

Suction cup high-resolution tags for cetaceans

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Advantages of archival suction cup tag technology

- Non-penetrating attachment to the epidermis without direct injury or risk of infection
- When whales notice the tag due to placement, they can shed the tags
- Attachment for short-term high-resolution acoustic or video tags to enable recovery of the tags for data recovery
- Reusable tag technology reduces the overall cost
- Programmable release times facilitate recovery
- Data collection can be maximized by deploying more tags



Main limitation to suction cup tag technologies

- Attachment times are variable (from hours to days) due to cup performance, skin condition and behavioral state



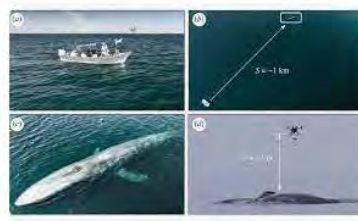
MDPI
Asset Tracking Whales ...



Discovery of Sound in the Sea
Passive Acoustic Recording Tags ...



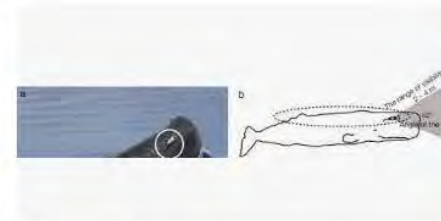
American Museum of Natural History
How to Tag a Whale | AMNH



Phys.org
use drones to affix suction cup tags ...



ResearchGate
digital tag to a surfa...



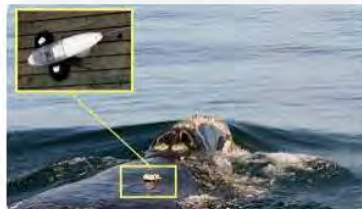
ResearchGate
tag deployed on a sperm whale ...



Ocean Alliance
SnotBot® Goes Tagging - Ocean All...



NOAA Fisheries - National Oceanic and Atm...
endangered North Atlantic right whales ...



Smithsonian Ocean - Smithsonian Institution
Whale Tracking Device | Smithsonian Ocean



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How to Tag a Whale | AMNH



The New York Times
Video Camera to a Humpback Whale ...



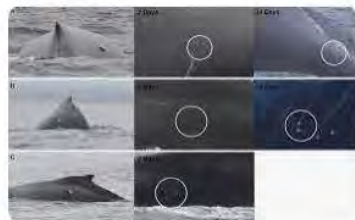
Griffith News - Griffith University
GPS suction tracker puts wh...



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use drones to affix suction cup tags ...



NOAA Fisheries - National Oceanic and Atm...
Lost Tag with Vital Killer Whale ...



ResearchGate
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pilot whale using a suction...



Ocean Alliance
SnotBot goes tagging...



NOAA Fisheries - National Oceanic and A...
Drone Tagging North Atlantic Right ...

History of suction cup tag technology

1981 – Deployment of suction cup time-depth recorders deployed by Goodyear

1998 – Crittercam – short-term time-depth/audio/video tag deployments on a range of cetacean species developed by Marshall/National Geographic

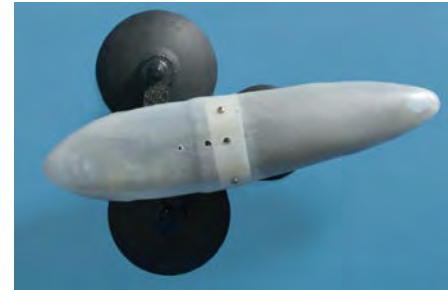
1999 - First high resolution archival acoustic and movement tags (Dtags) developed by Johnson & Tyack deployed on North Atlantic right whales

2000 - First Dtags deployed on deep diving sperm whales

2015 - First suction cup high resolution archival video and movement tags (CATS) deployed on humpback whales

