Protected species toolbox

Quantitative tools to assess the impact of anthropogenic activity on sea turtle populations

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Goals

Develop a suite of defensible, transparent, quantitative tools to evaluate the impact of human-caused mortality on sea turtle populations

Three-phase plan

- Population model with removals
  - Removal from different life stages
  - Removal as individual turtles or adult equivalents
- Investigate population monitoring metrics
- Apply and evaluate impact assessment tools

First phase

Establish spatial loggerhead population model

Impact of removals from different life stages

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Model structure and general overview

- Spatial matrix model
  - Annual survival and fecundity
  - 4 life stages
  - 3 regions (neritic north, neritic south, oceanic)
- Removals from the population in terms of individuals or adult equivalents, and affecting different life stages or regions

Simulated population trajectory minus removal

- Population projection

$$\mathbf{n}(t+1) = A\mathbf{n}(t)$$

- Removals

$$\mathbf{n}(t) = \mathbf{n}(t) - \mathbf{r}$$

Removals

- Standard: based on stage distribution (but adjusted so not heavy on stage 1)
- Weighted
  - 50% to neritic north, 50% to neritic south
  - 50% to oceanic
  - 50% to stage 1, 2, 3, or 4
- Individuals or adult equivalents (determined from model-based reproductive values)

Reproductive values

- Size-based proportions representing the contributions that individuals make to current and future reproduction

- Used to calculate adult equivalents

- Scaled so equals 1 for the breeding class and near 0 for youngest turtles, so one breeding adult = 1 adult equivalent
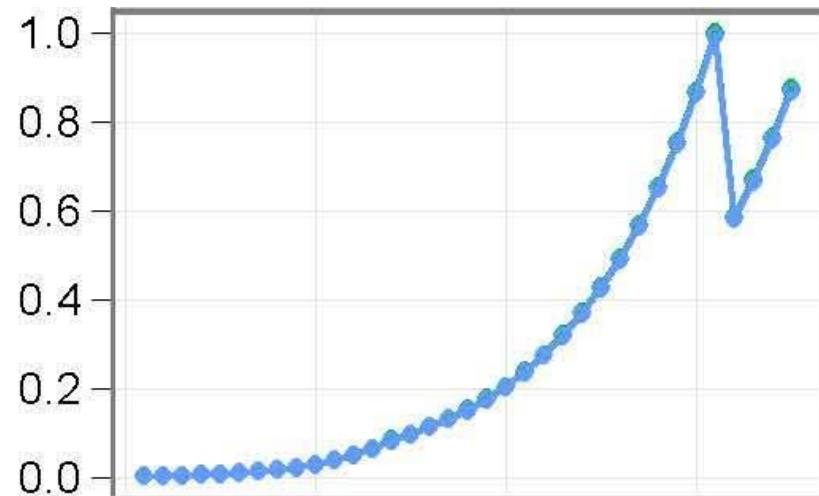
Results

Removal in terms of adult equivalents is robust to affected life stage
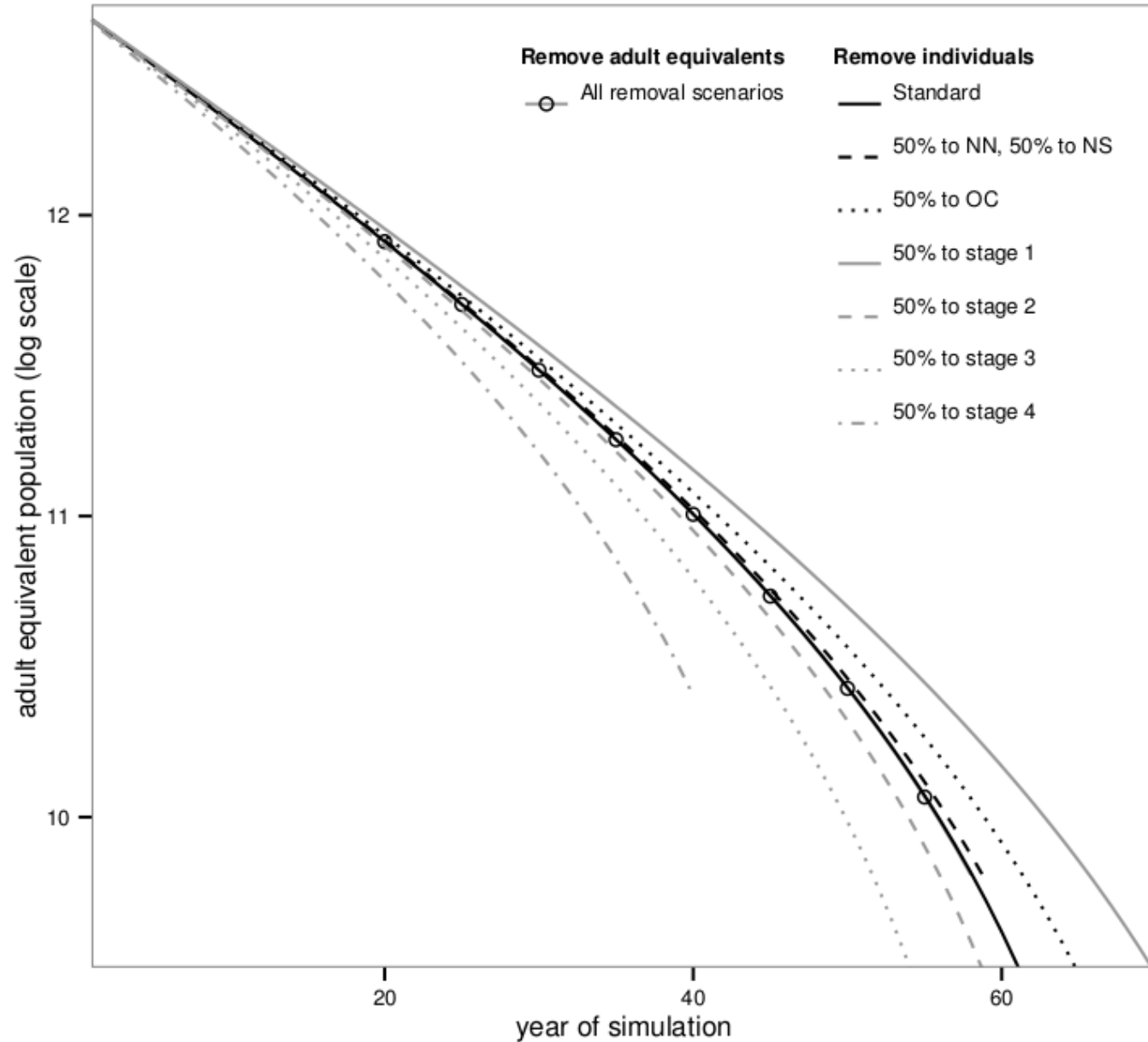
Second phase

