

SEARCH TACTICS OF ECHOLOCATING MALE SPERM WHALES IN A BIMODAL FORAGING MODE

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Four sperm whales were tagged in the Andøya Canyon (Andenes, northern Norway 69°25'N 15°45'E) with high resolution tags (DTAG) containing a hydrophone, a depth sensor, and 3-axis accelerometers and magnetometers (Johnson & Tyack 2003). Sounds were sampled at 96 kHz, while non-acoustic sensors were sampled at 50 Hz. Male sperm whales off northern Norway forage over a wide depth range (Teloni *et al.* 2008). Tagged whales displayed a dynamic foraging behaviour switching between shallow (maximum depth <300m), medium (300-1000m depth) and deep (>1000m depth) foraging dives (Fig.1). Here we study how sperm whales use their long-range biosonar to help select which depth to forage at.

HYPOTHESIS:

In a habitat offering multiple spatially segregated prey resources with differing cost-benefit tradeoffs, deep-diving predators may be opportunistic, spending time in any prey patch encountered as they pass through the water column, or they may plan foraging forays to maximize net gain. The long-range biosonar sensory system of sperm whales provides them, potentially, with the capability of examining the distribution of prey resources and planning dives from close to the surface before committing effort in diving. Here we test this hypothesis by comparing the production pattern of biosonar clicks to the depths at which prey are encountered.

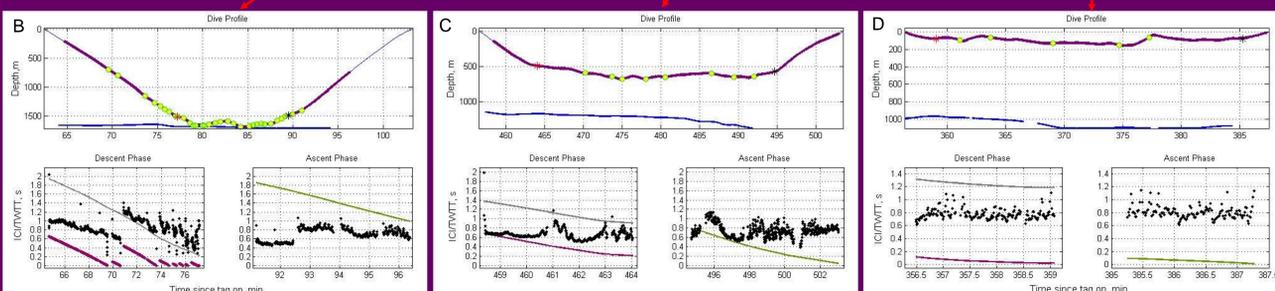
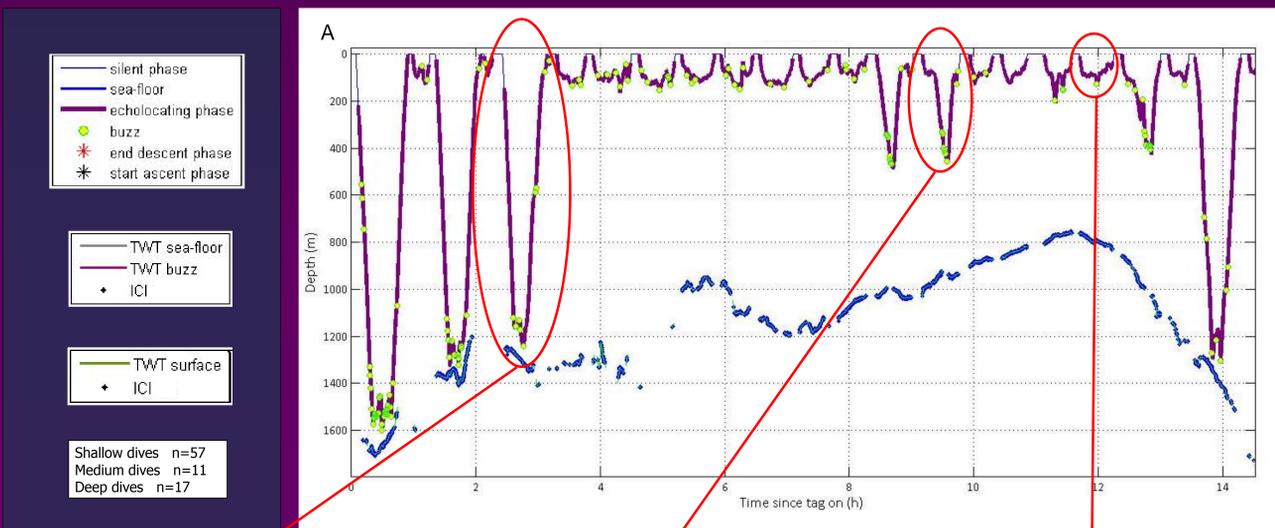