Dtags

Version 1



1999

Version 2



2001

Version 3



2010

Version 4



2016

CATS Tag



Design and Development of Suction Cup Tags

Improve Tag Design

Users in the Field

Maintain Pool Tags

Tag Pool

NSF

livingmarine RESOURCES

NAVY READINESS

University of St Andrews

UNIVERSITY OF MICHIGAN

Fisheries and Oceans Canada

NAVFAC
Naval Facilities Engineering Command
ENGINEERING AND EXPEDITIONARY WARFARE CENTER

Office of Naval Research
ONR
Science & Technology

WOODS HOLE OCEANOGRAPHIC INSTITUTION
1930

UNIVERSITAS ARHUSIENSIS

S

Compression, Neutral Height, Tension, Static, About to slide, Dynamic

2000 I 3A

NSF logo: A blue globe with a gear-like border and the letters 'NSF' in white.

livingmarine RESOURCES logo: A blue circular logo with an anchor and the text 'livingmarine RESOURCES'.

NAVY READINESS logo: A blue circular logo with an anchor and the text 'NAVY READINESS'.

University of St Andrews logo: A shield-shaped crest with a red lion and a book.

UNIVERSITY OF MICHIGAN logo: A large yellow letter 'M'.

Fisheries and Oceans Canada logo: A red and white Canadian flag.

NAVFAC logo: A blue logo with a compass rose and the text 'NAVFAC Naval Facilities Engineering Command ENGINEERING AND EXPEDITIONARY WARFARE CENTER'.

Office of Naval Research logo: A blue oval logo with an anchor and the text 'Office of Naval Research ONR Science & Technology'.

WOODS HOLE OCEANOGRAPHIC INSTITUTION logo: A circular logo with a sailboat and the text 'WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930'.

UNIVERSITAS ARHUSIENSIS logo: A circular logo with an anchor and the text 'UNIVERSITAS ARHUSIENSIS'.

S logo: A large orange letter 'S'.

Technical diagrams: Six diagrams showing suction cup tags under different force conditions: Compression (upward force F_P), Neutral Height (upward force F_P), Tension (upward force F_P), Static (rightward force F_D), About to slide (rightward force F_D), and Dynamic (rightward force F_D).

Flow diagram: A central circular flow diagram with four nodes: 'Improve Tag Design' (top, blue), 'Users in the Field' (right, yellow), 'Maintain Pool Tags' (bottom, green), and 'Tag Pool' (left, red). Arrows connect these nodes in a clockwise cycle. A large arrow also points from 'Tag Pool' to 'Users in the Field'.

Field images: A map of the United States with several small images of fish and people, representing users in the field.

3D model: A 3D model of a suction cup tag with a yellow-to-red color gradient, showing its shape and the suction cup.

Flow visualization: Three cross-sectional images of a suction cup tag showing the flow of water around it, with a color gradient from yellow to red.

Tag pool: A grid of 15 suction cup tags arranged in 3 rows and 5 columns.

Field equipment: An orange suction cup tag and a black camera, representing equipment used in the field.