Explore monitoring metrics

Allow variation in parameter estimates

Between simulations (parameter uncertainty)
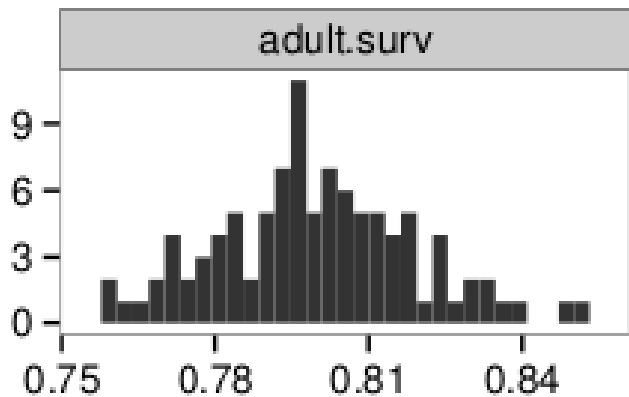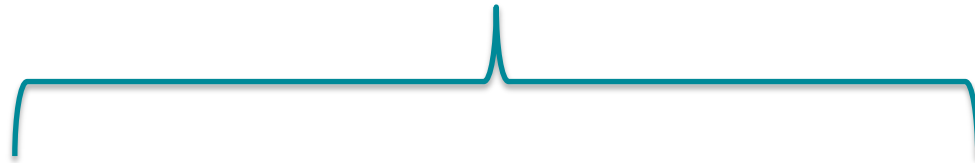
