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Evidence of Bowhead Whale Feeding Behavior from Aerial Photography

by

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ABSTRACT

Aerial photographs of the Bering-Chukchi-Beaufort population of bowhead whales (*Balaena mysticetus*) were analyzed to investigate their feeding habits, particularly epibenthic feeding near Barrow, Alaska. The analysis was based on mud visible on the dorsal surface of whales, resulting from feeding near the seafloor. A new photographic scoring system was developed and tested by bowhead experts, including subsistence whalers, to ensure an acceptable level of agreement on the analytical method. The tests resulted in > 93% agreement when whales were scored as muddy, and 100% when clean. Over 3,600 photographs were analyzed from 1985, 1986, and 2003-2007, including photos from surveys in spring and late summer and in both the Western and Eastern Beaufort Sea. Of all the photographs analyzed, 64% were scored as definitively muddy. In spring, ratios ranged from a low of 27% in 2003 to a high of 76% in 2004. In May of 1986 and when all four May sample sets off Barrow were combined, there was a significant difference (*t*-test, $P < 0.004$) between the proportion of muddy juveniles to the proportion of muddy adults, with muddy adults being more common. Tests in a flow tank demonstrated that mud can persist on bowhead whale skin for up to half a day, making it difficult to pinpoint where feeding occurred. Plots of whale sightings show that the Barrow area was a commonly used feeding ground during migrations in both the spring (61% of the sample were feeding, of which 55% were feeding epibenthically) and autumn (99% of the sample; 97% epibenthically). Epibenthic feeding in areas where petroleum extraction is underway with the risk of oil spills could have severe ramifications for bowheads.

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INTRODUCTION

Background

Bowhead whales (*Balaena mysticetus)* are circumpolar in distribution and inhabit the northern hemisphere only. Currently, the bowhead whale is listed as an endangered species and is an important subsistence resource for Eskimos (e.g., Stoker and Krupnik 1993). This study focuses exclusively on bowhead whales that occupy the Bering-Chukchi-Beaufort seas, often referred to as the BCB stock. Despite occurring in remote locations, BCB bowhead whales have been fairly well-studied (e.g., Burns et al. 1993), largely because they are endangered, hunted, and occur in areas that are of high interest to industrial development by petroleum companies. Aerial surveys to photograph these whales have been conducted intermittently during the past 30 years. In that time, scientists have amassed over 18,000 images which are now catalogued at both the Alaska Fisheries Science Center's National Marine Mammal Laboratory (NMML) in Seattle and LGL, ltd. environmental research associates, in Canada. The utility of photo-identification as a research tool has been well-documented, and applications include mark-recapture abundance estimation (Rugh 1990, Da Silva et al. 2000, Schweder 2003), survival analysis (Zeh et al. 2002), calving intervals (Miller et al. 1992, Rugh et al. 1992), and measurement of individual growth rates (Koski et al. 1992, Koski 1993). The primary objective of this research is to glean information about the feeding ecology of the BCB population from photographic analyses of bowhead whales.

BCB bowheads migrate from the northern Bering Sea in the spring, past Barrow and into the Eastern Beaufort Sea where they spend the summer feeding. In the autumn, they make the reverse migration back to the northern Bering Sea where they overwinter (Moore and Reeves 1993) (Fig.1). Bowhead whales feed sporadically during both the spring and autumn migrations while en route to the feeding grounds, but feeding is more prevalent in the autumn than the spring (Lowry and Frost 1984, Carroll et al. 1987, Lowry et al. 2004). However, Lowry et al. (2004) were the first to

report that feeding near Barrow in the spring is actually quite common, although the amount of food consumed appears to be lower in spring compared with autumn.

Feeding Behavior

Bowhead whales have three documented feeding strategies: surface feeding, water-column feeding, and bottom feeding (hereafter referred to as epibenthic feeding) (Würsig et al. 1989). Surface feeding can occasionally be documented photographically, showing whales with open mouths or in echelon formation, but aerial images cannot document water-column feeding. Whales that feed epibenthically, however, often become coated with mud which is easily detectable in photographs. Mud on the dorsal surfaces of whales is evident in many photographs in the NMML collection. The current research applies photo-analysis as a tool to study epibenthic feeding. Although visual, in situ assessments of bowhead whale feeding strategies are available (Ljungblad et al. 1986, Würsig et al. 1989, Würsig and Clark 1993, Landino et al. 1994), no published research has focused on analyzing photographs for clues to feeding behavior. This work builds upon ideas from Robyn Angliss (Angliss, pers. comm., NMML). In the 1990s, Angliss evaluated photographs for evidence of epibenthic feeding, and although her methodology and data sets differed from these, her work provided the springboard from which this study was launched.

Much of what is known about bowhead feeding comes from biological examination of stomach contents from animals taken in the subsistence hunt. Bowhead whales feed primarily on copepods and euphausiids but also consume amphipods, mysids, and animals such as fish and invertebrates in unsubstantial amounts (Lowry 1993, Lowry et al. 2004). Notably, although some studies have referred to epibenthic prey to mean epibenthic forms of mysids and amphipods (Hazard and Lowry 1984, Lowry 1993), the current study is presuming that bowheads are actually targeting epibenthic aggregations of copepods and euphausiids. There is evidence to support this presumption. Lowry (1993) stated that in 10 out of 12 stomach samples containing pebbles, the dominant prey were copepods and

euphausiids, and he suggested that this is likely indicative of whales feeding very near the bottom. Additionally, it is well known that copepods and euphausiids undergo diel vertical migrations in the water column such that they are at the surface at night and near the seafloor during the day as a predator avoidance strategy (Fortier et al. 2001, Hays 2003). Laidre et al. (2007) attached time-depth-recorders on bowheads during the day off West Greenland and found most dives were targeting the bottom. The researchers also conducted water column sampling for zooplankton and found that copepods were dense near the bottom, in concentrations that were several orders of magnitude greater than all other prey categories and at any other depth. The authors concluded that bowheads were likely targeting pre-ascension stage epibenthic copepods. They also report that after retrieving dorsally-mounted tags, some instruments had mud on them, suggesting recent contact with the bottom. Krutzikowsky and Mate (2000) also found that some of the bowheads they tagged in the eastern Beaufort Sea made long, deep dives that they presumed to be targeting calanoid copepods in the water column or near the seafloor. Zooplankton that descend to deeper water in the summer tend to be larger and have a greater lipid content than those found in the upper column (Hays 2003). Therefore, it may be advantageous for bowheads to target prey at greater depths in order to consume a more calorically dense meal.

Würsig et al. (1989) and Lowry (1993) suggested that juvenile bowheads may feed epibenthically more often than adults, based on behavioral observations and stomach contents. Hazard and Lowry (1984) posited that due to inexperience and shorter baleen, bottom-feeding may be more practical for juvenile whales. With proportionally smaller mouths, young whales may be more dependent than adults on prey concentrations near the seafloor. To address this question, whale lengths were used to categorize individuals into age classes and then tested for differences in the proportions of muddy juveniles to muddy adults. I also tested whether the proportion of muddy whales varies on a seasonal and/or inter-annual basis.

Objectives

The motivation behind the photographic analyses conducted in this study was fourfold: first to demonstrate that photographic analysis can be a useful tool to elucidate epibenthic feeding behavior; second to investigate how common epibenthic feeding is; third to corroborate evidence that feeding is common during the spring migration near Barrow; and fourth to explore the demographics of bowheads using this feeding strategy. These are the specific hypotheses tested:

H_o : the proportion of muddy whales in May 1985 = 1986 = 2003 = 2004

H_o : the proportion of muddy whales in spring = the proportion of muddy whales in late summer

H_o : the proportion of muddy whales near Barrow = the proportion of muddy whales in the Eastern Beaufort Sea

H_o : the proportion of muddy juveniles = the proportion of muddy adults

Justification

There are important management implications regarding the feeding habits of BCB bowheads, as the whales are migrating and feeding in active and proposed areas of oil exploration and development, both in Canada and offshore Alaska. Indeed, if a large proportion of the population is regularly muddied, than it behooves managers to research how oil spills may affect the substrate and subsequently the whales that are exposed to it. This study also emphasizes the importance of areas where there is evidence of feeding, areas that had previously been presumed to be only migratory corridors. Understanding bowhead feeding ecology is imperative for the continued protection of this endangered species, especially in a warming and rapidly changing ecosystem. This research is an important contribution to the general knowledge of this population of bowhead whales.

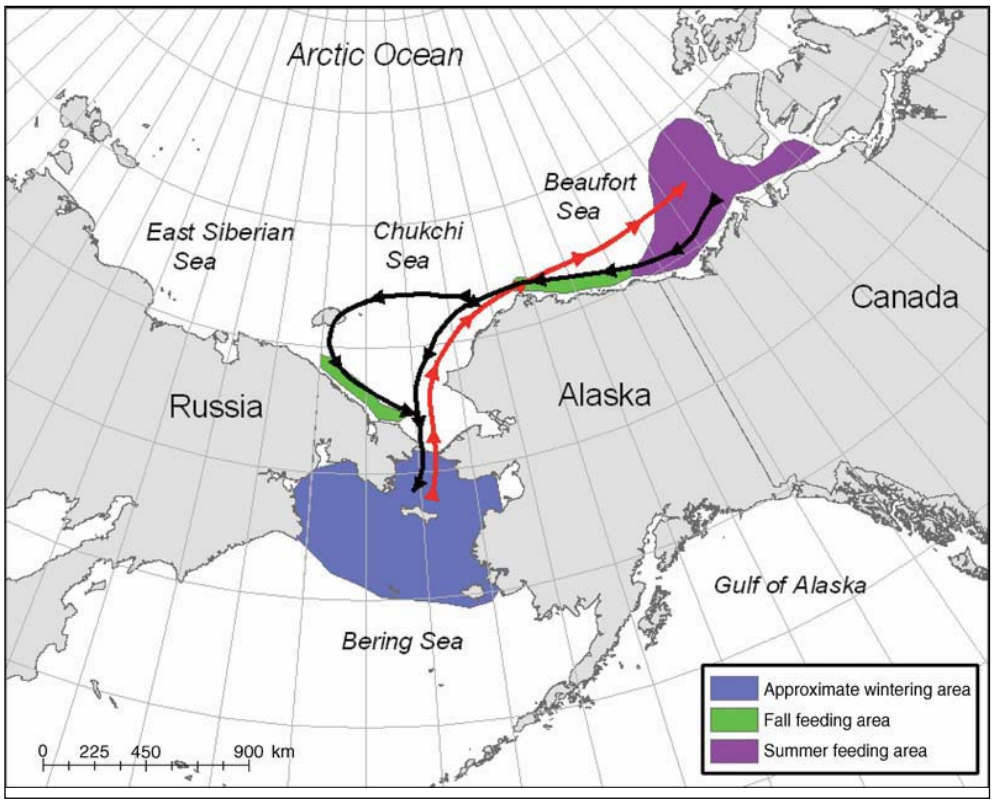


Figure 1. -- Generalized Bering–Chukchi–Beaufort (BCB) bowhead whale migration route, feeding areas, and approximate overwintering region. Red line with arrows shows spring migration north and east; black line with arrows shows autumn migration west and south (Moore and Laidre 2006).

METHODS

Study Area and Data Sets

There are over 18,000 images in the photographic collection at the NMML, so I had the opportunity to select the best photographic sample sets for this study (Table 1). Years 1985, 1986, 2003, and 2004 (Fig. 2) contained the largest and most consistent photographic samples in the Barrow area. In these years, an attempt was made to photographically capture the entire population of bowhead whales during the spring migration past Barrow in order to calculate abundance estimates of the stock (Zeh et al. 1993, Koski et al. In review). Since the abundance estimates were carried

out almost 20 years apart, this afforded the opportunity to compare the prevalence of epibenthic feeding off the Barrow area through time. These samples were limited further by looking at images taken only in May between 152º and 157º longitude, the period and area that was most consistently sampled. In addition to these four main sample sets, four other datasets were included to examine more variables. A sample set was included from the Eastern Beaufort Sea in Aug./Sept. 1985 to compare epibenthic feeding in two seas (Western vs. Eastern Beaufort Sea) and two seasons (spring vs. late summer) within one year. Also, images were evaluated from 2005, 2006, and 2007 off Barrow in Aug./Sept. so that recent data are included in this effort and to further examine the relationship between spring and late summer proportions of feeding whales.

Table 1. -- Data sets used to examine the proportion of the sampled aerial photographs of bowhead whales that had mud on their dorsal surfaces. Population estimates are from Zeh et al. (1993) and Koski et al. (in review). *2005, 2006, and 2007 were not representative samples of the population, so no attempt to discern the percent of the population captured photographically was made for those years.