Tag Deployment: Cantilever and Hand Poles

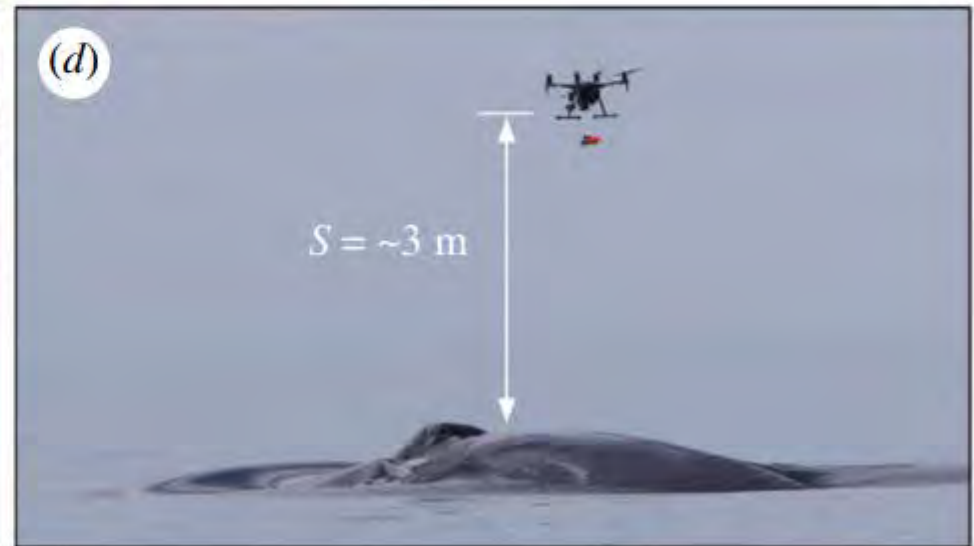
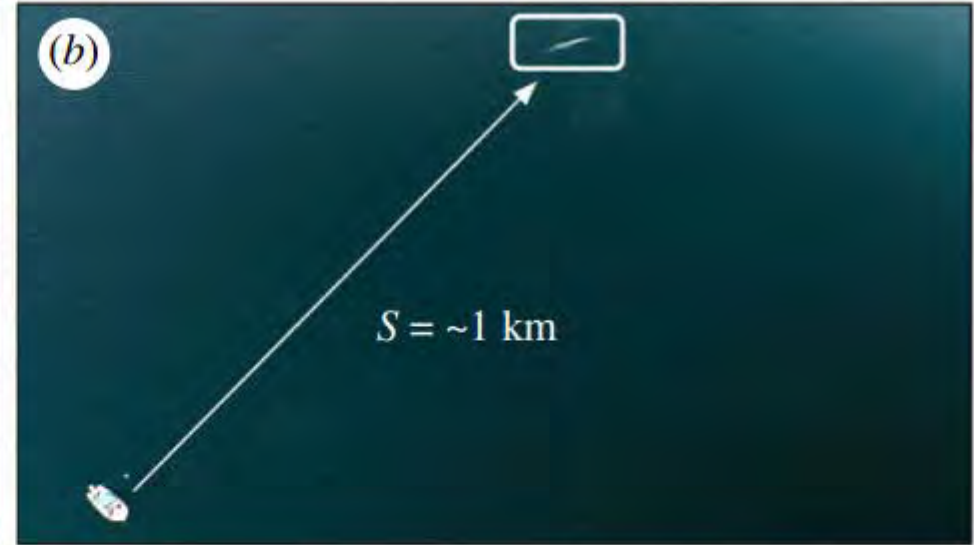