Within simulations (annual variability)
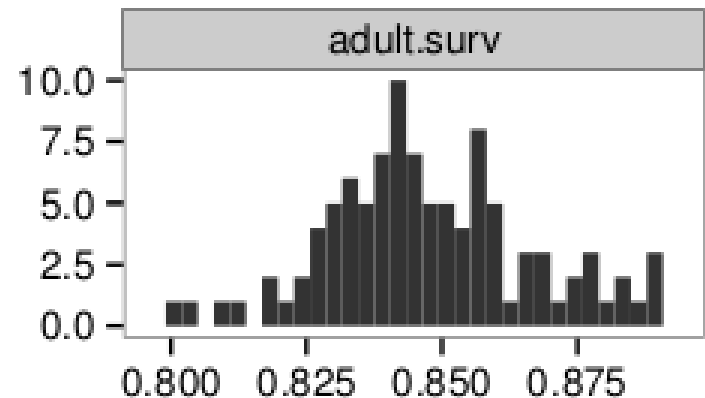
Population perturbations
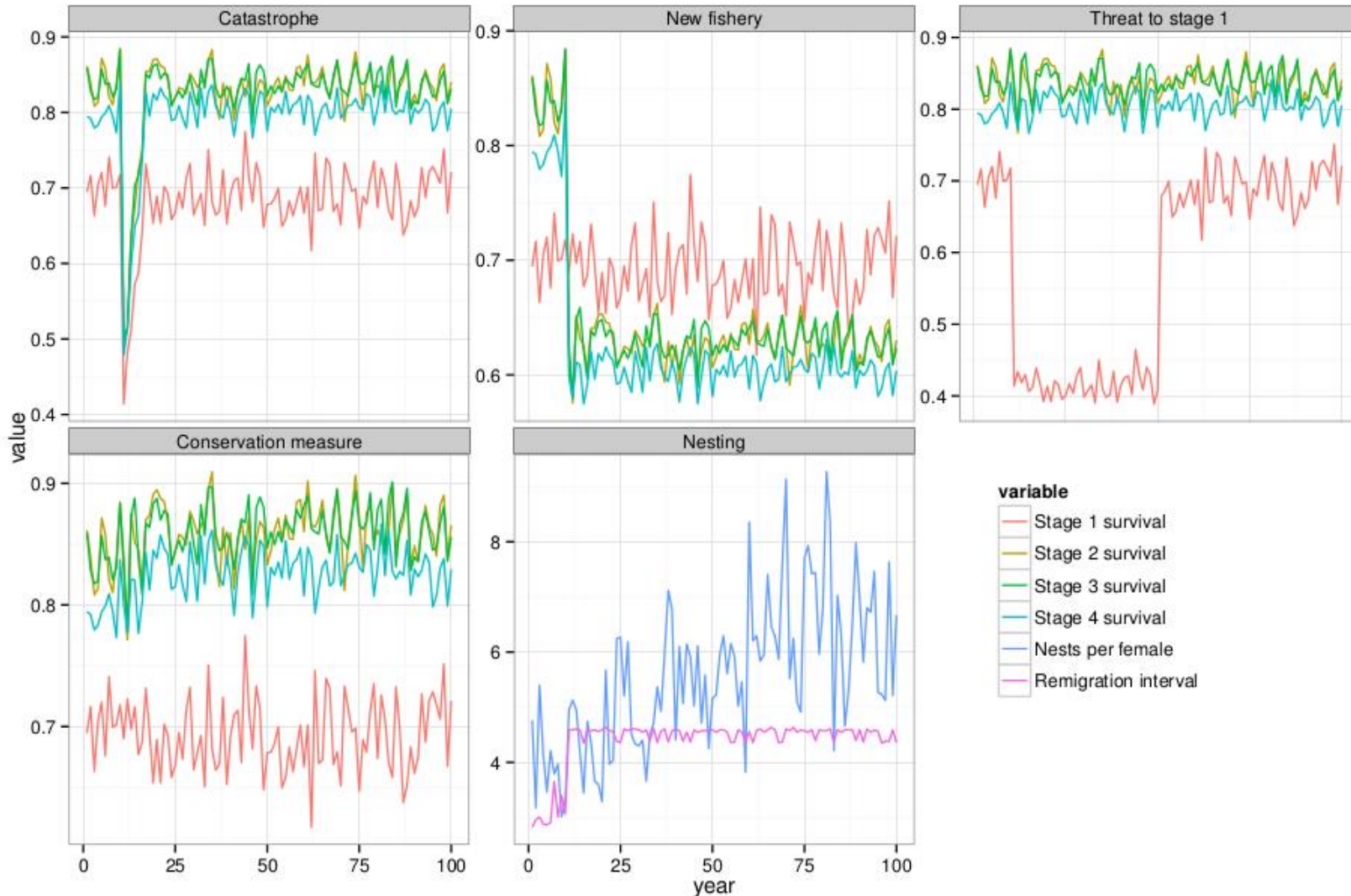
Monitoring index: nest counts
