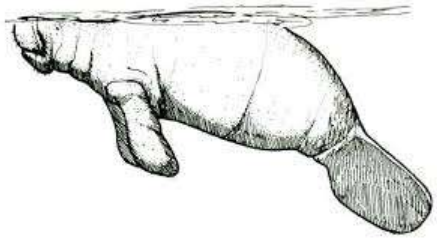




Estimating the contributions of anthropogenic and environmental factors to Florida manatee mortality

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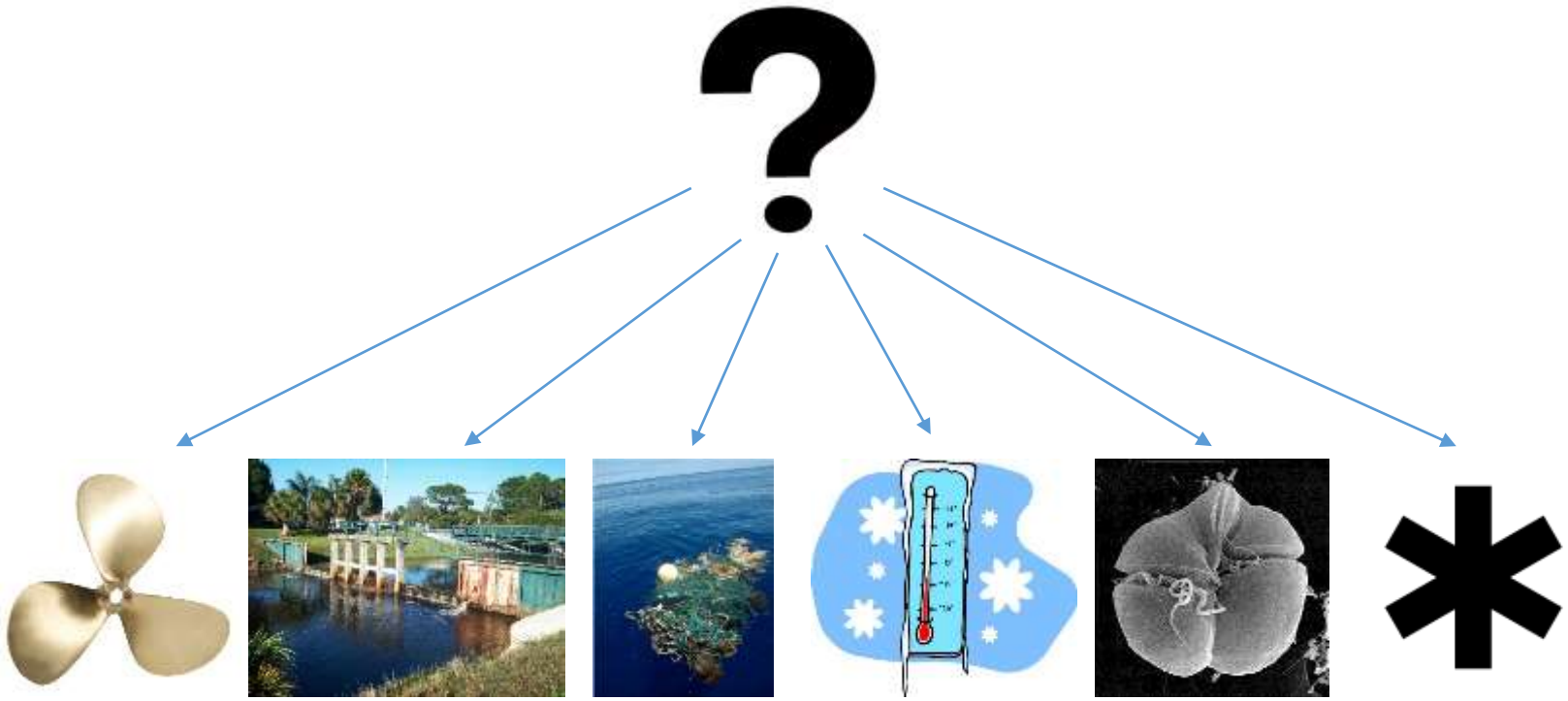
Cause of Mortality Analyses

