PRELIMINARY CALIBRATION OF VELOCITY METERS ON A CAPTIVE KILLER WHALE

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SUMMARY

Recent research on the diving behaviour of killer whales has involved the deployment of suction-cup attached time-depth recorder/velocity meter tags. The purpose of this study was to calibrate the velocity meters on these tags, by placing the tags on a captive killer whale. A video system was used to record the whale swimming past two points a known distance apart, from which its speed could be measured. Actual speed was then compared to speed recorded on the velocity meters, for tags in different positions on the body, in two different orientations, and with a number of different tags. In all cases, velocity readings recorded by the instruments were lower than true speeds, with clear position effects (meters were closer to true speed when placed anteriorally). Velocity readings differed between tags, as each tag housing was custom-made and of slightly different size and shape. These calibration trials can be used to assist in the interpretation of velocity readings recorded from tag deployments on wild killer whales.

INTRODUCTION

Cetaceans spend the vast majority of their time beneath the water's surface, where they are difficult to observe and study. Knowledge of the duration of dives, diving patterns, and proportion of time spent in the upper portions of the water column, are all required in calibration of surveys for estimating abundance. Determining diving patterns in relation to habitat or at night is important for assessing exposure to depth-specific threats (such as fishing gear or high-intensity underwater sounds), as well as for defining critical habitats and evaluating behavioral features such as night-time foraging rates. Methods for examining cetacean diving behavior are not well developed, and thus relatively little is known regarding their subsurface activities.

For some species of pinnipeds, studying diving patterns has been relatively simple, as individuals can be captured and instrumented when they haul-out on land, and instrument packages (tags) can be recovered (and frequently re-used) when they return later to the same haul-out site to breed or moult. Instrument packages usually contain microprocessor-based data-logging systems (e.g., time-depth recorders, TDRs) with sensors to measure characteristics such as an animal's depth and swimming speed, as well as environmental features such as water temperature. Until recently, there has been no easy way to use such tags on cetaceans, and knowledge of cetacean diving patterns have thus lagged far behind what is known for pinnipeds. Applications with cetaceans have been limited due to problems associated with deployment, attachment and retrieval of tags. All three of these aspects tend to be more complicated or expensive with cetaceans than they are with pinnipeds.

The instruments which have been deployed on both free-ranging cetaceans and on captured animals typically involve tags which penetrate the skin and anchor into the blubber or connective tissue. Unlike with pinnipeds, tags deployed on cetaceans are rarely recoverable, and the increased financial expenditures resulting from using new tags for each deployment generally result in small sample sizes. A further limitation with cetacean studies is that many investigators have relied on satellite-linked transfer of data, which imposes severe constraints on the detail of information which can be collected. As well, capturing cetaceans is often extremely expensive, logistically prohibitive, or potentially harmful, and remotely-deployed penetrating tags may only be appropriate for species with thick blubber layers. Combined, such problems have resulted in relatively few studies of cetacean diving behavior, both in terms of the number of instruments deployed and the number of species studied. One alternative method allows for short-term remote deployments of recoverable data-logging tags, which do not suffer from the same limitations of memory constraints or data transmission found with satellite-linked tags, and which can re-used a number of times. These tags are attached with suction-cups (Goodyear 1981), and have recently been used successfully with several species of cetaceans (e.g., killer whales - Baird et al. 1998; northern bottlenose whales - Hooker and Baird unpublished; short-finned pilot whales - Baird and Amano unpublished; Dall's porpoise - Baird and Hanson 1996; fin whales - Giard and Michaud 1997; gray whales - Malcolm et al. 1996). The tags can be deployed without capturing the animals, using either a crossbow or a pole, depending on how close it is possible to get to an individual.

However, there are a number of limitations to this method. Because of the remote-deployment method, placement of these tags in a specific, pre-determined location on the body is problematic. Orientation of the tag may also vary between deployments. As well, because of the suction-cup attachment, location of the tag on an animal's body may change during a deployment, often sliding back along the body. None of these limitations impact the recording of depth or temperature from these units, but velocity readings from such tags may be affected by these differences in placement/orientation (unlike studies with pinnipeds, see e.g., Boyd et al. 1995; Horning and Trillmich 1997; Blackwell et al. in press). In an attempt to determine how location on the body affects velocity readings, suction-cup attached tags which contained a velocity meter were deployed on a captive killer whale. Speed trials were then undertaken where actual speed could be measured, and compared with speed recorded from the velocity meters. Effects of the tag position on different parts of the body was addressed, as well as orientation of the tag, and differences between tags, since each tag housing is custom made. The purpose of this report is to present a preliminary analysis of the data collected from these trials.