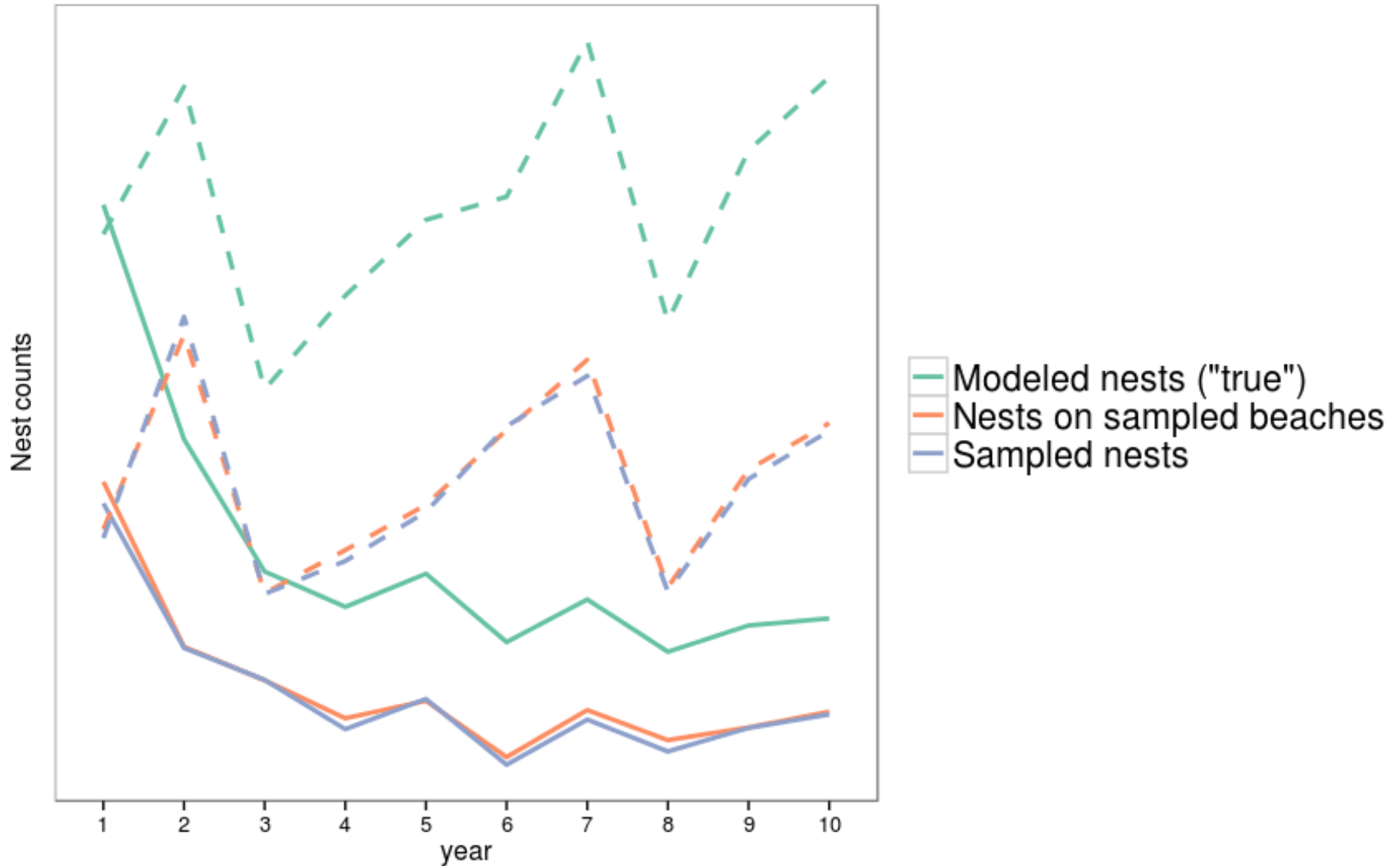
Monitoring index: aerial survey abundance estimates
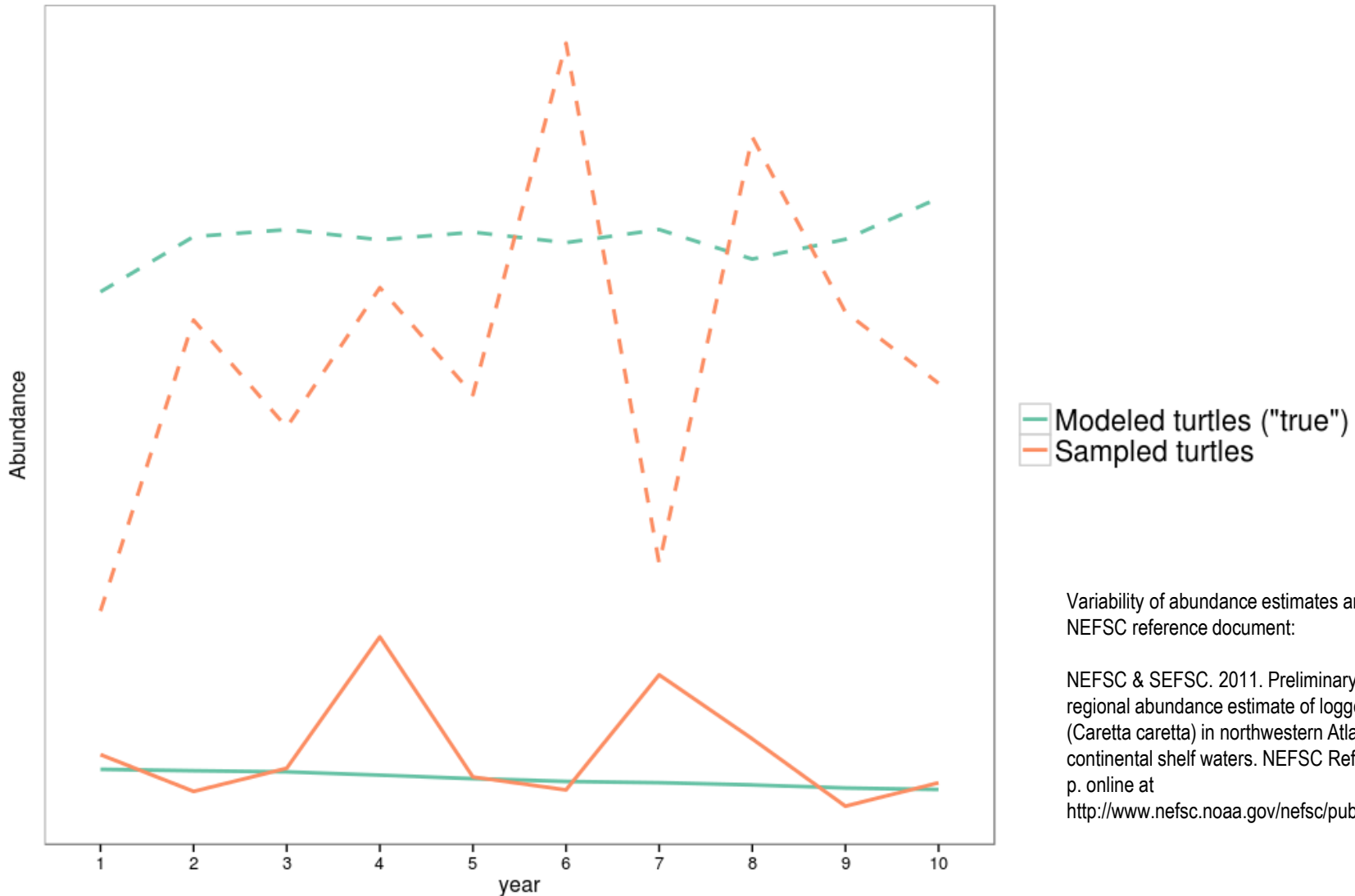
Variability of abundance estimates are based on a NEFSC reference document:

NEFSC & SEFSC. 2011. Preliminary summer 2010 regional abundance estimate of loggerhead turtles (Caretta caretta) in northwestern Atlantic Ocean continental shelf waters. NEFSC Ref Doc. 11-03; 33 p. online at http://www.nefsc.noaa.gov/nefsc/publications/

Results: Compare with adult equivalents
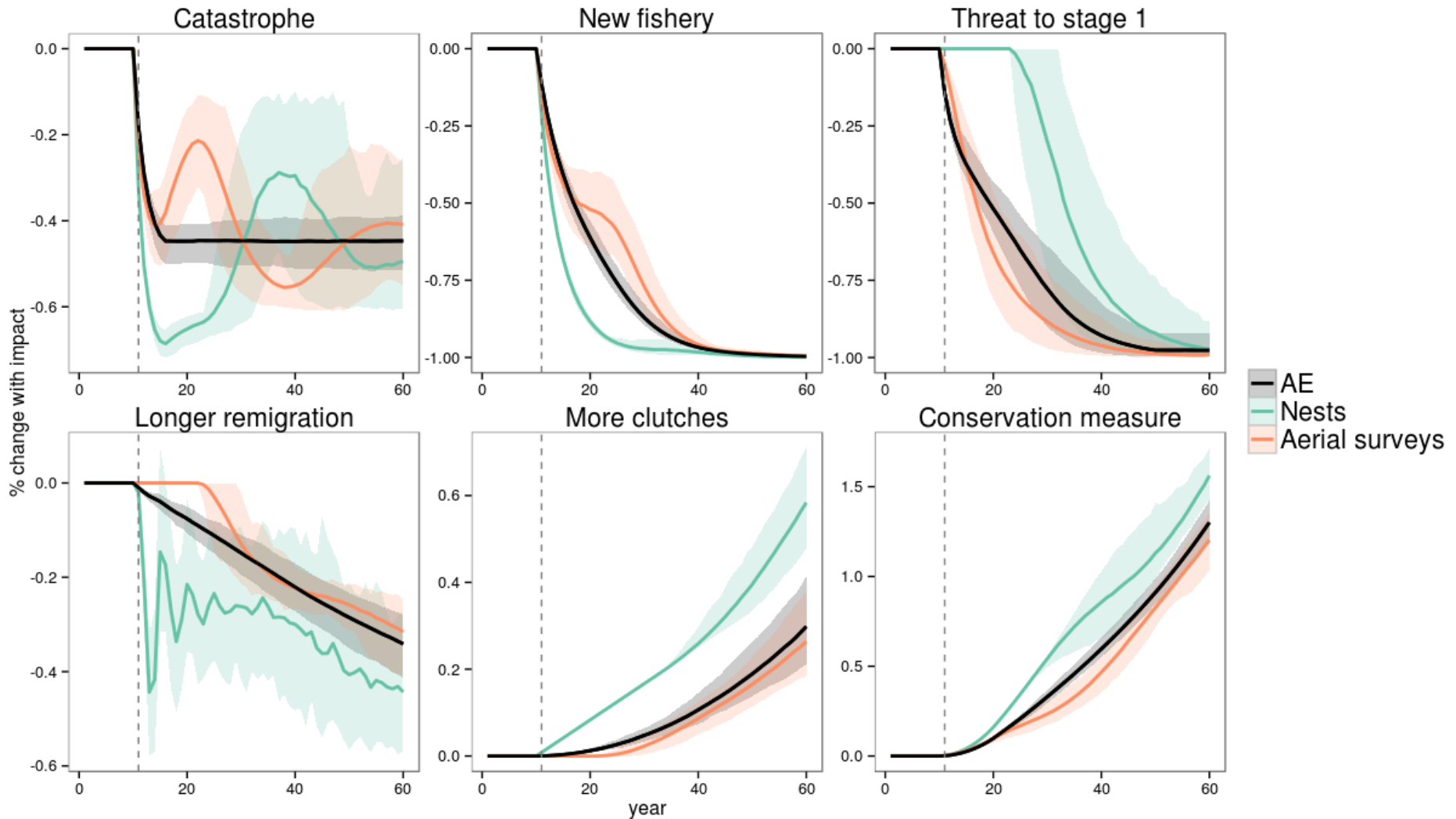
Third phase

Apply and evaluate new and existing tools

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Sea Turtle Assessment

Terceiro 2012

Lonergan 2011
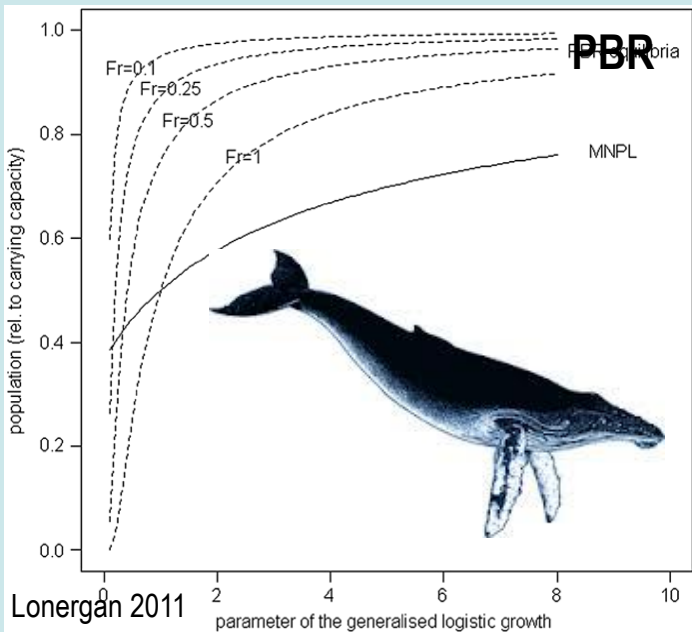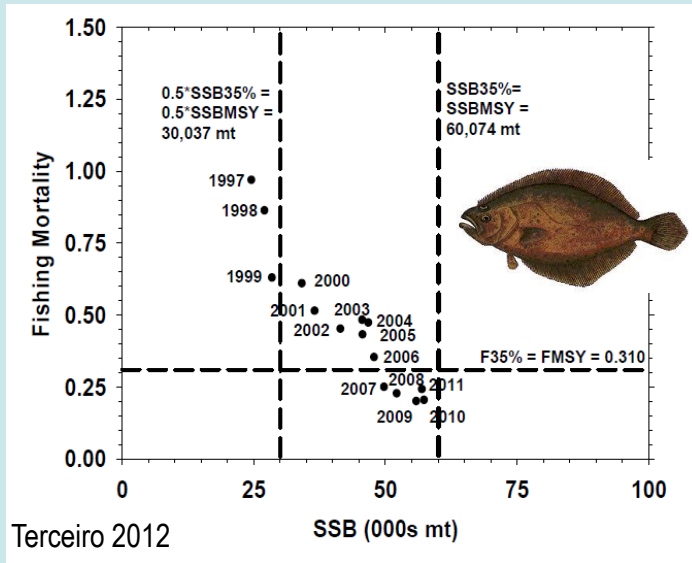
No standard reference points

