

Estimating uncertainty in whale location following visual or acoustic detection: Implications for dynamic management of North Atlantic right whales

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The USA and Canada employ dynamic management strategies to improve conservation outcomes for the endangered North Atlantic right whale. The tactics rely on near real-time knowledge of whale distribution generated from visual surveys and opportunistic sighting reports. Although near real-time passive acoustic monitoring systems have been operational for many years they have, for the most part, not been incorporated in dynamic management due to concerns over uncertainty in the location of acoustically-detected whales. This rationale does not consider whale movement or its contribution to location uncertainty following either visual or acoustic detection. The goals of this study were to estimate uncertainty in right whale location following acoustic and visual detection and identify the timescale at which uncertainties in the location of acoustic and visual detections become equal owing to post-detection whale movement. We simulated whale movement using an auto-correlated random walk model parameterized to approximate three common right whale behavioural states (traveling, foraging, and socializing). We then used a Monte Carlo approach to estimate whale location over a 96-hour period given the initial and evolving uncertainties arising from the acoustic and visual detection methods and whale movement. The results demonstrated that for either detection method the uncertainty in whale location increases rapidly following initial detection and can vary by an order of magnitude after 96 hours depending on behavioural state. The uncertainty in whale location became equivalent between visual and acoustic detections within 24 to 48 hours, depending on right whale behavior and acoustic detection-range parameterization. The results imply that using both visual and acoustic detections provide enhanced information for the dynamic management of this visually- and acoustically-cryptic and highly mobile species.

Uncertainty in right whale location following visual or acoustic detection

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Right Whale Management

		USA	Canada
Vessel	<i>Dynamic</i>	Voluntary <10 kt Dynamic Management Areas (DMAs)	Mandatory <10 kt zones in GSL shipping lanes
	<i>Static</i>	Mandatory <10 kt Seasonal Management Areas (SMAs)	Mandatory <10 kt in central GSL; Areas To Be Avoided (ATBAs) in critical habitats
Fishing	<i>Dynamic</i>	N/A	Fixed gear closures in GSL and critical habitats (48 h to pull gear)
	<i>Static</i>	Seasonal area closures, gear modifications, etc.	Static fixed-gear closures in southern GSL

More details in this session...



Sources of dynamic data

Visual

- Planes, vessels, etc.
- Benefits
 - Broad spatial coverage
 - Multiple data products
- Limitations
 - Availability bias
 - Expensive
 - Weather, day/night
 - Low endurance
 - Risk to personnel



Sources of dynamic data



Visual

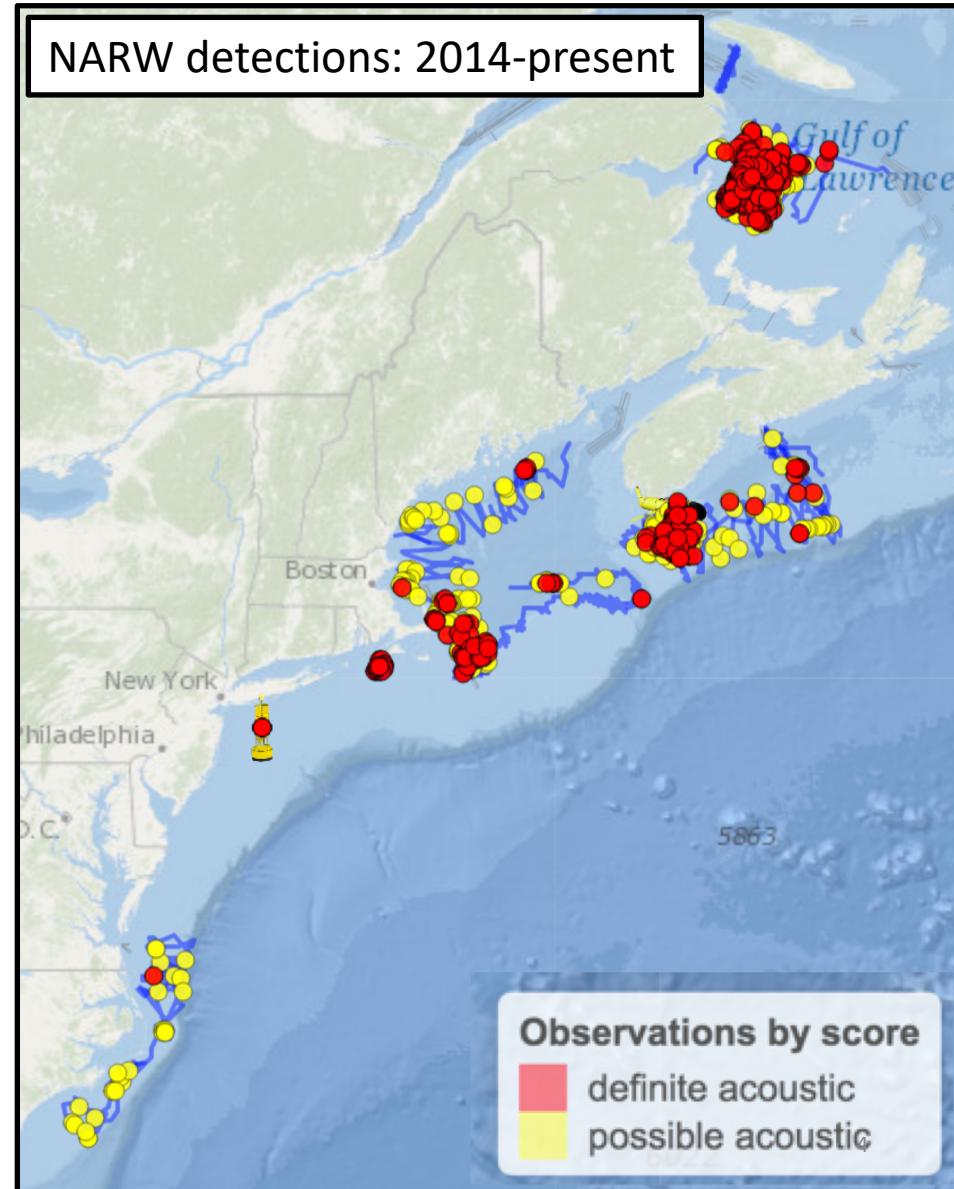
- Planes, vessels, etc.
- Benefits
 - Broad spatial coverage
 - Multiple data products
- Limitations
 - Availability bias
 - Expensive
 - Weather, day/night
 - Low endurance
 - Risk to personnel

Acoustic

- Ocean gliders, moorings, etc.
- Benefits
 - Inexpensive
 - Accurate
 - Persistent (months to years)
 - No risk to personnel
 - Provides ocean data (gliders)
- Limitations
 - Availability bias
 - Presence only
 - Location uncertainty

