October 9, 2013

Northern Elephant Seal

2nd Technical Research Paper Converted to Docent Friendly Summary Status

The following is a docent friendly summary of a Northern Elephant Seal (Mirounga augustirostis) Research Paper:

1. **a. Title of paper:** Three-dimensional resting behavior of northern elephant seals: drifting like a falling leaf

   b. Date of paper: published online 28 October 2009 doi: 10.1098/rsbl.2009.0719, Research done at Año Nuevo Apr & Nov 2005

   c. Authors: Yoko Mitani, Russel D. Andrews, Katsufumi Sato, Akiko Kato, Yasuhiko Naito and Daniel P. Costa

2. **a. What is this paper about:** This paper addresses the question of when and how northern elephant seals rest during their long migrations. Drift dives, characterized by a lower than average descent speed, are believed to be a resting dive. Previous studies of drift dives analyzed only two dimensions (left-right and head-tail), and offered no insight into the biomechanics of the drift dive. This paper analyzed drift dives of six Año Nuevo juvenile elephant seals. The seals were fitted with special three-dimensional motion-sensing devices that measured the seal's body position and three-dimensional diving path. The three dimensional measurements found that after an initial phase of rapid descent, the negatively buoyant seals rolled on their backs to belly up positions (ventral) and sank during the drift phase "wobbling periodically so they resemble a falling leaf." This drift pattern enabled the seals to slow their descent rate so they can rest without ending "up in the abyss" and to reduce the caloric expenditure to return to the surface. The "falling leaf" descent time allows time to rest, process food, or possibly sleep. Two seals during the belly up drift phase hit the sea bottom and did not react to contact with the sea floor. Reduced responsiveness to external stimuli is used as a behavioral criterion for sleep, and the lack of response to the sudden shock of hitting the sea bottom in the falling leaf phase suggests that this could be not only a rest phase but actually a sleep period. Because the falling leaf drift phase always started around 135 meters, the drift phase of the drift dive also provides a rest period at depths where the seals are less susceptible to predation.

   (Note – this is an excellent (and short) article, and we highly recommend reading it!)

3. **Why is this paper of interest to docents:** Año Nuevo visitors frequently ask when elephant seals sleep during their long migrations. Researchers have asked the same question. This paper provides significant new insights into how elephant seals rest at sea. Drift dives have been thought to be a resting/food-processing dive but there was little data on what actually happens during the drift dive, specifically during the middle drift phase. This paper found during the drift phase, the seals roll over on their backs, stop stroking and drift downward like a "falling leaf" to rest in the deep ocean. Resting in deep water has the added benefit of protecting the seals from near-surface predators. More than just establishing the drift dive as a rest dive, the results suggest the falling-leaf drift phase may be when elephant seals sleep.

4. **a. Background:** Most pinniped species spend considerable time onshore free from predators. Northern elephant seals with their long distance migrations lasting 2 - 8 months do not haul out. At sea, they spend 80 – 90% of their time underwater with only 2 – 3 minutes breathing intervals at surface between dives that average 20 minutes. Researchers have suggested that elephant seals do not rest at surface and instead may rest during deep dives that minimize energy expended through locomotion. Drift dives are one of the dive types that are thought to be food processing and/or resting dives. Drift dives include a rapid descent phase (C1), followed by a prolonged phase of slower descent (C2), ending with a fairly rapid ascent to the surface (C3). This pattern can be seen in ***Figure 1a* – Speed & Depth** at the end of this paper. It was initially thought that animals switched from active swimming to passive swimming at the start of the drift phase but a previous study of flipper stroke recordings from an animal borne video camera suggested that negatively buoyant seals stop stoking long before the C2 drift phase begins. Two-dimensional studies of drift dives did not explain why the rate of descent slowed and did not provide insight into the biomechanics of seals during the drift phase.

   b. Motivation: Researchers theorize that elephant seals rest during drift dives but could not pinpoint when and how. Researchers are also interested in drift dives to infer foraging success by comparing the vertical speed during the drift phase (C2) to determine whether the seals are changing their body composition and therefore their buoyancy. This study examined the behavior of seals during drift dives by analyzing three-dimensional diving behavior, stroking activity and body position to determine what causes the change in descent rate and gain insight into the function of the drift dive.

