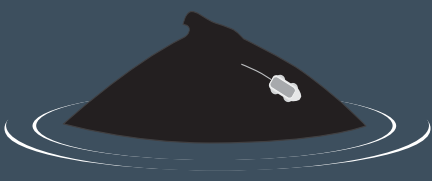


Understanding the ecological role of baleen whales in a rapidly changing Antarctic marine ecosystem



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BIOTELEMETRY AND BEHAVIORAL ECOLOGY



UNIVERSITY OF CALIFORNIA
SANTA CRUZ

Oregon State
UNIVERSITY

OSU



The Year of the Minke

Collaborators, Partners, Sponsors



Australian Government
Department of the Environment
Australian Antarctic Division



NATIONAL
GEOGRAPHIC



AWR
ANTARCTIC WILDLIFE
RESEARCH FUND



WWF



INTERNATIONAL
WHALING
COMMISSION



oneocean
EXPEDITIONS



Connecticut Yankee



Yankee Whaling



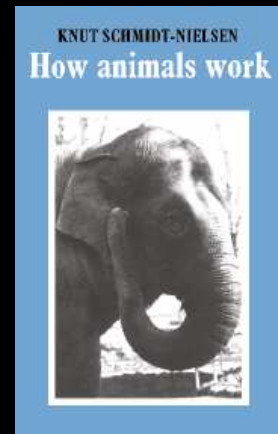
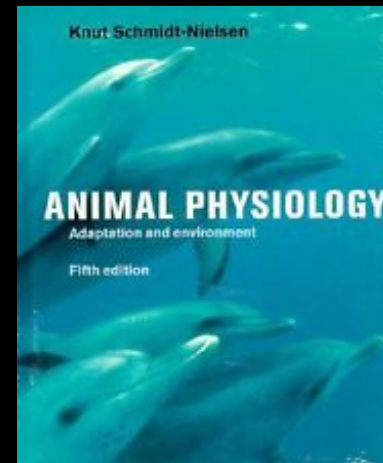
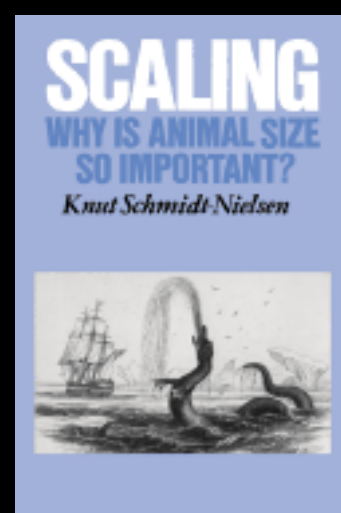
Nathaniel B. Palmer



Yale Whale

Know where you come from

- Ann Pabst (UNCW) → Knut Schmidt Nielsen
Functional Morphology, Anatomy & Physiology



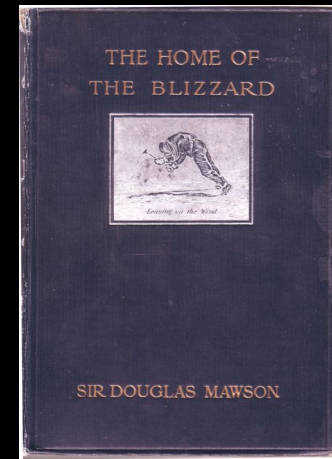
Know where you come from

- Andy Read (Duke) → David Gaskin: Behavioral Ecology



Know where you come from

- Brian Skinner (Yale) → Douglas Mawson: Antarctic Explorer, & Geology



- One of the penalties of an ecological education is that one lives alone in a world of wounds.

– Aldo Leopold



Ecological Foundation

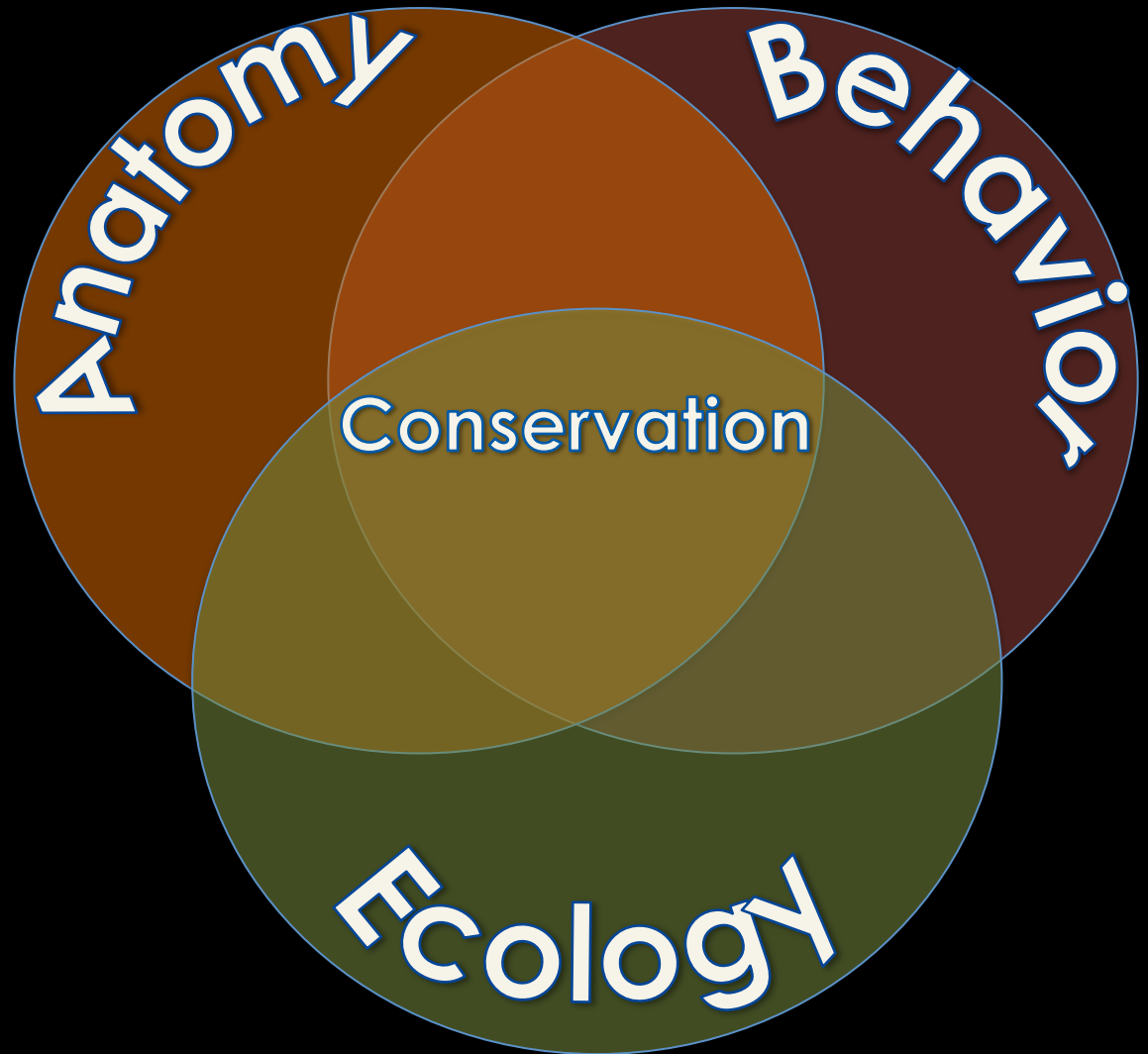
- Cetaceans are the largest animals to have ever lived
- Morphological, physiological, and behavioral adaptations for bulk feeding
- Decisions
 - How does the distribution and behavior of prey affect cetacean foraging ecology
- Environment
 - How does the physical and biological landscape affect cetacean behavioral ecology

My Ecological Mantra



- Telemetry is an incredible tool to measure and understand cetacean ecology
 - fine and broad spatio-temporal scales
- Understanding cetacean ecology requires an understanding of their environment
 - inter-disciplinary collaboration is essential
- Analytical and visualization tools can provide context and convey information
 - Scientific community, curriculum for classes, public outreach and education

Philosophy



Art Meets Science



Science Meets Art: Observation & Interpretation



'Once a painting is visually inventoried in as much detail as an analytical approach is introduced, using visual cues to draw conclusions and interpretations about the painting's content... the conclusions depend upon keen and thorough observation of fact, in an open-minded and unbiased manner, until the inventory is complete and the process changes from one of assemblage to interpretation'

UNFRAMABLE ◦ ARI FRIEDLAENDER





Commercial Whaling

- Near extirpation of baleen whales (>2 million)
 - 360,000 Blue,
 - 725,000 fin,
 - 260,000 humpback
- Created a void of krill predators
- Differential life histories and energetic demands confound species recovery
- Effects of changing conditions (e.g. sea ice) augments/diminishes foraging habitat and prey



Antarctic Peninsula Climate Change

Winter Air Temperature:

- Increased by 5C over 50 years

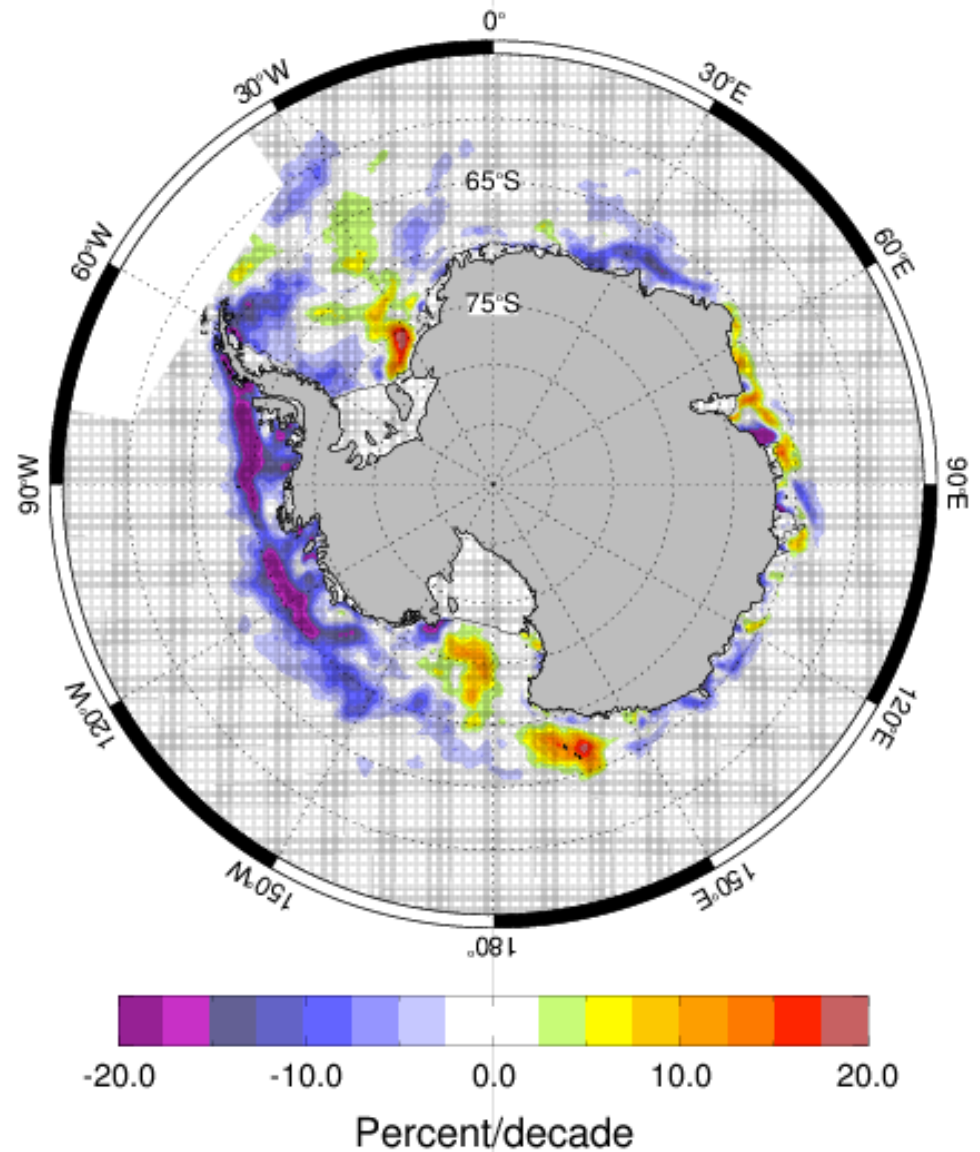
Sea Ice Cover:

- Decrease of >80 days of ice cover annually
- Frequency of 'heavy' ice years diminished

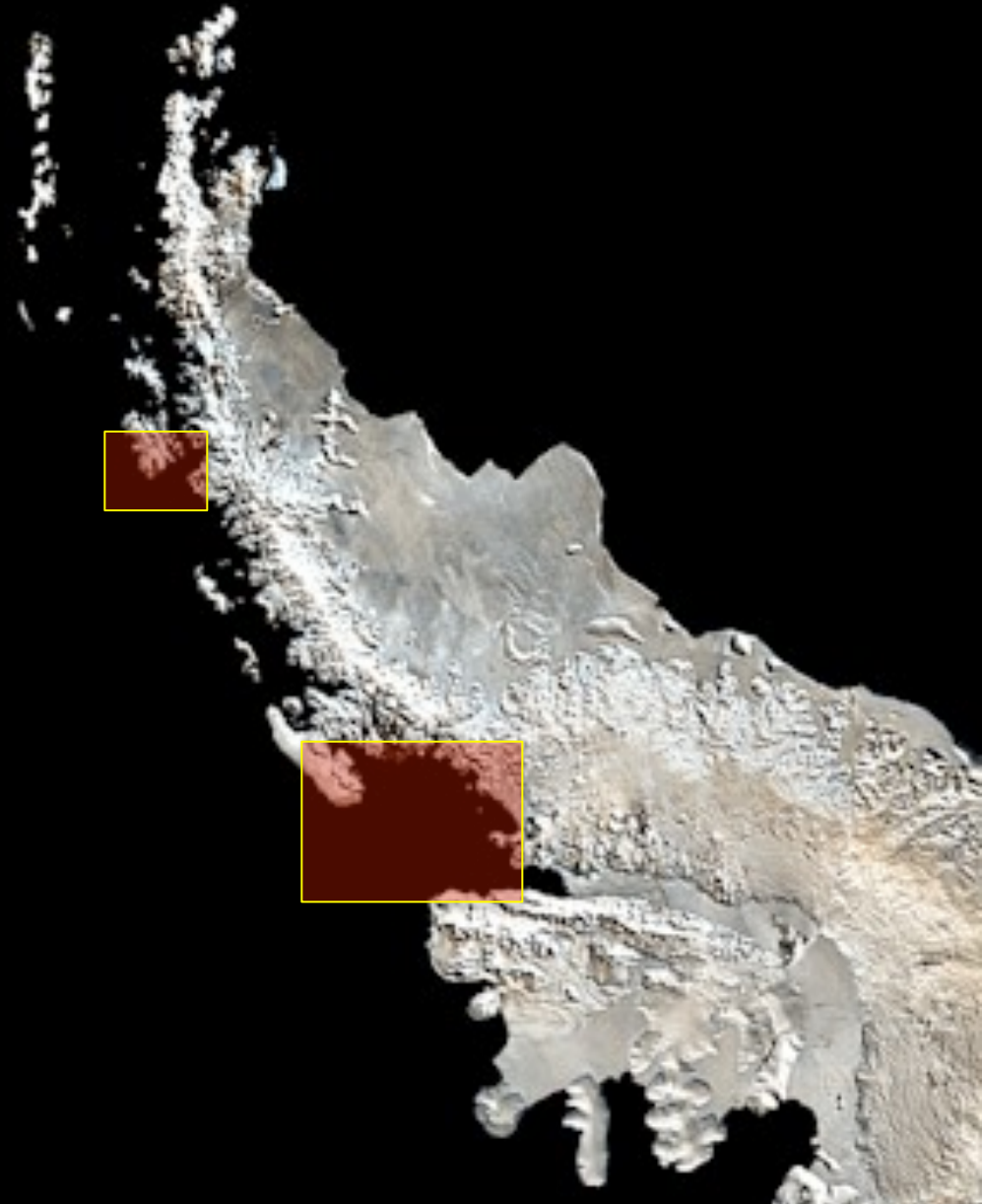
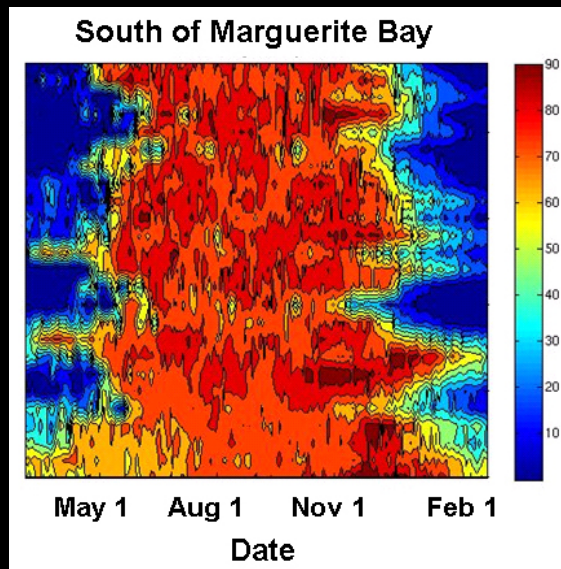
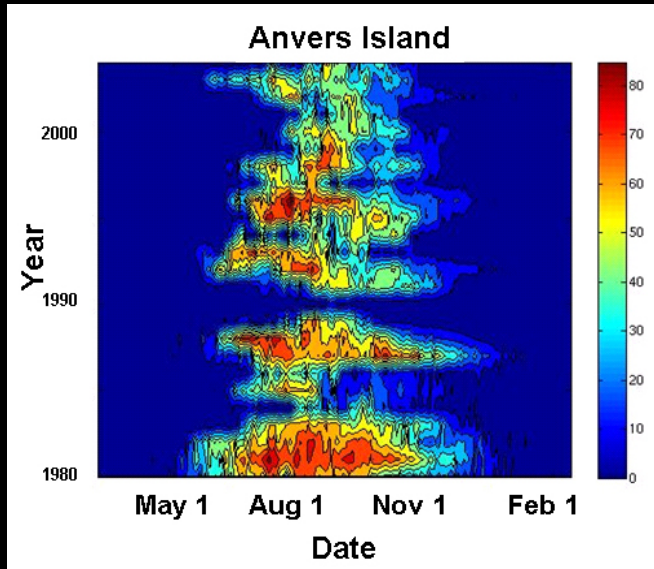


Trends in average January sea ice concentration for 1979-2007

Large declines in summer sea ice concentration along the Antarctic Peninsula and in the Amundsen and Bellingshausen Seas.