Tag Deployment: Uncrewed Aerial Vehicles

video content removed by MMC due to pdf upload size restrictions

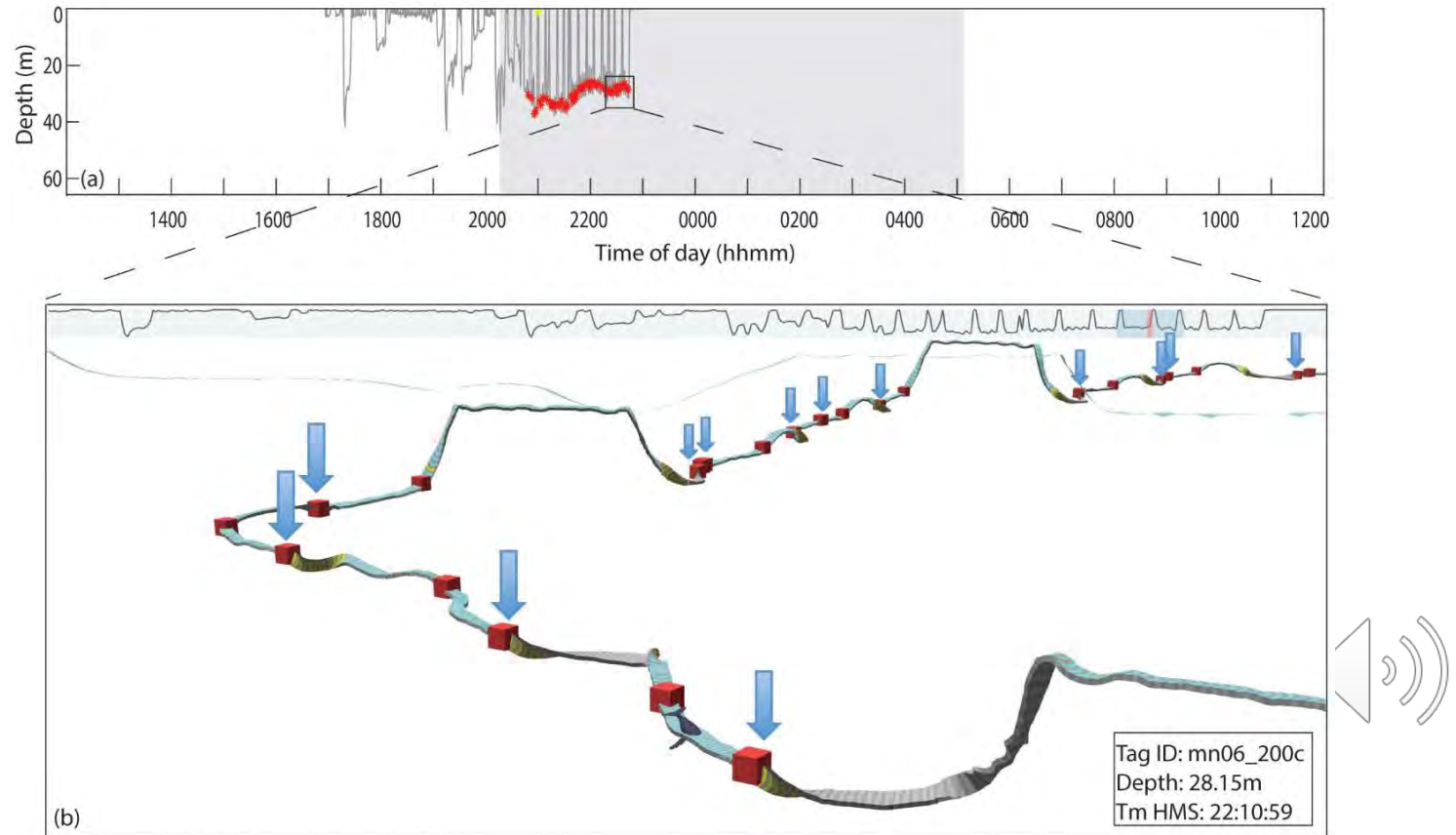


Tag Deployment: Uncrewed Aerial Vehicles



Behavior: *Fine Scale Movement and Acoustics*

- Synchronous orientation, position and environmental acoustic or video data
- High data volume audio, video and movement sensor datasets
- Designed for shortdeployments (hours – days)



Acoustic tags collect synchronous orientation, position and environmental data to provide context to the observed behaviors