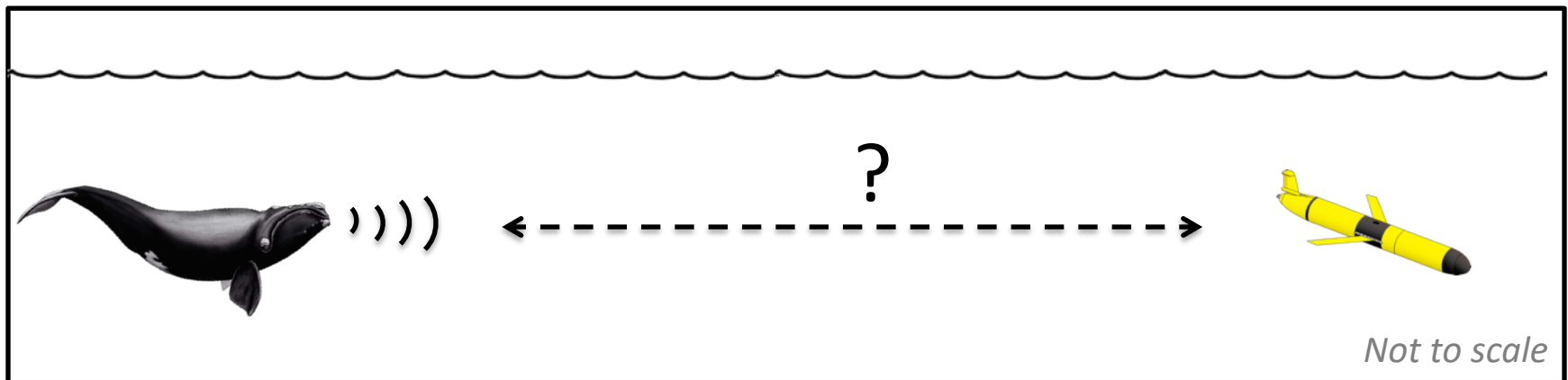
Acoustics for dynamic management

- WHOI near real-time PAM system
 - ~5000 days at sea and ~1500 right whale detections
 - Well-characterized and accurate (Baumgartner et al., 2019)
 - See Mark Baumgartner's talk (tomorrow 14:15)
- Additional systems coming online



Acoustics for dynamic management

- Detections are (mostly) **not used** by managers
 - Uncertainty in exact position of calling whale
- Does not consider whale movement, which can be substantial
 - BOF/GOM: ~80 km/day (Baumgartner and Mate 2005)
 - GSL: ~5 km/day to max ~40 km/day (see Leah Crowe's talk tomorrow at 1015)

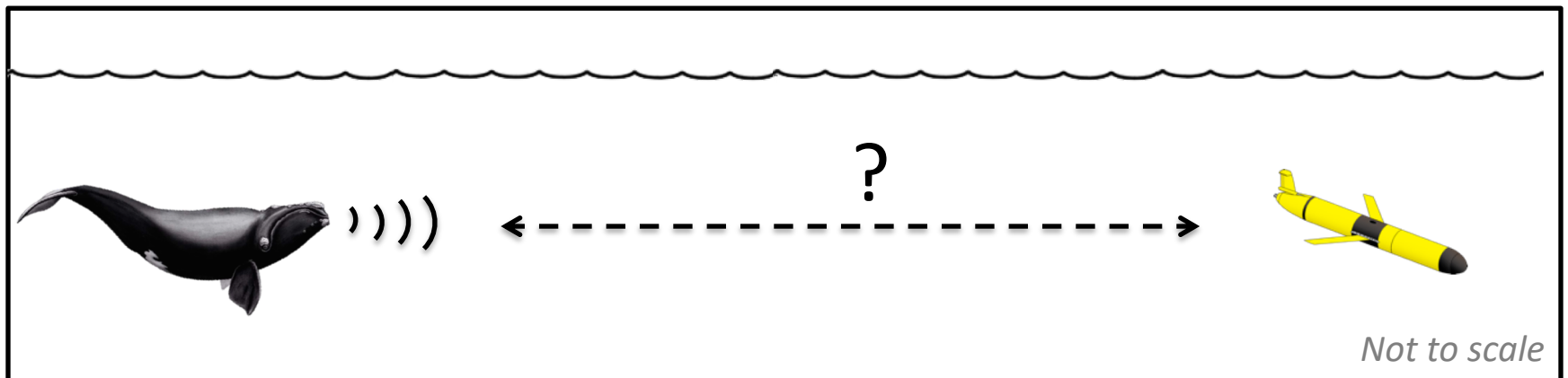


Acoustics for dynamic management

How much does detection range matter when you consider whale movement?

Approach

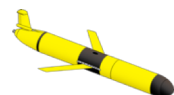
1. Simulate whale movements after visual and acoustic detection
2. Calculate and compare location uncertainties over time