Year	Month	Area	Number of images evaluated	Population estimate (95% confidence interval)	% of Population evaluated
1985	Aug./Sept.	E. Beaufort Sea	162	7,800 (5,700-10,600)	2%
1985	May	Barrow	440	7,800 (5,700-10,600)	6%
1986	May	Barrow	396	7,800 (5,700-10,600)	5%
2003	May	Barrow	929	11,800 (7,200-19,300)	8%
2004	May	Barrow	706	11,800 (7,200-19,300)	6%
2005	Sept.	Barrow	101	*	*
2006	Sept.	Barrow	566	*	*
2007	Aug.	Barrow	349	*	*
			Total= 3,649		

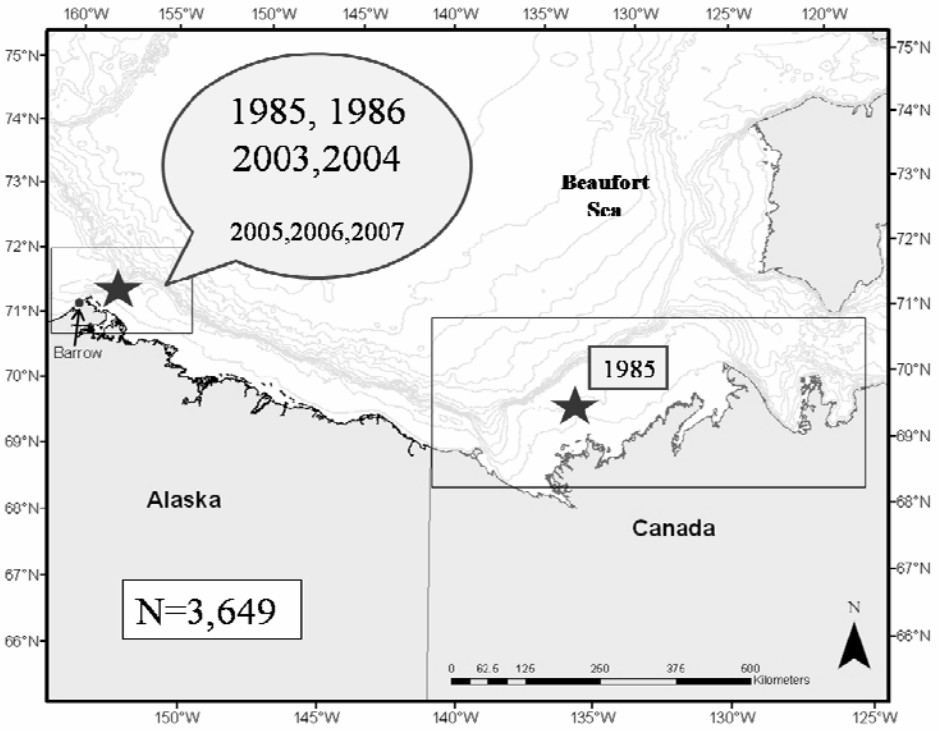


Figure 2. -- Data sets used in this study, with boxes depicting the general area where photographs were taken. Data sets from May 1985, 1986, 2003, and 2004 were the most robust, so they were the foundation of the analysis. Photographs from Aug./Sept. 1985, and 2005-07 were analyzed for comparative purposes.

Scoring Photographs

I was the only person to evaluate all of the photographs used in this study for evidence of feeding. However, as a precautionary measure before I began scoring, I needed to ensure that other people agreed with my assessments of feeding whales. A series of tests were designed in order to determine if my method of scoring was not only consistent and repeatable but also had an acceptably high level of agreement with others. I created two detailed tests of 50 images in Microsoft Access and gave them out to biologists at NMML after providing training (Appendix A). I then created a series of pivot tables in Microsoft Excel to compare the results. Then, based on input from those more extensive tests, a third test was created and given to bowhead biologists and subsistence whalers. This final test was much simpler and contained

only 15 images. For this test, experts only had to decide whether a whale in an image was muddy, clean, or they were unsure. Any score of unsure was then treated as a non-decision, since I threw out all unsure scores for analyses. See Appendix A for details of the different scoring and testing processes.

After testing was complete, I commenced scoring all of the images using a data-entry form in Access that was created to make the scoring process more efficient and consistent (Table 2; Appendix A). The photographic evaluations consisted of determining the presence/absence of mud in each of four zones on the body (rostrum, cheeks, back, and flukes), and my associated confidence for each decision. There were three possible levels of confidence to assign: definitely (> 90% sure); probably (> 70% sure); or unsure (< 70% sure). For all zones that were determined to contain mud, scores were also given for the amount of mud present (< 1/3, < 2/3, > 2/3), a description of the mud (streaky, blotchy, covered), and whether the coating of mud was thick or thin within the zone. Additionally, I scored for the presence of an open mouth visible in the photograph (not open, slightly open, wide open, indeterminable) and the associated confidence of that decision, and I scored for the presence of a mud plume near the whale as well. Finally, I reviewed all of my scores in the individual zones and made an overarching decision regarding whether the whale in the image was feeding (and what my cue was) or not. I restricted this decision to reflect that I had scored the evidence with at least 70% confidence (i.e., I did not make decisions based on evidence that I was “unsure” about). For a whale to be determined as feeding, evidenced by mud, it meant that I was “probably” or “definitely” sure there was mud present in at least one of the zones on the body.

The overarching feeding decision was then used for analyses. If I was unsure about mud on the body, "can't tell" was entered in the “Feeding” column on the form. Typically, uncertain scores were due to a small or thin layer of mud, the presence of sloughing skin, or a poor quality photograph. I looked at all photographs within my constrained data sets and simply rated poor quality images as “can’t tell” when I encountered them. No attempt beyond this was made to score the images for quality ratings applicable to this study.

Table 2. -- Scoring categories used for all photographic evaluations. Decisions on the presence/absence of mud were made separately for each of four body zones in every image (rostrum, cheeks, back, flukes).

Feeding	Open mouth descriptor	Mud	Confidence	Mud amount	Mud descriptor	Mud coating	Plume present
can't tell	no	no mud	definitely (>90% sure)	<1/3	streaks	thin	no
no evidence of feeding	slightly open	yes mud	probably (>70% sure)	<2/3	blotchy	thick	yes
yes: mud	wide open	can't tell	unsure (<70% sure)	>2/3	covered		
yes: open mouth	can't tell						
yes: feces							
yes: mud and open mouth							
yes: mud and feces							
yes: open mouth and feces							
yes: mouth, feces and mud							

Lengths

In order to compare the proportions of muddy juveniles to muddy adults, the results were limited to images with lengths that had been previously measured photogrammetrically. I considered the following whale lengths to represent certain age classes based on published data of calving, growth rates, and photogrammetric measurements (Withrow and Angliss 1992, Koski et al. 1993, Angliss et al. 1995):

Calves ≤ 6 m

Juveniles > 6 m and < 13 m

Adults ≥ 13 m.

I then excluded from analyses all calves and any oblique images with lengths between 11.5-12.9 m since oblique measurements are less accurate, and the potential error involved could mean the difference between assigning a whale the status of juvenile versus adult within those zones of overlap. This rarely happened, so almost all photos with lengths were included in analyses (5 out of 2,322 images were excluded). The scoring results were all queried in Access to determine proportions of feeding whales for all categories and projects. Tables were then created in Excel to summarize the data. An empirical logistic transform for binary data (Cox and Snell 1989) was used to transform the data for comparing proportions, and then a *t*-test was used to compare the proportions of juvenile to adult muddy whales and to compare year-to-year proportions of muddy whales (e.g., Appendix B). Only photos from 2005, 2006, and 2007 (summer near Barrow) were excluded from age-class analyses because they were not representative of the full population, so separating them by age class was not warranted.

Flow Tank Tests

A series of tests were conducted at the University of Washington's Friday Harbor Laboratories on San Juan Island in an attempt to learn about the flush rate of mud off of bowhead whale skin at various swim speeds. Noah Lawrence-Slavas, a mechanical engineer at NOAA's Pacific Marine Environmental Laboratories was consulted to help with the design, building, and application of all tests. A sample of

bowhead skin was obtained from a fluke that was stored in the freezer at NMML. It was cleaned and cut to a 10.5 × 17.5 cm rectangle (the largest uniform area that could be obtained from the sample), glued to fit a piece of plastic sheeting, and a 10 × 15 cm grid was drawn on the skin with a silver Sharpie pen resulting in 24 squares (2.5 × 2.5 cm). In order to minimize flow distortions, the skin-covered plastic was then flush-mounted and caulked into a larger piece of faired plastic. This larger piece of plastic filled the width of the flow tank allowing the skin to sit flush in the bottom of the tank to represent the broad head or back of a bowhead whale (Figs. 3a-c). The design was created in order to facilitate laminar flow over the skin. Based on the work of Legendre and Legendre (1998), the first 2/3 of a whale should have laminar flow over the body while the hind 1/3 would have turbulent flow due to propulsion by undulating flukes. The flow tank was small (overall length 2.4 m; working section was 0.15 m × 0.15 m × 0.57 m width × height × length, see Boller and Carrington [2006] for a schematic representation), so it was deemed inappropriate to try to add any curvature to the skin (since a section of skin as small as my sample almost anywhere on a bowhead would effectively be flat).

The tests were conducted at 0.83 m/s (3 km/h) and 1.67 m/s (6 km/h) to correspond to mean bowhead swim speeds and fast swim speeds, respectively (Zeh et al. 1993). I initially intended to also run tests at slow swim speeds (1 km/h), but since so little mud dissipated on the medium-speed tests, it was decided that running tests at a slower speed was unwarranted. Most tests were conducted with 4.9 cc (1 tsp) of Beaufort Sea mud (provided by the 2008 NMFS/RACE Beaufort Sea Survey, 6-22 Aug., collected within the Barrow study area) spread over six predefined squares within the grid drawn on the skin (Fig. 3d). Two tests were run at varying mud amounts (0.6 cc = 1/8 tsp and 14.8 cc = 1 tbsp) to test how mud thickness affects flushing. Another test was run using mud extracted from the beach at Friday Harbor Laboratories to analyze the sensitivity of the test to varying mud compositions. Finally, for the last test, the caulking that held the skin in place was cut in order to raise the skin to an angle of 30º in an attempt to create turbulent flow over the skin and evaluate mud flushing rates under a different flow regime.

All tests were recorded with a Sony DVCAM mini-video recorder set to record continuously for the first 5 minutes of each test and then set to record for 2 seconds at 5-minute intervals thereafter. Additionally, still photographs were captured with a Nikon D-200 and a Canon PowerShot SD300 digital camera. Flow patterns (laminar vs. turbulent) were analyzed with potassium permanganate dye using a Redlake Motionscope high-speed video camera shooting at 500 frames/sec. The high-speed video camera was also instrumental in calibrating the fluid velocity in the tank by counting moving air bubbles frame-by-frame and ensuring it corresponded to the speed the tank was set at.

After completion of the tests, the Sony DVCAM video clips were imported into Windows Movie Maker software and converted 8 clips per test into JPG images for analysis. The 8 clips were chosen based on the time increments that I wanted to compare: 0 minutes, 1 minute, 5 minutes, 10 minutes, 20 minutes, 30 minutes, 1 hour, 2 hours. Those JPGs were then converted into pdfs in Adobe Acrobat 8 Professional, which enabled me to use the area measurement tool to draw borders around the six squares and the mud within them in order to estimate proportions of mud remaining for each time interval (Fig. 4).

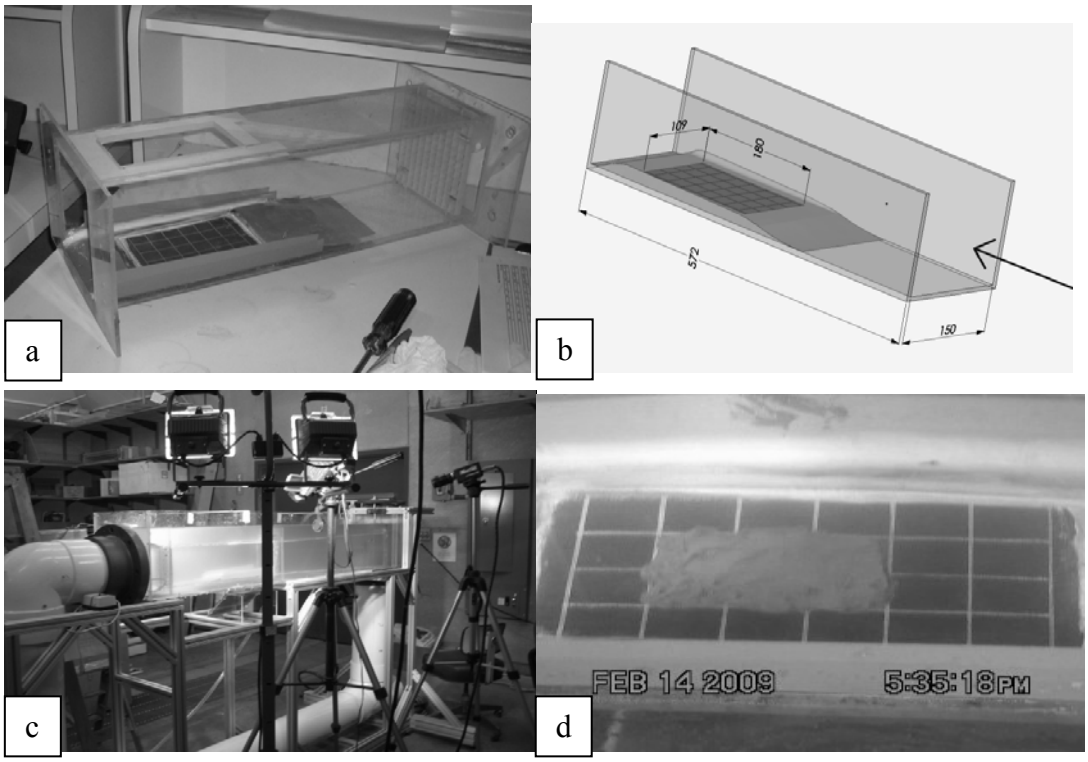


Figure 3. -- (a) Bowhead skin marked with grid lines and caulked into the working area of the flow tank. (b) Schematic of the design with measurements in mm (provided by Noah Lawrence-Slavas). (c) Flow tank. (d) Close-up of mud on skin under water.

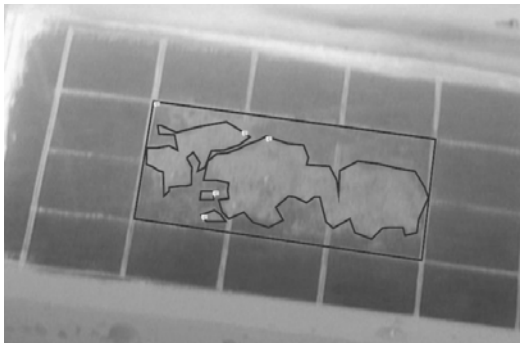


Figure 4. -- Adobe Professional Area Measurement tool was used to analyze images to determine the proportions of mud remaining on test squares throughout each test.