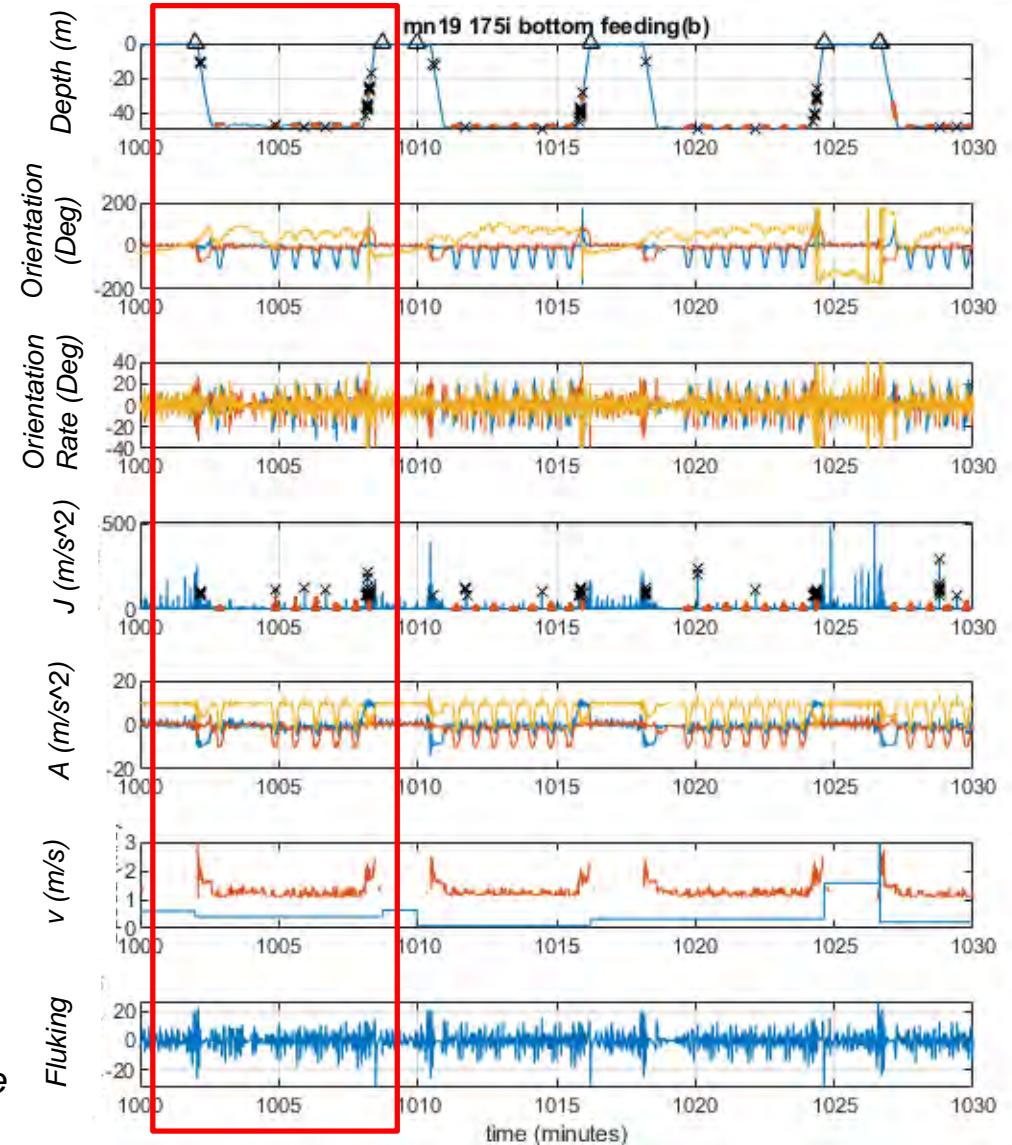
Behavior: *Fine Scale Movement and Video*