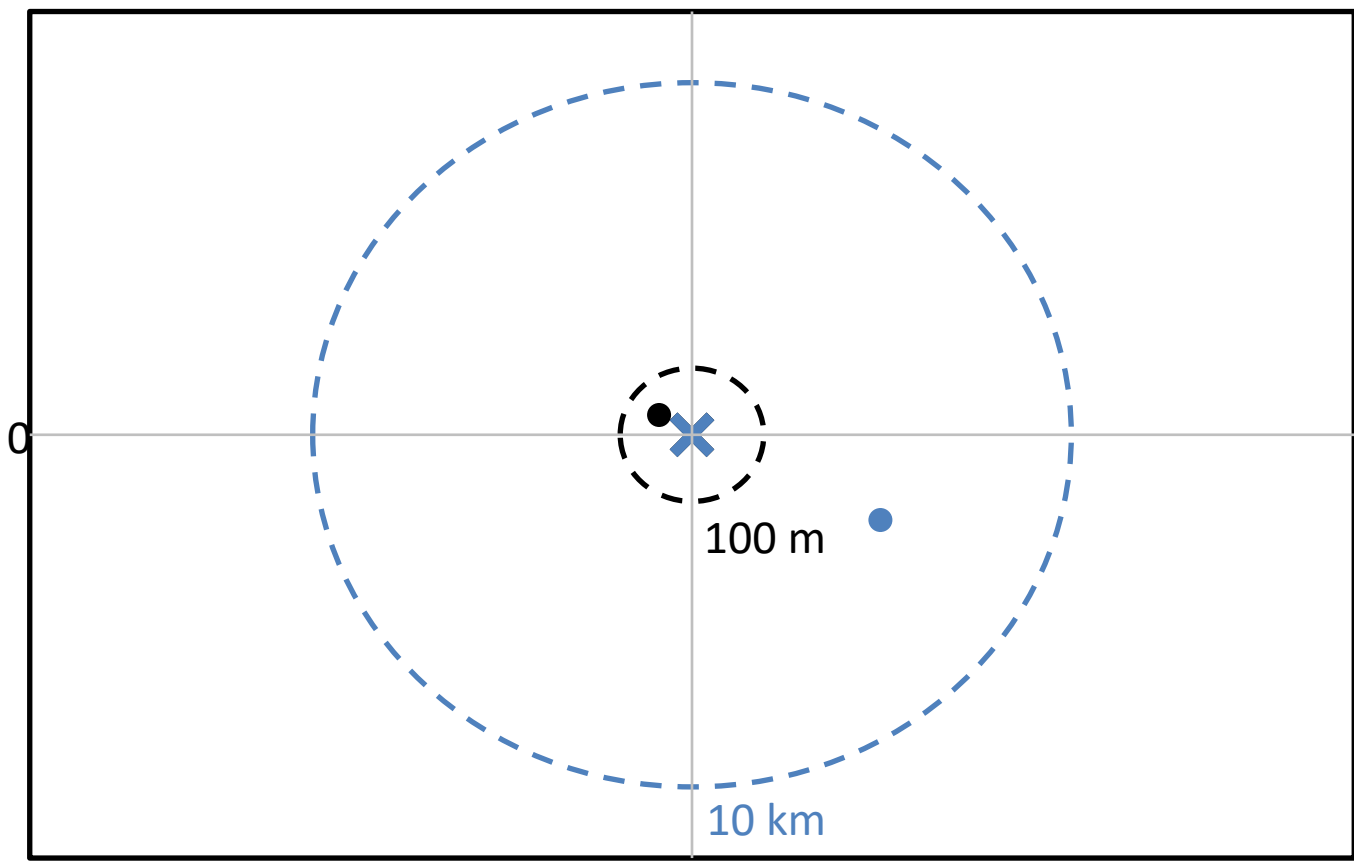
1. Place whale in model domain according to visual or acoustic uncertainty



Visual



Acoustic



Whale Location

✕ Reported

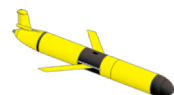
● Actual

Not to scale

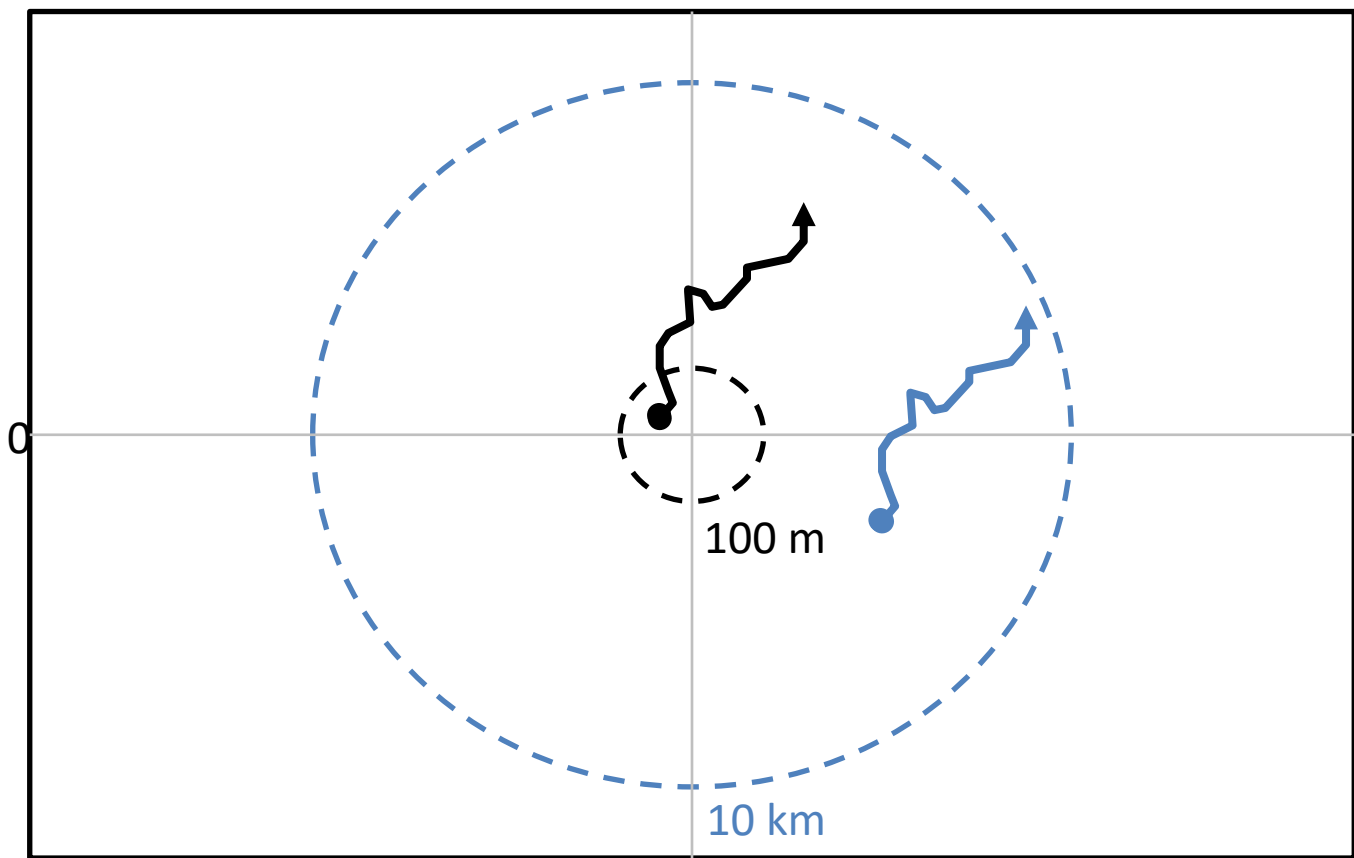
2. Simulate whale movement over a 96-hr period