Antarctic Peninsula Sea Ice Change: Climate migration



Antarctic Krill (*Euphuasia superba*)

- Primary food for whales, seals, penguins, seabirds
- Tightly coupled with sea ice
 - Summer foraging
 - Over-wintering habitat
- Winter sea ice extent linked to krill survival
- Sea ice extent affects recruitment and distribution of krill



Responses to Prey/Habitat Availability

- Change in distribution
 - Adelie penguins decreasing, Gentoo penguins increasing along the WAP
- Alter demography
 - reproductive rates
- Change foraging behavior and fitness
 - longer trip durations
 - Increase energetic costs



Objectives



- Quantify the movement patterns and behavioral ecology of baleen whales
- Relate foraging behavior to dynamic environmental features
- Understand population growth and health
- Evaluate the effects of disturbance (e.g. climate migration) on baleen whales
- Use knowledge to promote education and enhance conservation/policy measures

Quantitative whale movement ecology

Understanding movement causes
and consequences for species distribution
and behavior

The four stages of marine animal movement

1. Where are the animals? What are they doing?
2. How does their distribution and behavior change over time?
3. Is their behavior related to the environment?
4. What are the consequences of global change on animal distribution and behavior?

Multi-Sensor Tags

- non-invasive
- suction cups
- up to 48 hours
- time, depth, temperature
- 3-axis accelerometers, magnetometers, gyros
- sensors sample up to 400 Hz
- audio to 242 kHz
- 2k Video
- VHF
- GPS



Humpback Whales





Foraging

- Predator foraging strategies depend on:
 - Physical constraints
 - Prey behavior
- Behavior leading to prey capture vary
 - Timing, duration, constitution
- Plasticity in appetitive behaviors
 - Leads to higher predation rates
- Example...



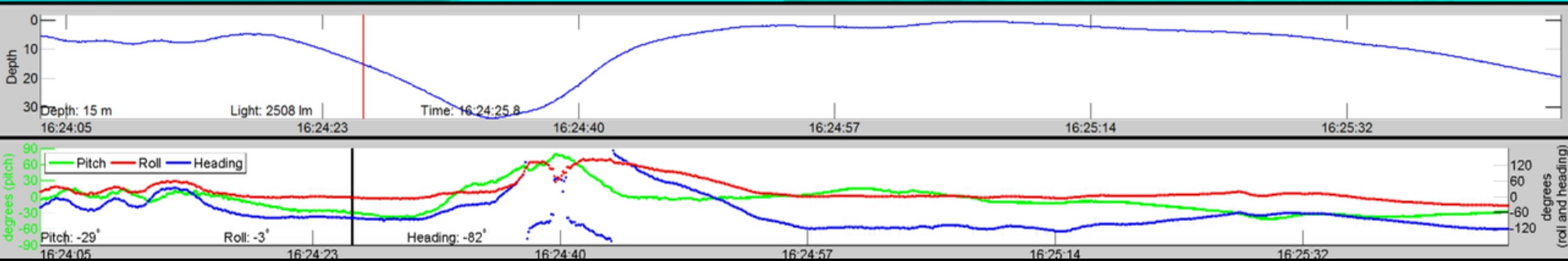
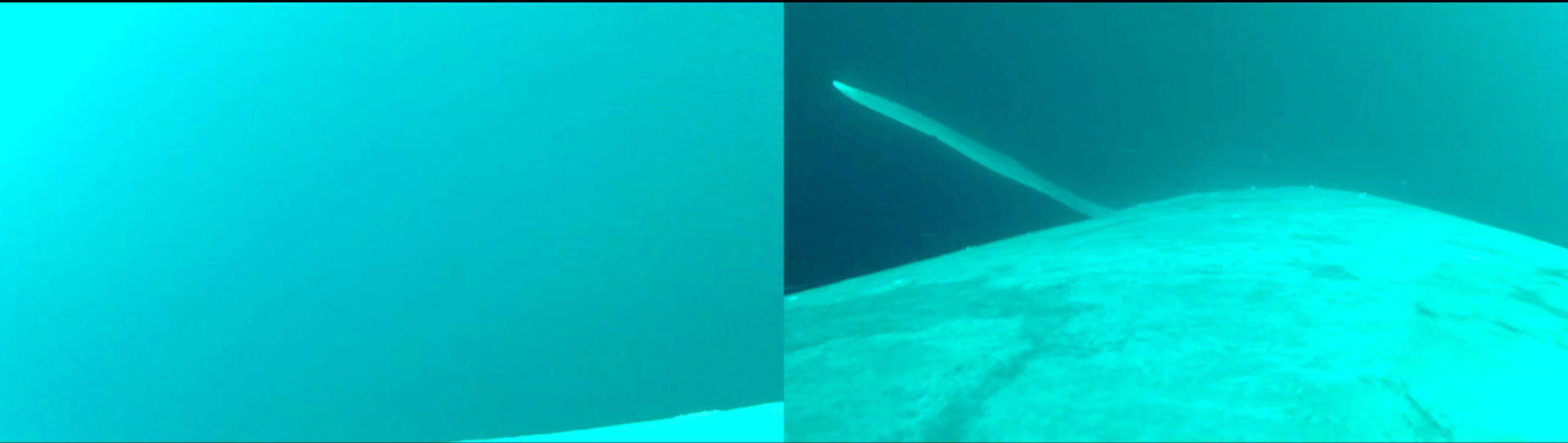
Appetitive plasticity: Prey Behavior



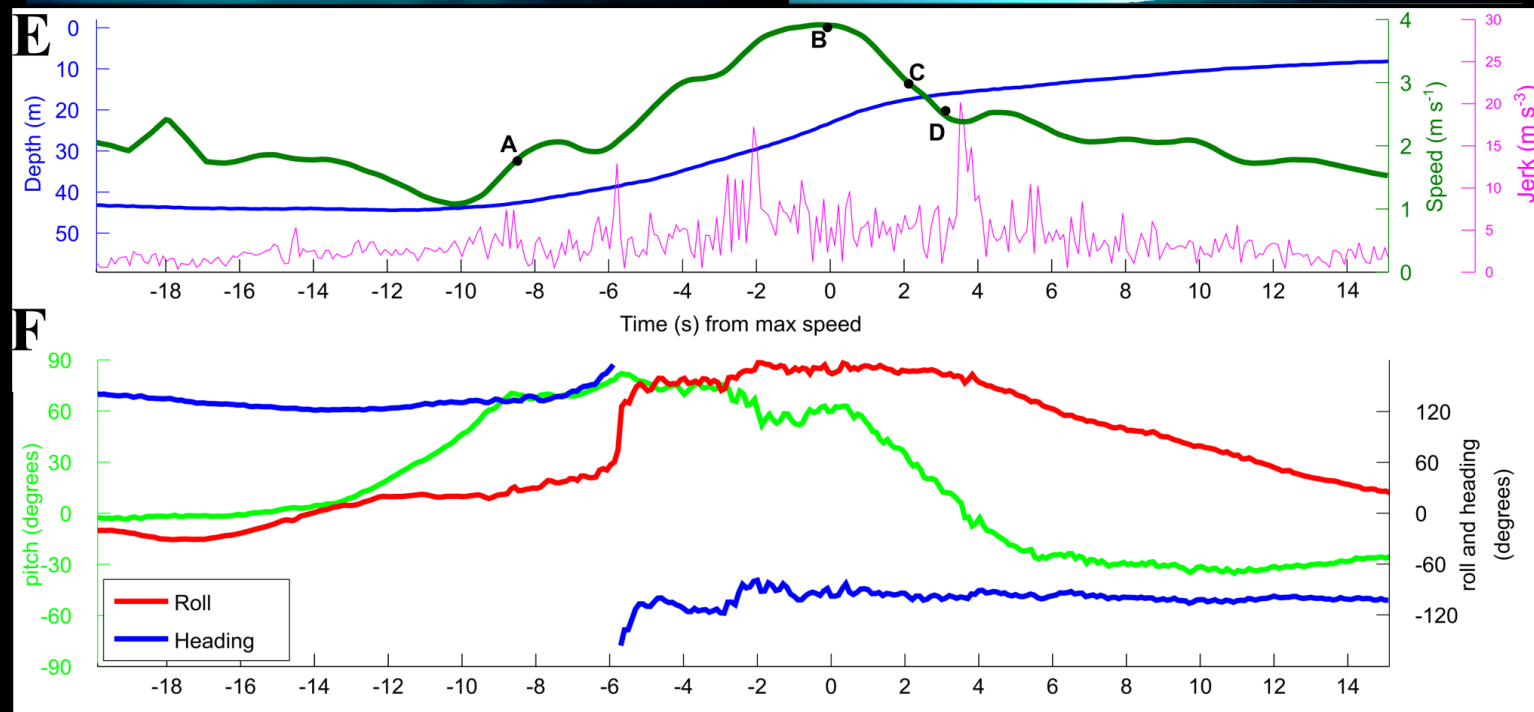
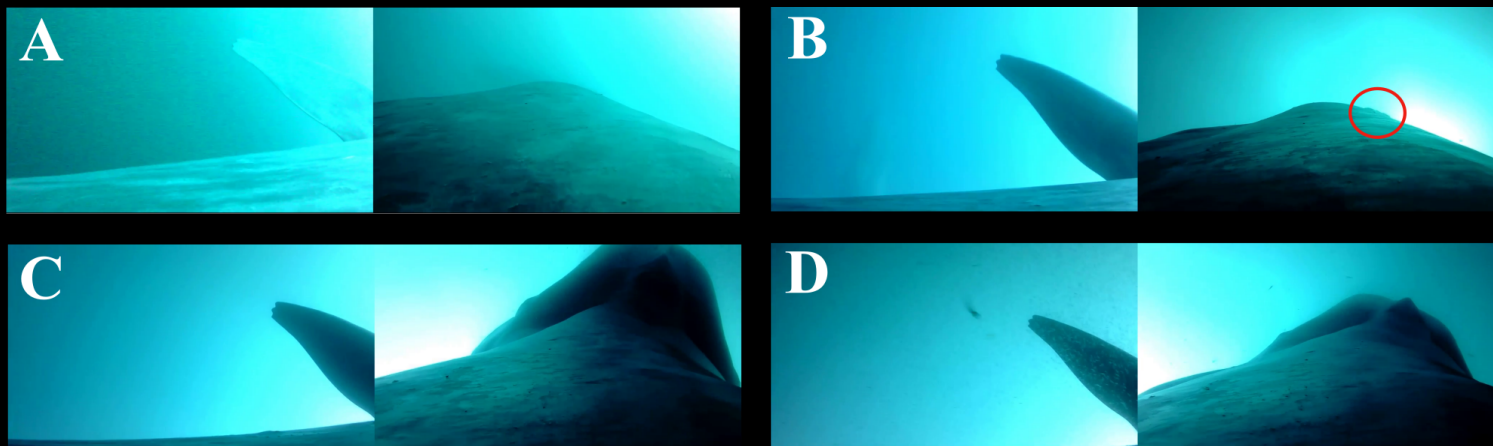
Appetitive plasticity: Prey Behavior



