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Small Scale Behaviour of Large Scale Subjects: Diving Behaviour of a Gray Whale (*Eschrichtius robustus*)

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*In August, 1994 we carried out a pilot study of gray whale (*Eschrichtius robustus*) diving behaviour. Using a recoverable time-depth recorder we successfully tracked the underwater behaviour of a single animal for 8hrs 21m. The data, detailing 651 dives of four different types, provides the first opportunity to analyze underwater activity in this species and adds the gray whale to the growing list of cetaceans whose dive behaviour are now subject to study. We also create a graph of time spent at depth detailing the use of different parts of the water column. This report is preliminary in nature, but serves to open this aspect of gray whale behaviour to scrutiny, which is needed in this species. It is one of the most heavily involved whales in terms of interactions with humanity and requires detailed knowledge on which to base future management regimes.*

Introduction

Geography provides a useful forum in the sciences as it allows for the integration of different research methods focussed on a single research question with relative ease. When employed in the realm of environmental science, biogeography lies at a critical juncture between ecology and resource management, capable of forging a link between understanding the ecological foundation of the resource and implementing effective conservation management techniques in the social domain.

When the resource base consists of wild animals, biogeography is a powerful tool, its spatial emphasis useful in a number of ways traditional ecologists may not readily appreciate. In addition, spatial studies provide an excellent medium for researching fugitive subjects, those whose behaviour is partially invisible to us. By plotting a series of points when the subject is visible we can begin to more closely predict the possibilities for behaviour when the animal is not visible, through our growing understanding of the animal's goal(s). Thus by steadily increasing and analyzing our database we engage in a process of continually refining our scale of measurement, and as we have done in this case, utilize new techniques to uncover novel information.

This paper reports on biogeographical research into underwater behaviour of gray whales (*Eschrichtius robustus*). The report is preliminary in nature, based on the data we received during the initial attempt to use computer driven time-depth recorders on this species. The data is based on a single animal, and we do not present this as a definitive analysis of diving behaviour. Rather, we show that diving behaviour can be measured in this way, and that the information can be used to open new windows into the whale's world.

Biogeography and Gray Whale Research

Whale research involves subjects whose behaviour is invisible in much greater proportions than it is visible. These animals live in a three dimensional world, and it is their behaviour in the z dimension, or depth, which is, for the most part, invisible to the researcher. The water column, however, is a vital part of the whale's domain. As Kramer (1988) points out these animals may be more accurately conceptualized as underwater species needing to forage for spatially localized oxygen supplies, rather than surface dwellers forced to dive for prey at depth. Understanding whale ecology, as well as determining the potential for human disturbance of the animals, will rely on obtaining knowledge of whale behaviour in all three dimensions, the third, and invisible one, being the least well known.

The gray whale is one of the best known of all the whales (Pike 1962; Rice and Wolman 1971; Jones *et al.* 1984). Still, along with most other whale species, its underwater behaviour is poorly understood. Feeding behaviours of the gray whale are well studied (Murison *et al.* 1984; Nerini 1984; Clarke *et al.* 1989; Guerrero 1989); however, they are largely based on research of surface behaviour or quantitative analysis of prey distributions (Nerini & Oliver 1983; Oliver &

Kvitek 1984; Oliver *et al*. 1984; Kim & Oliver 1988; Weitcamp *et al.* 1992).

Gray whales are one of the most heavily utilized whale species for recreational purposes both during their annual migration and on tertiary feeding grounds (Tilt 1985, Duffus 1988). The whales in these instances are close to shore and populated areas, making them easily accessible. Our yearn to observe them, however, lacks a basic understanding of what they are doing around us. The concern that whale-watching vessels could potentially impact upon the whales cannot be assessed with any certainty until their baseline, natural behaviours are catalogued.