Visual



Acoustic



Not to scale

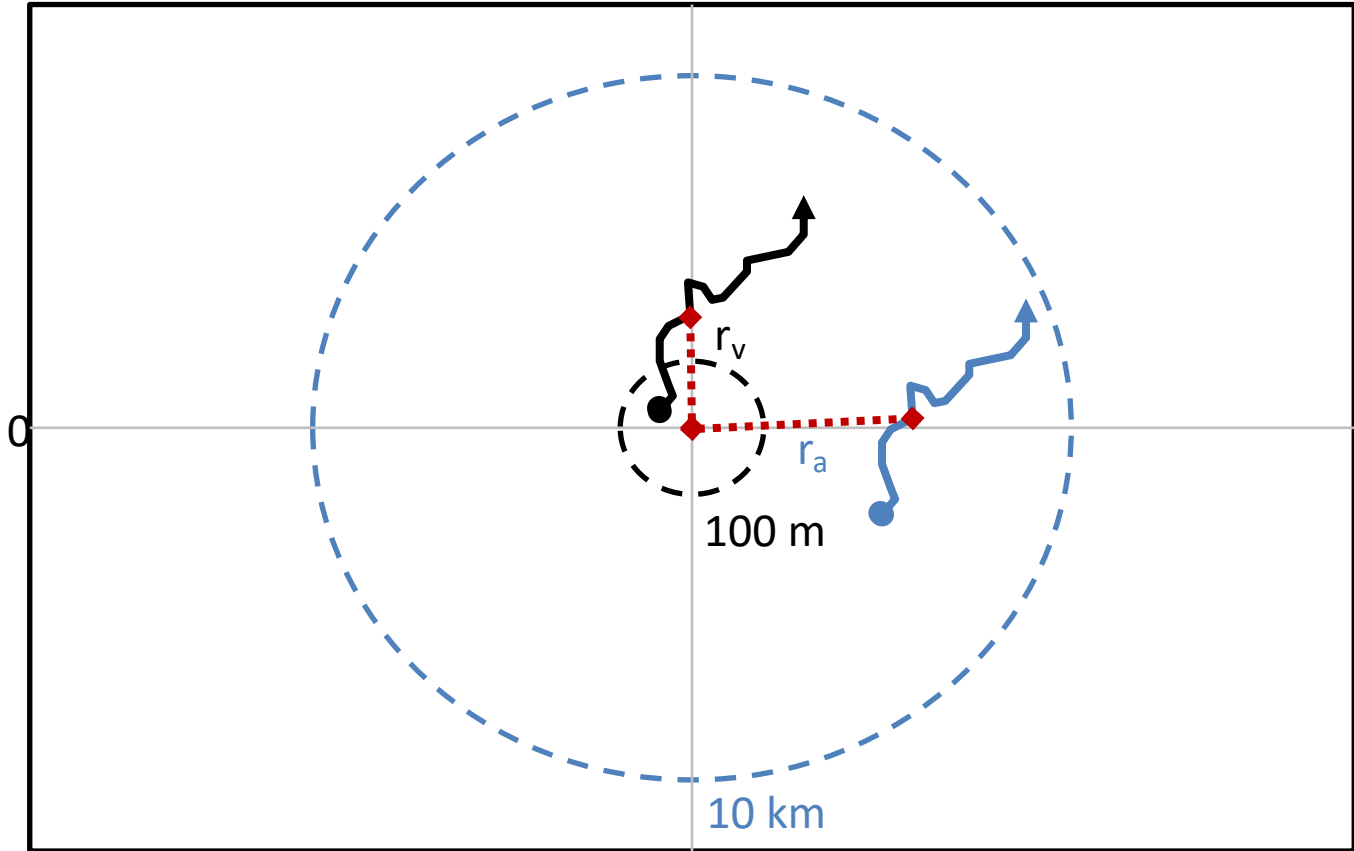
3. Calculate and compare ranges from initial (reported) position



Visual



Acoustic



Not to scale

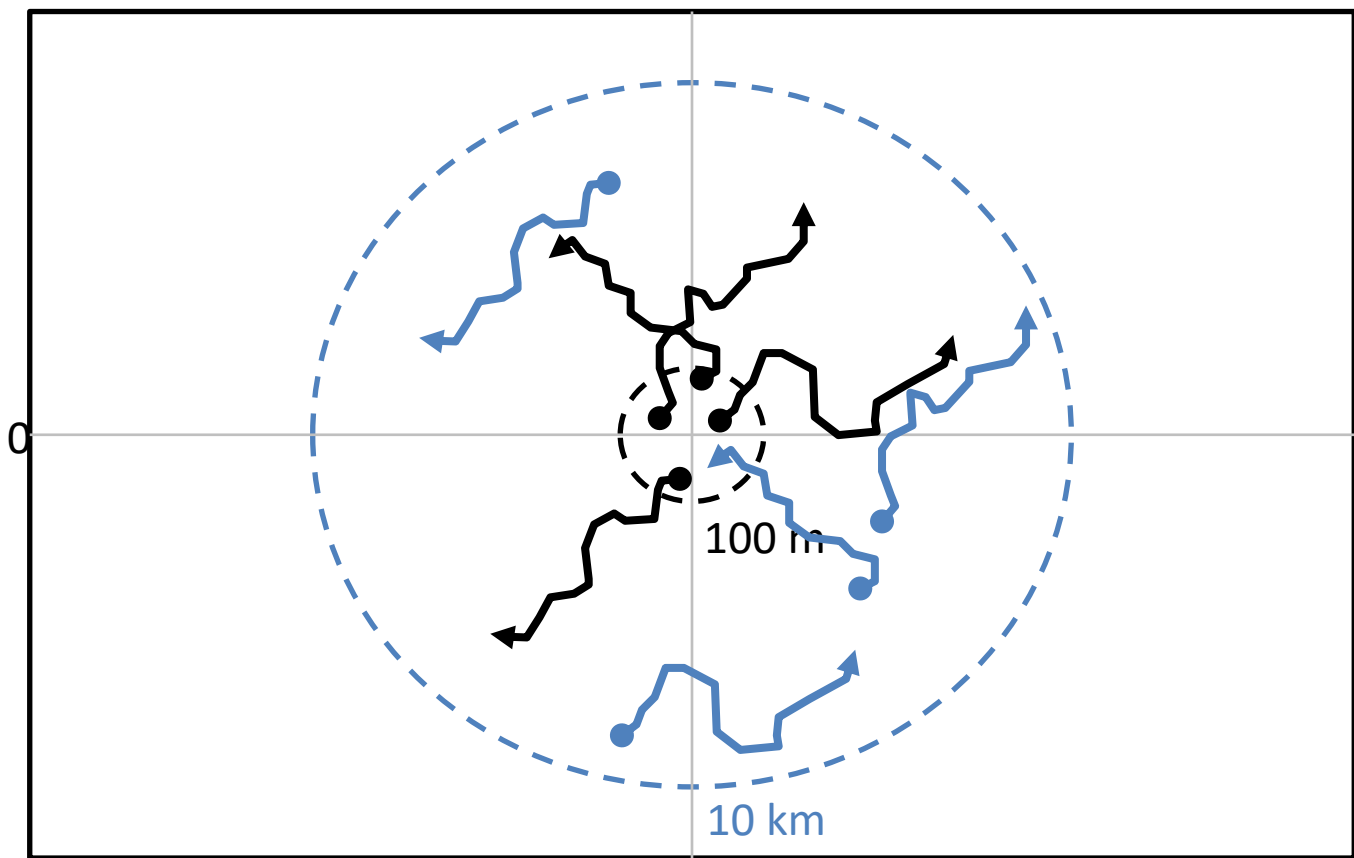
4. Repeat 100k times to approximate all possible whale positions / trajectories