- Fractions of mortality or cause-specific mortality (CSM) rates from carcass recovery and necropsy
  - Radio-telemetry
  - Public reporting / convenience sampling
  - Both
- Generally large number of carcasses where cause of death is undetermined
- Existing methods either ignore those or put in own category

Modeling Changes in Mortality

- Unusual mortality events (UMEs)
- Sometimes can estimate effects from other sources of information, such as capture-mark-recapture (CMR) studies
- May occur in years or situations where don't have reliable estimates of mortality
- Because CMR doesn't include cause of death, difficult to ascribe changes in mortality to UME



Method

Baseline Analysis

- Bayesian hierarchical model
- Accounts for uncertainty due to carcasses with undetermined cause of death
- Total carcasses due to a cause (in year) sum of determined and undetermined
- Model undetermined carcasses due to each cause as multinomial from total undetermined and fractions for undetermined

Baseline Analysis

- Model total carcasses due to each cause as multinomial from total carcasses and fractions for total
- Uninformed Dirichlet priors for total and undetermined baseline fractions
- Implemented in Python with PyMC

Baseline Analysis

- Tricky thing is incorporating undetermined cause

$$\left\{ y_{r,t,i}^{(a)} \right\} \sim \text{Multinomial}\left(y_{r,t,tot}^{(a)}, \left\{ \eta_{r,t,i}^{(a)} \right\} \right)$$

$$x_{r,t,i}^{(a)} = y_{r,t,i}^{(a)} + z_{r,t,i}^{(a)}$$

$$\left\{ x_{r,t,i}^{(a)} \right\} \sim \text{Multinomial}\left(x_{r,t,tot}^{(a)}, \left\{ \theta_{r,t,i}^{(a)} \right\} \right)$$

where *r* is region, *i* is cause,

t is year, (*a*) is age,

y is undetermined carcasses,

and *z* is determined carcasses

Sample Row of Data

Year	Age	Area	Habitat	Boats	WCS	Debris	Cold	Tide	Other	Undet.	Total
2009	Adult	SW	Low	12	1	1	0	2	1	13	30

One possibility:

Undetermined

Year	Age	Area	Habitat	Boats	WCS	Debris	Cold	Tide	Other
2009	Adult	SW	Low	3	2	2	2	2	2

Total

Year	Age	Area	Habitat	Boats	WCS	Debris	Cold	Tide	Other	Total
2009	Adult	SW	Low	15	3	3	2	4	3	30

Modeling Additional Mortality

$$\theta_{t,i} = \begin{cases} \pi_i & \text{where } t \notin U \\ (\pi_i + f)/(1+f) & \text{where } t \in U \text{ and } i = c \\ \pi_i/(1+f) & \text{where } t \in U \text{ and } i \neq c \end{cases}$$

$$f = \frac{d_{add}}{d_{base}}$$

$$d_{add} \sim \text{Uniform}(0, 1 - d_{base})$$

$\theta_{t,i}$ is fraction in year t from cause i, π_i is baseline fraction, f is additional fraction factor, d_{add} is additional mortality rate, and d_{base} is total baseline mortality

- Can change just total fraction or both total and undetermined fractions
  - Does number of undetermined carcasses due to that cause go up during UME?
- Total baseline mortality is estimated separately