GIS Analysis

Whale sighting locations for all photographs that were scored for this study were plotted in ArcGIS 9.2 in order to visualize patterns that may emerge when comparing year-to-year locations of feeding and non-feeding whales. A box was superimposed on the first map showing the entire study area; the box depicts the area of effort within which images were evaluated.

RESULTS

Testing of Scoring System

Test 1 and Test 2 (50 images tested by NMML biologists)

Three people at NMML took the same test twice (with a simplified scoring system for Test 2), and one additional person took Test 2 only. Agreement was always highest when evaluating mud presence, amount, and confidence in any zone, and agreement was lowest when scoring for mud descriptors (thick/thin, streaks/blotchy/covered). Therefore, it is useful to compare decisions on the amount of mud on a whale, but it is unreliable to trust people's descriptions of mud. In other words, mud presence was adequately categorized and then taught and found repeatable, while the mud descriptors used in this study are too subjective or vague to be repeatable. Therefore, although every photograph was scored completely, the word descriptors were ignored in all further analyses.

In total, 70 different pivot tables were created comparing each permutation of scorers for each scoring category. Here, a very simplified, overarching summary is provided (Table 3). For this summary, all scorers were combined together (minus myself) and the sum of their definitive "yes" and "no" decisions (>70% sure) was divided by my sum in order to obtain the percentages listed below. Therefore, the percents in Table 3 reflect the percent agreement of others' scores to mine but not the reverse. Surprisingly, I was almost always the most conservative scorer, which means other people made more definitive decisions than I did. It is interesting to note that the back region on the whale received the lowest agreement in scores for both tests. Rugh et al. (1998) also found that bowhead backs were the hardest to categorize during the original testing of a scoring system for photographic identification of bowheads, although the delineation of zones on whales was different in their study.

Table 3. -- Percent agreement of NMML biologists' definitive decisions on mud presence or absence compared to my decisions for both scoring tests. Test 2 was a simplified form of Test 1.

Zone	Test 1 Agreement (2 scorers)	Test 2 Agreement (3 scorers)
Rostrum	84%	90 %
Cheeks	96%	89 %
Back	73%	81 %
Flukes	79%	89 %
Overall	85%	88 %

Test 3 (15 images tested by bowhead experts)

Agreement was very good between bowhead experts (subsistence whalers and biologists specializing in bowhead research) and myself when comparing images that I scored as muddy or clean. Not surprisingly, scores were much more variable for the photos that I had scored as "unsure" (Fig. 5). After removing images that I was uncertain about, there was 100% agreement for images that I scored as clean and 93.8% agreement on images I scored as muddy. There were three cases when I scored an image as muddy, but a single person had scored that same image as clean. The analysis only applied data from definitive decisions (a whale was considered muddy or clean), not the "unsure" category. These results support my methods of scoring and 'assignment' of feeding that I present in this study. Due to the high level of agreement (93.8% to 100%), it was decided that it was unnecessary to have anybody else score the photographs for this research.

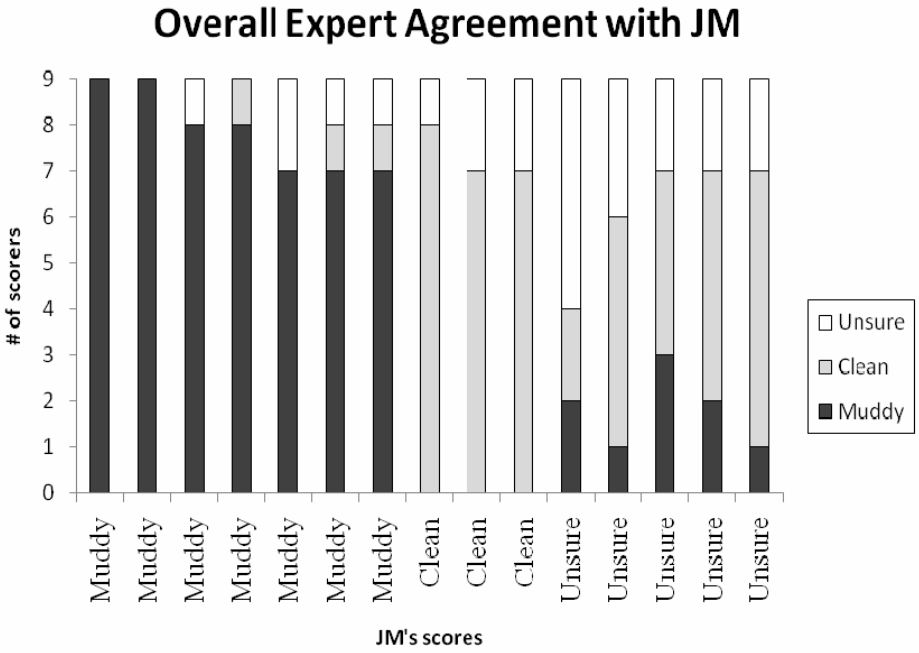


Figure 5. -- Results of the scoring test given to bowhead experts compared to my scores (JM) on 15 images.

Testing of Mud Flush Rates

A total of 12 tests were conducted in the flow tank (Fig. 6). The first (and longest) test consisted of 4.9 cc of mud at medium speed. After 9 hours, there was still a detectable amount of mud (~1/4 of the square) on the skin; however, this amount of mud would probably not be detectable in an aerial photograph. After this test, I decided that it was necessary to limit the test run time to 2 hours and to run most tests at fast flow rates so that more change could be detected within reasonable time spans. Typically, mud flushed at a faster rate during the first minute of a test as a result of bringing the flow tank up to full speed. After the tank flow stabilized from this initial surge, the mud flushed much more slowly throughout the remaining 2 hours. Generally within 2 hours 4.9 cc of mud at fast speed (6 km/hour) was almost all gone (3 replicates), whereas the same amount exposed to medium speed (3 km/hour) water flow (2 replicates) was almost all still present.

The results from testing variations of mud thickness, mud type, and angle of incidence of the skin were as expected. In order to apply 0.6 cc of mud over the full

area equally, it was necessary to spread it in a very thin layer over the six squares. The result was that a thin layer of mud was more persistent than thick mud. The test of 14.8 cc of mud dissipated very quickly, probably within 10 minutes, but it made the water so murky that it was hard to see exactly when it became totally clean. The test with the skin set at a 30º angle and the test using mud from Friday Harbor also yielded a fast dissipation of mud; it was all gone within 10 minutes.

When applying mud, an attempt was always made to smooth the sample with the back of a finger so that all tests would be of equally smooth mud. However, the mud was so sticky that it inevitably stuck to my fingers in some areas and created peaks. Although this method seems somewhat crude, it probably better mimics the spread of mud on a whale in the wild. Irregularities in the mud surface caused higher ablation rates which then flushed off the whale skin first. In all tests, the mud flushed by breaking off in chunks and rolling over the back of the skin as it peeled away. Test results were adjusted in an attempt to minimize the impacts of varying mud applications as well as mud dissipating as a result of the water flow reaching full speed, by throwing out the first minute of testing and using $t = 1$ as the baseline for subsequent proportional observations. Except for the test with angled skin, it appeared that the water flow was mostly laminar, as determined by eye but also checked on a high-speed video camera using dye in the water.

Based on these tests, it seems reasonable to conclude that mud stuck to a fast (6 km/hour) swimming bowhead would be flushed from the whale within a couple of hours. For a whale swimming at roughly 3 km/hour, a typical speed for a bowhead, a coating of mud might be present for nearly half a day but probably less than one full day. A whale swimming at consistently slow speeds might retain mud on its body for over a day. Whales swim at varying speeds within a day, in accordance to varying behavior (i.e., feeding vs. migrating). Feeding whales generally swim more slowly than migrating whales. Mud flush rates will vary depending on the thickness of the mud entrained on the whale and also the location on the body. One would expect mud to flush quicker off the hind one-third of the body where propulsion is generated by

undulating flukes than the front two-thirds of the body, an expectation substantiated by the work of Legendre and Legendre (1998).

In order to ground truth the flow tank tests, queries of the bowhead photographic database were run to see if there were examples of individual whales that were captured photographically at different times and with varying feeding designations. Due to aerial survey protocols designed to minimize recaptures by flying opposite to the direction of migration, it is difficult to find many examples of the same whale photographed within one day. There were 470 within-day matches (out of 3,649 images); however, most of these were taken very close in time. This sample size dwindled to 34 when the query was limited to images taken >15 minutes apart. Furthermore, when I only queried matches that were taken more than 2 hours apart (a time scale consistent with the flow tank tests), there were only 8 matches remaining. The longest time that mud persisted on a whale within these sample sets was just over 4 hours (see Appendix C). There were no examples where a whale was photographed muddy and then clean in subsequent photos. There was also no documentation of mud completely flushing from a whale from these sample sets. Whales with mud on them reduced the likelihood of being recognized in subsequent photographs if the mud changed substantially.

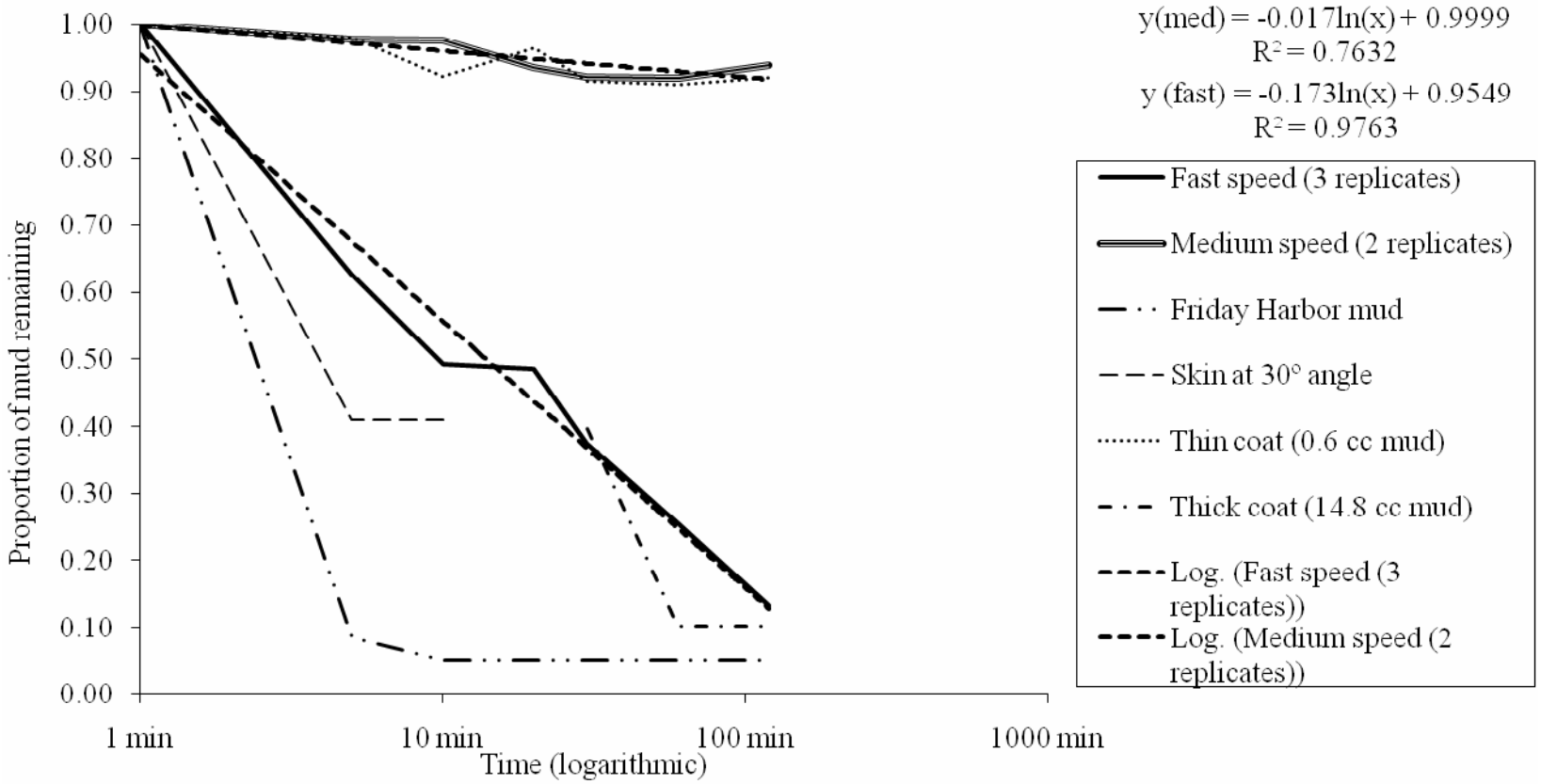


Figure 6. -- The proportion of mud remaining on a bowhead skin sample under various conditions in the flow tank for 2 hours. Unless otherwise stated, tests were run at fast speed with 4.9 cc of mud. Note that not all tests are shown here. The first three tests were conducted with inconsistent protocols and so are not displayed (including the 9-hour test).

Interannual Variation of Epibenthic Feeding

Greater than one-half of all photographs analyzed showed evidence of epibenthic feeding, but there were clear interannual variations in the data (Figs. 7, 8). Combining all sample sets yielded a total of 64% definitively muddy whales (this combines the "mud" and "mud and open mouth" categories). Proportions of muddy whales from each May sample off of Barrow were all significantly different from each other. Only when May 1986 was compared to the remaining three May samples combined was no significant difference found (Table 4). When all four May sample sets off Barrow were combined, 55.4% showed clear evidence of epibenthic feeding, 39.2% showed no evidence of feeding, and 5.4% had visibly open mouths. May 2003 stood out as having the smallest proportion of feeding whales, and 2004 had the largest proportion of feeding whales (27% and 76%, respectively) (Fig. 9).