Management strategy evaluation

Ecological and Management Scenarios

Quantitative Methods

1-RVLL?

2

3

4
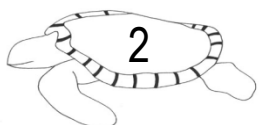
Questions?

3 regions

- Represent foraging areas
- Neritic north, neritic south, oceanic
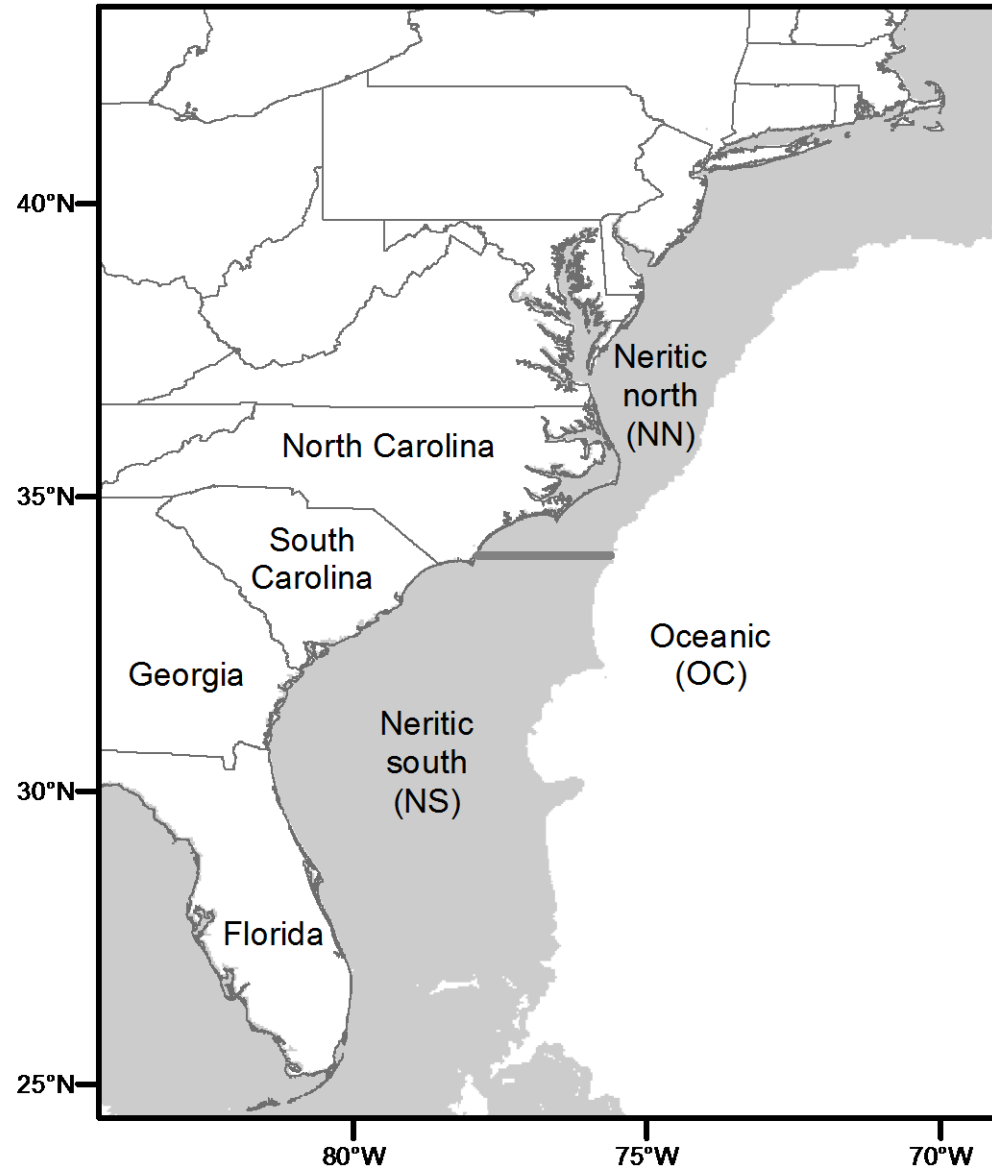
Survival and remigration rates

Stage	Stage description	Oceanic (O) or neritic (N)	Approximate CCL (cm)	Duration (d) (years)	Estimated survival rate (S^*)	Harvest-corrected survival rate (S) Neritic (NN & NS)	Oceanic (OC)
I	Hatchling and oceanic juvenile	O	Hatchling – 60.45	13 (10, 18)	0.744 (0.588, 0.878)	0.745	0.744
II	Small juvenile	N, O	60.46-75.72	10 (9, 12)	0.830 (0.740, 0.890)	0.836	0.830
III	Large juvenile	N, O	75.73-101.5	7 (4, 12)	0.835 (0.740, 0.925)	0.841	0.836
IV	Adult	N, O	101.5	indefinite	0.841 (0.770, 0.925)	0.847	0.841