Humpback Whale Foraging

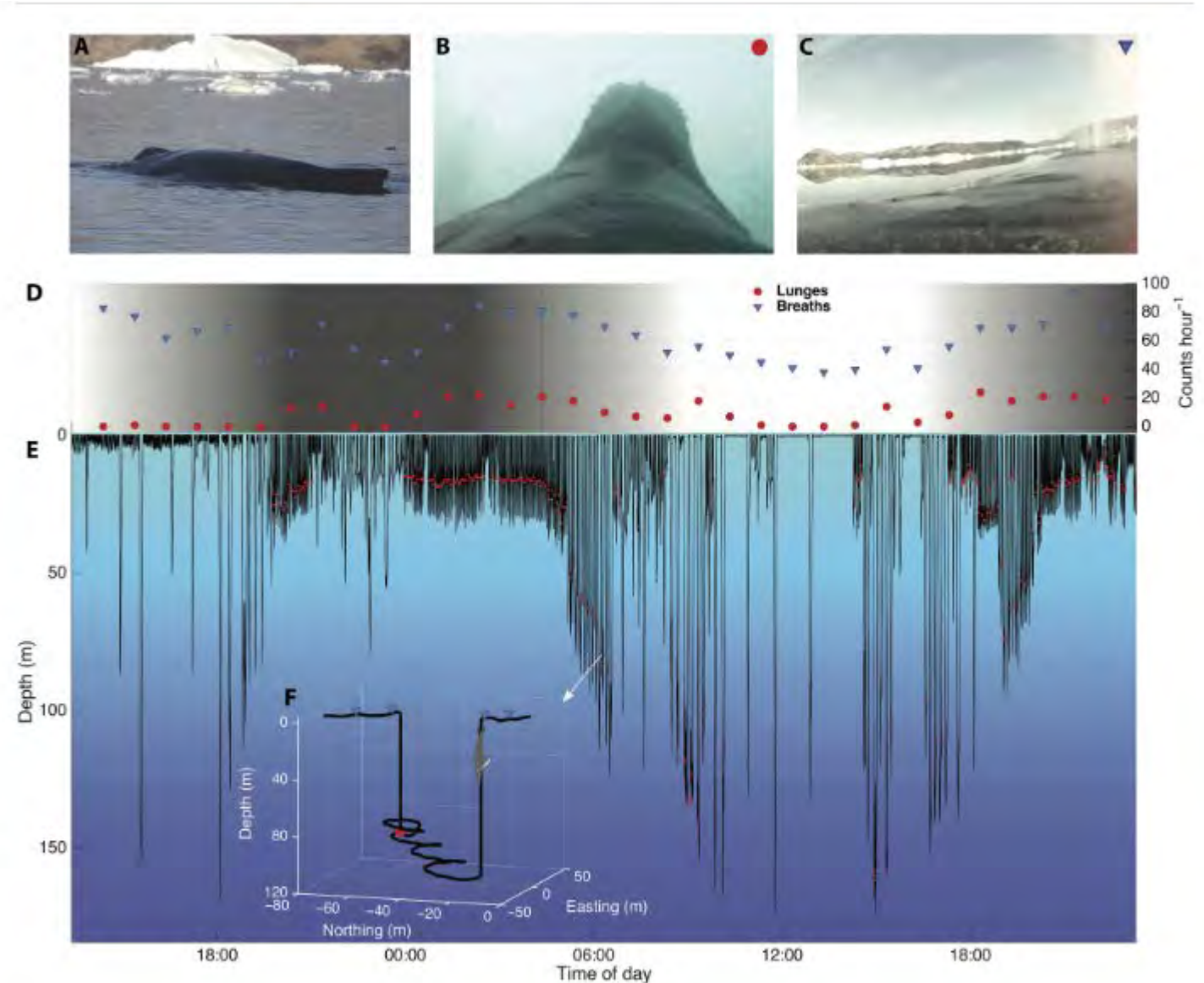


Ware, Colin, et al. "Bottom side-roll feeding by humpback whales (*Megaptera novaeangliae*) in the southern Gulf of Maine, USA." *Marine Mammal Science* 30.2 (2014): 494-511.



Insights only possible from acoustic/video tag data

- Direct observation of predator/prey interactions
- Detailed context, call types and call rates of sub-surface sound production to inform passive acoustic monitoring
- Behavioral response to sounds in the environment
- Subsurface behaviors and behavioral interactions



Right whale suction cup tag discoveries

Response to disturbance

Nowacek et al. 2001, Johnson & Tyack 2003, Nowacek et al. 2004, Parks et al. 2011, Christiansen et al. 2020

Passive acoustic monitoring

Matthews et al. 2001, Parks et al. 2012, Parks et al. 2019a,2019b, Nielsen et al. 2019, Dombroski et al 2020.