The proportion of muddy whales in late summer in the Eastern Beaufort Sea was notably different from the proportion of muddy whales off Barrow in late summer (Fig. 10; Table 5). When the three samples sets in late summer off of Barrow were combined, 97% were muddy, 1% showed no evidence of feeding, and 2% had open mouths. The expectation that the proportion of feeding whales in photographs would be higher in late summer compared to spring is upheld with these data. The combined sample sets off Barrow in May of muddy whales were highly significantly different than the combined late summer samples from the Barrow area ($P<<0.001$). For all data comparisons, I first transformed the data (normalized the proportions) by using an empirical logistic transform (Cox and Snell 1989). The normalized data were then able to be compared by using a simple *t*-test (2-tailed) to test for significant differences (see Appendix B for example).

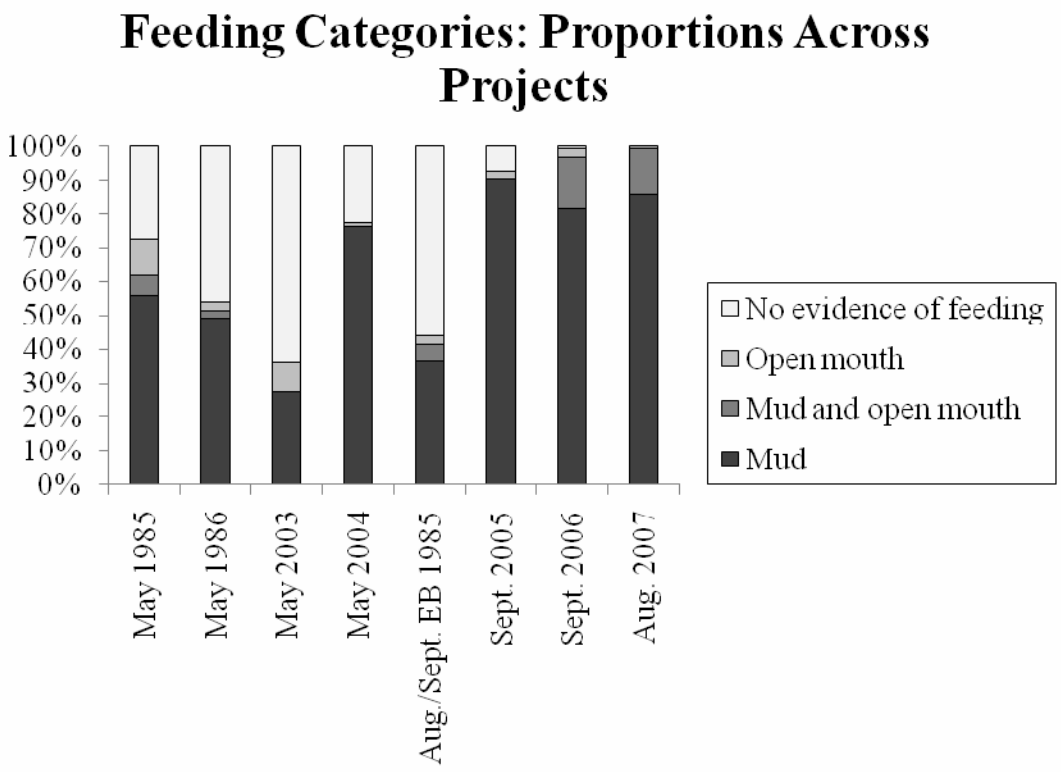


Figure 7. -- Proportions of photographed whales that were assigned definitive feeding categories. All samples are from the Barrow area, except Aug./Sept. EB which denotes the Eastern Beaufort Sea.

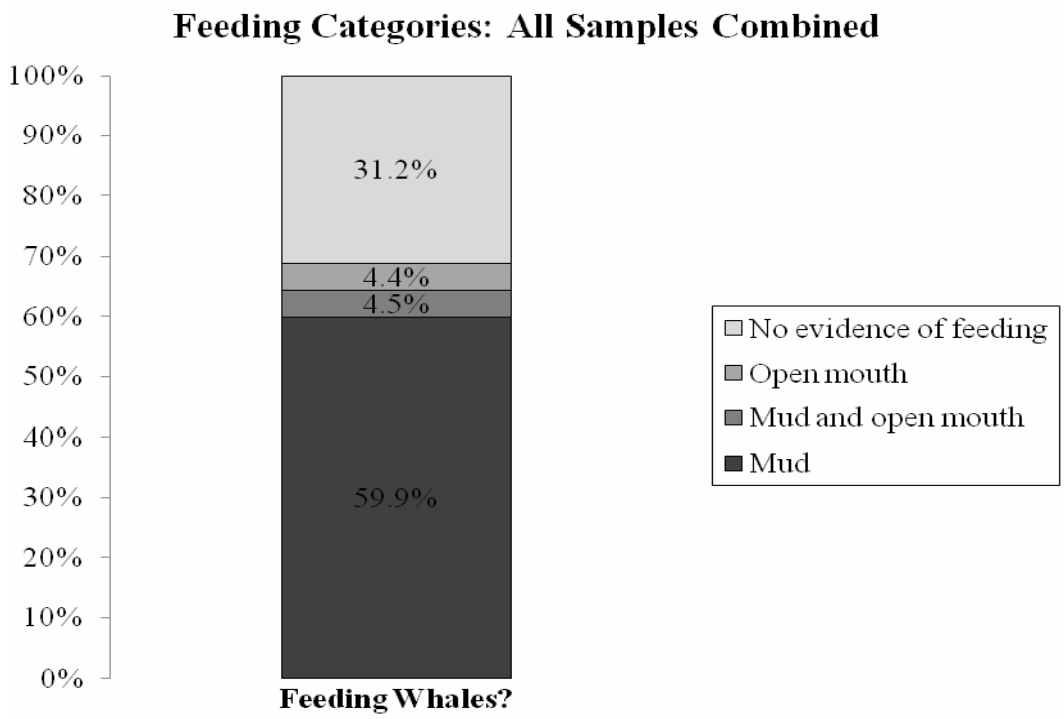


Figure 8. -- Proportions of whale feeding categories with all sample sets combined.

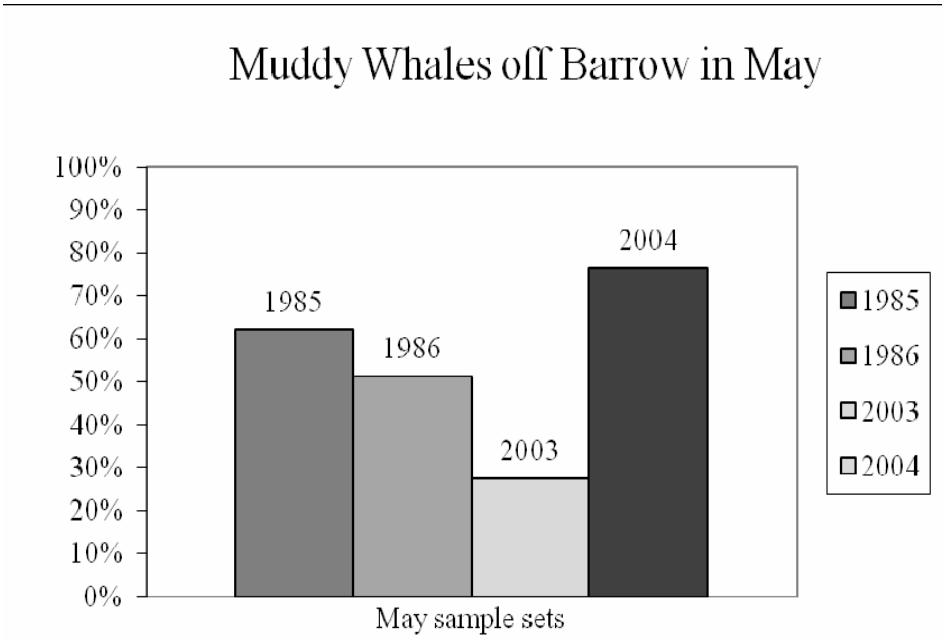


Figure 9. -- Proportions of muddy whales in photographs from all May sample sets off Barrow.

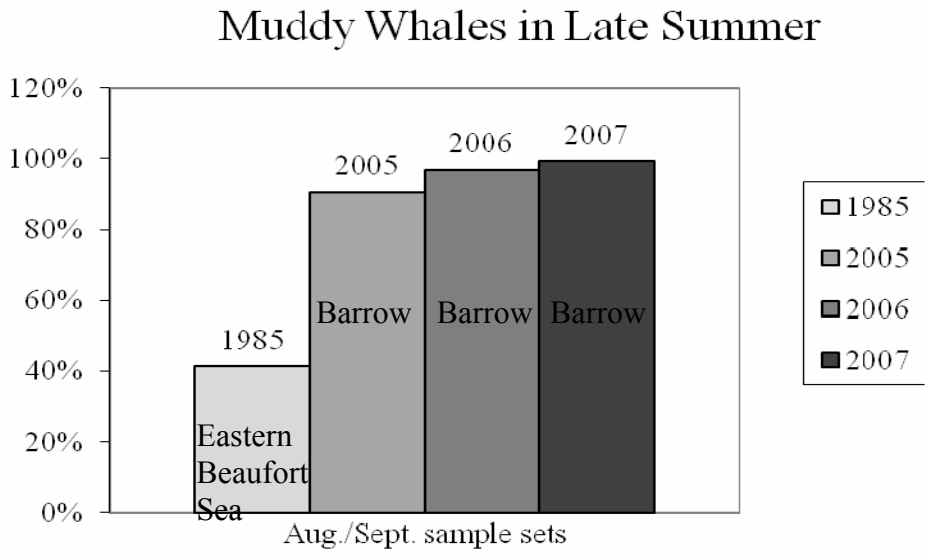


Figure 10. -- Proportions of muddy whales in photographs from all late summer data analyzed.

Table 4. -- Results from *t*-tests for significant differences between the proportions of muddy whales among sample sets, after performing empirical logistic transform. Data are from the Barrow area in May unless otherwise noted.

	1985	1986	2003	2004	All Mays
1985	——	0.09	<<0.001	0.002	0.046
1986		——	<0.001	<0.001	0.46
2003			——	<<0.001	<<0.001
2004				——	<<0.001
1985 EB*	0.001				0.01

*1985 EB represents the sample from Aug./Sept. in the Eastern Beaufort Sea and is included here to show how it compared to the Western Beaufort Sea within the same year as well as compared to the combined May samples off Barrow.

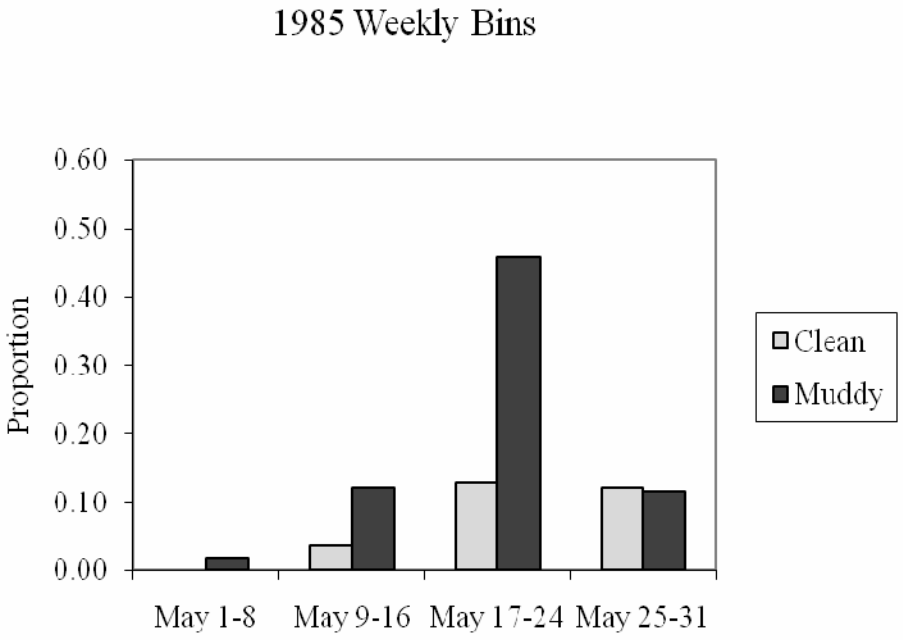
Table 5. -- Results from *t*-tests for significant differences between the proportions of muddy whales among data from late summer sample sets, after performing empirical logistic transform. Data are from the Barrow area unless otherwise noted.

	2005	2006	2007	All Barrow
2005	——	0.06	0.01	
2006		——	0.18	
2007			——	
1985 EB*				<<0.001

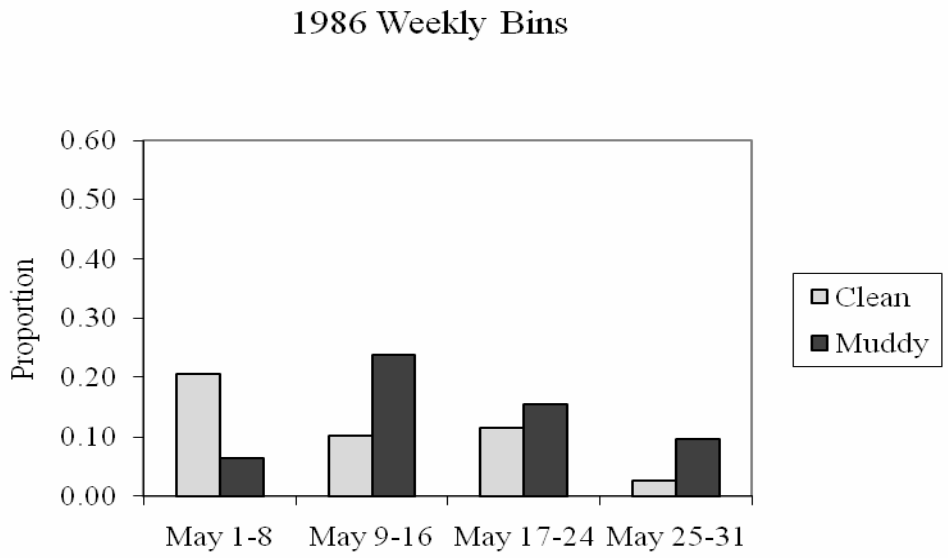
*1985 EB represents the sample from Aug./Sept. in the Eastern Beaufort Sea.