Remigration interval (yr)	Observed	Mortality-corrected
1	0.019	0.014
2	0.466	0.412
3	0.348	0.362
4	0.130	0.159
5+	0.037	0.053

Fecundity

Elements of calculating fecundity for nesting female

nests per nesting female per year	eggs per nest	egg survival (i.e., proportion of eggs hatched)	proportion of female offspring	year 1 survival
5 (2, 8)	109 (89, 125)	0.53 (0.11, 0.82)	0.5 (0.35, 0.80)	0.744

$$F = 5 \times 109 \times 0.53 \times 0.5 \times 0.744 = 107.5 \approx 108$$

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Standard removals

Region		Stage	w (stable age distribution; by stages)	w_r (w rescaled)	p (proportion ITS removed)	r (turtles removed)	r_{AE} (adult equivalents removed)
ner	NN	1	0.0006	0.0045	0.0044	18.70	4.74
		2	0.0031	0.0686	0.0674	285.06	72.17
		3	0.0006	0.0132	0.0130	54.98	13.92
		4	0.0002	0.0034	0.0034	14.21	3.60
	NS	1	0.0183	0.1455	0.1430	604.77	153.12
		2	0.0249	0.5549	0.5455	2,306.38	583.93
		3	0.0048	0.1070	0.1052	444.85	112.63
		4	0.0046	0.1029	0.1011	427.54	108.24
	OC	1	0.9263	0.3000	0.0051	21.45	5.43
		2	0.0138	0.5780	0.0098	41.33	10.46
		3	0.0027	0.1115	0.0019	7.97	2.02
		4	0.0003	0.0105	0.0002	0.75	0.19

Model structure: patch-specific

$$
\begin{pmatrix}
0.745 & & & & & & & & 108 & & & \\
 & \ddots & & & & & & & & & & \\
 & & 0.745 & & & & & & & & & \\
 & & & 0.836 & & & & & & & & \\
 & & & & \ddots & & & & & & & \\
 & & & & & 0.836 & & & & & & \\
 & & & & & & 0.841 & & & & & \\
 & & & & & & & \ddots & & & & \\
 & & & & & & & & 0.841 & 0.847*0.014 & & & & & & 0.847 \\
 & & & & & & & & & 0.847*0.053 & & & \\
 & & & & & & & & & 0.847*0.159 & 0.847 & \\
 & & & & & & & & & 0.847*0.362 & & 0.847 \\
 & & & & & & & & & 0.847*0.412 & & & 0.847
\end{pmatrix}
$$

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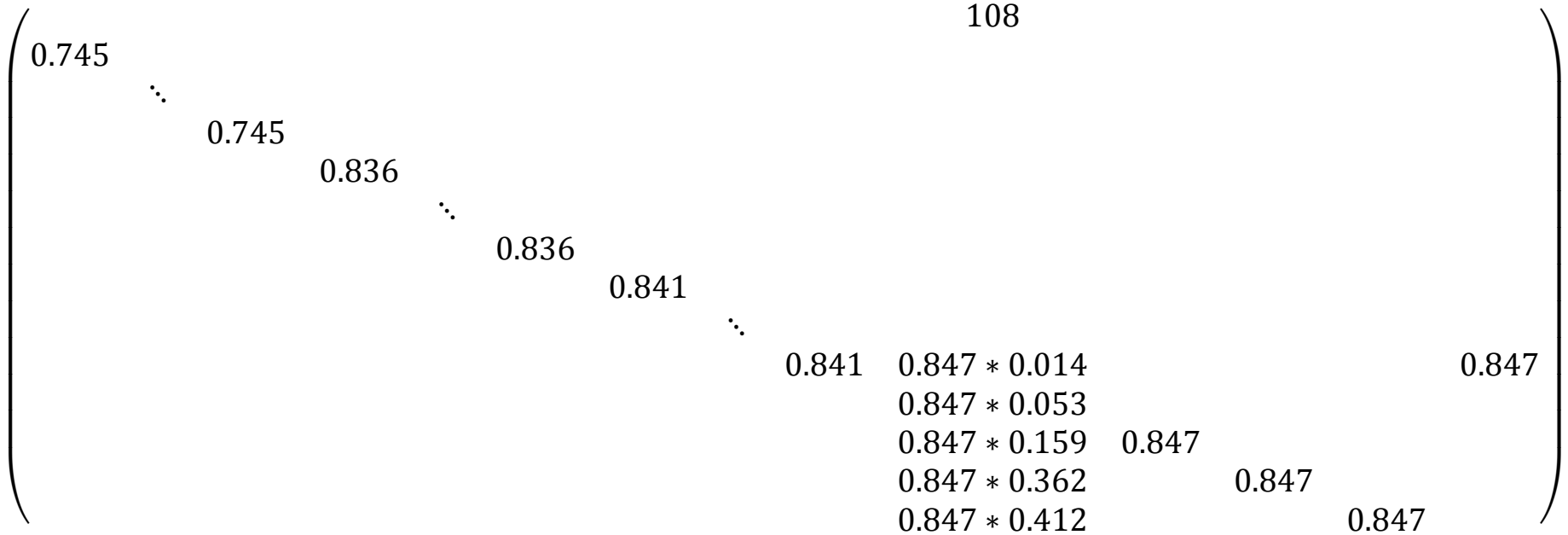
Model structure: metapopulation