METHODS

Speed trials were undertaken between 16-21 March 1998, at the Oregon Coast Aquarium, with an adult male killer whale ("Keiko"). The tags used are the same tags used by Baird et al. (1998) with wild killer whales, Hanson et al. (1998) with Dall's porpoise, Hooker and Baird (unpublished) with northern bottlenose whales, and Baird and Amano (unpublished) with short-finned pilot whales. The tags were attached to the whale's body via an 8 cm diameter suction cup, available from Canadian Tire. The suction cup was attached to the tag body with a loop of Tygon tubing. The tags contain a VHF radio transmitter with a wire antennae (coated in plastic), and a Mk6 TDR (Wildlife Computers, Redmond, WA). The velocity sensor on this unit (Flasch Electronics velocity sensor) records speed by having water flow through a forward-facing inlet and causing a turbine to spin, and the number of turbine revolutions is converted to speed in meters per second (calibrated by Wildlife Computers). These components are mounted in a custom-made housing constructed of syntactic foam, which is coated in plastic. The syntactic foam allows the tag to float to the surface after release from a whale, with the VHF antenna clear of the water. The maximum dimensions of the tags (excluding suction-cups and antennae) are 25 cm by 7 cm by 4 cm. Tags weigh approximately 380 grams. Each tag housing is hand-made, thus the precise dimensions vary between tags.

Prior to deployment of tags, the internal clocks were synchronized with the time code generator on a video recording system, and the TDRs were set to records velocity at one second intervals. Between 2 and 10 trials were undertaken in each of 13 training sessions over the 6 day test period. For each set of trials, the whale was instrumented with between 1 and 3 tags (Figure 1), and instructed to swim at speed around the pool. High-8 video footage was taken from an under-water viewing port on one of the long sides of the pool, of passes by the whale past two poles hung vertically (and weighted at the bottom to prevent movement) against the far side of the pool (Figure 2), approximately 30' apart (exact distance varied between days, but was measured for each day). A frame code was imprinted on the video footage, so that the time interval for travel between the two poles could be determined to within 1/15th of a second. Tag number (1 through 4), orientation (with the velocity meter against the skin or facing away from the skin), and location on the body (mid-back in front of the dorsal fin, at the base of the dorsal fin on the right side of the body, on the caudal peduncle, between the pectoral flippers, or at the base of the dorsal fin on the left side of the body beneath the curled over fin) were recorded. For some trials two tags were placed side-by-side in the middle of the back, approximately 5-8 cm apart.

Upon recovery of a tag, data were downloaded in a hexidecimal format to a PC, and the program *3M* (Wildlife Computers) was used to convert the data to an ASCII listing. Statistical analyses of the data were undertaken with the program *Systat.* True speed was determined for each pass by the set of poles using the passby time noted from the video recording, and the distance between the poles each day, and was converted to meters/second for comparison with data from the velocity meters.

RESULTS AND DISCUSSION

A total of 83 trials were undertaken, with between one and three tags on the whale during each trial. From analysis of the video footage it was necessary to eliminate a total of

12 trials from the analyses, as speed or orientation of the whale was not constant, or because the whale was at the water's surface during the passes, resulting in one or more tags coming clear of the water during the pass. Details on the tag placement and orientation for trials is presented in Table 1.

Data presented in Table 2 are mean and standard deviation values of the ratio of velocity recorded by a TDR versus velocity measured from the video recordings. In general, the velocity readings from all tags and locations are substantially lower (40-95%) than actual speeds measured from video recordings. Ratios vary both between tags in a particular location (e.g., midback) and for each tag in different locations on the whale's body. The inter-tag variability is likely due to minor differences in tag shape and size (since the tag bodies are each custom hand-made), as well as the configuration of the release mechanism on the suction cup (some cups had release mechanisms, some did not), which disrupts or obstructs water flow into the turbine. Differences between values from placement of the tag on different parts of the body are likely due to changes in water flow characteristics associated with body shape (e.g., tags placed posterior to the widest point of the body may have more turbulent, rather than laminar flow).