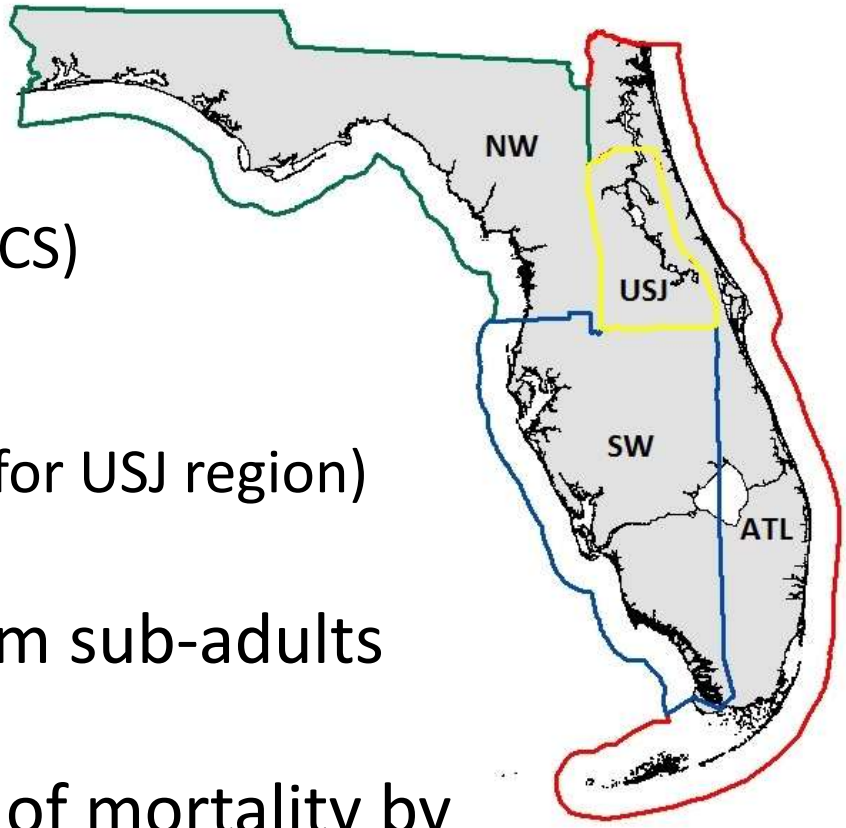
Application

Carcass Recovery and Necropsy

- Florida Fish and Wildlife Conservation Commission (FWC) has had 24/7 wildlife alert hotline last 30 years for public reporting of wildlife issues
- Staff members respond to reports of injured and dead Florida manatees
- Necropsies performed by trained staff
- Data used
  - December 1995 – November 2013
  - Exclude perinatal and carcasses with undetermined length

Baseline Analysis

- Causes of death
  - Watercraft
  - Water control structures (WCS)
  - Marine debris
  - Cold
  - Red tide (fraction fixed at 0 for USJ region)
  - Other
- Analyze calves separate from sub-adults and adults
- Estimate baseline fractions of mortality by region



Additional Red Tide Mortality

- Estimate additional mortality from red tide in moderate and intense red tide years (SW region only)
  - Moderate years: 2002, 2003, 2005, 2006, and 2012
  - Intense years: 1996 and 2013
- Additional mortality factor only affects total fraction
- Baseline mortality estimates from photo-ID CMR analysis (separate)

Additional Cold Mortality

- Estimate additional mortality fractions from cold in normal, cold, and severe years, by habitat quality, region, and age class
- Using that and estimates of baseline mortality, estimate additional mortality rates (by habitat quality and age class only)
- Habitat-specific and modify fractions of undetermined in same way as total
- Need to be able to estimate additional mortality due to cold by age class, habitat, and winter severity

Additional Cold Mortality Table

ADULT	**Winter Severity**		
WW Habitat Quality	*Normal*	*Cold*	*Severe*
High-quality	0	0	?
Medium-quality	0	0	?
Low-quality	0	?	?

SUBADULT	**Winter Severity**		
WW Habitat Quality	*Normal*	*Cold*	*Severe*
High-quality	0	0	?
Medium-quality	0	?	?
Low-quality	?	?	?

CALF	**Winter Severity**		
WW Habitat Quality	*Normal*	*Cold*	*Severe*
High-quality	0	0	?
Medium-quality	?	?	?
Low-quality	?	?	?

Discussion and Assumptions

Research and Management Implications

- Put threats into context for manatee managers and stakeholders
- Key part of manatee population viability analysis
  - Evaluate threats by taking away one at time, see how affects viability
  - Test scenarios of proportional changes in threats
  - Test scenarios of changing frequencies or strengths of unusual mortality events

Some Key Model Assumptions

- Cause-specific mortality rates are additive – when one mortality rate increases, the others are unchanged
- The cause of death does not affect the probability of being recovered
- Fractions of mortality (both undetermined and overall) did not vary between years, except as modeled
- Combining our method with telemetry-based CSM would permit relaxing some assumptions

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