Visual



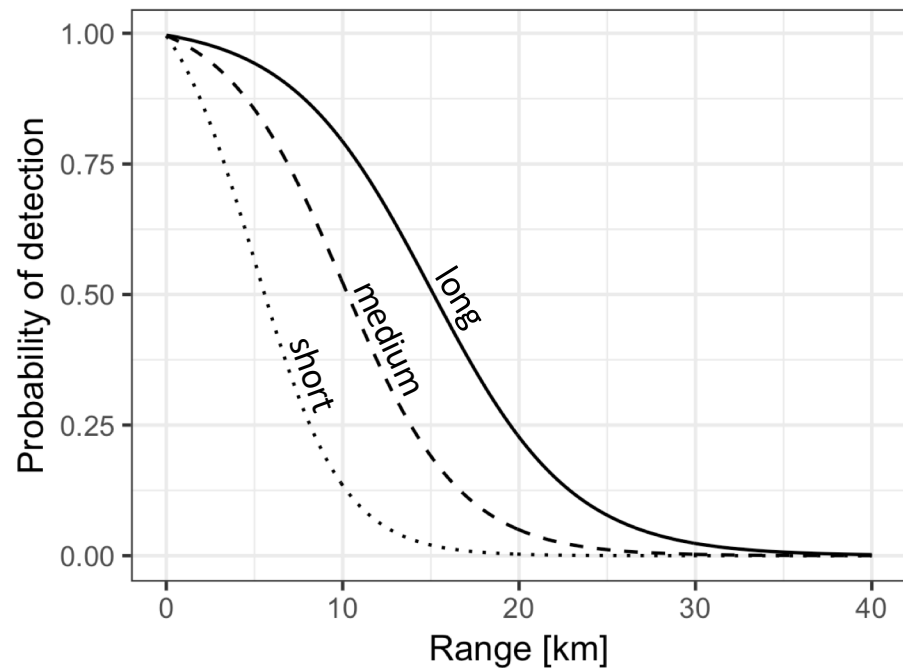
Acoustic



Not to scale

Model parameterization

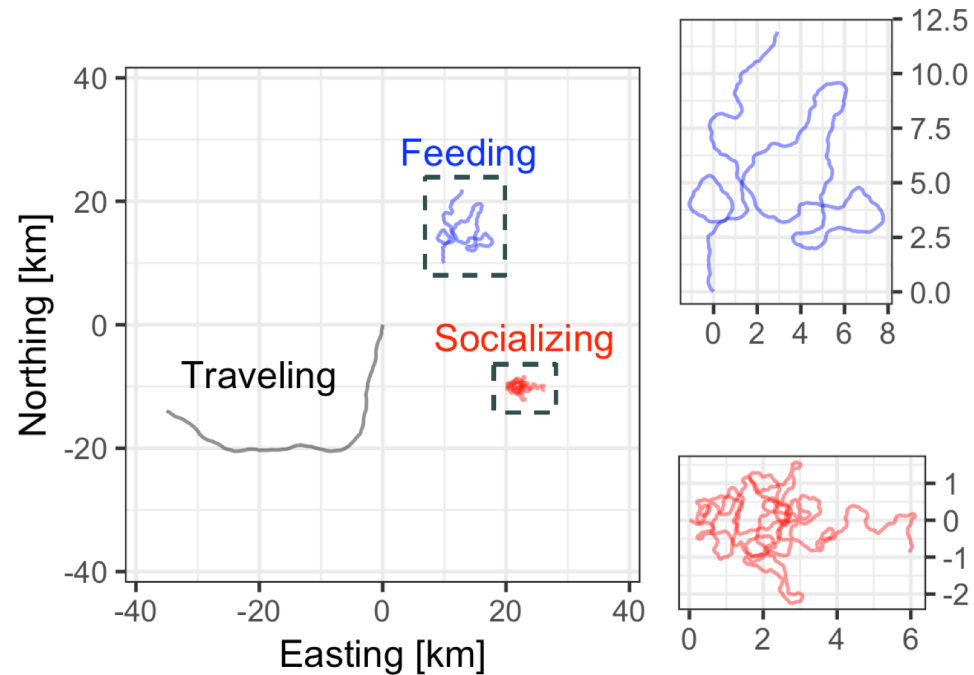
Acoustic detection ranges



Short, medium, and long

Johnson et al *in prep*; Laurinolli et al 2002

Movement behaviors

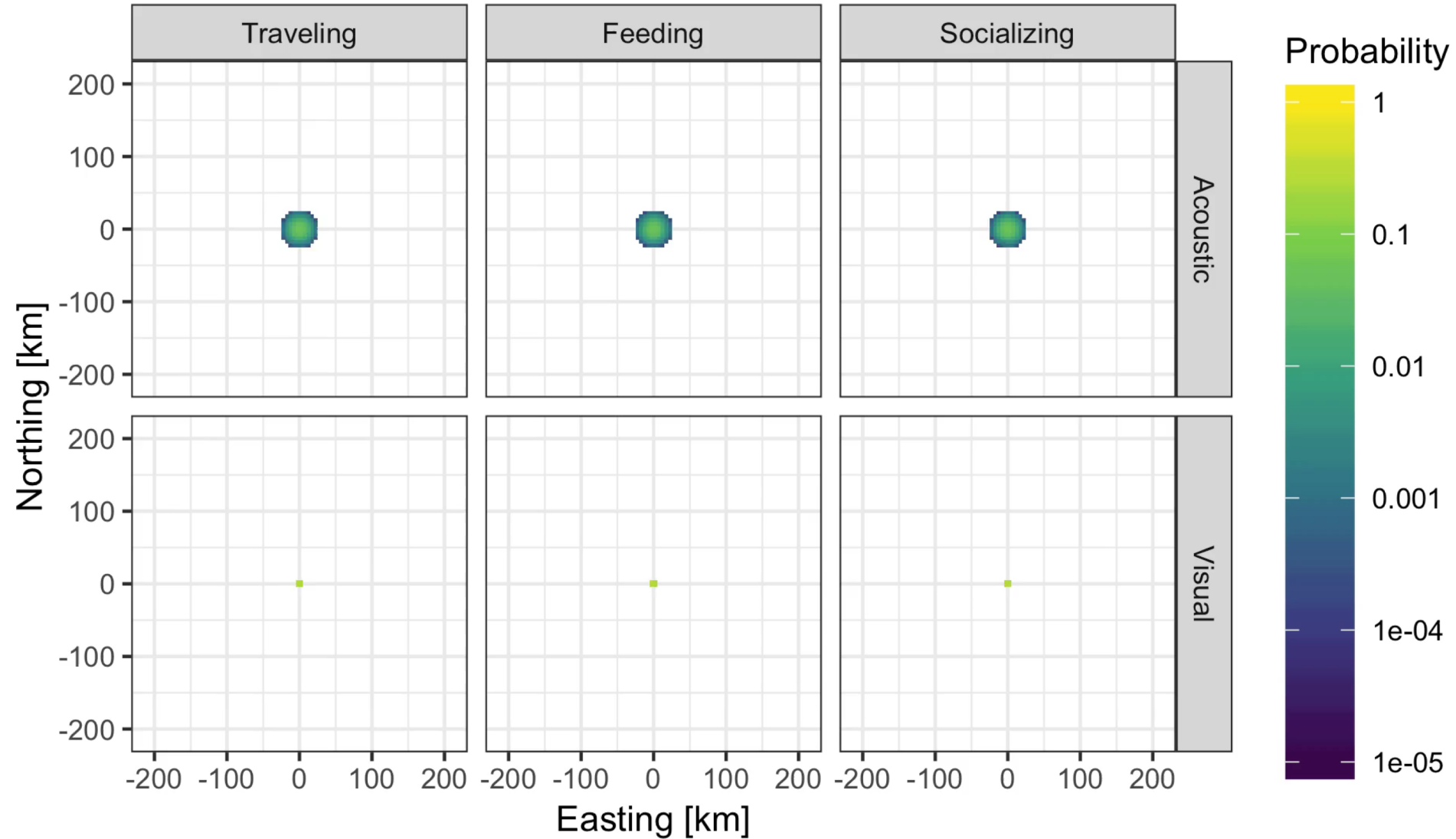


Traveling, feeding, and socializing

Van der Hoop et al 2012; Mayo & Marx 1989

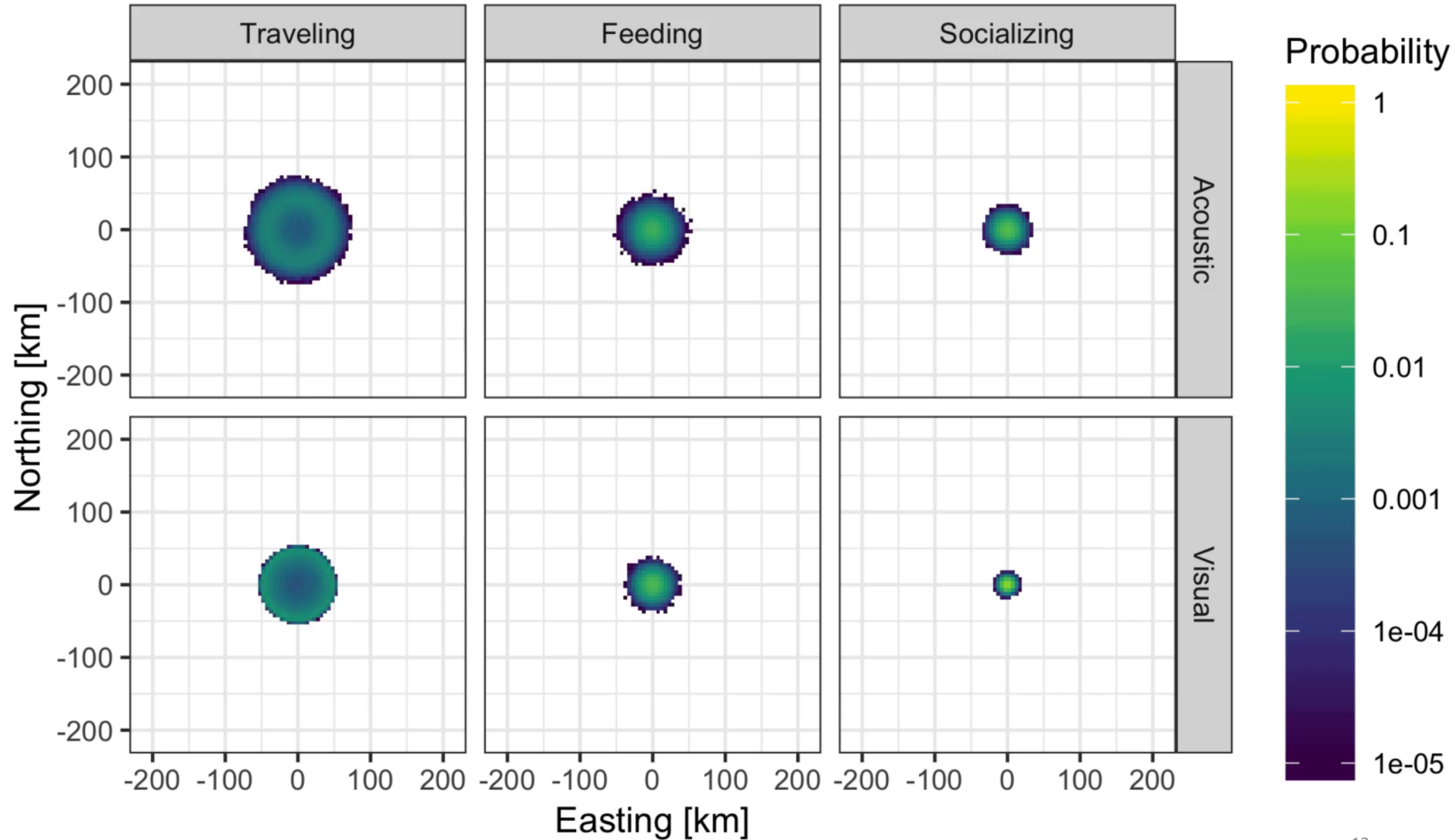