Combining video & movement data to study maneuverability and prey type

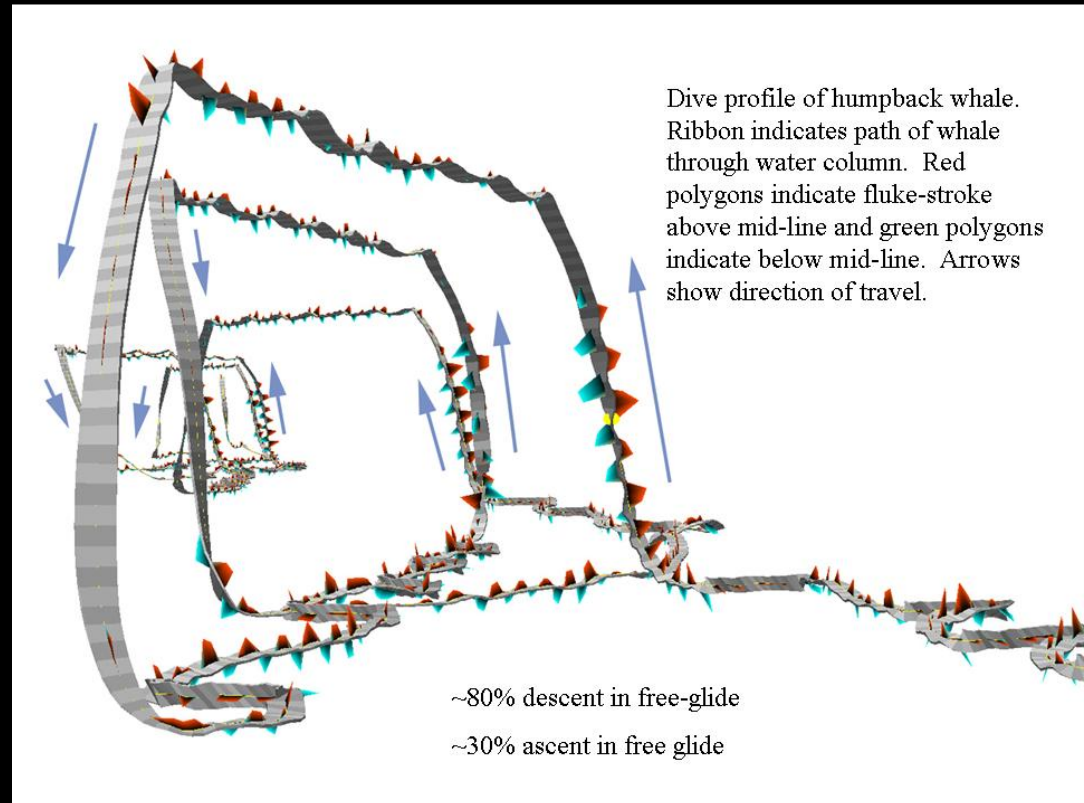


Depth, Pitch, Roll, Heading

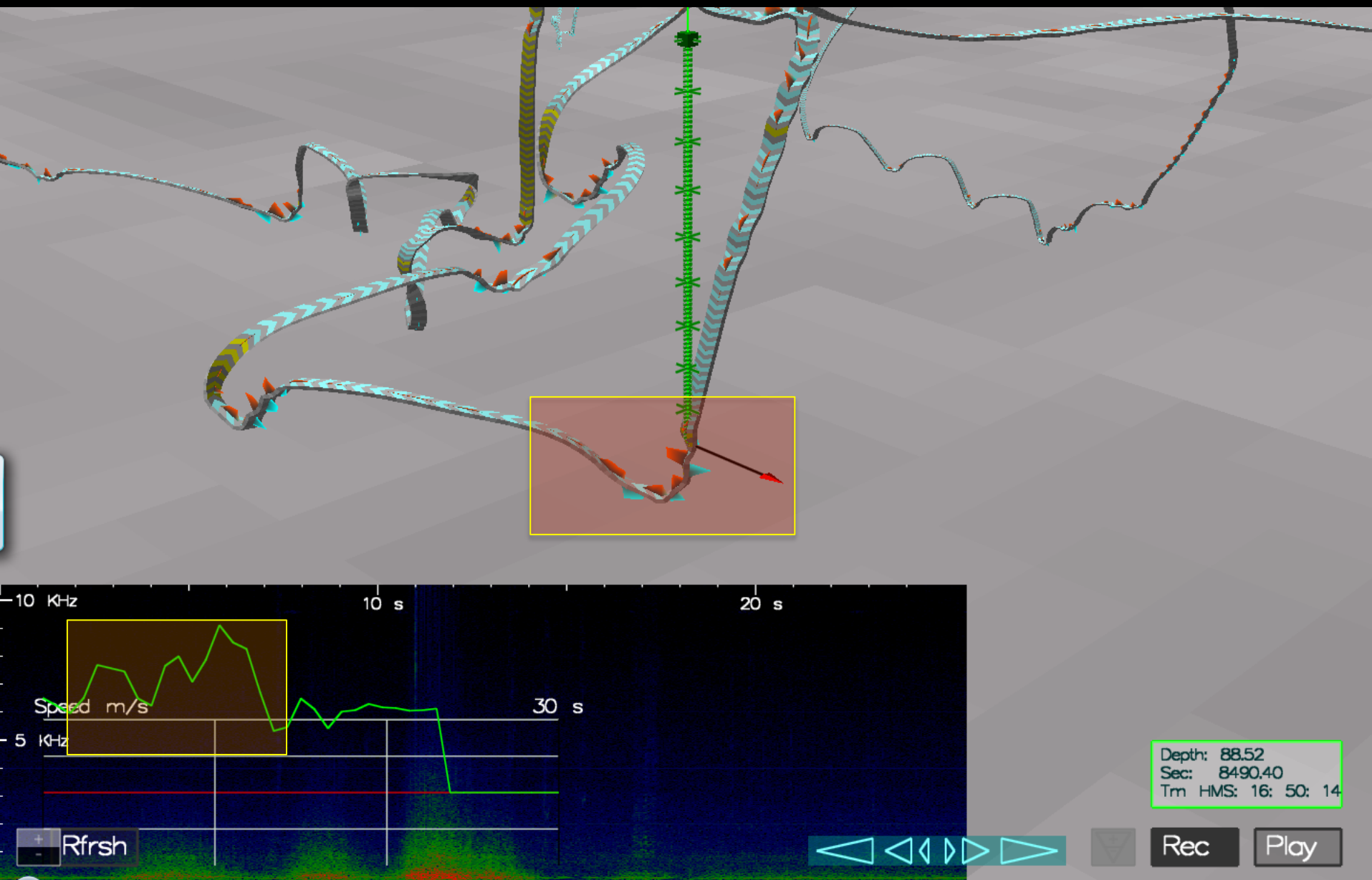


Whale Tag Analysis

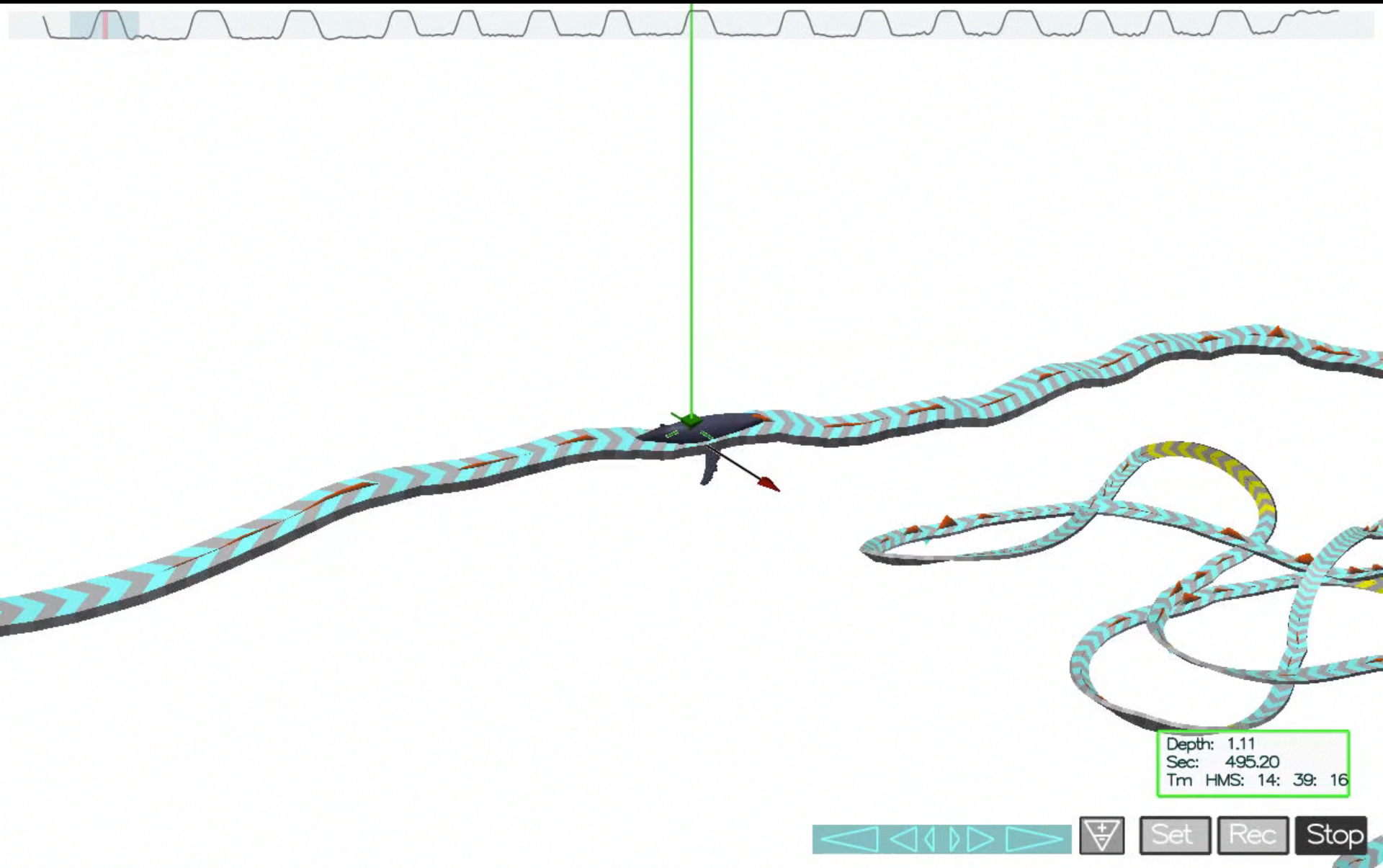
- Trackplot (Ware et al. 2006)
 - Visualize underwater movement patterns
- Behavioral Sequencing
 - Link observed and tag behaviors
- Ribbons indicate the orientation of the whale
- Red and blue teeth are fluke strokes



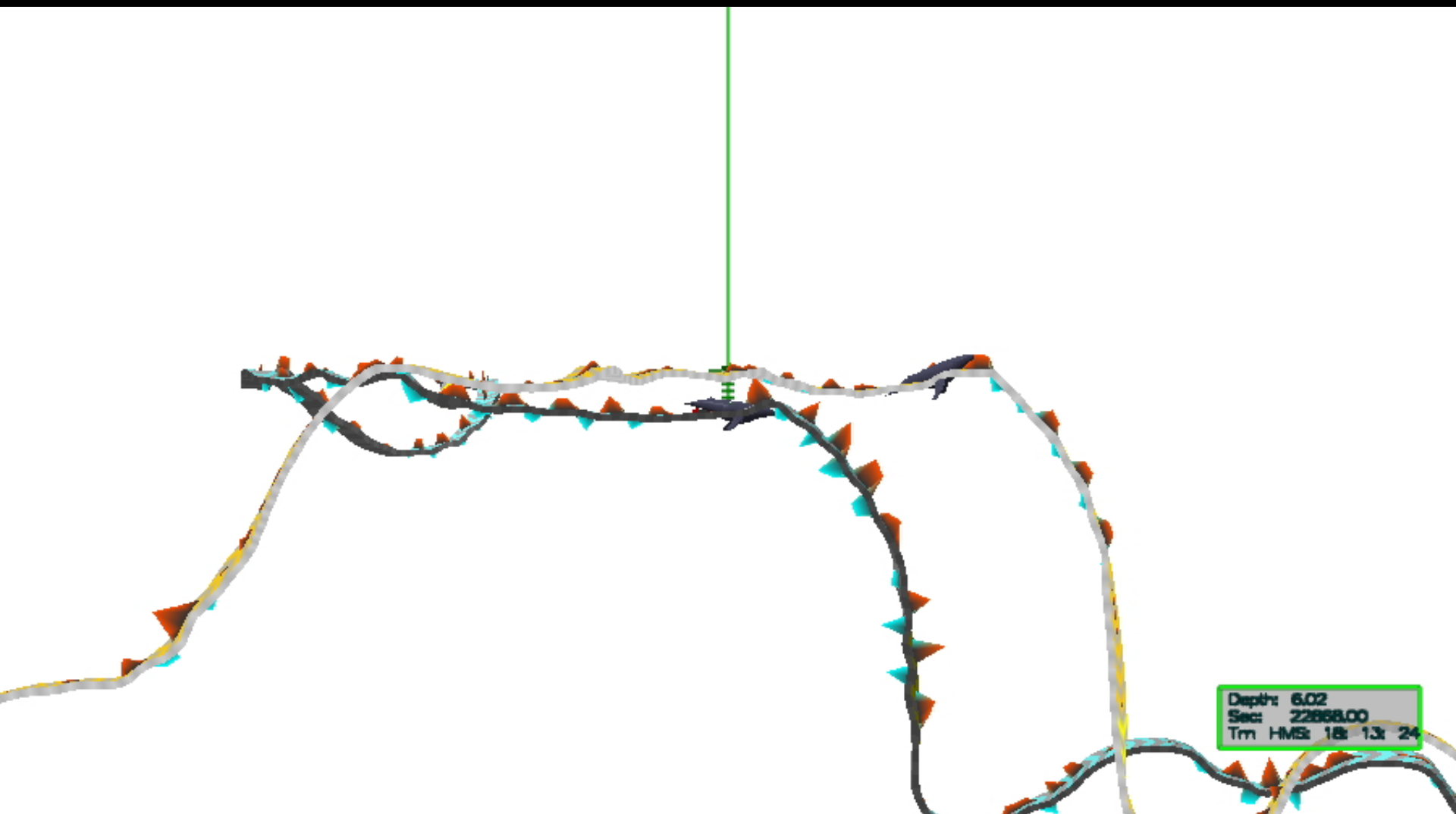
Using sound to find feeding



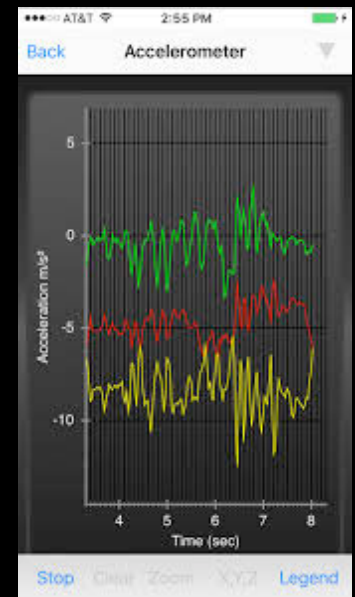
Quantifying foraging behavior



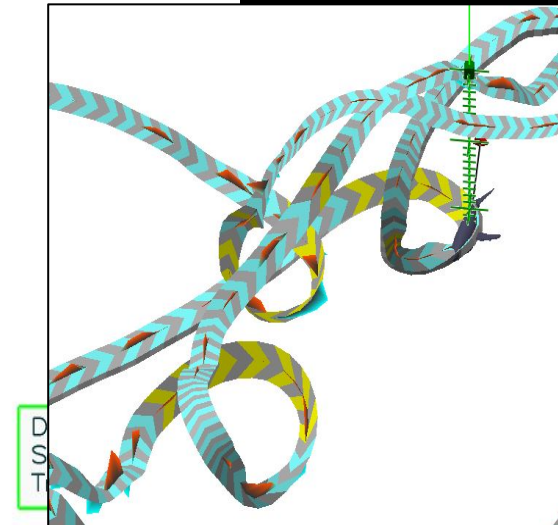
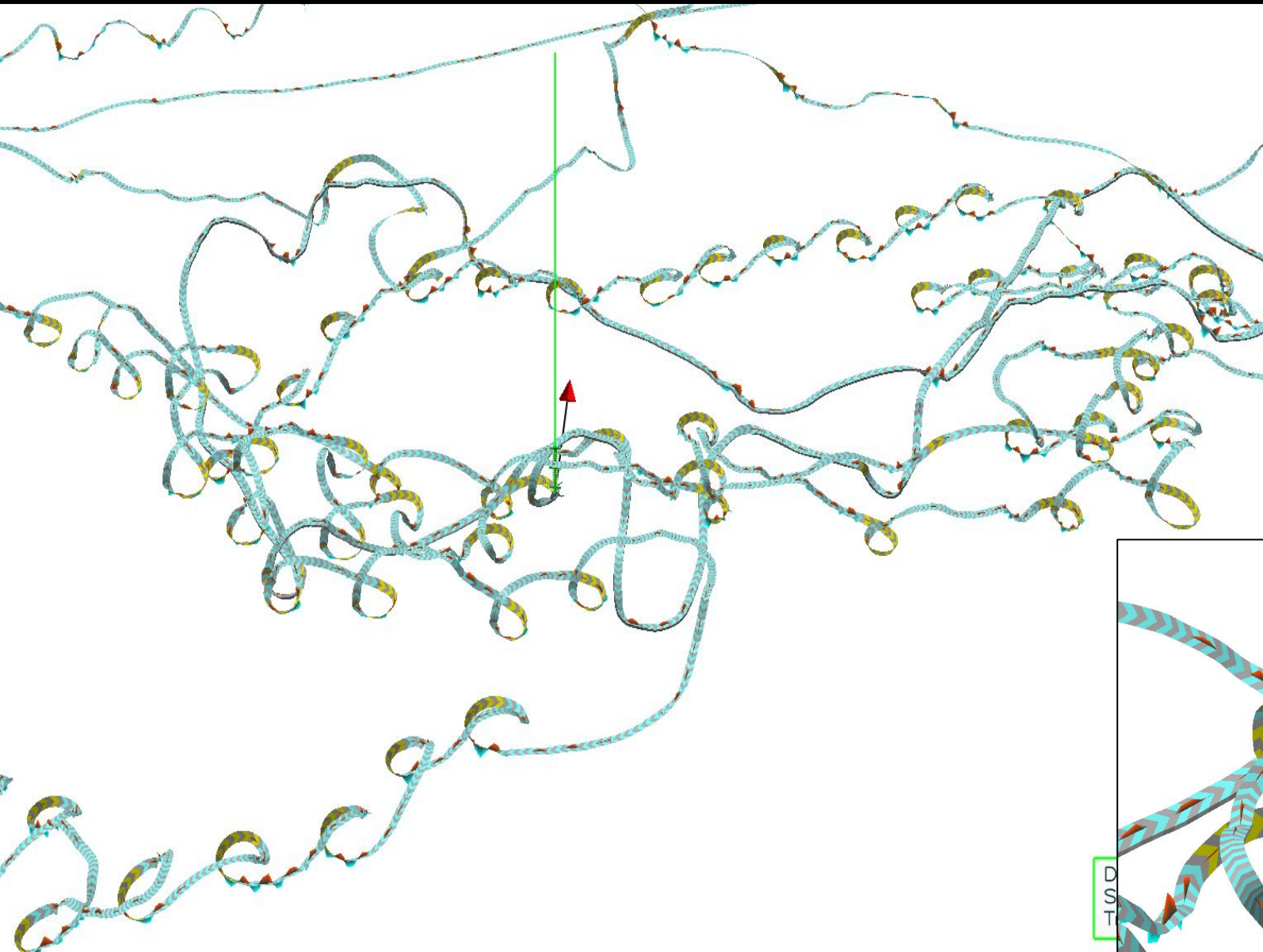
Mom & Calf