105 x 105 matrix

$$\mathbf{B} = \begin{pmatrix} \mathbf{B}_{NN} & 0 & 0 \\ 0 & \mathbf{B}_{NS} & 0 \\ 0 & 0 & \mathbf{B}_{OC} \end{pmatrix}$$

Movement matrix

- Each $\mathbf{M}_i$ is a 3 x 3 matrix

$$\mathbf{M} = \begin{pmatrix} \mathbf{M}_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \ddots & 0 & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & 0 & \mathbf{M}_1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \vdots & 0 & \mathbf{M}_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \vdots & 0 & \ddots & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \vdots & 0 & \mathbf{M}_2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \vdots & 0 & \mathbf{M}_3 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \vdots & 0 & \ddots & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \vdots & 0 & \mathbf{M}_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & \vdots & 0 & \mathbf{M}_4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \vdots & 0 & \ddots & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \mathbf{M}_4 \end{pmatrix}$$

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Movement between patches

Stage		I			II			III			IV		
						Origination							
Patch		NN	NS	O	NN	NS	O	NN	NS	O	NN	NS	O
Destination	NN	0.001	0.001	0.001	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03
	NS	0.019	0.019	0.019	0.65	0.65	0.65	0.65	0.65	0.65	0.92	0.96	0.92
	O	0.98	0.98	0.98	0.33	0.33	0.33	0.33	0.33	0.33	0.05	0.01	0.05

Projection matrix

- Multiply **B** and **M** (plus some other magic) to get **A**

$$\mathbf{A} = \begin{pmatrix} \mathbf{B}_{NN,NN} & \mathbf{B}_{NN,NS} & \mathbf{B}_{NN,OC} \\ \mathbf{B}_{NS,NN} & \mathbf{B}_{NS,NS} & \mathbf{B}_{NS,OC} \\ \mathbf{B}_{OC,NN} & \mathbf{B}_{OC,NS} & \mathbf{B}_{OC,OC} \end{pmatrix}$$

- Population projection:

$$\mathbf{n}(t+1) = A\mathbf{n}(t)$$

Annual loggerhead ITS (lethal)

Biological opinion	ITS	date
NMFS' approval of the tilefish fishery management plan	3	Mar 2001
Implementation of the Deep-Sea Red Crab, *Chaceon quinquedens*, fishery management plan	1	Feb 2002
Endangered Species Act section 7 consultation on the fishery management plan for the dolphin and wahoo fishery of the Atlantic Ocean	0.67	Aug 2003
Sea turtle conservation measures for the pound net fishery in Virginia waters of the Chesapeake Bay	2	Apr 2004
Reinitiation of consultation on the Atlantic pelagic longline fishery for highly migratory species	143	Jun 2004
Amendment to the fishery management plans (FMP) of the U.S. Caribbean to address required provisions of the Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act	0	Aug 2005
The continued authorization of snapper-grouper fishing in the U.S. South Atlantic exclusive economic zone (EEZ) as managed under the snapper-grouper fishery management plan of the South Atlantic region, including Amendment 13C to the SGFMP	22.33	Jun 2006
The continued authorization of fishing under the fishery management plan (FMP) for coastal migratory pelagic resources in the Atlantic and Gulf of Mexico	11	Aug 2007
The continued authorization of fishing under the fishery management plan (FMP) for spiny lobster in the South Atlantic and Gulf of Mexico	1	Aug 2009
The continued authorization of fishing under the fishery management plan for the stone crab fishery of the Gulf of Mexico [F/SER/2005/07541]	1.33	Sep 2009
Endangered Species Act Section 7 reinitation consultation on the federal Atlantic herring fishery management plan (FMP) **(Internal NMFS memorandum to document that the fishery was not likely to adversely affect protected species, so no formal biological opinion completed.)	0	Feb 2010
The continued authorization of reef fish fishing under the Gulf of Mexico (Gulf) reef fish fishery management plan (RFFMP)	191	Sep 2011
Reinitiation of Endangered Species Act (ESA) Section 7 consultation of the continued implementation of the sea turtle conservations regulations, as proposed to be amended, and the continued authorization of the Southeast U.S. shrimp fisheries in federal waters under the Magnuson-Stevens Act	7,701	May 2012
Endangered Species Act Section 7 consultation on the Atlantic sea scallop fishery management plan	112	Jul 2012
Endangered Species Act Section 7 consultation on the continued implementation of management measures for the American lobster fishery	1	Aug 2012
Endangered Species Act Section 7 consultation on the NEFSC research vessel surveys as well as two cooperative gear research studies to be overseen by the NEFSC protected species branch (PSB)	1	Nov 2012
Continued authorization of the Atlantic shark fisheries via the consolidated HMS fishery management plan as amended by Amendments 3 and 4 and the federal authorization of a Smoothhound fishery	26	Dec 2012
Endangered Species Act Section 7 consultation on the continued implementation of management measures for the Northeast multispecies, monkfish, spiny dogfish, Atlantic bluefish, Northeast skate complex, mackerel/squid/butterfish, and summer flounder/scup/black sea bass fisheries	239	Dec 2013

Monitoring index: total adult females estimated from nest counts

- Average nesting frequency
  - Nest every 3 years
  - 4 nests per nesting year
- Total annual adult females = annual "sampled" nests / 4
- Total adult females = 3-year running sum of total annual adult females

This PDF was later amended to make the document 508 compliant.

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