Figure 1: A) Dive profile from a tagged sperm whale showing shallow, medium and deep foraging dives. Whales emit usual echolocation clicks to search for prey and buzzes signal prey capture attempts. The depth of the sea-floor was derived from the two way travel time (TWT) of echoes from whale clicks. This TWT was multiplied by half of the speed of sound throughout the water column and the resulting bottom depths were interpolated using a Kalman filter / Rauch smoother. B, C, D) Examples of deep (B), medium (C) and shallow (D) dive (note the different scales). Top panels: detailed view of the occurrence of buzzes and distance to the sea-floor during the dives. Lower left panels: inter-click interval (ICI) of usual echolocation clicks ($0.22 \text{ s} > \text{ICI} < 2.5 \text{ s}$) produced by the whales since they start clicking until the end of the descent phase (e.g. first time whale's pitch becomes positive; signalled by a red cross in the dive profile). The TWT to the sea-floor and to the median buzz depth of the dive, in the case of shallow and medium dives, and to the following buzz depth, in the case of deep dives, are plotted with grey and red lines, respectively. Lower right panels: ICI of usual echolocation clicks produced by the whales since they start the ascent phase (i.e. from the time when the animal is last orientated downwards; signalled by a black cross in the dive profile). The TWT to the water surface is plotted with a green line.

Interpretation: The ICI shows little variation in shallow and medium dives ranging from 0.6 to 1s (some 450 to 750m maximum echo-target distance). In contrast, ICI in deep dives shows two modes: i) ICI adapts initially to the depth of the pelagic prey layer; ii) closer to the sea-floor, ICI adjust to the distance to the bottom, coinciding with the location of the benthopelagic prey targeted in these dives. Whales echolocate throughout the ascent with a stable ICI between approximately 0.6 and 1s (some 450 to 750m maximum echo-target distance), but emit few buzzes, suggesting a reduced foraging rate. Ascent clicking is unusual and has not been reported from studies of sperm whales (mostly nursery and bachelor groups) made at lower-latitudes.

CONCLUSIONS:

- Male sperm whales, in contrast to females, echolocate during the ascent phase of dives with few attempts to capture prey, suggesting that ascents are used to locate the food layer for the next dive.
- The variations in the start depth of searching for food using echolocation (Fig.2), and the inter-click intervals used (indicative of foraging ranges) (Fig.3) strongly suggest that sperm whales make foraging prediction/decisions before the start of each dive.
- The adjustment of the ICI during the descent phases (Fig.1) reflects the foraging choices pre-planned by the whales.
- The ICI of shallow and medium dives are not shorter than those of deep dives. Whales echolocating in the epipelagic and mesopelagic zones use a long-range ICI adjusted to find prey out to some 300-700 meters. In contrast, whales targeting benthopelagic prey adjust their ICI to the sea-floor/prey layer and seem to have shorter target ranges when close to the bottom.

PREDICTIONS:

- Whales will start searching for food (clicking) earlier in shallow dives than during deep dives and are not expected to click on the ascent (Fig.2).
- Inter-click intervals (ICI) at the beginning of the dives are expected to be shorter in shallow dives than in medium and deep dives, indicating an adaptation of the sonar search range of the whales to the location of the targeted prey layer (Fig.3).
- ICI in shallow and medium dives should be mostly stable because whales forage upon shallow, short range food layers. In contrast, ICI during the descent part of deep dives should decrease gradually as the whale approach the prey layer (Fig.1).

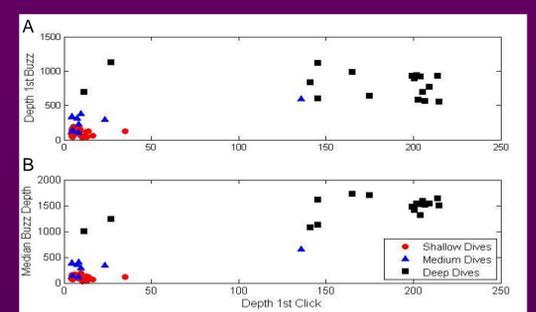


Figure 2: Depth of the first click emitted in the dives against the depth of the first buzz (A) and the median buzz depth (B), coloured by dive type. Whales start echolocating earlier in shallow dives, and do not search for food at all at epipelagic depths in deep dives. Whales leave the surface knowing if they will perform a deep or shallow dive.

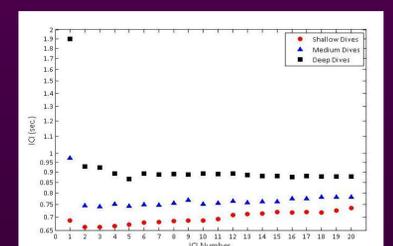


Figure 3: Mean inter-click intervals (ICI) for the first 21 clicks in the three dive categories. Whales tend to start searching for food using a lower ICI in shallow and medium dives. This is consistent with a shorter inspection range in shallow as opposed to deep dives.

Acknowledgements:

Thanks to the research team at Andenes for their help gathering the data. This work was funded in part by a grant from the Carlsberg Foundation to Bertel Møhl. NA is currently funded by a Marie Curie International Outgoing Fellowship within the 7th European Community Framework Programme.

References:

- Johnson M. & Tyack P.L. 2003. A digital acoustic recording tag for measuring the responses of wild marine mammals to sound. *IEEE J. Oceanic Eng.* 28, 3-12.
- Teloni V., Johnson M., Patrick M. & Madsen P. 2008. Shallow food for deep divers: dynamic foraging behavior of male sperm whales in a high latitude habitat. *J. Exp. Marine Biology and Ecology.*