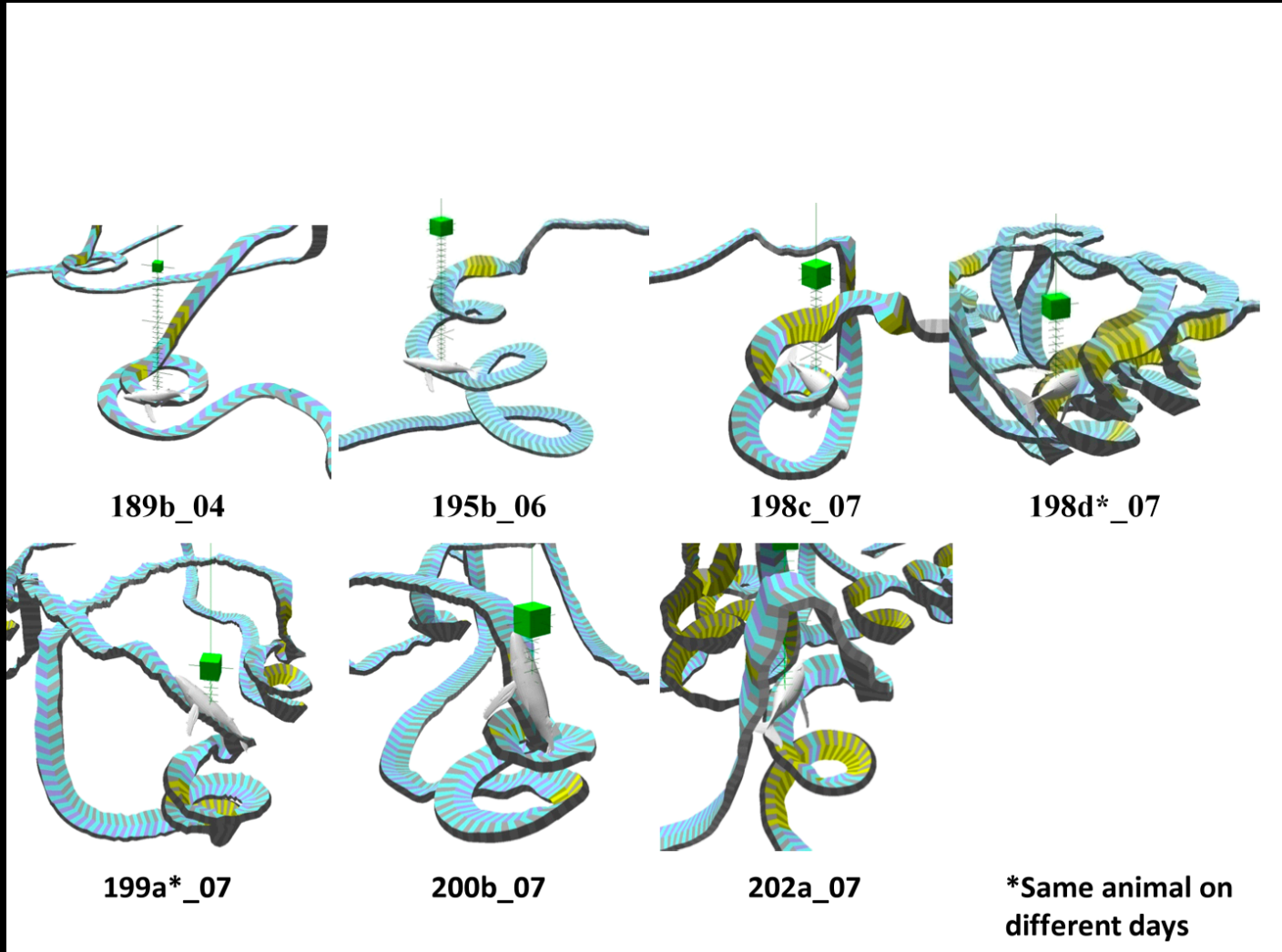
Playing with tag data



Bubble net feeding in Antarctica



How do you eat?



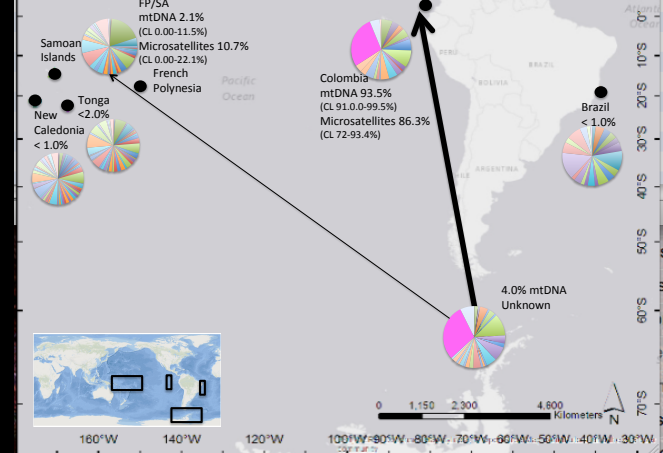
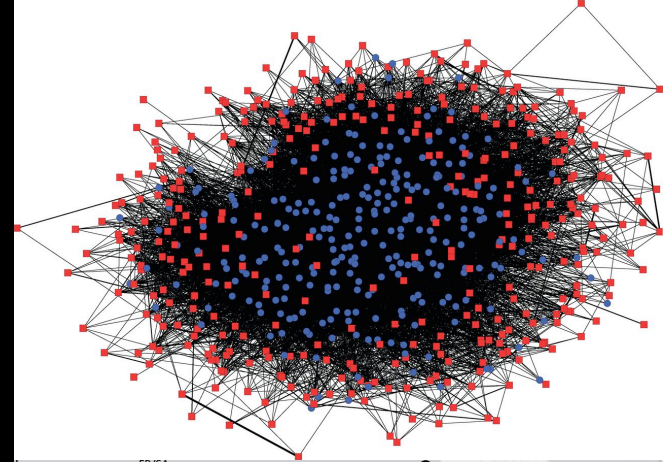
Tracking the spread of new foraging behaviors

Network-based diffusion analysis reveals the cultural spread of a naturally occurring foraging innovation over a period of 27 years.

Support for models with a social transmission component was 6 to 23 orders of magnitude greater than for models without.

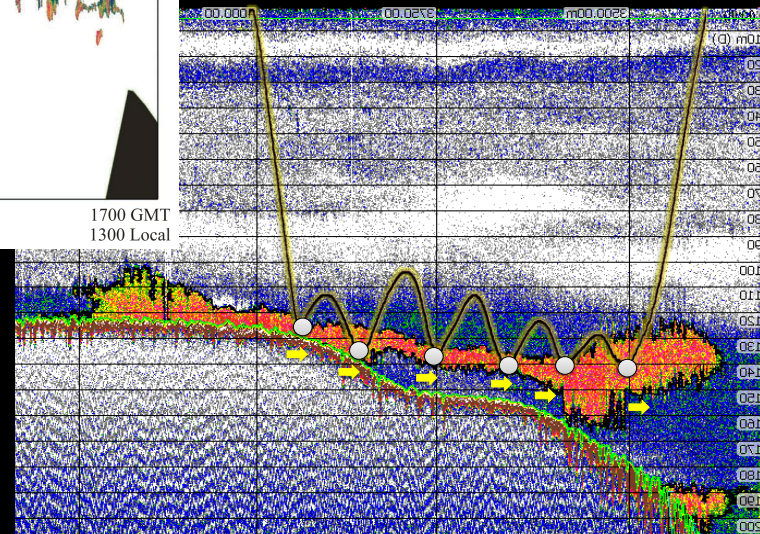
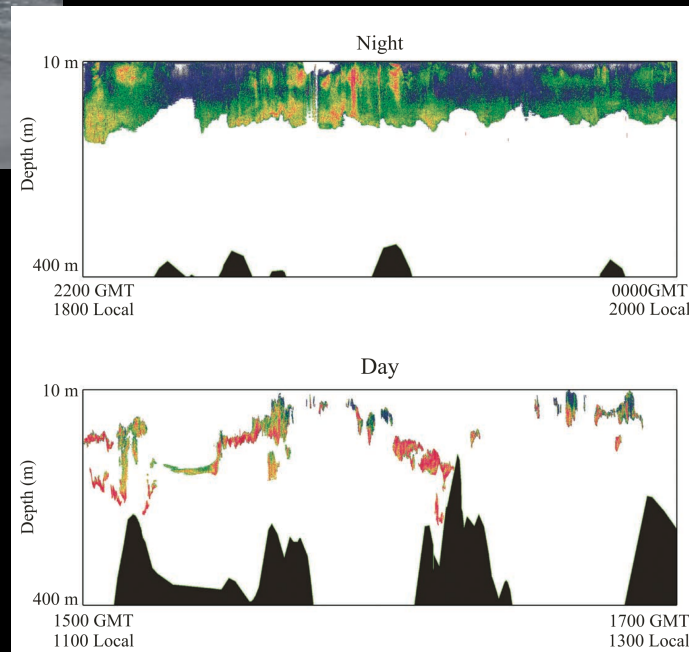
The spatial and temporal distribution of sand lance, a prey species, was also important in predicting the rate of behavior acquisition

(Allen et al. 2013, *Science*, Albertson et al. In Press, Mastick et al. In review)



Prey Mapping

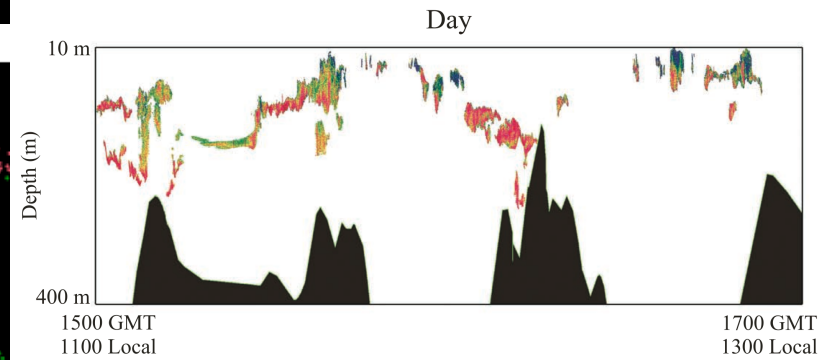
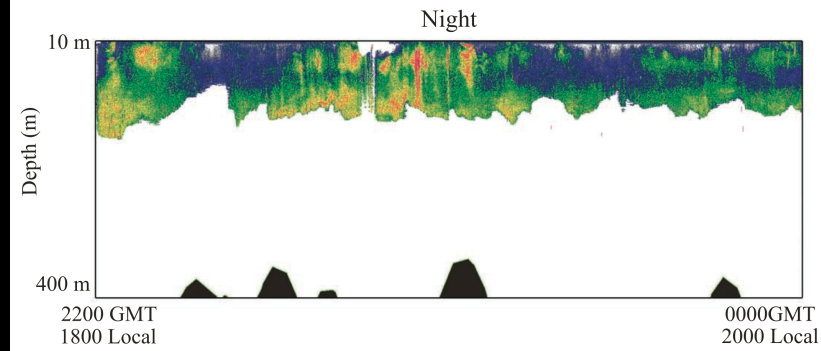
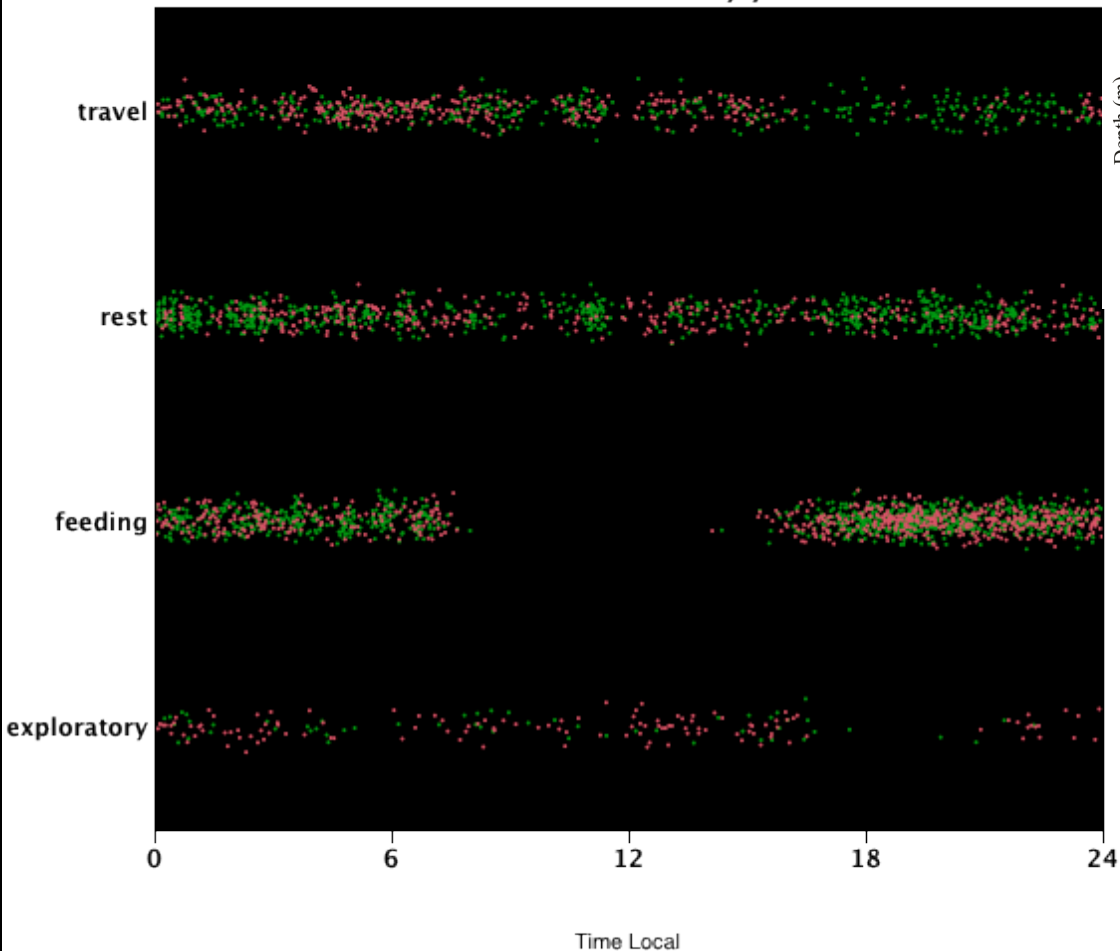
- Use echosounders to determine: distribution, abundance, and density of krill



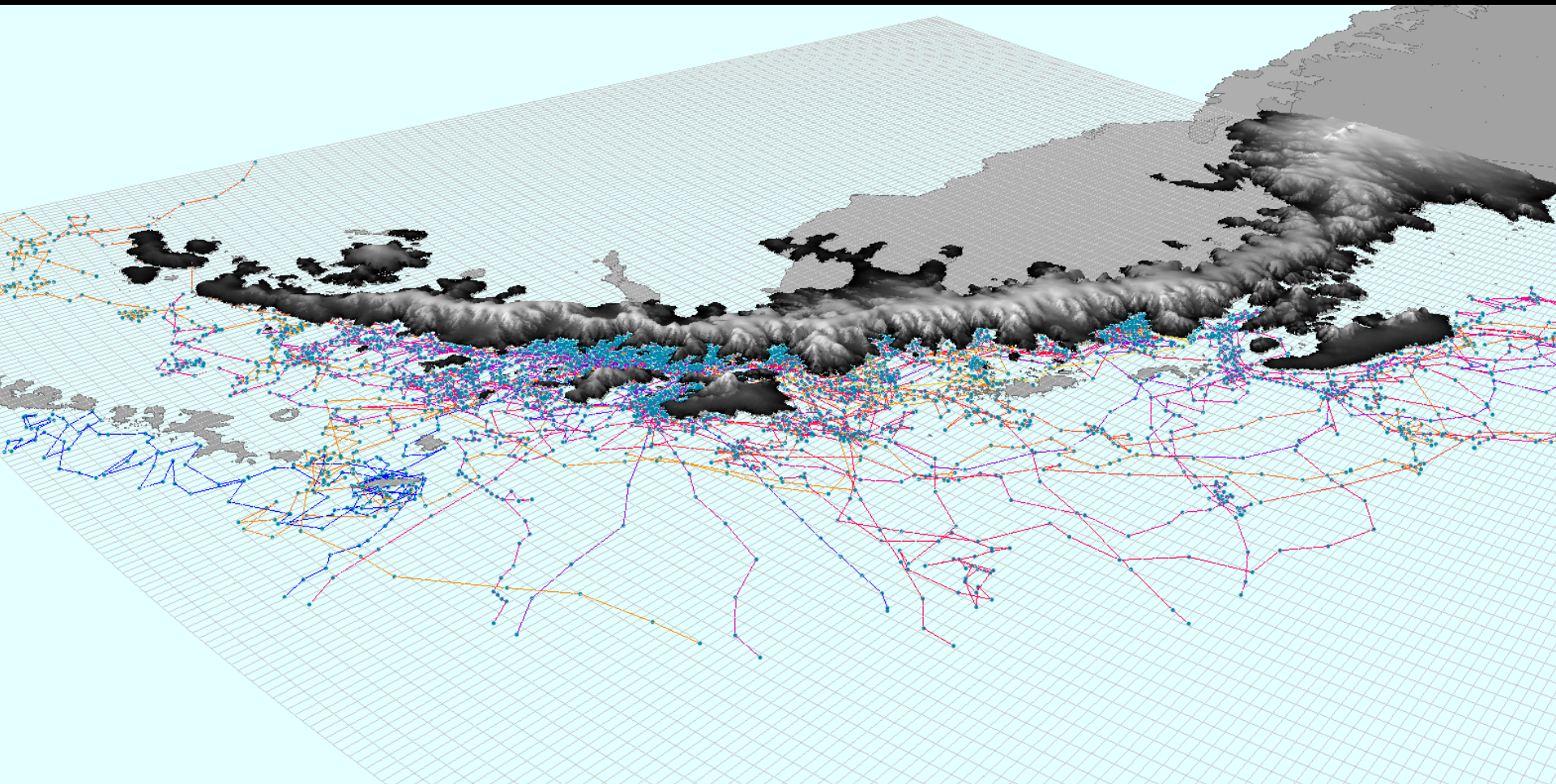
- Link fine-scale foraging behavior with prey