Temporal Variation in Epibenthic Feeding

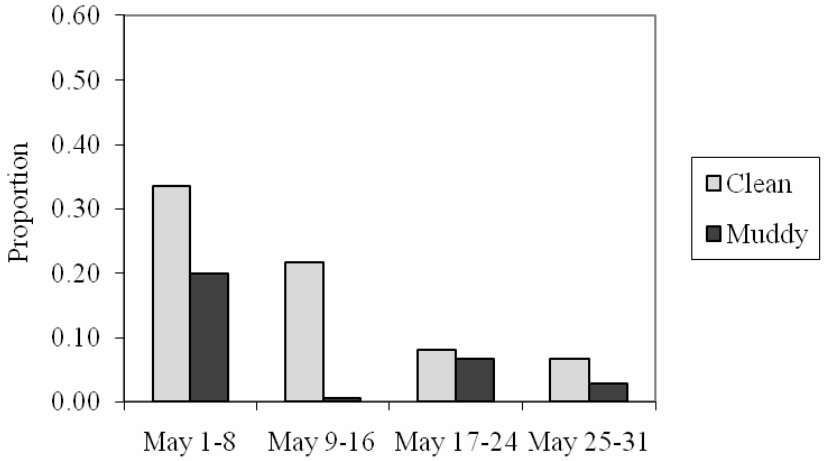
An objective of this research was to investigate whether there was a pattern to the timing of when whales feed epibenthically off of Barrow. To accomplish this, Excel charts were created showing muddy and clean whales from May photographs for each year. Data were separated into weekly bins to visualize if there was any obvious pattern to the timing of muddy versus clean whales among years (Figs. 11a-e). The plots fail to show an apparent pattern of when bowheads engage in epibenthic feeding in May off Barrow.



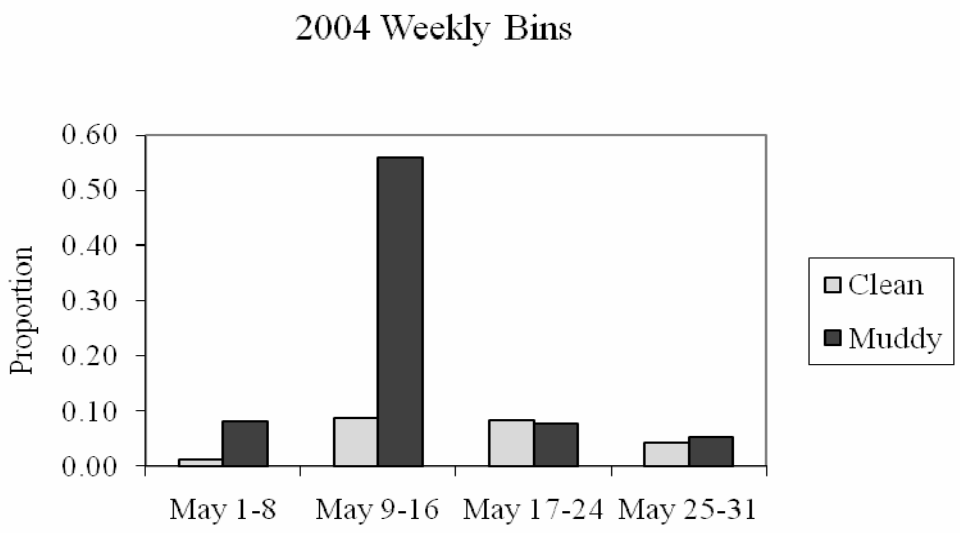
a


1986 Weekly Bins
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Proportion
May 1-8
May 9-16
May 17-24
May 25-31
Clean
Muddy

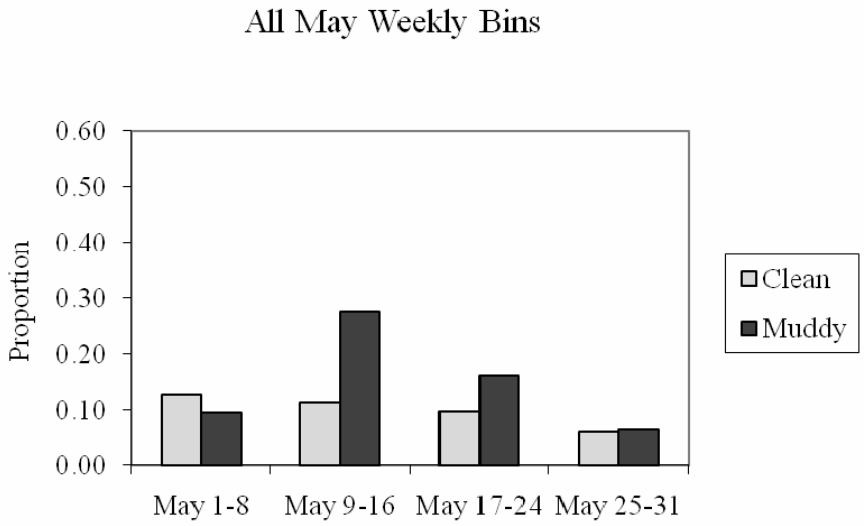
b


2003 Weekly Bins
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Proportion
May 1-8
May 9-16
May 17-24
May 25-31
Clean
Muddy

c



d



e

Figure 11. -- Proportions of muddy and clean whales separated into weekly bins from photographs in May in order to explore if a temporal pattern exists to epibenthic feeding in May off Barrow, Alaska. (a) 1985, (b) 1986, (c) 2003, (d) 2004, (e) all four Mays combined.

Spatial Variation of Epibenthic Feeding

No obvious pattern emerges in the series of ArcGIS maps (Figs. 12-18) to suggest that feeding whales are consistently located separately from non-feeding whales. However, there is a limit to determining feeding locations through photographic analysis since mud is so persistent on bowhead whale skin. Therefore, feeding whale locations were not analyzed with respect to bathymetry. It is clear from this analysis, however, that the Barrow area is an important and commonly used feeding area during both the spring (55% of the sample were muddy) and fall (97% of the sample) migrations, and in agreement with published records wherein whales seem to prefer shelf waters off of Barrow (Moore 2000, Moore et al. 2000, Moore and Reeves 1993).

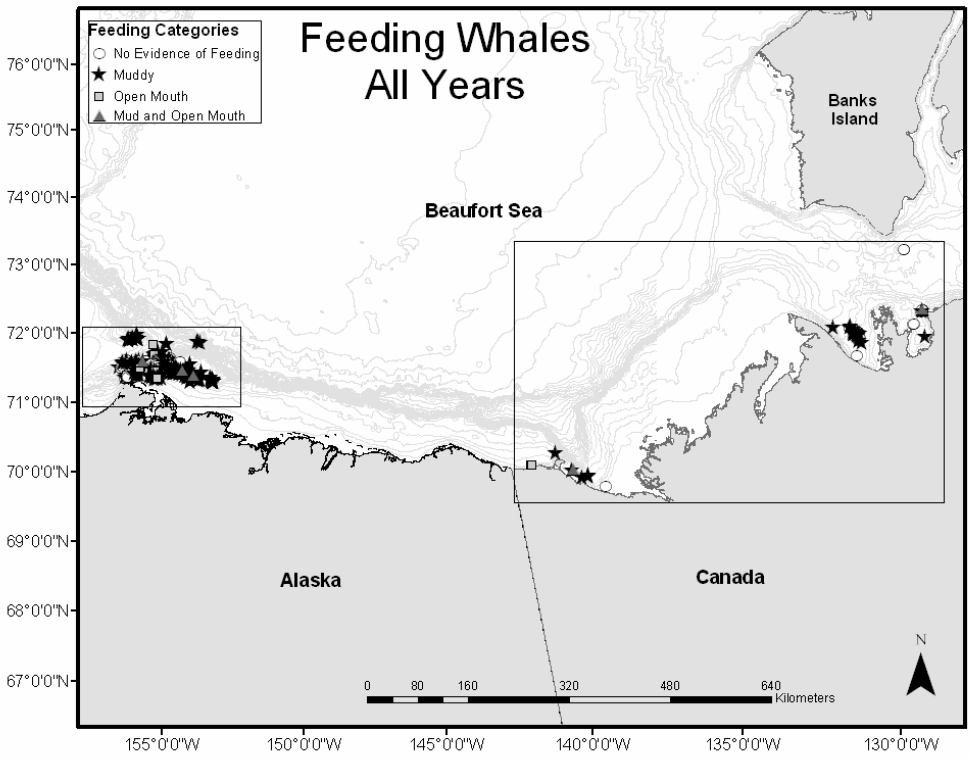


Figure 12. -- Overview of locations of feeding (and non-feeding) whales from photographic evaluations for all projects. Boxes depict the general area where photographs were taken. A scarcity of sighting locations in the Eastern Beaufort Sea is a reflection of sample size and is not considered representative of whale distribution.

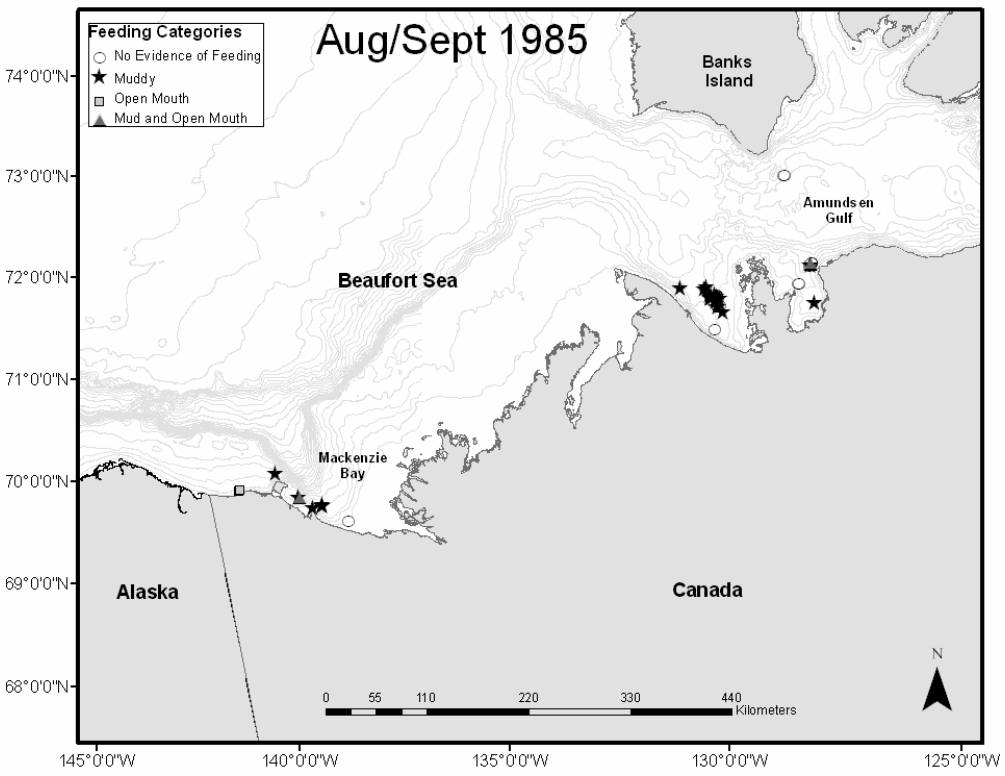


Figure 13. -- Locations of feeding (and non-feeding) whales in late summer, Eastern Beaufort Sea, Canada. A scarcity of sighting locations in the Eastern Beaufort Sea is a reflection of sample size and is not considered representative of whale distribution.

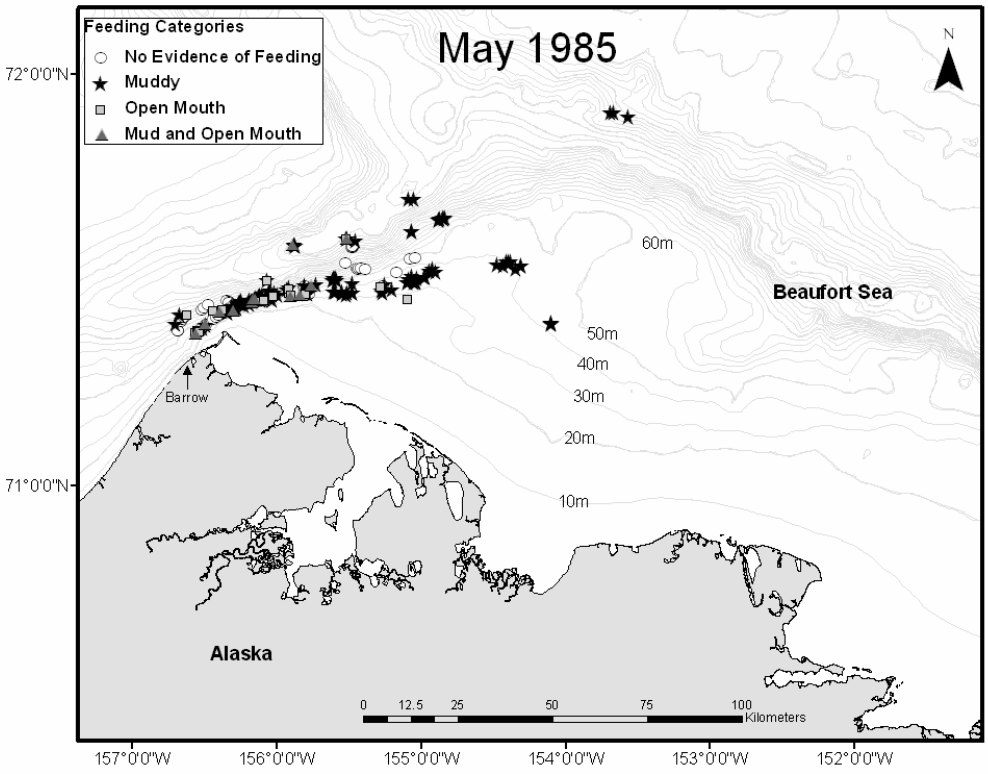


Figure 14. -- Locations of feeding (and non-feeding) whales in May 1985 off Barrow, Alaska.