Clayoquot Sound, on the west coast of Vancouver Island represents a portion of the gray whale's tertiary feeding grounds (*sensu* Kim and Oliver 1989), which stretch from the Gulf of Alaska to Baja, California, Sur. Each summer a small portion of the population remains there to feed instead of continuing north to the primary and secondary feeding grounds in the Bering and Chukchi Seas. Recently, concern has grown over the increasing popularity and growth of a whale-watching industry out of the western Vancouver Island ports of Ucluelet and Tofino. These two locations provide easy access to the whales during their migration and to those animals which remain to feed for the summer. Summer is a crucial time in the gray whale's yearly cycle, as the animals will not feed to any great extent once they have left the area until they return again the following summer (Rice and Wolman 1971; Swartz 1986). Potential disruption of this spatial pattern by whale-watching vessels thus poses an ecological concern, as well as an economical concern to local communities for whom sustainability of the industry is a major concern.

The Diving Study

One purpose of our ongoing study into gray whale diving behaviour is to gain an understanding of various aspects of underwater behaviour. Based on the precepts of optimal foraging strategy (Kramer 1988) we hypothesize that whales will make efficient use of the water column, using the near-surface waters during short dive sequences that replenish oxygen supplies, and bottom waters to gain access to prey. The animals should maximize their time near the resource site, while reaching some optimum in terms of oxygen replenishment at the surface. We do not know at what level gray whales optimize oxygen storage as that demands detailed knowledge of a complex physiological relationship, but here make the a priori assumption that the animals spend little time between those

Figure 1 Hypothetical time-depth budget for gray whales, showing larger proportions foraging and obtaining oxygen, using the water column between for travel or possibly other activities.

two depths (Figure 1). If they do, there may be other factors operating that influence animal's decisions to stay at particular depths with no obvious gain, i.e. oxygen or prey.

We began our pilot diving behaviour study using a VHF transmitter tag to test the attachment and recovery techniques in late July 1994. We successfully planted a tag using a crossbow, after an initial failure using a 5 metre aluminium pole. The time-depth recorder (TDR) tag was attached to a single animal on August 6, 1994, at the south-west corner of Flores Island (49° 14′ N, 12° 08′ W), Clayoquot Sound. The recoverable, buoyant tag body incorporated a VHF transmitter (Special Dart 4, Telonics, Mesa Arizona) and the TDR (Mark IV, Wildlife Computers, Woodinville, Wash.). The computer's sampling interval was set at the maximum, to record the animal's depth once per second. The tag was attached via an 8 cm. soft rubber suction-cup with a galvanic-magnesium timed-release mechanism. The tag was fired from a 45 kg. pull crossbow from a distance of about 10 meters and was placed high on the animal's left flank.

The tag remained attached to the whale for 8 hours, 21 minutes, collecting data from 651 dives. It was recovered via the VHF transmitter signal and a 3 element yagi antenna. Following recovery the data was downloaded from the TDR and prepared for analysis with Wildlife Computers DIVE ANALYSIS software.

Results

Data were downloaded in two formats, an ASCII listing (n=29842), of each single depth reading, which was subsequently transferred directly into a statistics program (SYSTAT) for analysis of time-depth behaviour, and an hexadecimal format for initial analysis with DIVE ANALYSIS (Wildlife Computers). In both cases data correction procedures were applied to correct the zero and adjust to a calibration factor required for variance induced by water temperature changes.

In the DIVE ANALYSIS program each dive, defined as a passage below 2 meters and back to the surface, was plotted, several statistics were calculated and the dive was labelled. We initially divided the dive profiles into four separate types, based on maximum depth, bottom time, dive time and dive morphology (Duffus, Wischniowski, and Malcolm, in prep.). We have labeled these dives; ventilation, deep ventilation, intermediate, and feeding, based on their purported function (Figure 2). While we can be fairly sure of the function of ventilation dives and feeding dives, the two intermediary forms are difficult to assess. We await the collection of more data before speculating further on the meaning of those behaviours.