Example run: medium detection range

Elapsed time = 0 hrs



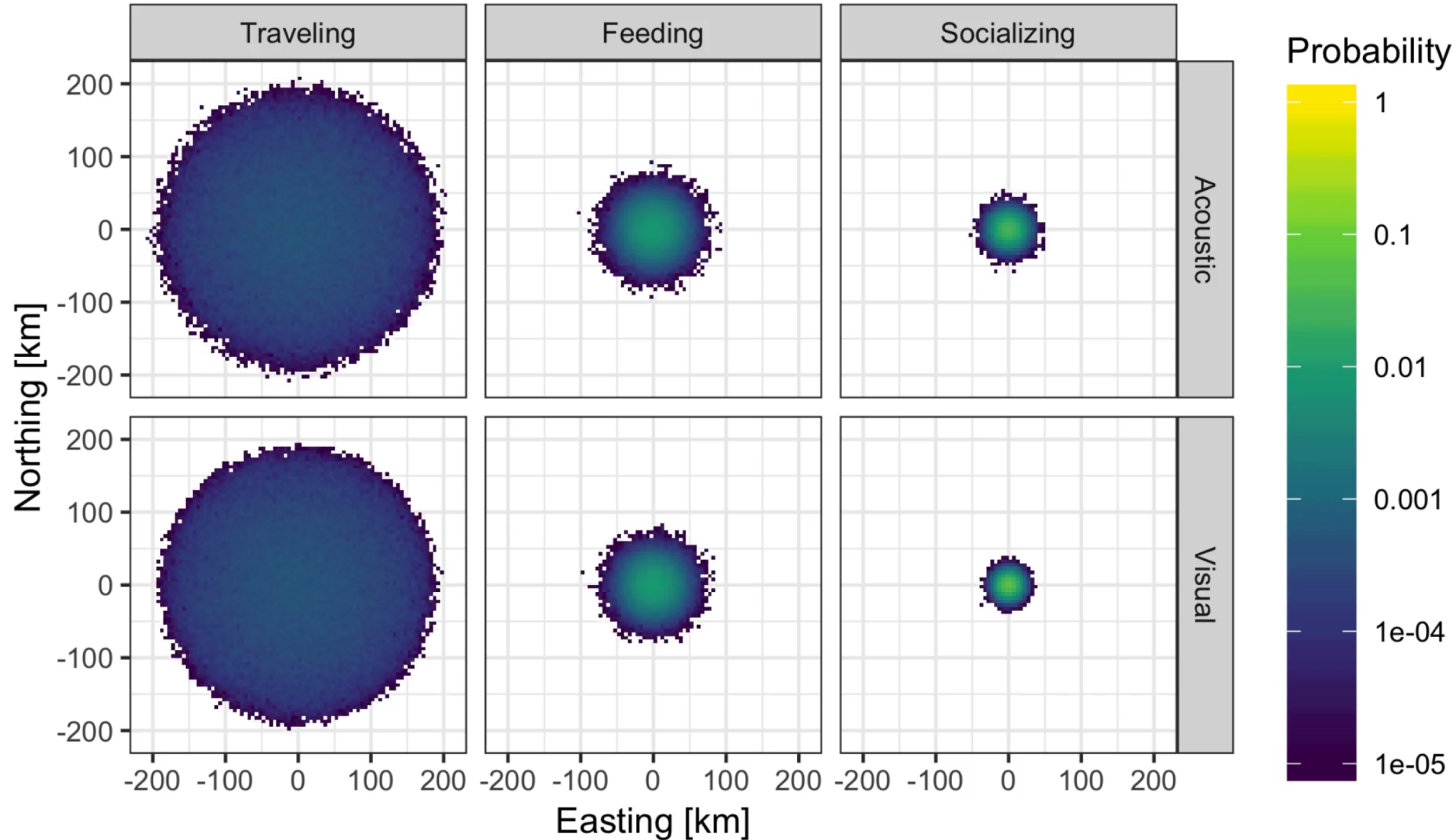
Example run: medium detection range

Elapsed time = 24 hrs



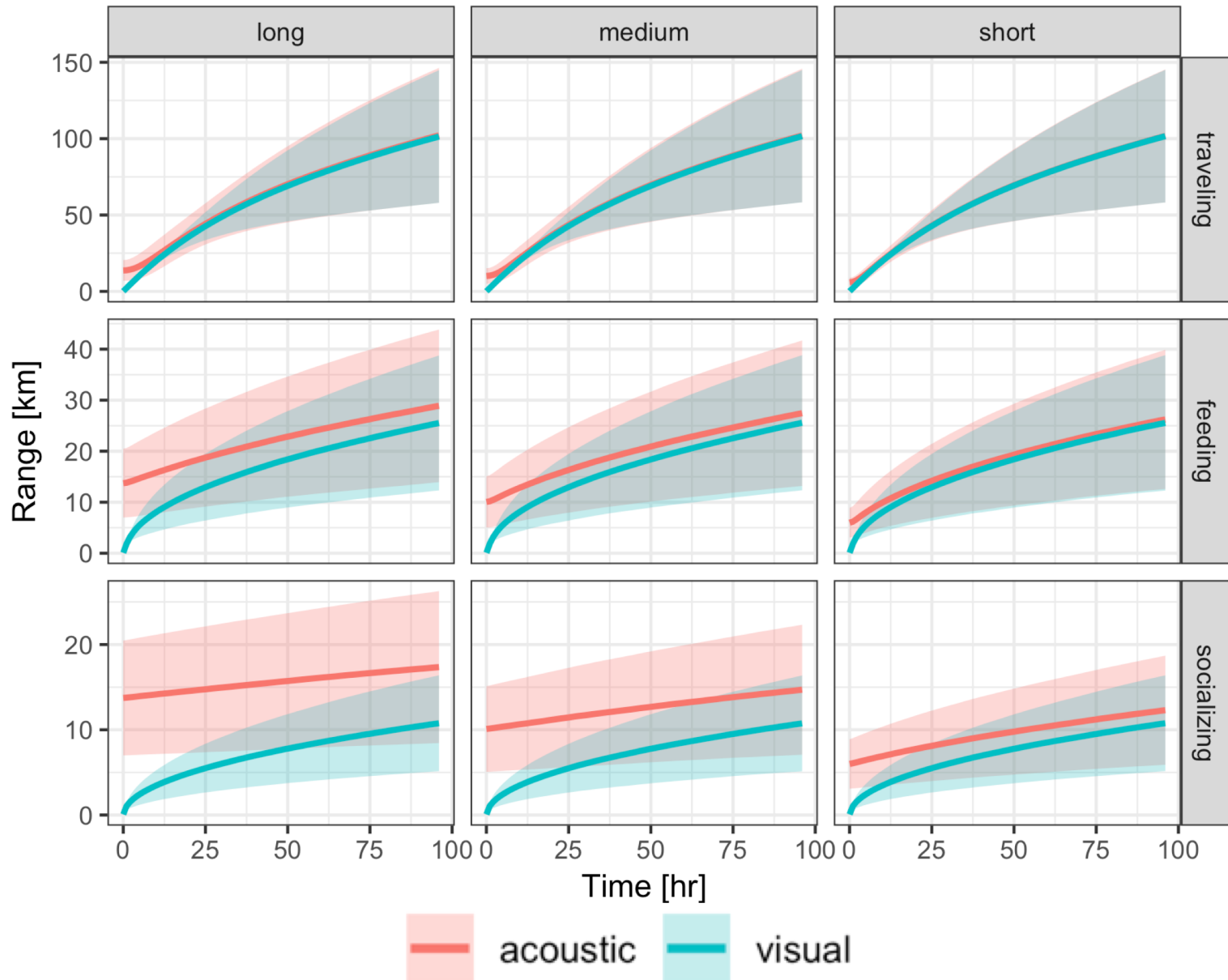
Example run: medium detection range

Elapsed time = 96 hrs



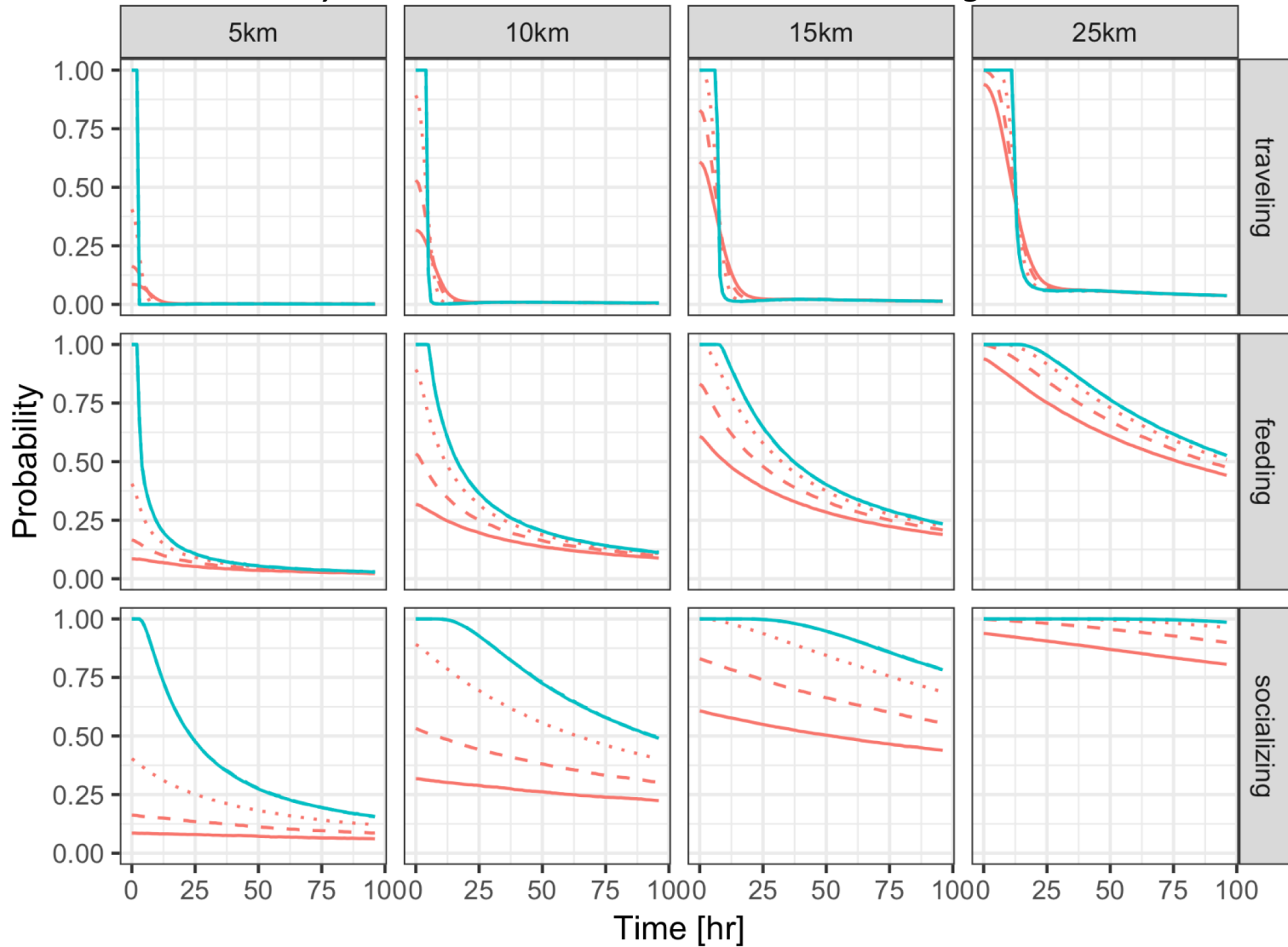
Location uncertainty

How does whale location uncertainty change over time?



Management Context