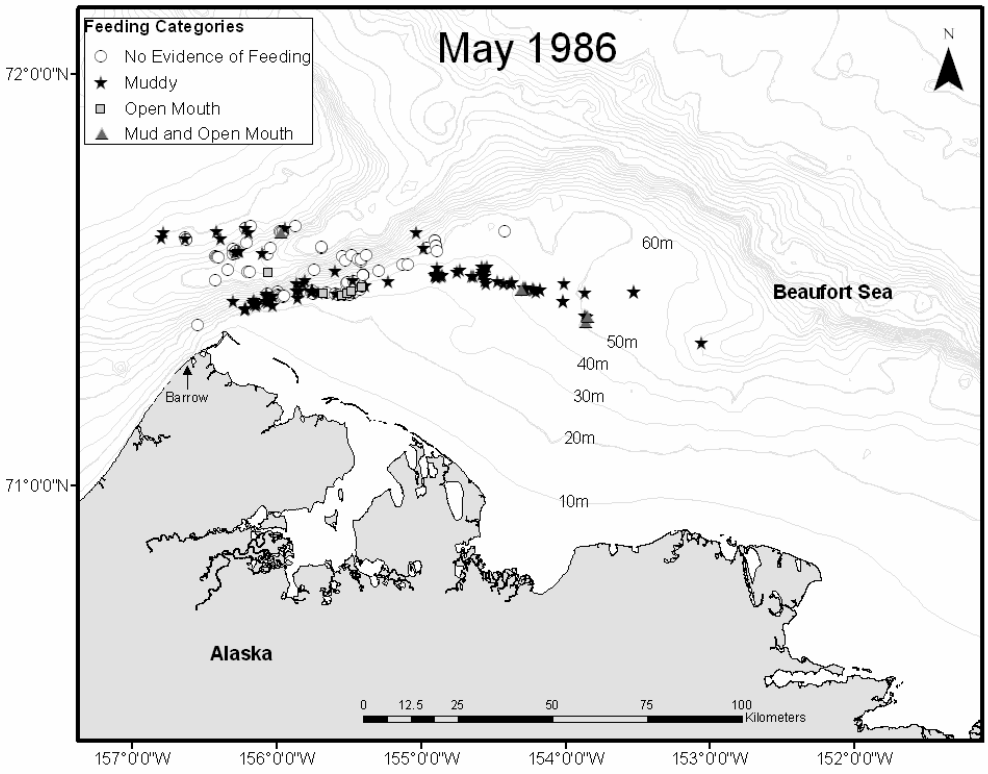


Figure 15. -- Locations of feeding (and non-feeding) whales in May 1986 off Barrow, Alaska.

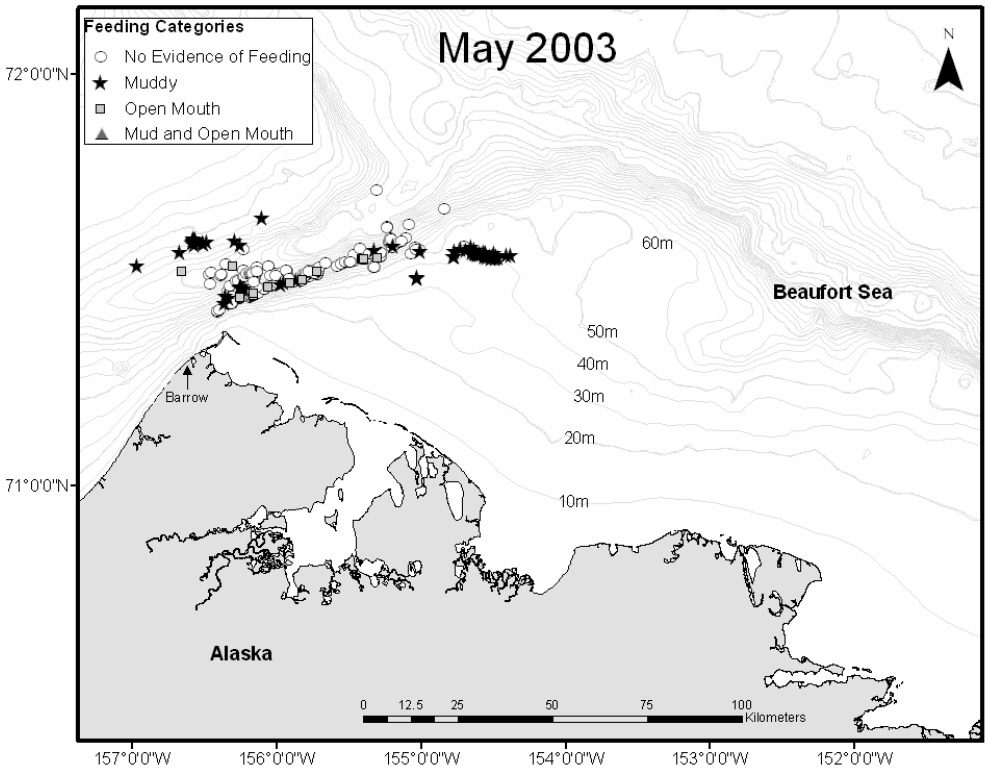


Figure 16. -- Locations of feeding (and non-feeding) whales in May 2003 off Barrow, Alaska.

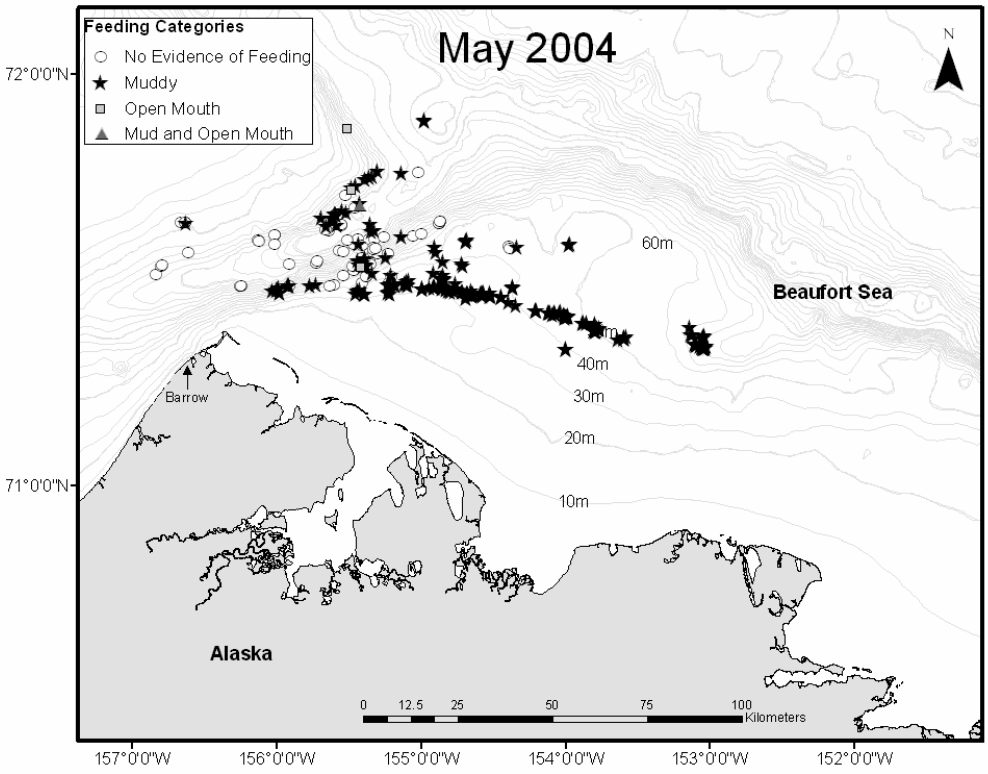


Figure 17. -- Locations of feeding (and non-feeding) whales in May 2004 off Barrow, Alaska.

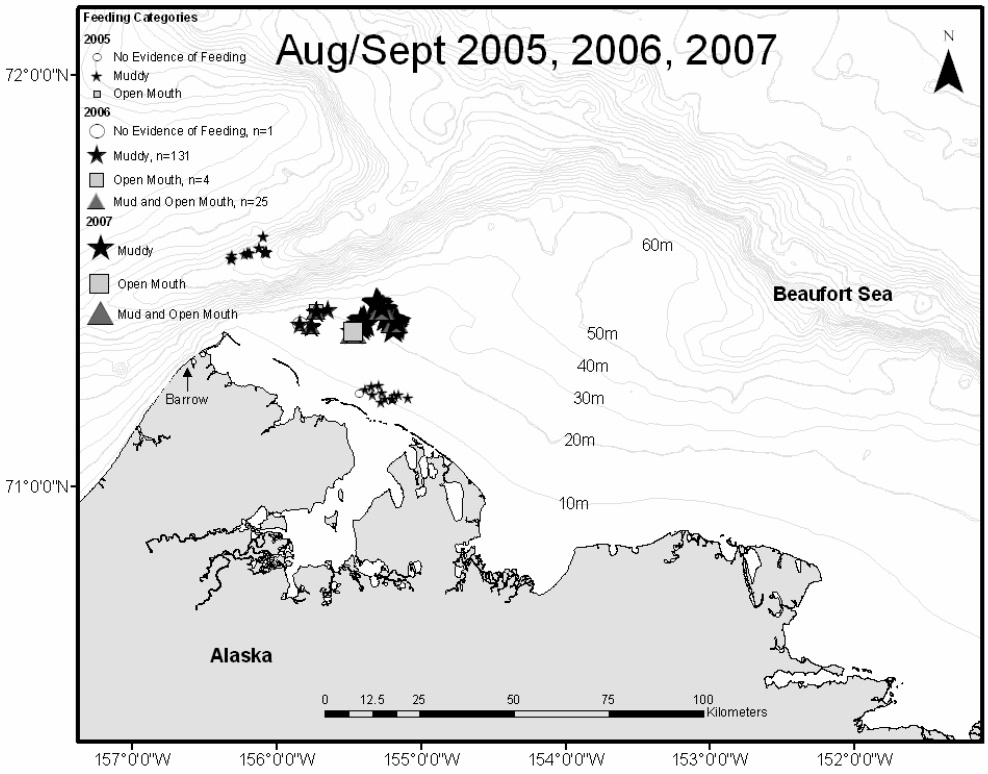


Figure 18. -- Locations of feeding (and non-feeding) whales in late summer 2005, 2006, and 2007, off Barrow, Alaska. Positional data were approximate in 2006, so the symbols represent the outermost bounds of all sighting locations, and sample size is shown in the legend for this sample set.

Age Class and Epibenthic Feeding

For most of the sample sets evaluated, there was no difference between the proportion of muddy juveniles to muddy adults. In May of 1986 and when all four May sample sets off Barrow were combined, there was a significant difference (*t*-test, $P < 0.004$), with muddy adults being more common. For all data comparisons, a simple *t*-test (2-tailed) was used to test for significant differences, after performing an empirical logistic transform (Cox and Snell 1989) on the data to normalize the proportions. See Tables 6-8 for data summarizations and statistics.

Table 6. -- Total numbers of juveniles and adults per feeding category (from the Barrow area unless otherwise noted).

Year	Juveniles	Adults	Total
1985			
Muddy	49	68	117
Clean	19	28	47
All*	76	109	185
1986			
Muddy	27	59	86
Clean	41	29	70
All	71	88	159
2003			
Muddy	27	39	66
Clean	64	91	155
All	106	137	243
2004			
Muddy	61	186	247
Clean	12	61	73
All	73	250	323
All 4 Mays			
Muddy	164	352	516
Clean	136	209	345
All	326	584	910
1985 EB**			
Muddy	15	19	34
Clean	14	32	46
All	29	53	82

***** "All" represents all photos that I made a "feeding decision" on; therefore, this also includes whales with open mouths. ** "EB" stands for Eastern Beaufort Sea.

Table 7. -- Proportion of juveniles and adults by feeding category (from the Barrow area unless otherwise noted).

Year	Juveniles	Adults	Total
1985			
Muddy	0.42	0.58	1.00
Clean	0.40	0.60	1.00
All*	0.41	0.59	1.00
1986			
Muddy	0.31	0.69	1.00
Clean	0.59	0.41	1.00
All	0.45	0.55	1.00
2003			
Muddy	0.41	0.59	1.00
Clean	0.41	0.59	1.00
All	0.44	0.56	1.00
2004			
Muddy	0.25	0.75	1.00
Clean	0.16	0.84	1.00
All	0.23	0.77	1.00
All 4 Mays			
Muddy	0.32	0.68	1.00
Clean	0.39	0.61	1.00
All	0.36	0.64	1.00
1985 EB**			
Muddy	0.44	0.56	1.00
Clean	0.30	0.07	1.00
All	0.35	0.65	1.00

***** "All" represents all photos that I made a "feeding" decision on, therefore also includes open mouths. ** “EB” stands for Eastern Beaufort Sea.

Table 8. -- Proportion of muddy juveniles and adults (from the Barrow area unless otherwise noted). The *P*-value results from a *t*-test for significant differences between the proportion of muddy juveniles and adults within sample sets, after performing empirical logistic transform.