Foraging Decisions

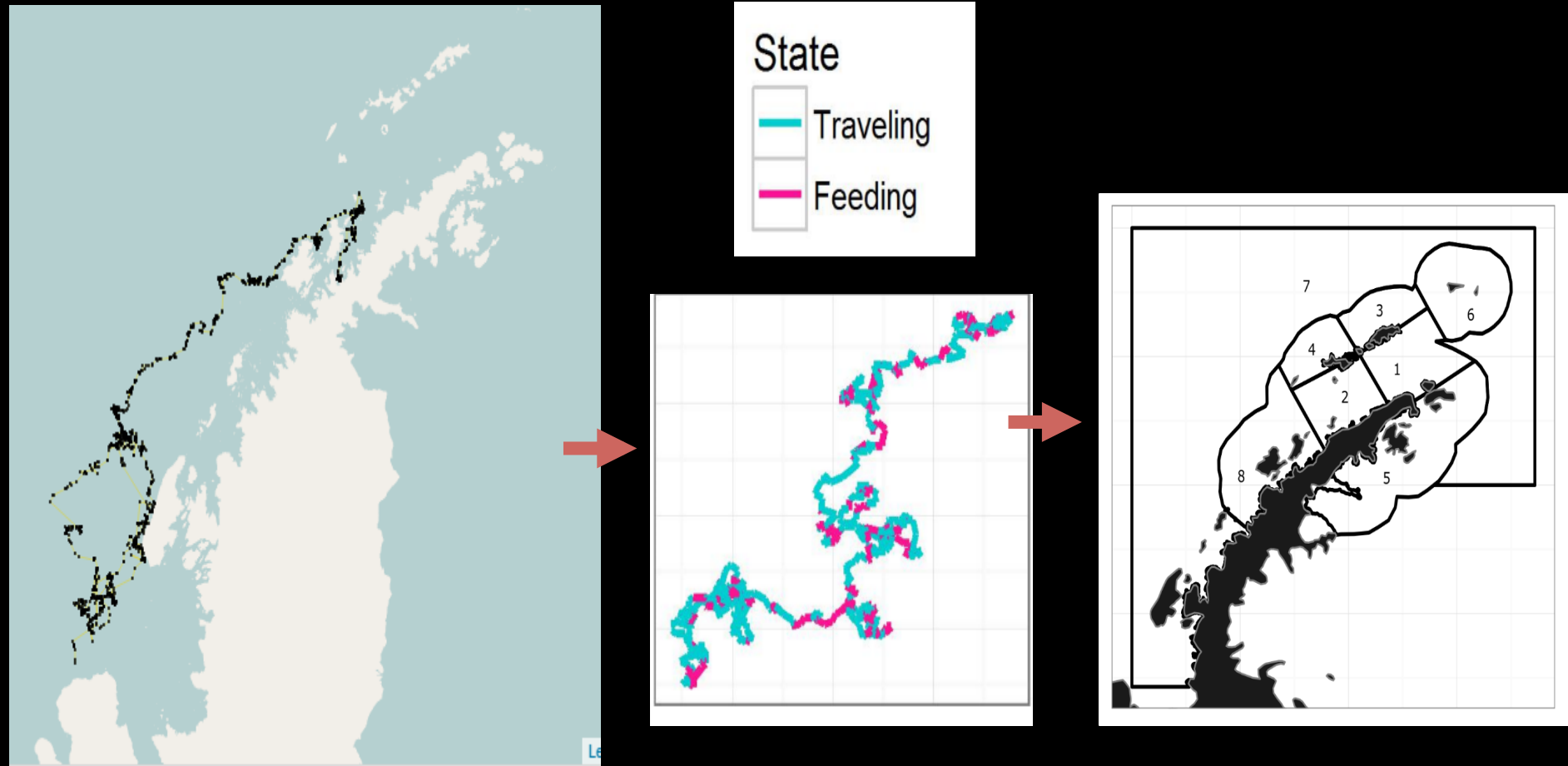
Behavioral State vs. Time Local by year



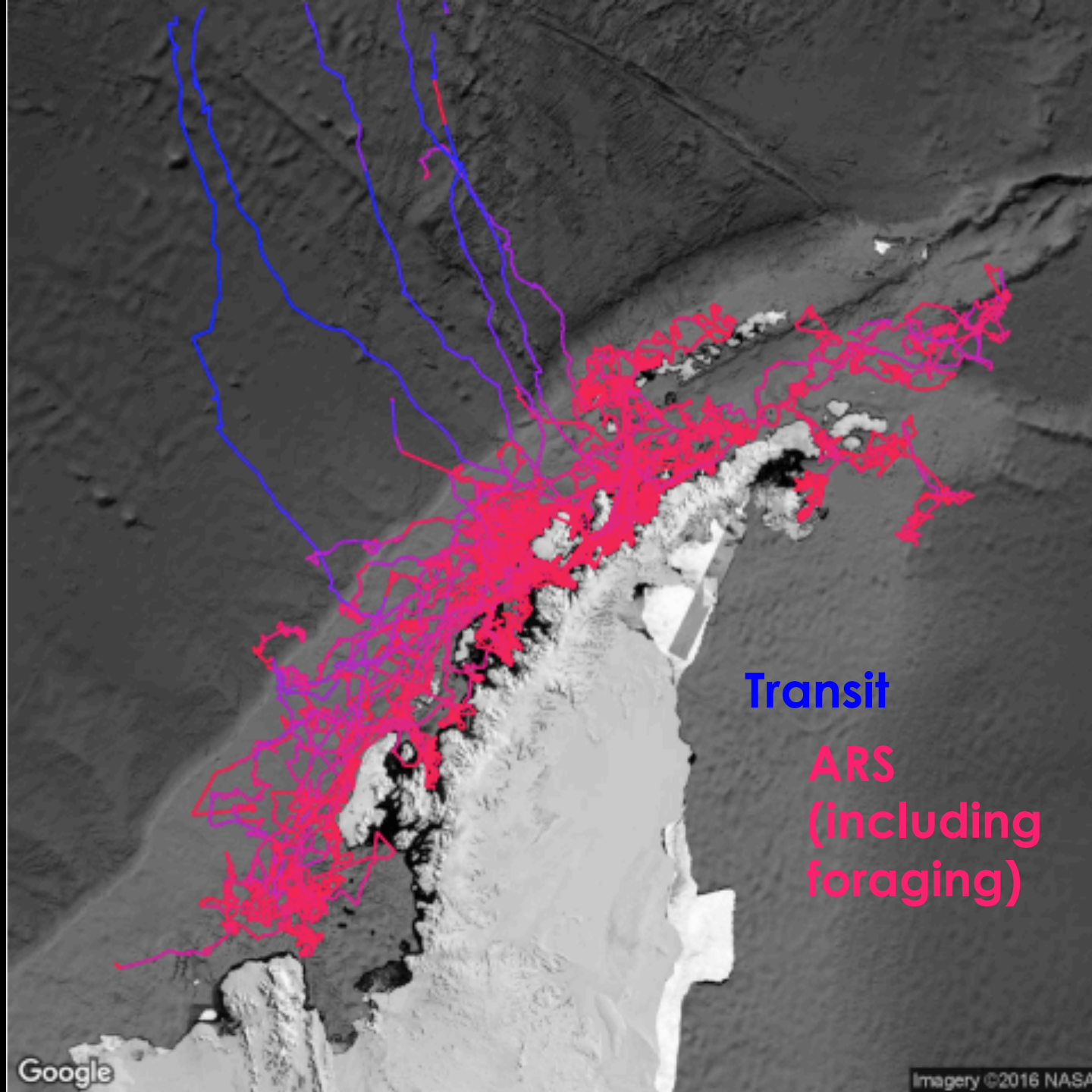
Using long-term satellite telemetry to study the movements, distribution and relative density of cetaceans across the Western Antarctic Peninsula



Where are whales foraging?



Multi-state behavioral movement model



Transit

ARS
(including
foraging)

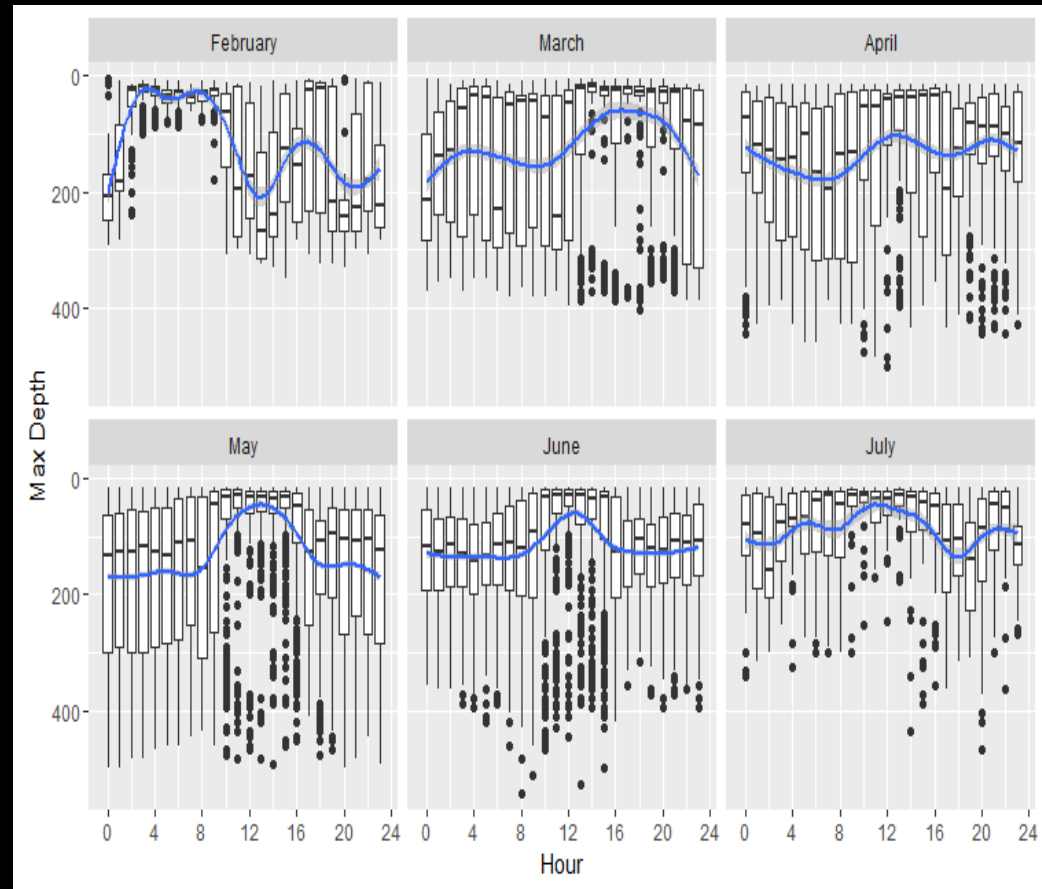
The four stages of marine animal movement

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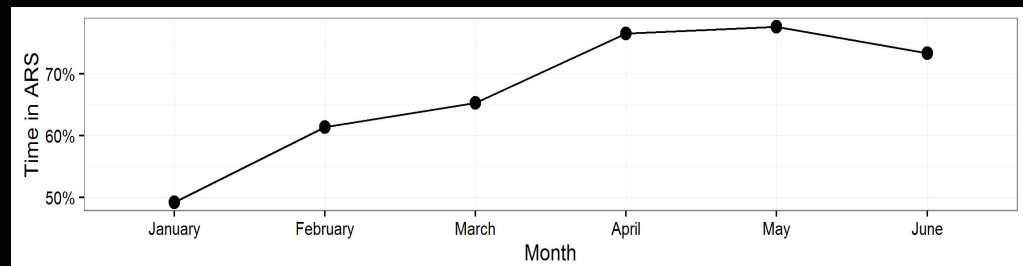
Monthly Dive Patterns and foraging rates

Feeding earlier in the day, more variable overall?

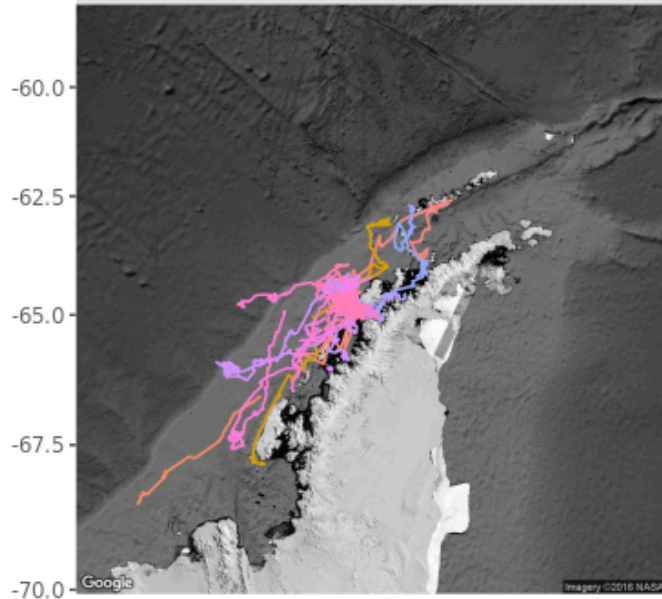
Resting during the day, more uniform across individuals