   c. Method: In April and November 2005, six juvenile northern elephant seals were captured at Año Nuevo State Reserve, California, and fitted with a data logger containing speed, depth, temperature and tri-axial acceleration as well as magnetometry sensors (three-dimensional data logger), and satellite transmitters. The seals were released in Monterey Bay, and when they returned to land, data loggers were retrieved. Data were analyzed for diving behavior including flipper stroking rate and three-dimensional movement. Drift dives were defined using swim speed and depth data as dives where the C2 drift phase was more than 40% of the total dive duration, had constant descent with low vertical speed (< 0.4 meters), and continuously low swim speed (<0.5 meters).

   d. Results: 45 drift dives were identified from the 4 of the 6 juveniles. Mean depth was 373 meters; mean duration was 23 minutes. **Figure 1a**, at the end of this paper, presents results of behavioral sequence dive analysis using 7 different measures (7 legends). At the beginning of the drift dive, seals dove almost vertically, stroked continuously, and increased to maximum swim speed. While still in the descent phase (C1), they next slowed swimming speed. At a mean depth of 221m, they stopped stroking and begin a prolonged glide (C2) lasting an average of 11.6 minutes, which accounted for 50% of dive duration. In all drift dives, the seals rolled over from normal dorsal (belly down) to “belly-up” (ventral) position and maintained this position during the C2 drift phase. The “belly-up” and low speed swim phase started simultaneously in 43 dives and began at a mean depth of 267meters. During the belly-up C2 phase, almost no flipper strokes (0 – 4 per minute) were performed, and “the body wobbled slowly by pitching and yawing” in all drift dives. (**Figure 1b**). Almost as soon as the belly-up phase ended, the seals began to ascend.

4. a. Important take away information for docents.

- This study provides important new details about what happens during elephant seal drift dives and how the seals rest at sea during the drift dives
- The drift phase (middle phase) in drift dives:
    - Looks like a "falling leaf" dropped from a tree branch fluttering from side to side
    - Is characterized by the seal rolling onto its back belly-up (dorsal to ventral), positive pitch, and a lack of stroking
    - Function is not searching for food
- Function of belly-up posture is unclear, although if seals are not actively maintaining body position and could be unconscious, the thicker blubber layers on their ventral surface may cause the body to roll belly-up during the passive gliding
- The finding that seals hit bottom in the "falling leaf" phase without responding strongly suggests that the drift phase involves more than rest and could be when the elephant seal sleeps at sea
- While the number of animals included in the study and the total number of dives analyzed were small, the consistency of the belly-up (ventral) position with lack of stroking on all dives is a very robust finding
- The falling-leaf drift phase occurred at depths that protect the elephant seal from near-surface predators (Mean depth dive: Orca = 150m, White Shark < 50m) and after an initial high rate of descent that gets them out of the danger zone relatively quickly
- Rolling over on their backs to belly-up body position, the "falling leaf" drift phase, and seals appearing to "sleep" on the bottom are exciting findings to share with Año visitors

b. Interesting observations in the paper:

- "Falling leaf" dives were observed in clusters and are unlikely to function as prey searching since falling leaf drift dives peaked in the morning following shallow foraging dives during the night.
- The drift phase falling-leaf wobble trajectory was primarily circular (Figure 1b), but fluttering, combined circular and fluttering, and straight trajectories were also observed.
- By changing the pitch of their dive during the falling-leaf phase from nose down to positive, elephant seals increase their drag substantially and slow their descent dramatically to slowly drift down
- The slowed descent rate and belly-up posture prevents seals from drifting too deep and reduces the cost of ascent
- In unusual cases when elephant seals are positively buoyant, they drift up during the middle phase (C2).
- Drift-and-bottom-rest dives suggest that seals may not be alert during the falling-leaf phase
- With captive aquatic mammals, sleep is studied by recording electroencephalogram (EEG) and eye closure. This is almost impossible with deep diving mammals. An alternative definition of sleep uses behavioral criteria of a sustained period of quiescence in a species-specific posture or site with reduced responsiveness to stimulation. In this study, northern elephant seals showed inactivity with no flipper strokes and a stereotypical belly-up posture. They also displayed reduced responsiveness to stimulation in falling-leaf phase when they hit the bottom floor.