Regression analyses were undertaken to compare video and velocity meter speed readings for each tag in each position/orientation on the body. In each case the significance values for the constant in each regression were greater than 0.05, thus the intercept for the regression lines were not significantly different from zero, and the relationships between actual speed (measured off the video) and speed recorded by the velocity meters appear to be linear. The relationship between actual speed and speed recorded by the velocity meters was significant for only 6 of 14 cases (Table 3), and r-squared values (the proportion of variation explained by the relationship between the two variables) were low (ranging from 0.233 to 0.820 for the significant relationships). However, sample sizes for many of these trials were relatively small, so in some cases it is difficult to assess whether the high degree of variation observed relates more to fluctuations in the tag's movements while on the whale, versus small sample size biases.

It is clear from the results of these tests that calibration of velocity meters is required in order to provide a realistic understanding of the implications of data collected from these instruments. Inter-tag differences make calibration of each unit particularly important, and when deployed on whales, careful noting of the location and orientation of a tag is required. Tests undertaken to date will be of great value in the interpretation of data collected from these tags on wild killer whales, but because of the small sample sizes for some tags in some positions, and the obvious need to calibrate tags in both orientations, further speed trials are clearly required.

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Table 1

Location information for tag speed trials. For each time shown between 2 and 10 trials were undertaken.

DATE	TIME	TAG 1	TAG 2	TAG 3	TAG 4
16 March	1400	dorsal fin base	-	-	-
16 March	1600	midback	-	-	-
17 March	all	midback	midback	-	-
18 March	1400	midback inverted	-	between pectorals	-
18 March	1600	midback	-	midback	-
19 March	0900	midback	-	midback	-
19 March	1400	peduncle	-	dorsal fin base	-
19 March	1600	peduncle inverted	-	dorsal fin base	-
20 March	0900	dorsal fin inverted	-	midback	midback
20 March	1300	midback inverted	-	underfin	midback
21 March	0800	peduncle	-	midback	dorsal fin base
21 March	1100	midback	-	peduncle	midback
21 March	1500	-	-	-	dorsal fin base

Table 2

Average of velocity readings in comparison to true speed for each tag/location/orientation.

TAG/POSITION	# OF TRIALS	MEAN	SD
tag 1/midback	27	0.6252	0.1156
tag 1/dorsal fin base	7	0.4760	0.0316
tag 1/peduncle	7	0.4056	0.0526
tag 1/midback inverted	10	0.7425	0.3274
tag 1/dorsal fin base inverted	5	0.9492	0.0856
tag 1/peduncle inverted	4	0.9312	0.0227
tag 2/midback	8	0.8527	0.2203
tag 3/midback	21	0.7694	0.2594
tag 3/between pectorals	6	0.5638	0.2055
tag 3/dorsal fin base	11	0.6169	0.1004
tag 3/peduncle	6	0.4884	0.1090
tag 3/under fin	5	0.5133	0.0732
tag 4/dorsal fin base	9	0.4115	0.0713
tag 4/midback	17	0.9250	0.1283

Table 3

Results of regression analyses for comparisons of velocity readings to true speed for each tag/location/orientation.

TAG/POSITION	# OF TRIALS	R-squared	P
tag 1/midback	27	0.329	0.001
tag 1/dorsal fin base	7	0.135	0.223
tag 1/peduncle	7	0.0	0.939
tag 1/midback inverted	11	0.140	0.155
tag 1/dorsal fin base inverted	5	0.820	0.022
tag 1/peduncle inverted	4	0.740	0.091
tag 2/midback	8	0.410	0.052
tag 3/midback	21	0.233	0.015
tag 3/between pectorals	6	0.623	0.038
tag 3/dorsal fin base	11	0.813	<0.001
tag 3/peduncle	6	0.0	0.402
tag 3/under fin	5	0.593	0.079
tag 4/dorsal fin base	9	0.821	<0.001
tag 4/midback	17	0.604	<0.001