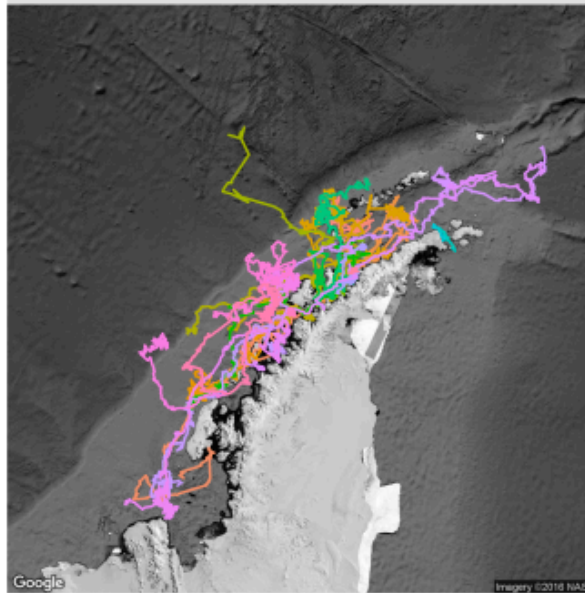
Increase foraging rates over time



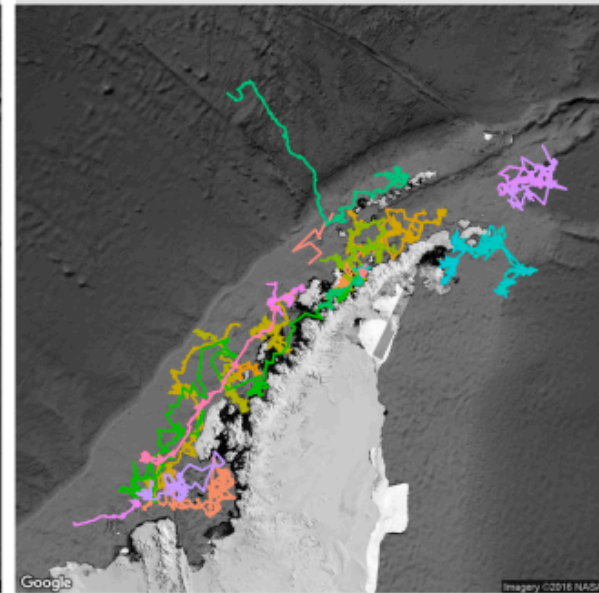
January



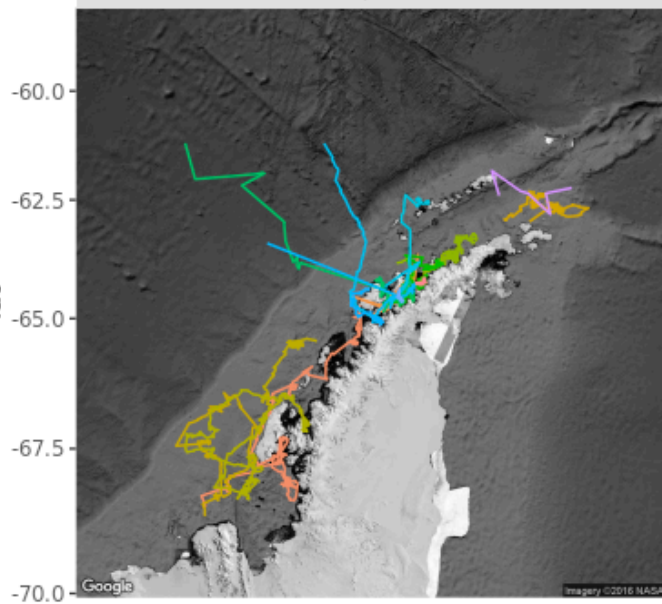
February



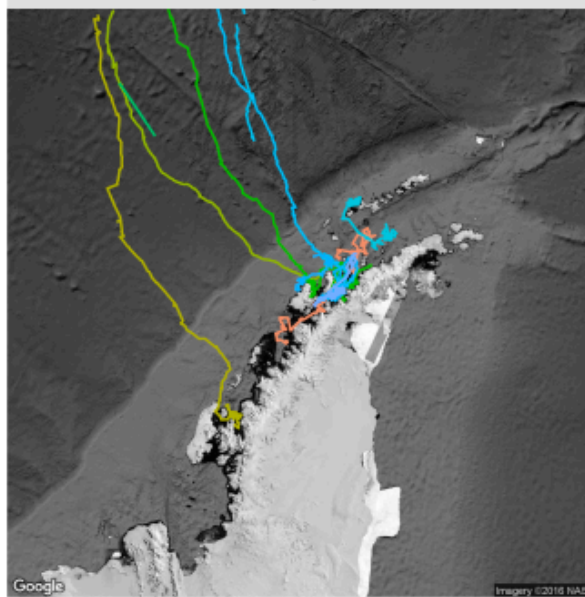
March



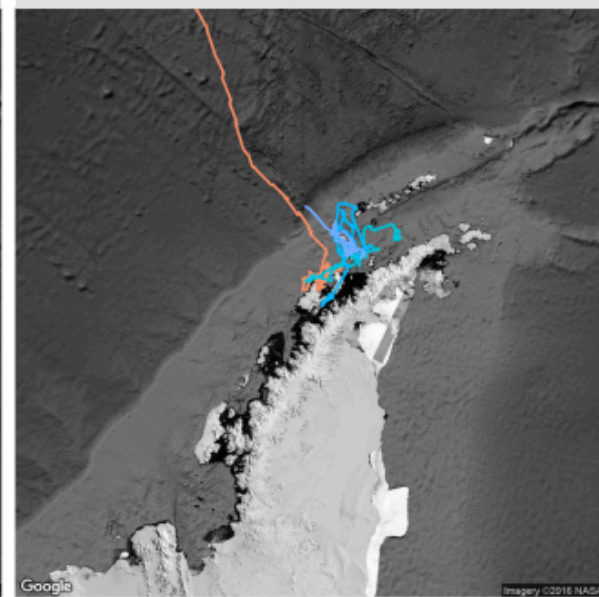
April



May



June



Seasonal Home Ranges

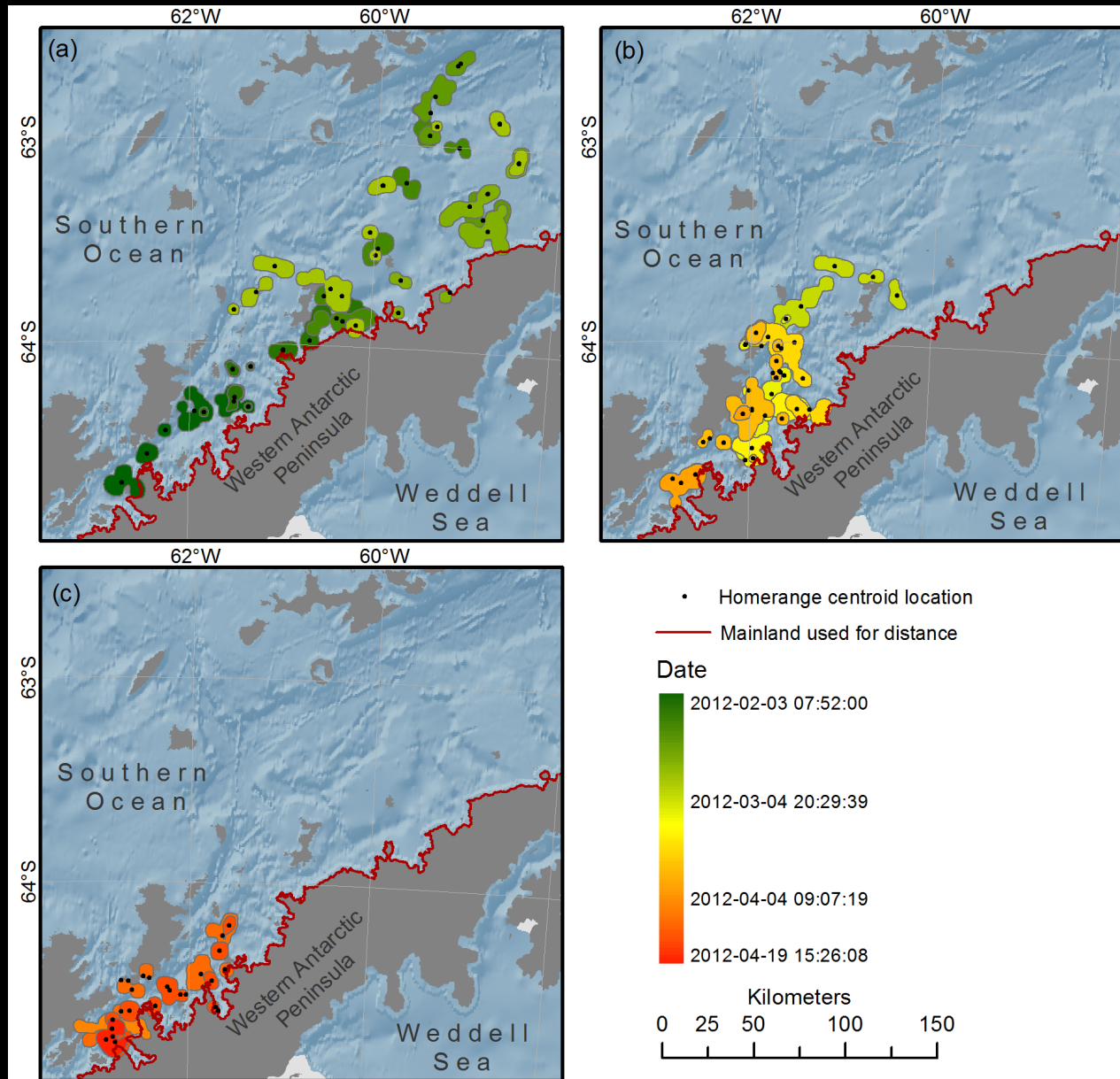
Curtice et al. 2015

Home Range Size

Jan → May

Distance to Coast

Jan → May

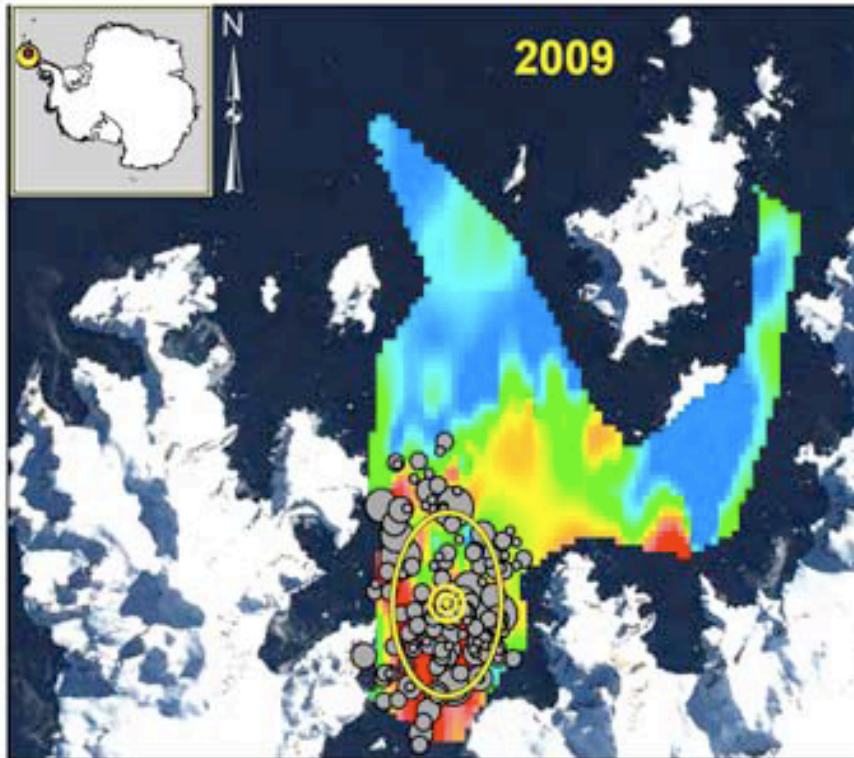


The four stages of marine animal movement

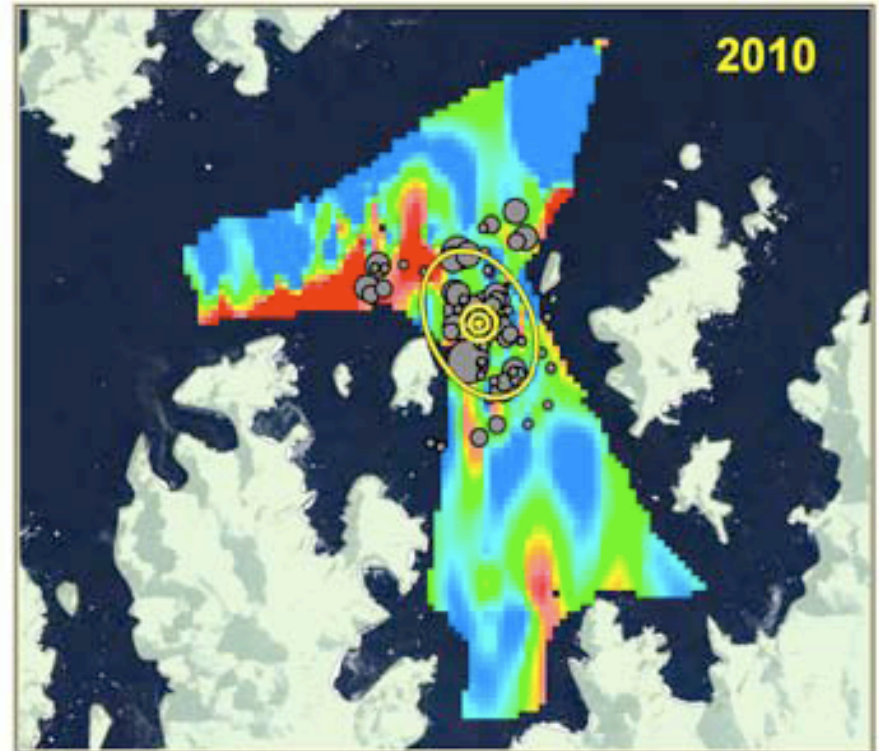
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Krill and Whales in Wilhelmina Bay