Year	Juveniles	Adults	Total	*P*-value
May 1985	0.64	0.62	0.63	0.78
May 1986	0.38	0.67	0.54	0.0005
May 2003	0.25	0.28	0.27	0.61
May 2004	0.84	0.74	0.76	0.12
All 4 May's	0.50	0.60	0.57	0.004
1985 E.Beaufort Sea	0.52	0.36	0.41	0.17

DISCUSSION

This is among the first work done to analyze aerial photographs of bowhead whales for evidence of epibenthic feeding. The focus of this study has been the BCB bowhead whale population, particularly in the Barrow area. It has been known that whales occasionally become muddied while feeding, but the fact that this feeding strategy is so commonly employed has not been evident in the literature. This is largely due to the fact that most aerial observations of feeding whales have been in the Eastern Beaufort Sea, an area long recognized as the main feeding ground for the BCB bowheads (Lowry 1993). In this region, it seems likely that water column feeding is the most common feeding strategy. Indeed, Würsig and Clark (1993) go so far as to state that water column feeding is "undoubtedly by far the most common feeding mode." However, the Barrow area, where the whales are known to migrate by, has been under-appreciated as a feeding area and therefore, less aerial effort, such as circling for an intense behavioral study, has focused on observation of feeding behavior there.

This study reveals that the epibenthic feeding strategy is a common feeding behavior in the Barrow area. It is important to note that bowheads are generally present in shallower water in the western compared to eastern Beaufort Sea, so the fact that whales off Barrow tend to feed closer to the substrate may not be surprising. Like all large whales, bowheads feed where prey is most dense. It is also well known that copepods and euphausiids instinctively to make diel vertical migrations in the water column such that they are located deeper during daylight hours as a predator avoidance strategy (Fortier et al. 2001, Hays 2003). Additionally, in late summer, zooplankton tend to enter into a state of diapause and remain in deeper water, when their lipid reserves are highest to carry them through the upcoming winter when food resources are low (Baumgartner et al. 2003a). It seems that whales utilizing both a water column feeding strategy and those feeding epibenthically are actually targeting the same prey species. Baumgartner et al. (2003b) found that right whales target

copepods that aggregate just above the bottom mix layer, regardless of the depth at which the bottom mix layer was present. Evidence exists to indicate that right whales, like bowheads, occasionally feed near the bottom on dense layers of prey and return to the surface muddy (Stone et al. 1990, Clapham 2004).

Near Barrow, the vertical migration of prey may be limited due to shallow shelf waters, whereas prey may migrate deeper in the eastern Beaufort Sea and still remain in the water column. Results from echosounder surveys in the eastern Beaufort Sea in September 1985 and 1986 showed that zooplankton biomass in nearshore areas was greatest near the bottom (depth range 10-30 m), but in the inner and outer shelf zones, biomass was greatest at depths between 10 and 40 m (Griffiths et al. 1987). Griffiths et al. (1987) also found that average zooplankton biomass was highest in the nearshore and inner shelf areas (coastal of the 50 m contour) compared to the outer shelf area (seaward of the 50 m contour), with copepods being the dominant zooplankter in the nearshore areas. From analysis of stomach contents of whales landed at Barrow, it appears that bowheads are primarily targeting euphausiids off Barrow, especially in late summer (Lowry et al. 2004). Griffiths et al. (1987) also found higher biomass of euphausiids in the western compared to eastern Beaufort Sea.

Würsig et al. (1985) presented the first published observations of muddy bowhead whales. They saw whales surfacing with mud streaming out of their mouths in quantities they describe as "too great to have been picked up incidentally while feeding in the water column near the bottom." The authors suggested that at times the whales were actually feeding directly on the seafloor. However, Würsig and Clark (1993) explained that bowheads were most likely skimming clouds of prey just above the bottom substrate (i.e., epibenthic prey) and not targeting infaunal prey. That bowheads feed near the bottom is supported by analysis of stomach contents (Lowry 1993). Additionally, in 1989 near Point Lonely (approximately 135 km east of Barrow and within the study area), scientists made seven dives in the vicinity of feeding whales that were seen with mud streaming out of their mouths (Wartzok et al. 1990). Benthic cores contained little fauna, but plankton net tows 10-100 cm above the bottom yielded copepods. Wartzok et al. (1990) reported that the suspended

sediments within 1m of the sea floor were so thick that visibility was nil, and they concluded that the bowheads must have been feeding near the bottom (rather than in it), and that feeding in this sediment-laden layer caused the mud to be visible as plumes streaming out of the whales' mouths. They also noted that there was no evidence of bottom disturbance by bowheads in that area.

Würsig and Clark (1993) postulated that feeding epibenthically may be a strategy that is employed most often, and possibly exclusively, by juvenile bowhead whales. There has been some evidence in stomach content analyses that juveniles may target bottom prey more than adults, but the difference was not significant (Lowry 1993, Lowry et al. 2004). Budge et al. (2008) found a statistically significant correlation between body length and fatty acid composition in the blubber suggesting that diet varies with age. However, some of the small whales in their sample set may have still been nursing which could explain some of the difference. Interestingly, this research showed that there was no statistical difference for most of the years examined (including the eastern Beaufort Sea sample) between the proportion of muddy juveniles to the proportion of muddy adults. However, in the only two sample sets that showed significant difference, it was adults that comprised the largest proportion of epibenthic feeders, not the juveniles.

This research corresponds well with the long-held belief that bowheads feed more during the autumn than during spring migrations (e.g., Lowry and Frost 1984). There is photographic evidence that 99% of all bowhead whales near Barrow in August and September of 2005, 2006, and 2007 were feeding, and of these, 97% were feeding epibenthically. In May near Barrow in 1985, 1986, 2003, and 2004, 61% of the whales were feeding (of these 55% were feeding epibenthically).These percentages are higher than has been determined from stomach content analyses. Lowry et al. (2004) found that 76% of whales harvested in the autumn migration past Barrow had been feeding, and 34% of whales harvested in spring off Barrow had food in their stomachs. However, Lowry et al. (2004) explained that stomach content analyses are likely to underestimate feeding. For example, if too much time elapses before a stomach can be examined, then the food may continue to be digested before contents

can be analyzed. Also, some samples are in such poor condition that evaluations of prey are severely hampered. It's interesting to consider that mud may stay on the skin of a bowhead longer than food stays in its stomach.

The utility of analyzing photographic data for evidence of feeding bowhead whales in the Barrow area has proven quite successful. Additionally, the analytical method of scoring created for this study has been shown to be legitimate. The feeding categories developed here were successfully taught to other biologists with reasonable repeatability and agreement in the results. It is particularly noteworthy that bowhead biologists and whalers displayed high levels of agreement with my assessments of mud on the whales' skin. Although there is a limitation to detecting the precise location where feeding occurred, these data can be used to show generalized areas where feeding was underway. There is photographic proof that mud can persist for over 4 hours on an individual bowhead (Appendix C). Also, this study endeavored to conduct a laboratory test simulating near real-world conditions of flush rates of Beaufort Sea mud, collected from the Barrow area, off of bowhead whale skin in salt-water at flow speeds corresponding to bowhead whale swim speeds. The evidence from the flow tank tests suggests that mud in the Barrow area can persist on bowhead skin for up to 9 hours, if not more. If this test adequately represented a swimming whale, than that particular individual could have become muddied as much as 27 km away (swimming at an average speed of 3 km/hour) (Appendix C). However, it is expected that the controlled nature of the flow tank tests resulted in an overestimation of mud persistence because a swimming whale likely encounters more variable and complex dynamics (e.g., wave action when surfacing to breathe, differing mud amounts, and swim speeds throughout a day) than could be simulated in the laboratory.

It would be beneficial toward understanding bowhead feeding dynamics if a time-depth-recorder tag could be attached to a bowhead feeding in the Barrow area. A tag could helpdocument the vertical location of the whale relative to the seafloor. Also, pitch and roll data could elucidate how whales are oriented when feeding near the seafloor. It has been suggested that they may turn upside-down when feeding just

above the substrate but this remains unverified. A more detailed understanding of the concentrations and behavior of zooplankton in the Barrow area is needed as well. Understanding the behavior of the whales' prey will be very helpful in understanding how whales have adapted to feed on the prey.

This research, examining aerial photographs of bowhead whales, highlights the need to continue collecting photographs of this population as an effective means to learn and monitor the many facets of bowhead ecology. Indeed, photographic analysis has documented that epibenthic feeding is an important strategy for bowheads. Over 64% of the aerial photographs showed whales with distinct evidence of mud, and many more images had equivocal evidence not used in these analyses. This predominance of feeding in an area often thought to be only a migratory corridor emphasizes the need for managers to consider the danger of oil spills, particularly with respect to how oil may become trapped in sediment. In an area of ever increasing interest to oil exploration and development, it is vital to consider the possibly severe ramifications that oil spills may have upon feeding bowhead whales.

ACKNOWLEDGMENTS

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CITATIONS

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APPENDICES

Appendix A: Scoring Photographs

Original Scoring Scheme (not tested)

The original photographic scoring system was a very simple method of scoring the photographs in a Microsoft Access database for evidence of feeding (Table A1). There was one feeding column and two mud columns delineating whether mud was present on the head or the back and how much mud was present in general terms. When mud covered < 1/3 of the area, it was considered it to be a small amount of mud and when it was > 1/3 of the area, it was scored to reflect a significant amount of mud. Finally, a comment column was used to describe any rare events such as the color of feces or presence of a mud plume or sloughing skin. The comment column was also used to designate if an image needed to be double-checked because I questioned a score and wanted the image to be checked by another person.

Table A1. --Original scoring system (not tested).

Feeding?	Mud on head?	Mud on back?	Comments
0 = cant tell	0 = can't tell	0 = can't tell	Mud plume
1 = No (no evidence)	1 = no mud	1 = no mud	Color-red feces
2 = Y mud	2 = small mud	2 = small mud	Sloughing
3 = Y open mouth	3 = signif. mud	3 = signif. mud	Double-check
4 = Y feces	9 = not evaluated	9 = not evaluated	
23 = mud and open mouth			
24 = mud and feces			
34 = open mouth and feces			
9 = not evaluated			

After all images from 1985 and 1986 were scored, the scoring system was reassessed. There were apparent downfalls to using the scoring system, namely that some information was lost due to the over-simplification of the codes. For instance, there was no way to denote confidence regarding mud presence (i.e., there was no way to differentiate "obvious mud" from "possible mud").

Test 1 (50 images tested by NMML biologists)

It was decided that adding a column for the confidence of the score was essential. Also, scoring for the presence of mud on the entire head precluded one from making any possible assessments of how the whale was feeding. For example, if a whale fed upside down, one would expect to see its rostrum covered with thick mud more often than its cheeks (and the reverse to be true if the whale fed on its side). In addition, it was decided that flukes should be included in the scoring process. Initially, it was decided to ignore flukes in the scores because they are usually not visible compared to the rest of the body. Also, it seemed that flukes could get muddy just by swimming close to the seafloor without necessarily indicating feeding. As can be seen in Table A2, columns were added to show whether mud was present in four zones on the body (rostrum, cheeks, back, and flukes), and a series of dropdown menus within an Access form allowed us to score how confident we were that mud was present, the apparent quantity of mud, a brief description of the mud, and whether it was thick or thin. We also scored whether or not a whale's mouth was open (slightly or wide) or indeterminable. When there was no mud present for any given zone, we also gave a confidence score relating to that decision. When a score of "can't tell" was given for a zone, then we didn't fill out anything else.

After designing this new scoring system, a set of 50 images were selected (Table A3) to test whether the categories were logical and how much scorers would agree on decisions within the categories. The test was given to two people at NMML and was compared to my test as the baseline. Instructions were given to each person, and attempts were made to convey the same information to both scorers, including a training set of 21 images that we discussed together. The sample photos were kept with them as a reference set to use when they took the test.

Table A2. -- Test 1. Mud columns were filled out separately for each of four body zones in every image (rostrum, cheeks, back, flukes).

Feeding?	Open mouth descriptor	Mud	Confidence	Mud amount	Mud descriptor	Mud coating	Plume present
Can't tell	Slightly open	No mud	Definitely (>90% sure)	<1/3	Streaks	Thin	No
No evidence of feeding	Wide open	Yes mud	Probably (>70% sure)	<2/3	Blotchy	Thick	Yes
Yes: mud		Can't tell	Likely (>50% sure)	>2/3			
Yes: open mouth			Possible (>30% sure)				
Yes: feces			Unsure (>10% sure)				
Yes: mud and open mouth							
Yes: mud and feces							
Yes: open mouth and feces							
Yes: mouth, feces, and mud							
Not evaluated							

Table A3. --50 images tested by NMML biologists.

030107	032809	0313505	0403908	0413609
030708.1	037706	0313506	0403909	0413810
030803	038104	0401808	0404404	0414306
030805	039706	0402005	0404405	0414307
031503	0311303	0402007	0404610	0414510
031510	0311508	0402407	0406902	0414602
031808	0312310	0402409	0407702	0415707
032104	0312803	0402909	0409908	0415708
032505	0313007	0403310	0411408	0416705
032808	0313209	0403907	0413608	0416706

Test 2 (50 images tested by NMML biologists)

After discussions with the testers, it was concluded that there was a need to simplify the test. Therefore, the last three confidence scores were collapsed (likely, possible, and unsure) into one category called "likely." This new "likely" column was defined as less than 70% confident of mud (or no mud), and in the analyses it would be treated as "unsure" and therefore not counted (but it was called "likely" so people wouldn't hesitate to use it). The intent was to filter out all the images in the lower confidence categories. A few other minor things were changed such as adding "no" and "can't tell" options under open mouth and a "covered" option under the mud descriptor to capture when the zone is covered in mud and therefore can not be described in a streaky or blotchy pattern. After the test (Table A4) and associated Access form (see Figure A1 for visual aid of the scoring form) were updated, another test of the same set of 50 images was given to the same scorers and one new scorer. However, this time, a training protocol was provided (see below) which explained all of the categories and denoted specific points necessary to make when training people. It was hoped that this more systematic training approach would not only aid the scorers in taking the test but also improve agreement among them. In both training sessions from the first and second test, a binder of reference photos was provided and used to discuss scoring categories, and sample scores were given for some of the reference images. The sample binder stayed with the scorer while they took the test.