Of particular interest here is the use of space at various locations in the water column. Figure 3 illustrates the proportion of time at depth from our depth readings (n=29842). Readings were categorized per metre, summed then lumped into 2 metre classes for presentation.

We do not carry the analysis further at this point. The sample of one whale strongly limits the ability to generalize. More detailed analysis using methods proposed by Baird (1994), and Schreer and Testa (1995) may be applied to evaluate dive geometry, levels of relatedness among dive types, and the analysis of sequences of dives once the database includes several individual animals in a wider variety of circumstances.

Figure 2 Profiles of four dive types exhibited by a single gray whale recorded by a time-depth recorder, August 6, 1994, Rafael Point, Clayoquot Sound.

Discussion

The results of our preliminary research are informative. The presence of two intermediary dive forms, while not unexpected are revealing. The traditional ventilation-feeding dive sequences are evidence of foraging behaviour similar to that which has been documented elsewhere in the literature (Guerrero 1989) and in other parts of this research not yet completed. The lower frequencies of the two

Figure 3 Proportion of time spent at depth by a gray whale tagged for 8h 21m, n=29842 depth readings.

intermediate dive types, n=19 for deep vent and n=50 for intermediate dives, compared with the ventilation and feeding dives, n=497 and n=85 respectively, and the range of potential causal factors for dives (such as the presence of various numbers of whale-watching vessels throughout the tagging period), makes them difficult to analyze at this stage.

The visual comparison of proportion of time at depth between our hypothetical distribution (Figure 1) and the actual distribution (Figure 3) indicates an reasonable fit. This whale spent little time in the water column. The majority of time was near the surface (mean depth of ventilation dives=2.3m) and near the bottom (feeding dives mean depth=16.7m, mean bottom depth 18m). We note here that our original hypothesis regarding time at depth was generated specifically based on feeding observations from previous years in the area when the animals fed almost exclusively on benthic prey inhabiting the first few centimeters of relatively level, sandy benthos. While not part of this analysis, these animals were feeding on an unusual prey type, planktonic crab larvae (*Petrolisthes* spp. and *Pachycheles* spp.), swarming over a rocky benthos. Although the prey were capable of vertical movement in the water column, SCUBA diver observation indicated they were just suprabenthic at that time the tagged animal was feeding. The prey patch, however, may have been "thicker" (i.e. a greater distance from the patch's deepest margin (essentially the ocean bottom) to its shallowest margin) than a benthos prey patch. This, along with a greater variability in bottom terrain due to the rocky benthos, may have produced a prey patch meters deep rather than centimeters deep, and could account for the depth of feeding dives ranging between 14 and 22 meters. The animal fed in a restricted space (2 km^2), along with several other whales, indicating that the prey was concentrated in this particular area.

This report details the first time a time depth recorder has been used on this species. In fact diving studies on all cetacean species are still quite rare. The initial time at depth data, and the dive profiles serve to sharpen our hypotheses rather than provide definitive conclusions. Winn *et al*. (1995) point to the difficulties attempting to generalize on a small number of animals, yet find even small samples revealing.

Researching spatial behaviour on a micro-scale allows for a very fine scale of measurement. A sampling interval of one second on the TDR allows us to detect very small variations in the diving behaviour patterns. Identifying even slight deviations in behaviour patterns will be important in the future when attempting to determine the potential of vessel influence on whale movements.

Conclusion

With data on a single animal we can not yet ascertain what small scale variations are simply noise and which are significant behaviour deviations. We have not been able to ascribe biological meaning to all dive types and as of yet the causal links between dive types are not yet known. We have demonstrated the utility of the research technique to this species, devised the first approximation of their use of the water column, and documented a minimum of four dive types in the tertiary feeding grounds.

The results of the pilot study reveal an effective research method to gain insight into the link between behaviour and ecology. It serves well to begin the establishment of patterns, and provides a basis for understanding behaviours related to vessel traffic which may ultimately be useful in managing recreational and other interactions (Duffus & Dearden 1992).

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