Biomass density estimates from ADCP Backscatter

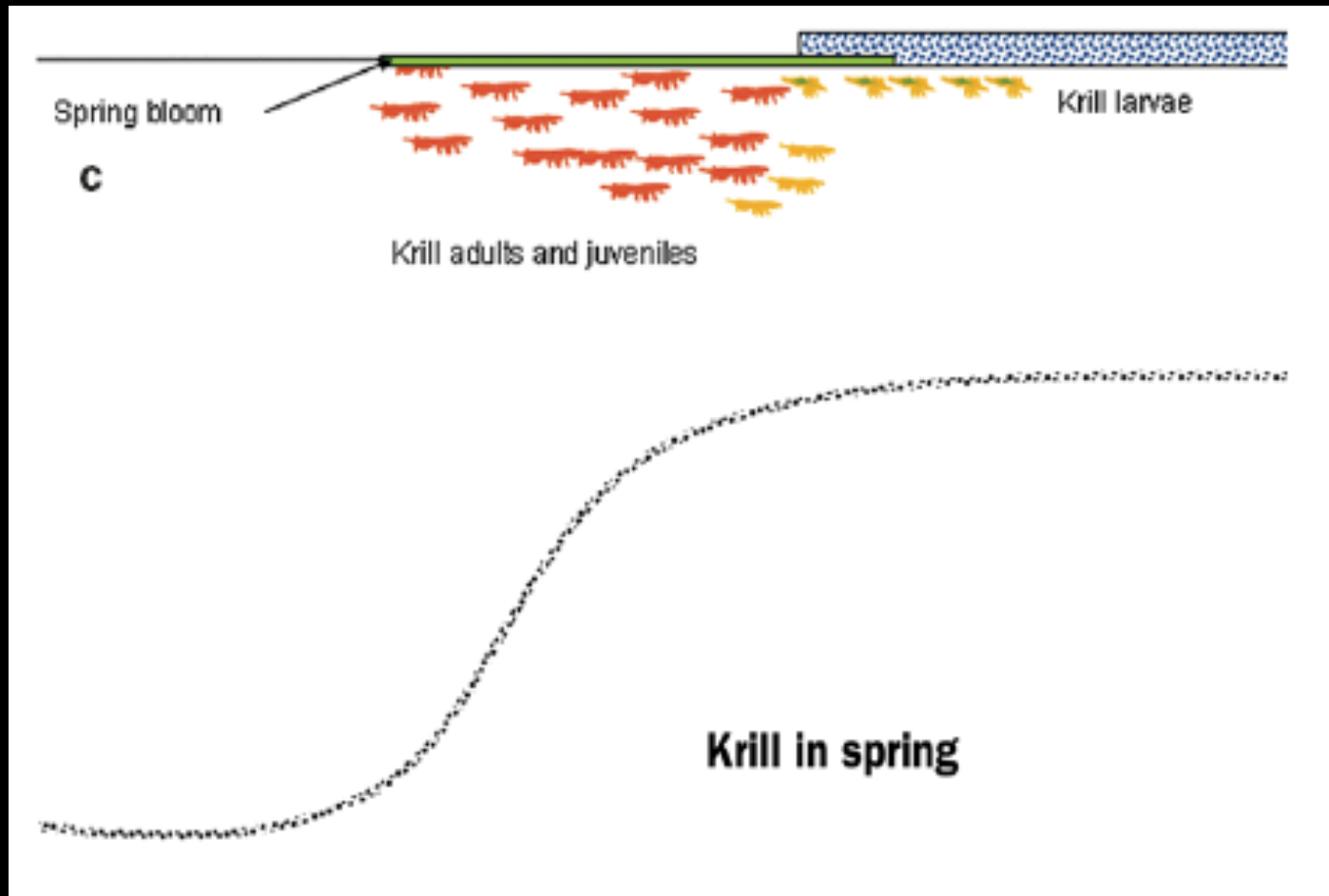


500 humpback whales
~2.3 million tonnes of krill



300 humpback whales
~1.2 million tonnes of krill

Krill life cycle & seasonal movement

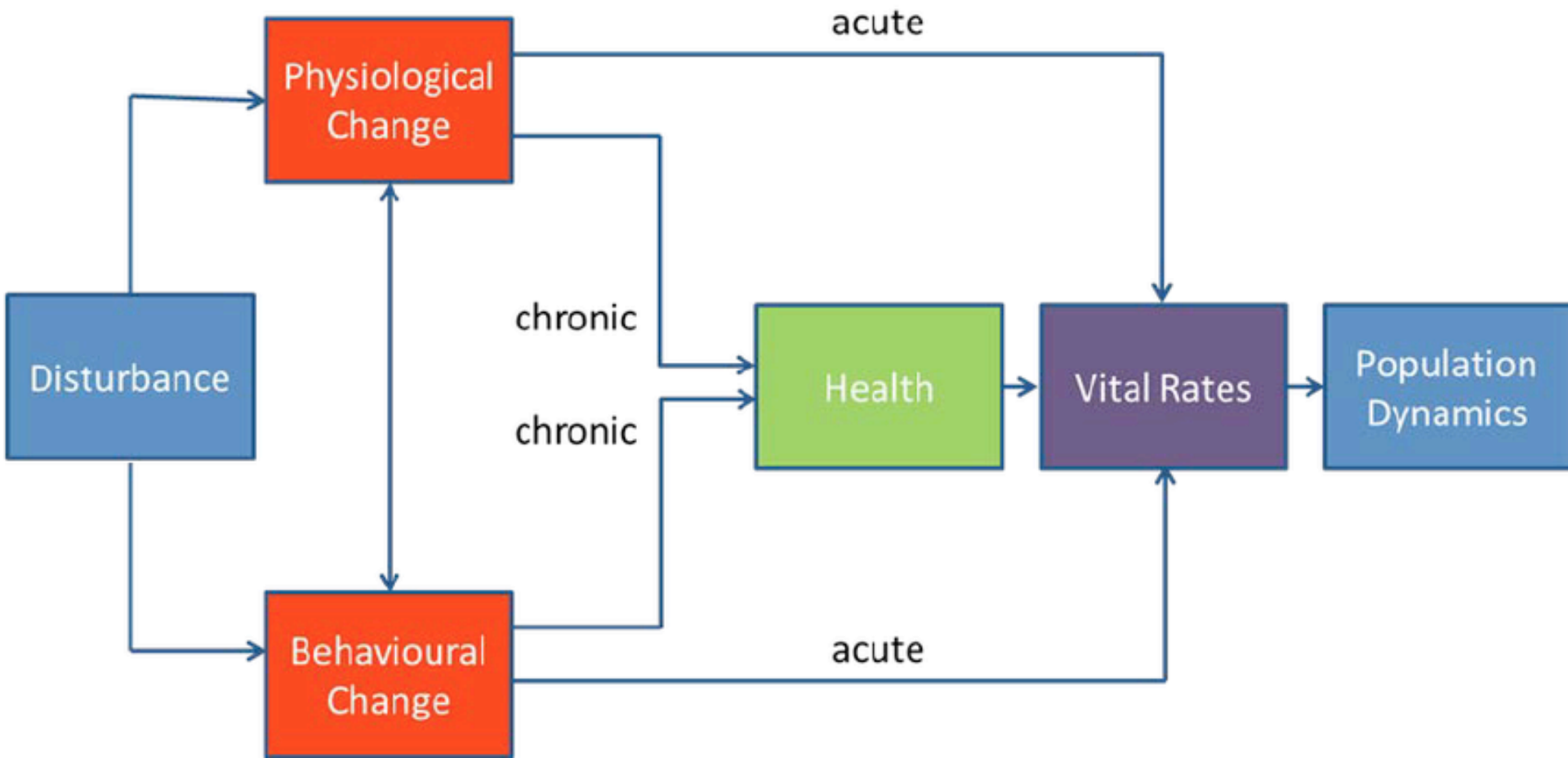


The four stages of marine animal movement

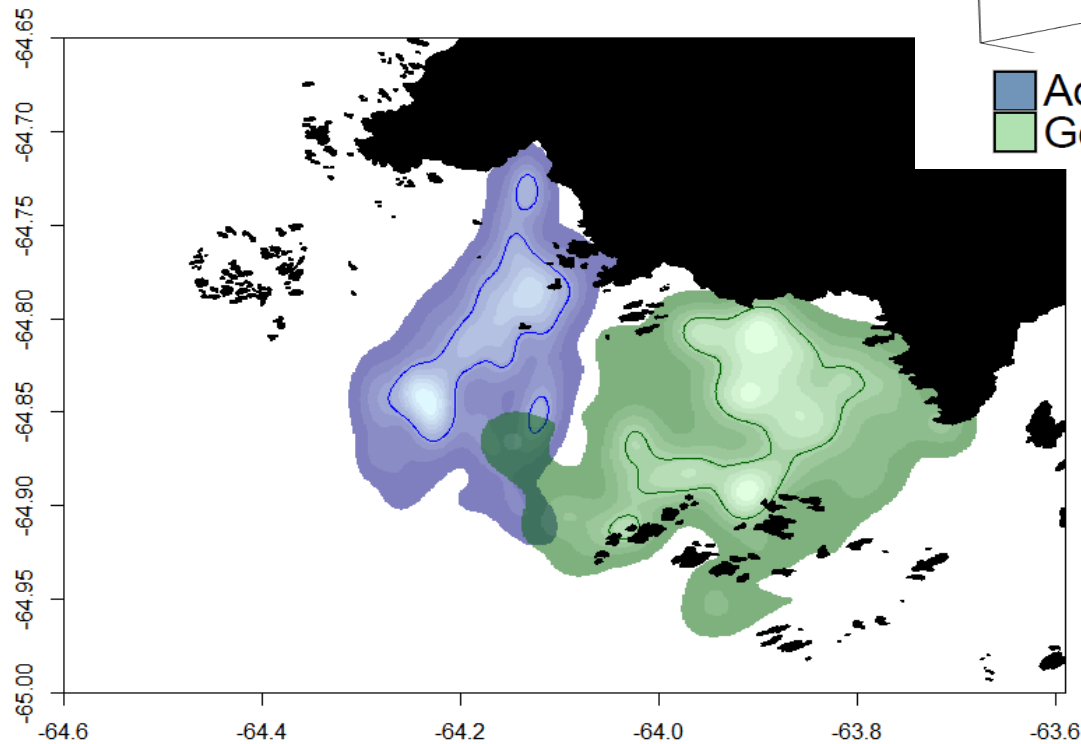
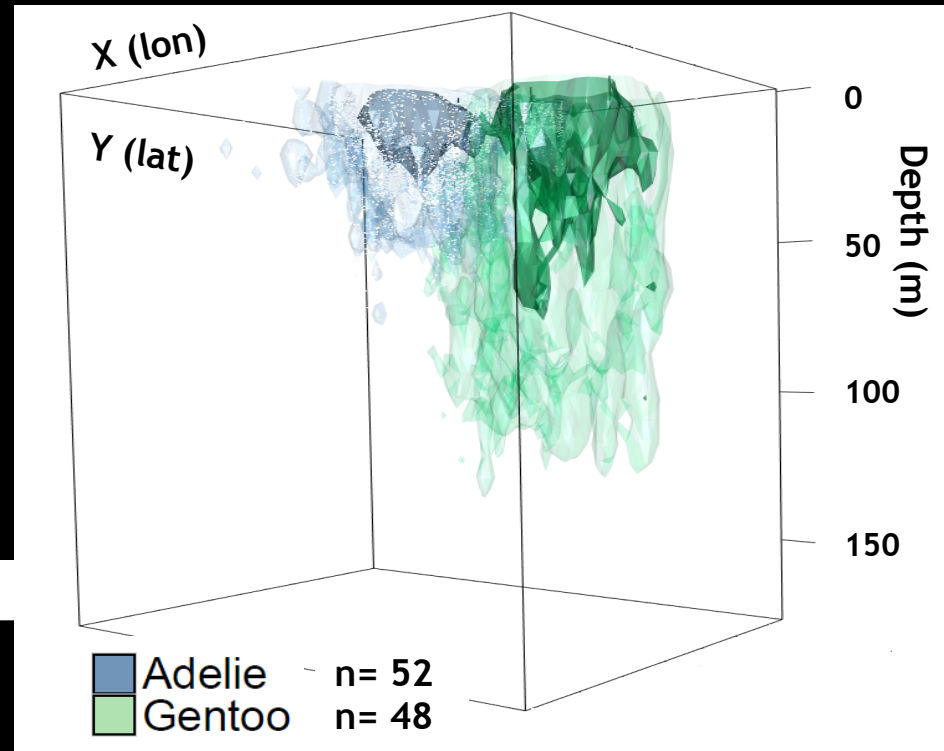
1. Where are the animals? What are they doing?
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3. Is their behavior related to the environment?
4. What are the consequences of environmental change on animal distribution, behavior, populations?

Assessing the impacts of change: PCOD Bio-energetic Model

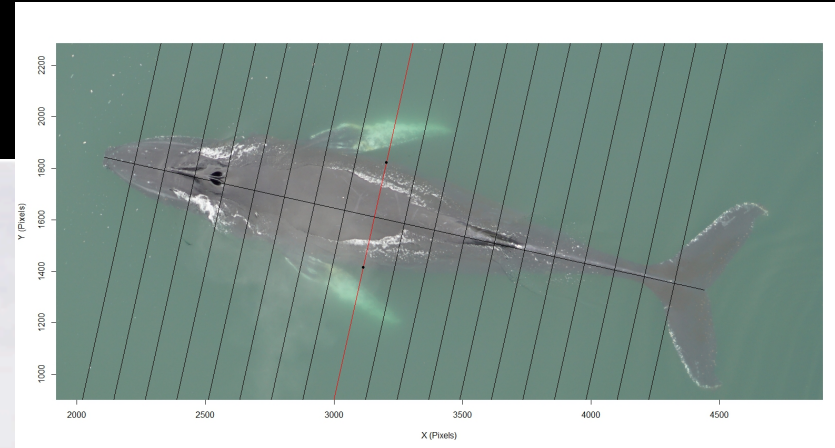
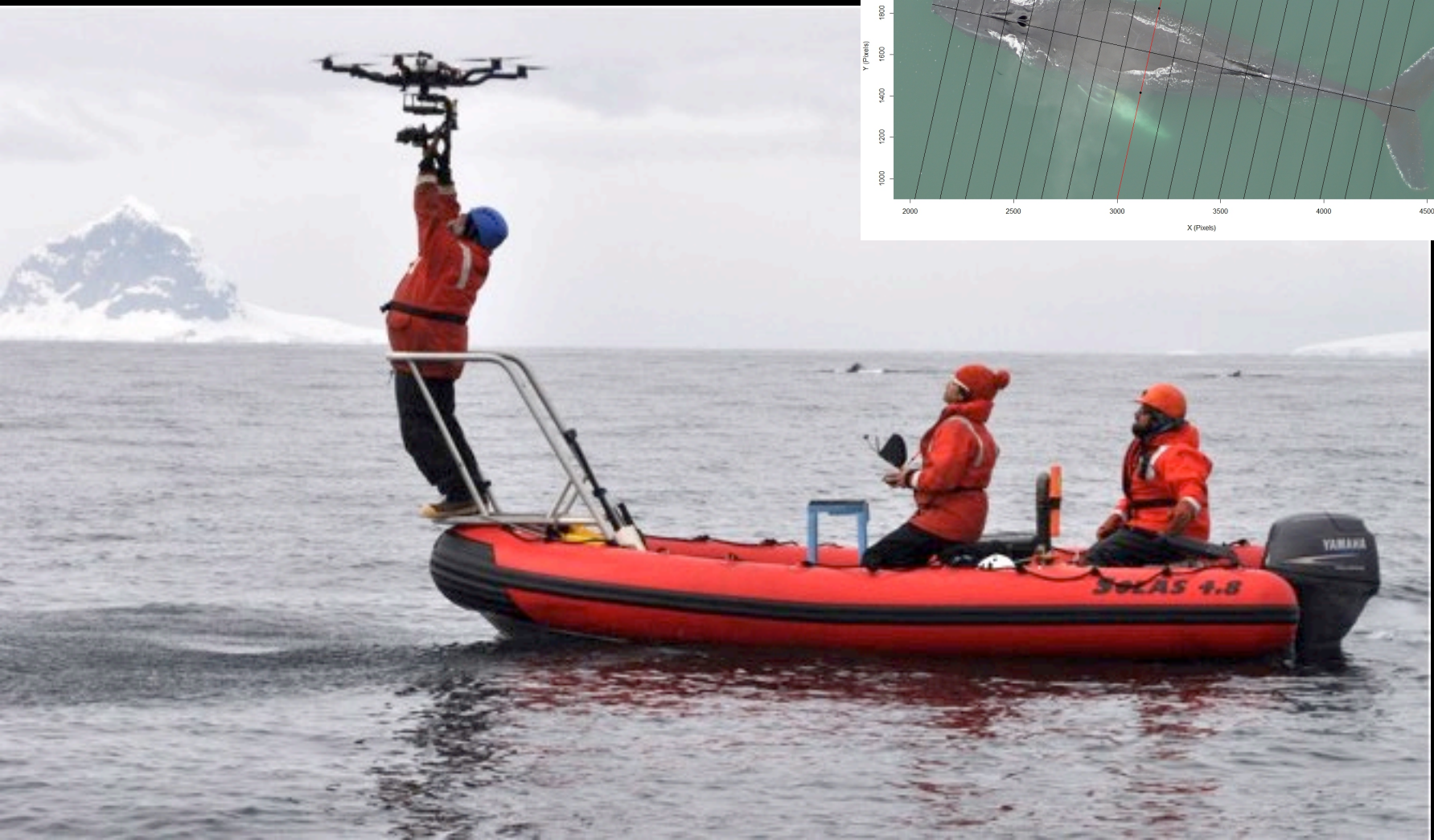
Villegas-Amtmann et al. 2015



Spatial overlap With krill predators and potential for competition (including seals...)



Seasonal/Interannual Changes in Body Condition



Seasonal Changes in Body Condition



Summer



Fall

Interannual Changes in Body Condition



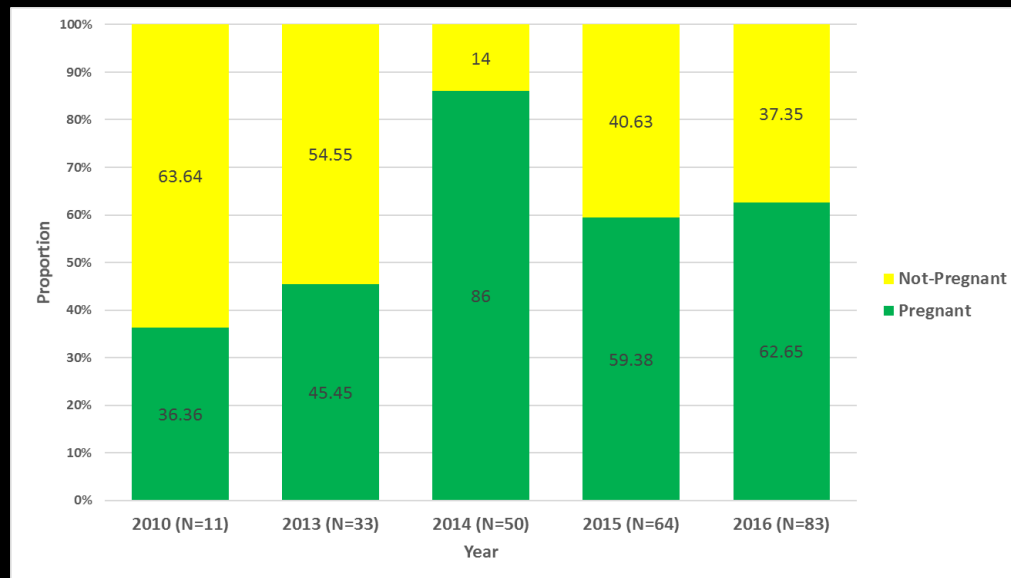
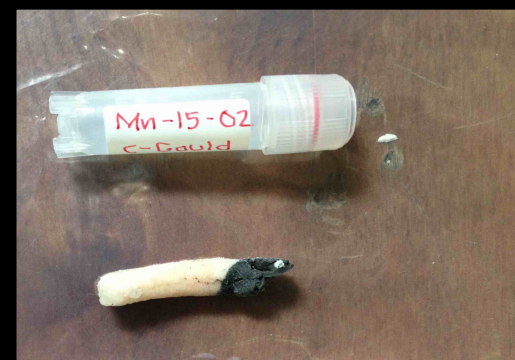
Summer



Fall

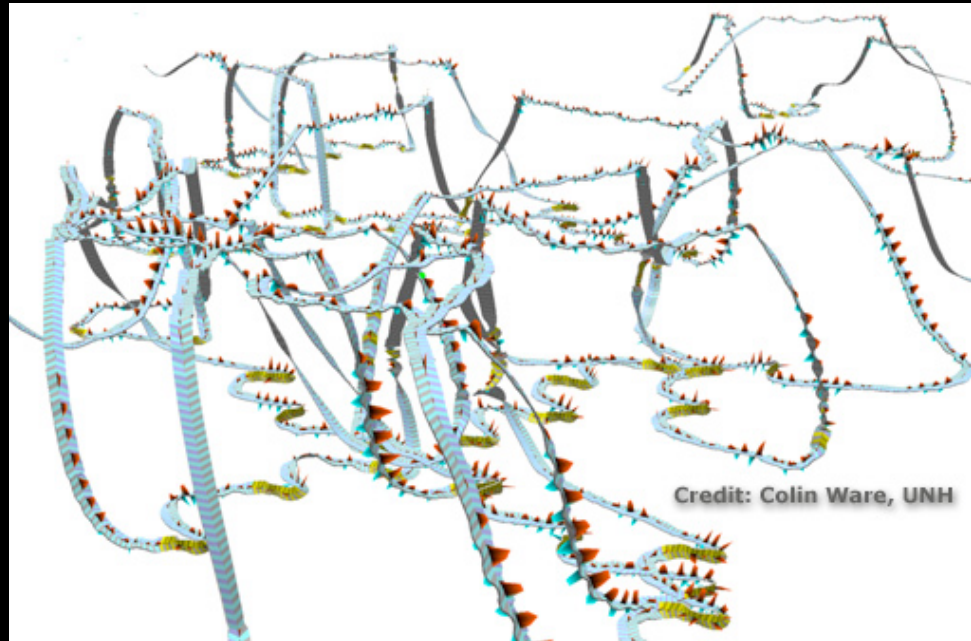
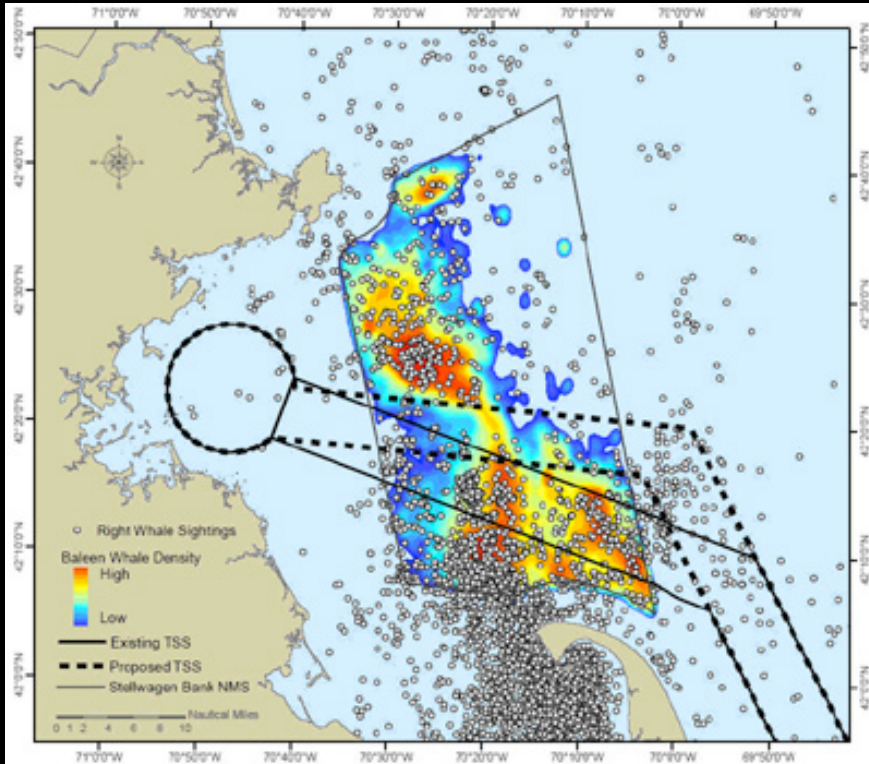
Linking change to demography