Figure 1

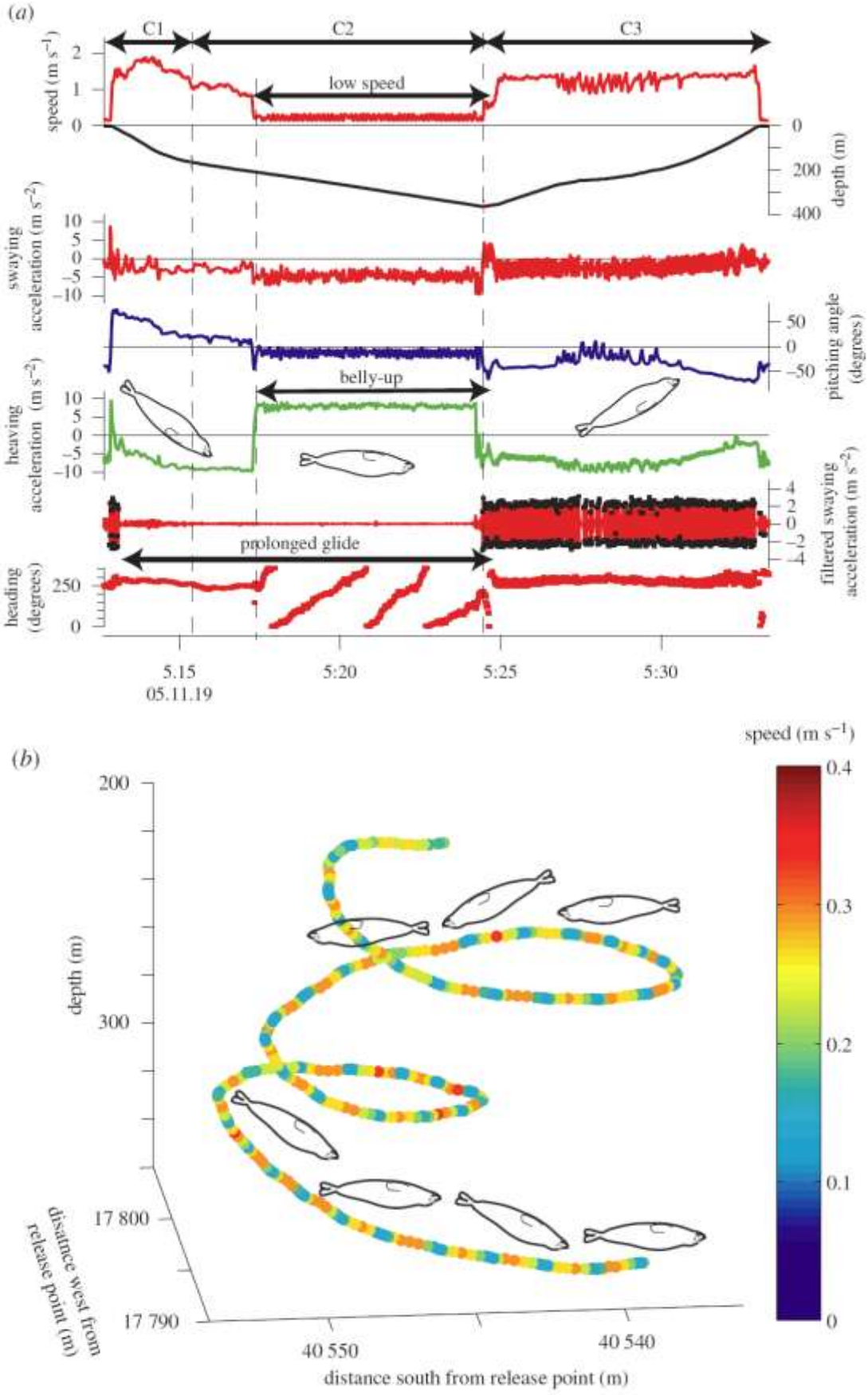
(a)
C1
C2
C3
low speed
speed (m s−1)
depth (m)
swaying acceleration (m s−2)
pitching angle (degrees)
belly-up
heaving acceleration (m s−2)
filtered swaying acceleration (m s−2)
prolonged glide
heading (degrees)
5.15
05.11.19
5:20
5:25
5:30
(b)
speed (m s−1)
depth (m)
distance west from release point (m)
distance south from release point (m)
17 800
17 790
40 550
40 540

Figure 1.