Foraging

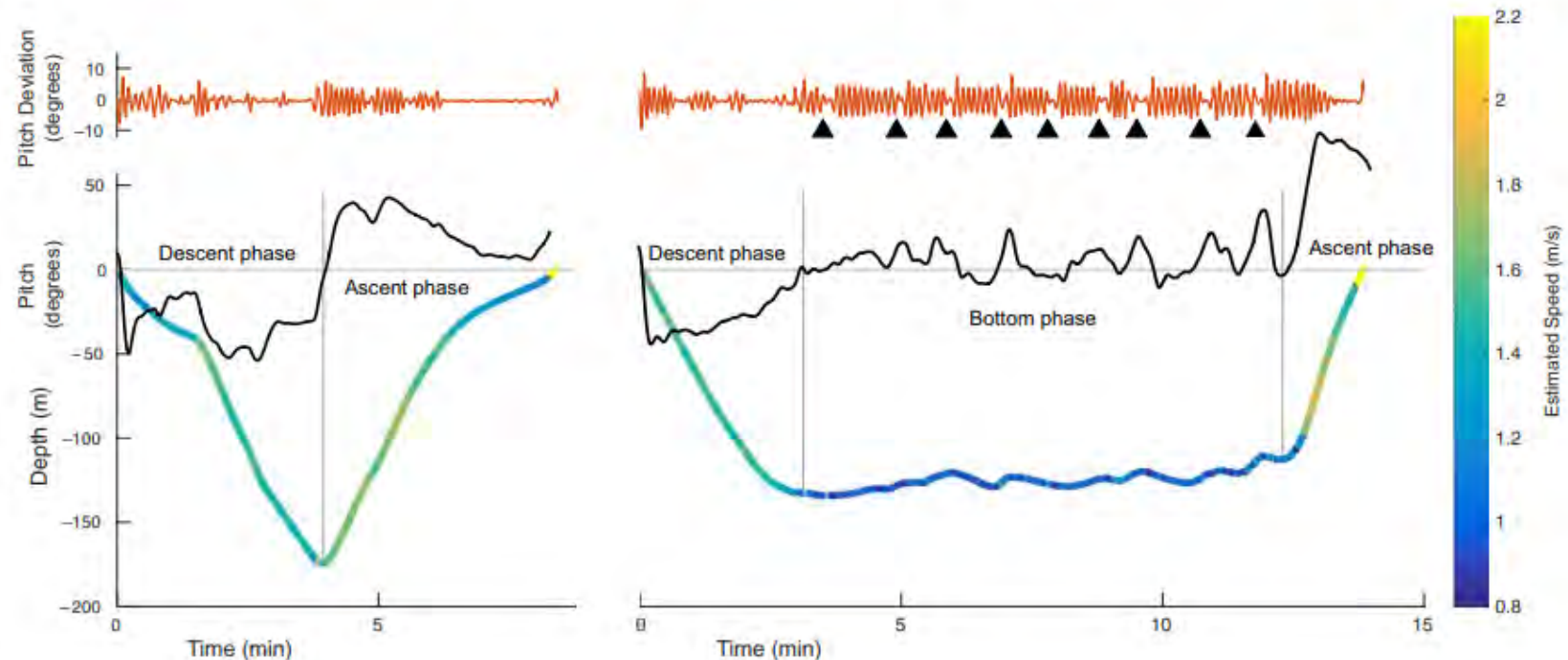
van der Hoop et al. 2019, Parks et al. 2012

Health

van der Hoop et al. 2014, Nousek-McGregor et al. 2014, van der Hoop et al. 2017

Behavioral Ecology

Root-Gutteridge et al. 2018, McCordic et al. 2016



Van der Hoop, J. M., Nousek-McGregor, A. E., Nowacek, D. P., Parks, S. E., Tyack, P., & Madsen, P. T. (2019). Foraging rates of ram-filtering North Atlantic right whales. *Functional Ecology*, 33(7), 1290-1306.

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