How likely is a whale with behavior A within range B at time C?

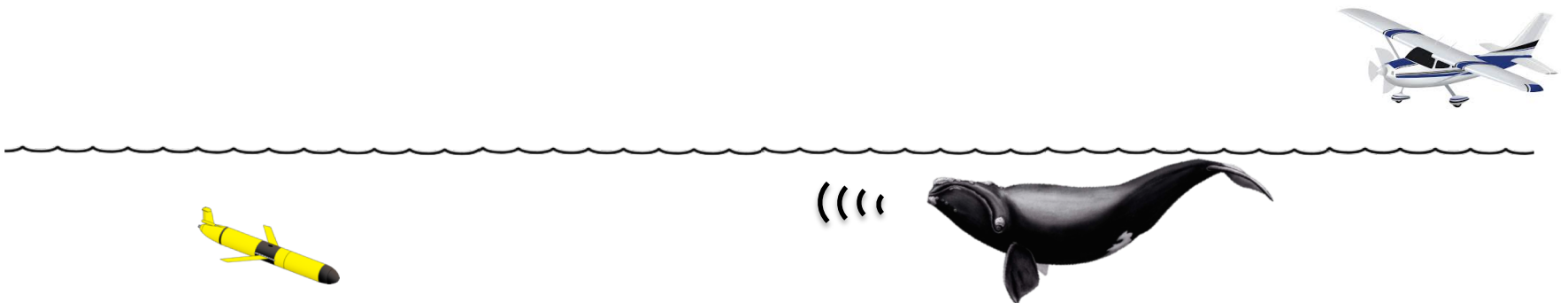


Detection range: — long - - medium ··· short Platform: — acoustic — visual

Conclusions

- Right whales are not points on a map; management must consider movement
- Acoustic and visual detections provide equally uncertain estimates of whale location on management timescales
- Dynamic management should target large areas dominated by low-displacement behaviors (socializing, feeding)
- Need to incorporate acoustics into dynamic management

Excluding acoustic detections only impedes right whale recovery



Questions?

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Kim Davies, Delphine Durette-Morin, Meg Carr, Kim Franklin, Christoph Renkl, Keith Thompson, Daniel Morrison, Marcia Pearson, and others

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