- Let ρ be an independent parameter (oil toxicity, fecundity, annual maturation/survival proportion)
- Let $\|\mathbf{P}(n)\|_1$ be the total population at time n
- Transient population growth is

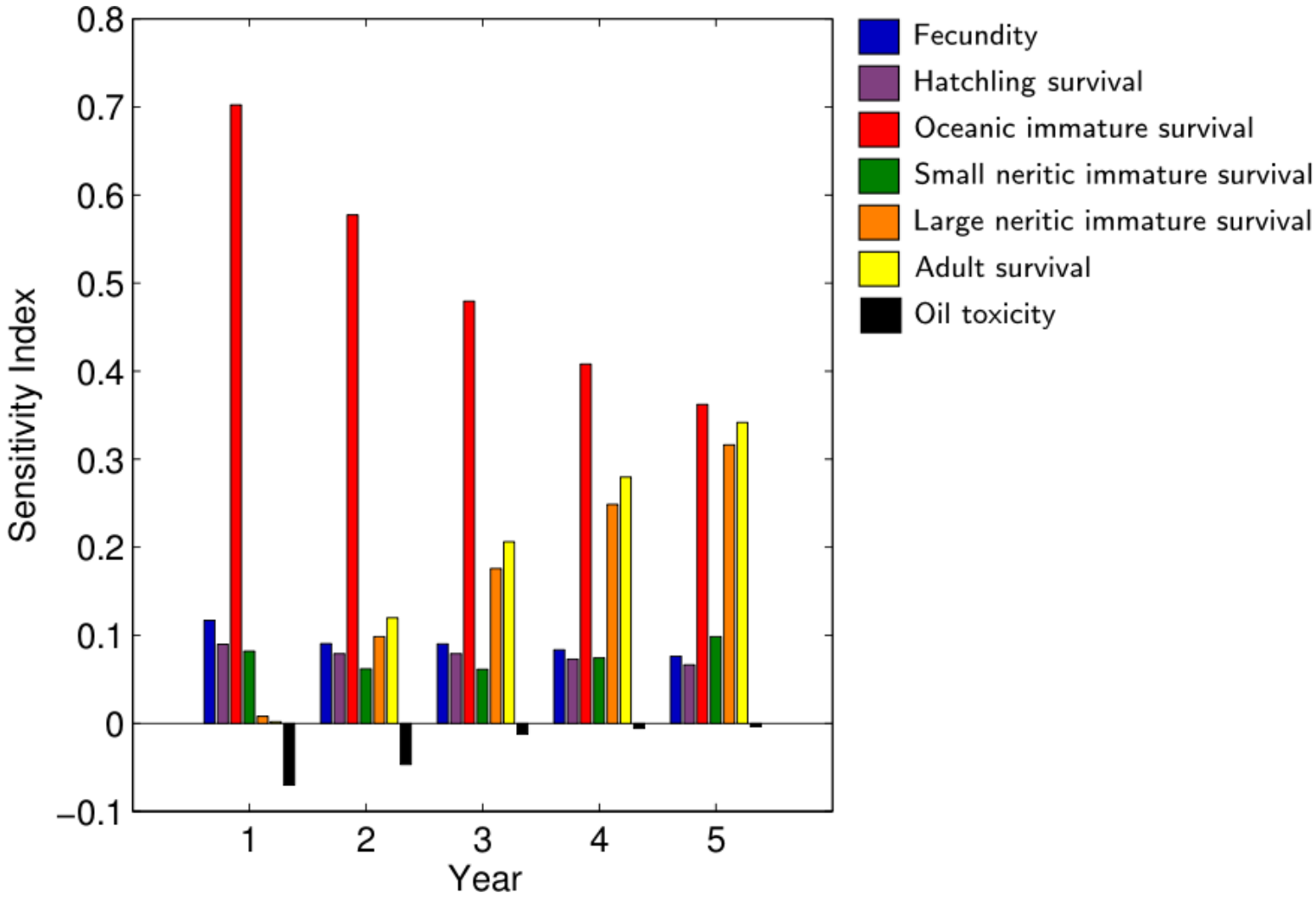
$$\mathbf{GR}(n) = \frac{\|\mathbf{P}(n)\|_1}{\|\mathbf{P}(n-1)\|_1}.$$

- Transient sensitivity index is

$$\mathbf{TSI}_\rho(n) = \frac{\rho}{\mathbf{GR}(n)} \frac{\partial \mathbf{GR}(n)}{\partial \rho}.$$

Transient Sensitivity Indices

Gulf spill with proportional susceptibility and $\theta = 50\%$:



Transient Sensitivity Indices

First year:

- Fecundity
  - Protect nesting beaches
  - Relocate nests
- Oil toxicity
  - Controlled burning
  - Dispersants?

Second year and later:

- Oil toxicity, second year only
- Large neritic immature and adult survival
  - Remove turtles from burn zones
  - Enforce TED use

Future Research

In biology:

- Effect of oil on sex ratio and life cycle parameters
- Data on adult foraging migrations

In oil spill model:

- Model flow of oil
- Simulate cleanup and conservation methods

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