	Summer	Fall	Chittleborough 1958
Not pregnant, no calf	29.80%	25.60%	8.50%
Pregnant, no calf	49.70%	60.50%	71.30%
Not pregnant, with calf	11.80%	2.30%	11.70%
Pregnant, with calf	8.70%	11.60%	8.50%
% Pregnant	42.40%	83.30%	42.11%
Total	n = 161	n = 86	n = 94



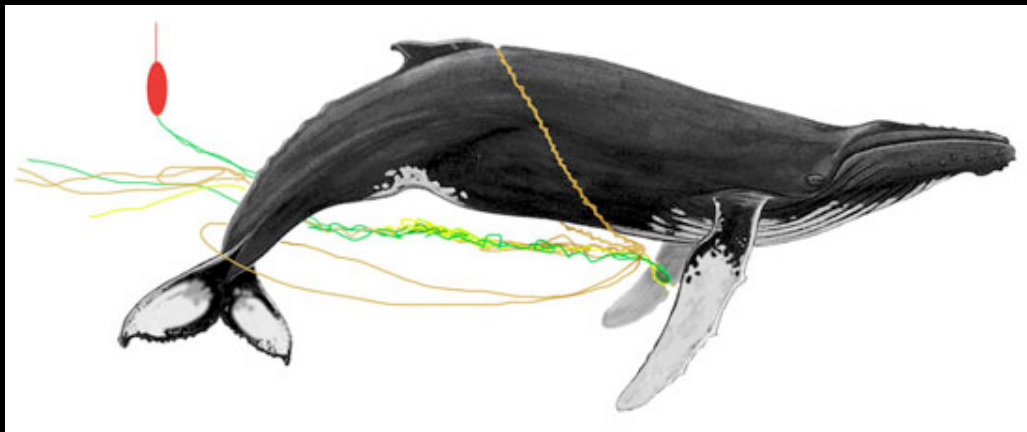
So What?

Conservation



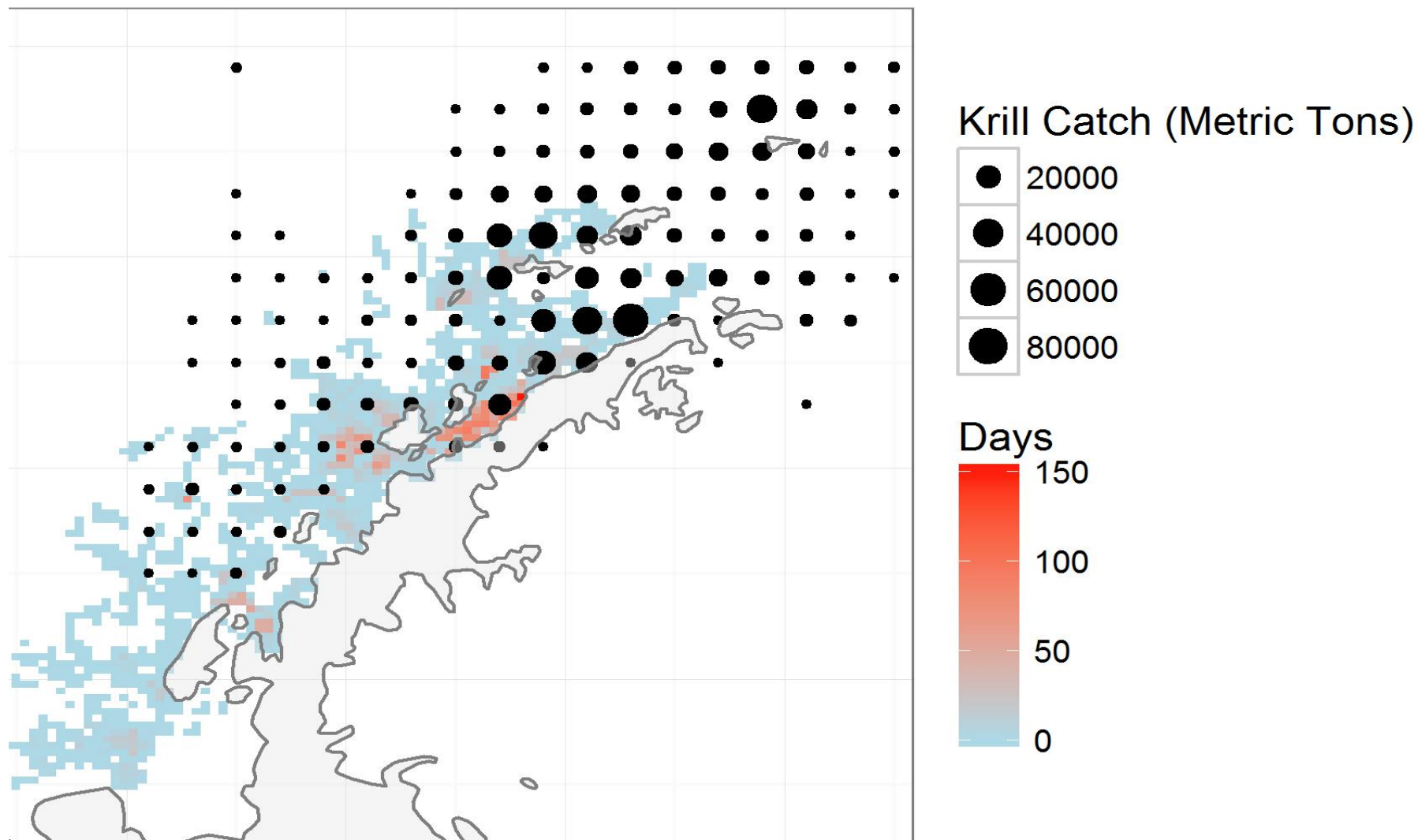
Human-Whale Interactions

- Entanglement in fishing gear
 - Bottom set lines
 - mid-water nets

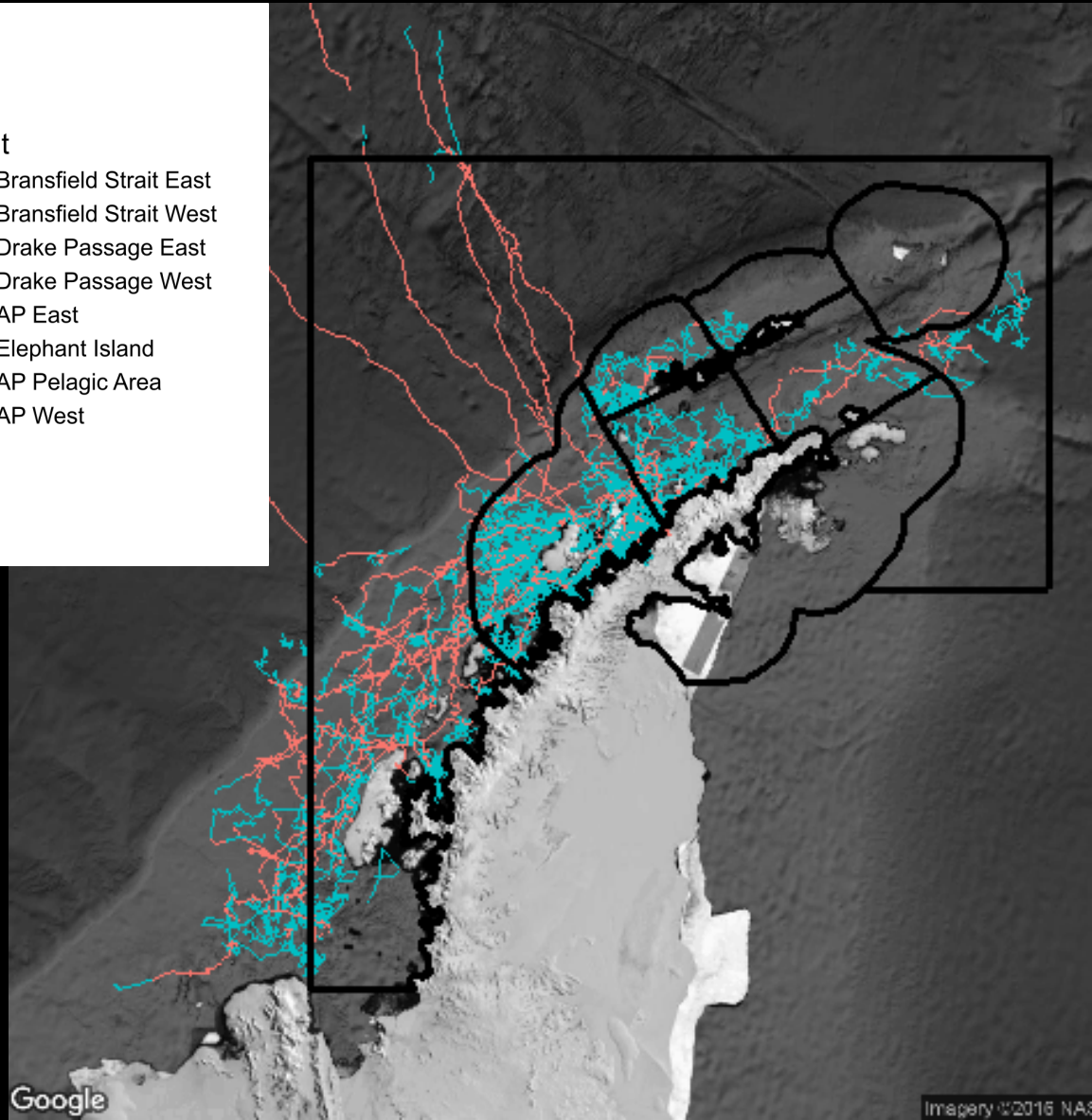
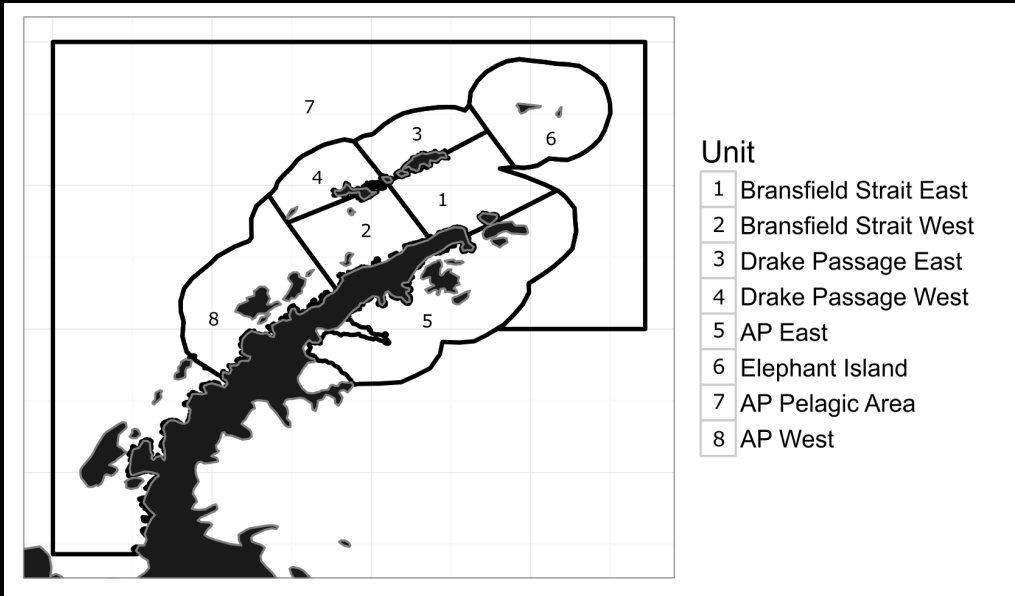


Overlap with Krill Fisheries

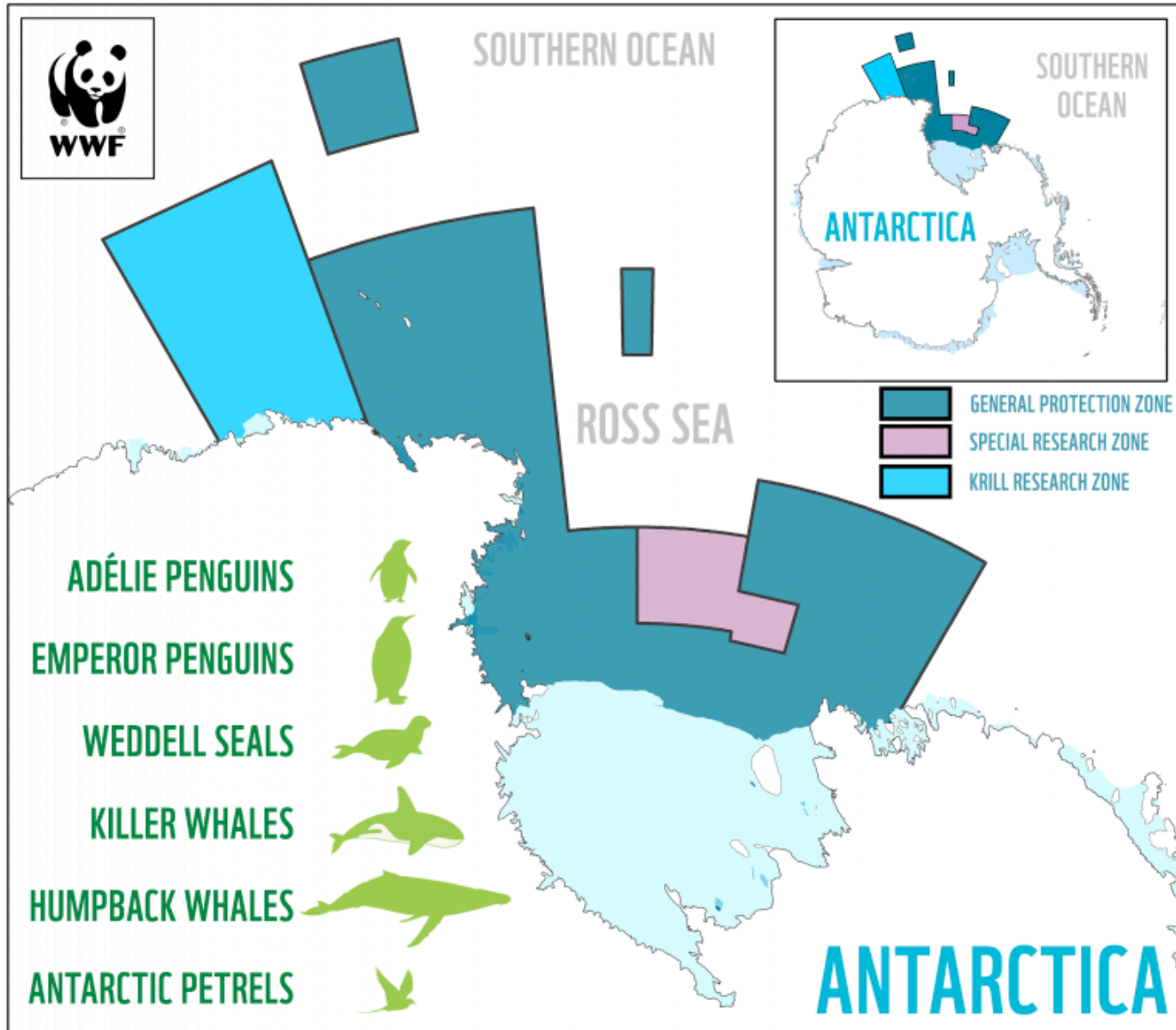
Area-restricted Search



Overlap with Krill Fisheries



ICONIC ANTARCTIC SPECIES PROTECTED!



1,550,000 KM² OF ROSS SEA PROTECTED

International Court of Justice