(a) Behavioral sequence and (*b*) three-dimensional trajectory during belly-up phase of a typical drift dive of northern elephant seal juvenile. Seals stroked regularly and dived vertically in the beginning of the drift dive. Filtered swaying acceleration showed that seals stopped stroking and began gliding down owing to negative buoyancy in the middle of C1 continuing through C2. When pitching angle turned positive, the low-speed and belly-up phase started. During this phase, the seals' body wobbled in a cycle of about 10 second duration.

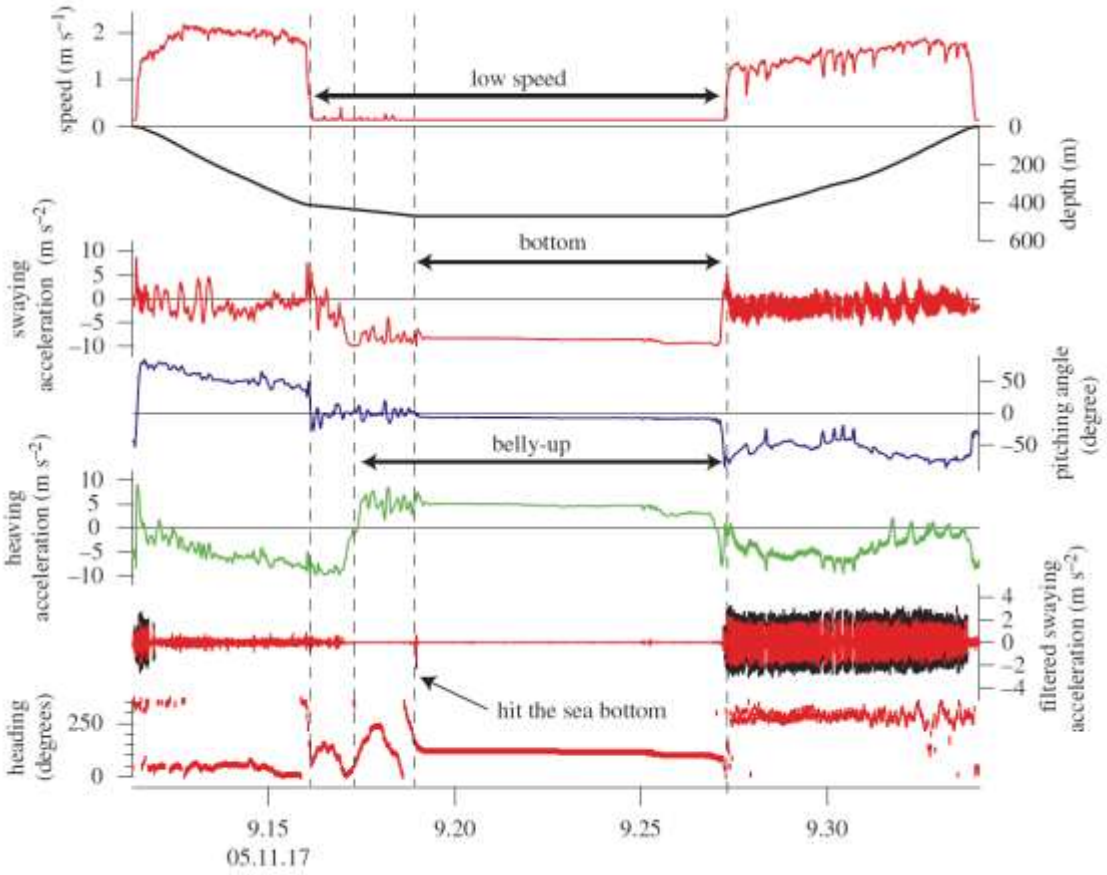

Figure 2.

Behavioral sequence of an 'additional dive'. During the belly-up phase, the seal hits the sea bottom and then remained immobile for over 5 min, suggesting that the seal may have been sleeping during the belly-up drift phase.