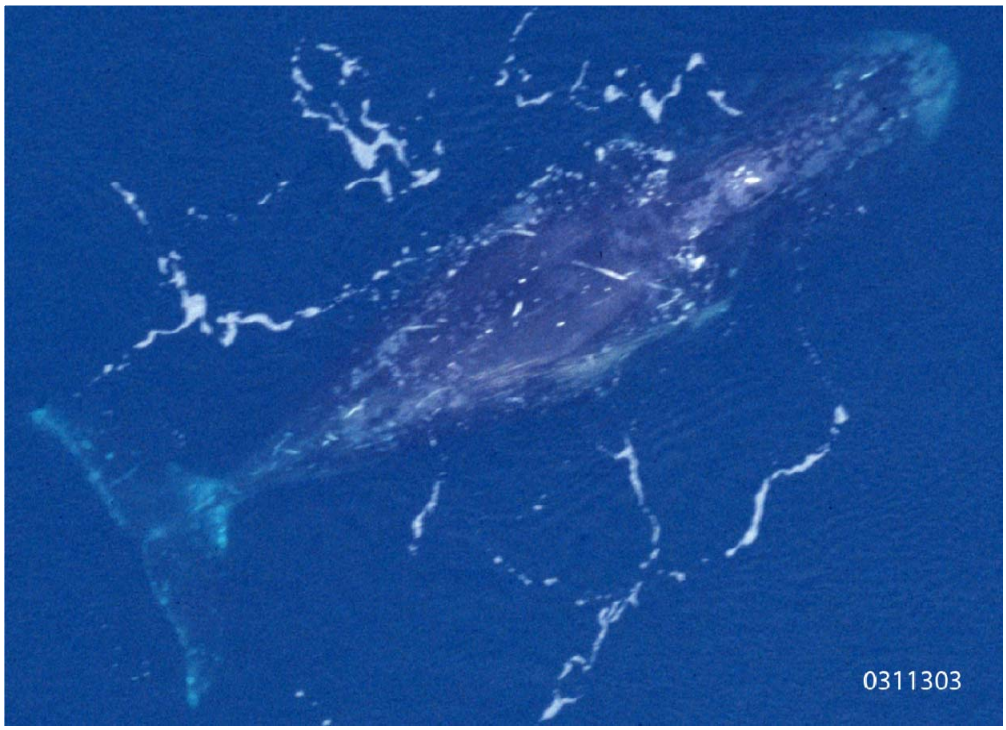
Table A4. -- Test 2. Mud columns were filled out separately for each of four body zones in every image (rostrum, cheeks, back, flukes).

Feeding	Open mouth descriptor	Mud	Confidence	Mud amount	Mud descriptor	Mud coating	Plume present
can't tell	no	no mud	definitely (>90% sure)	<1/3	streaks	thin	no
no evidence of feeding	slightly open	yes mud	probably (>70% sure)	<2/3	blotchy	thick	yes
yes: mud	wide open	can't tell	likely (<70% sure)	>2/3	covered		
yes: open mouth	can't tell						
yes: feces							
yes: mud and open mouth							
yes: mud and feces							
yes: open mouth and feces							
yes: mouth, feces and mud							

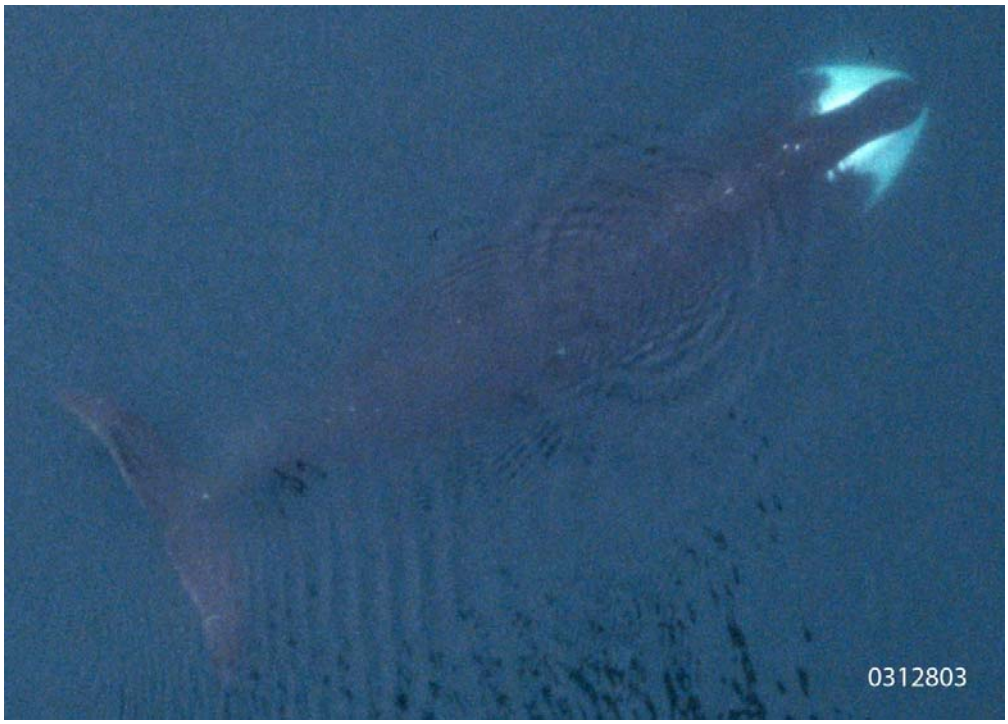
Test 3 (15 images tested by bowhead experts)

The comparisons among scorers from Tests 1 and 2 (between each other, between themselves, between tests) quickly became onerous and complicated beyond merit regarding the simple intention of proving that other people generally agree on my decisions regarding evidence of feeding whales. Therefore, it was decided to give out a very simplified test to whalers and bowhead experts to ensure that people familiar with bowhead whales agree with my categorical feeding decisions. A subset of 15 images (see below) was assembled for these experts to score. Images were intentionally selected from Test 2 based on previous tester's agreement, such that 5 photos were images on which all scorers agreed were muddy, 5 showed no evidence of feeding, and 5 had uncertainty and disagreements in the scores. This variety was chosen to explore how experts would score the range of photos that I had to score for this study. This test forced people to make a decision on whether a whale was muddy or clean and whether they were "definitely sure," "probably sure," or "unsure" of that decision. No explanation or delineation into zones was made; they simply scored each whale image for the presence/absence of mud. In addition to the standard training reference set of 21 images, I also wrote a new and much simpler set of scoring definitions that they could refer back to when taking the test (see below for definitions and example test form).

Test 3 Images

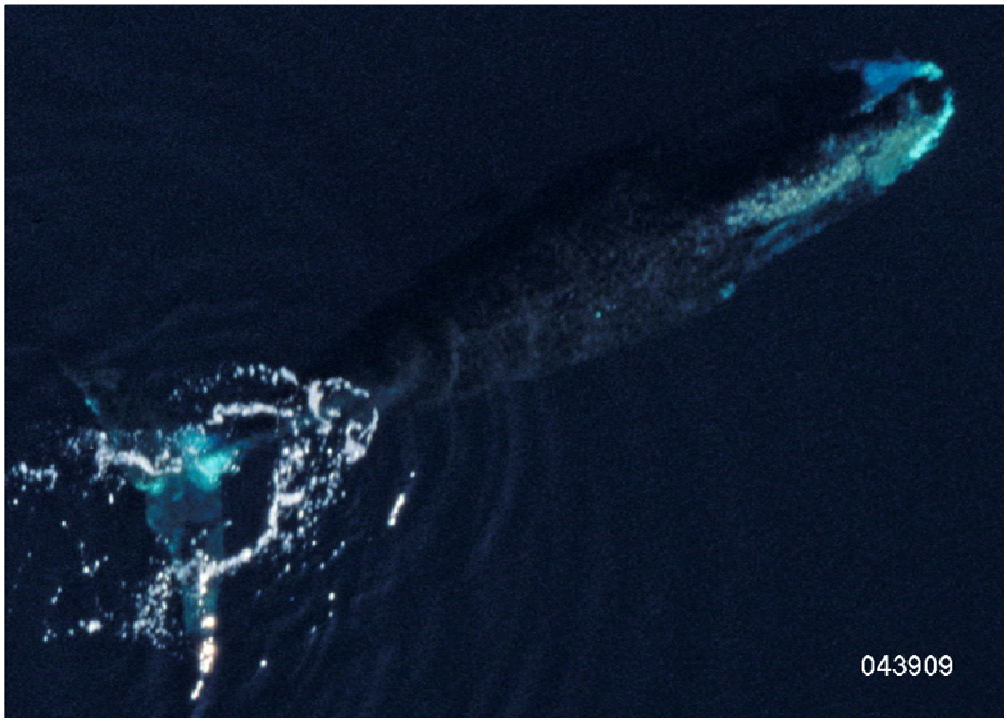

0311303

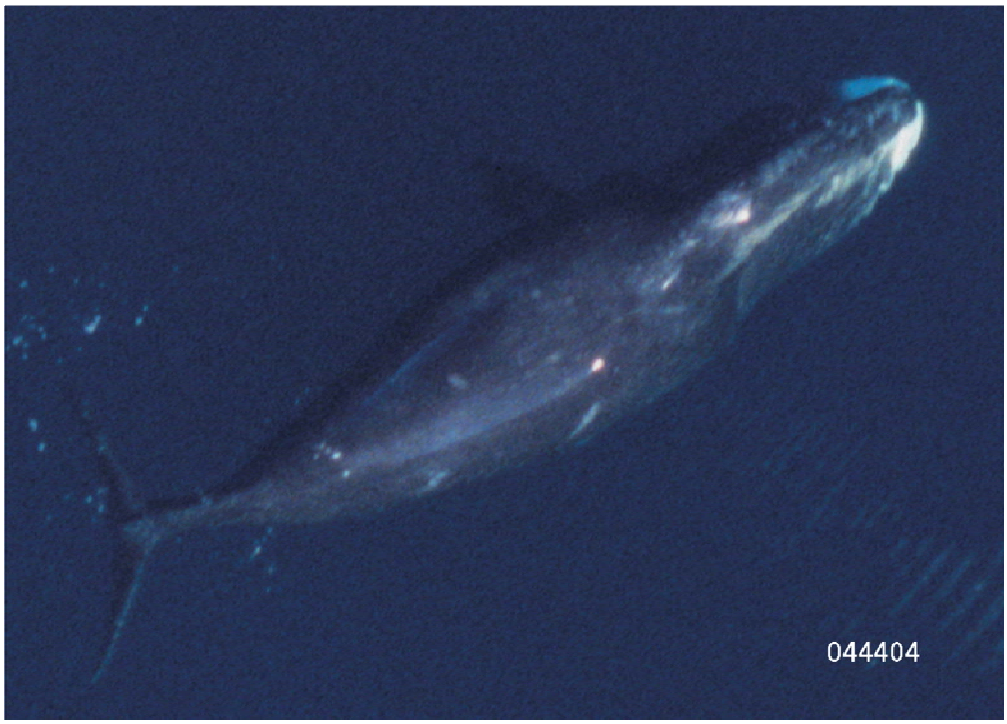

0311508


0312803


043310

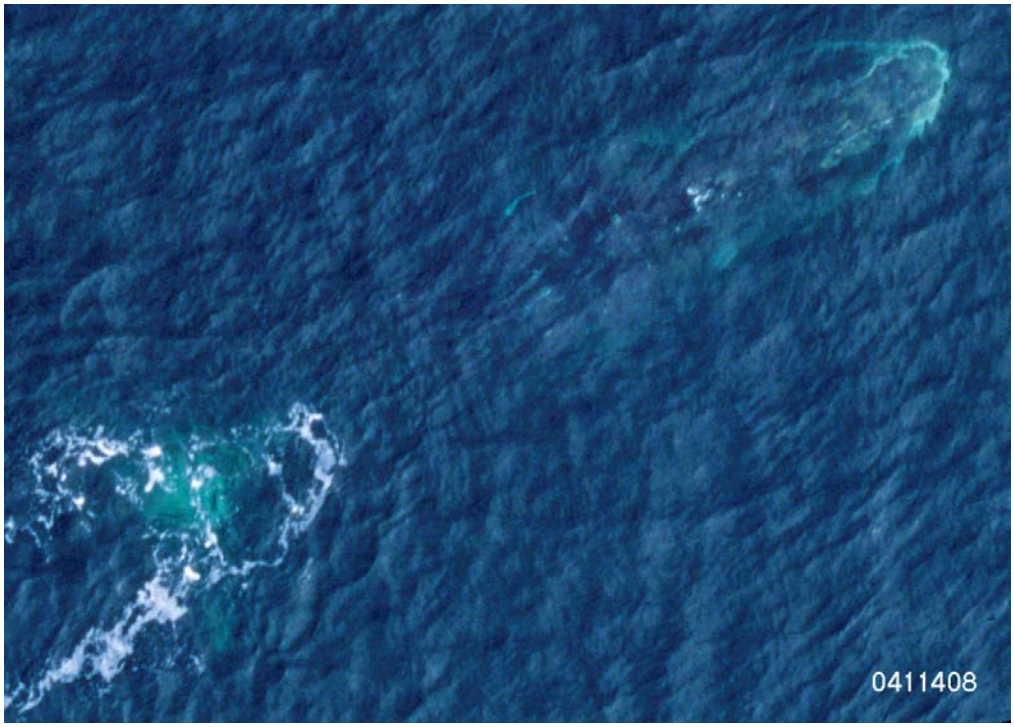

043907


043909


044404

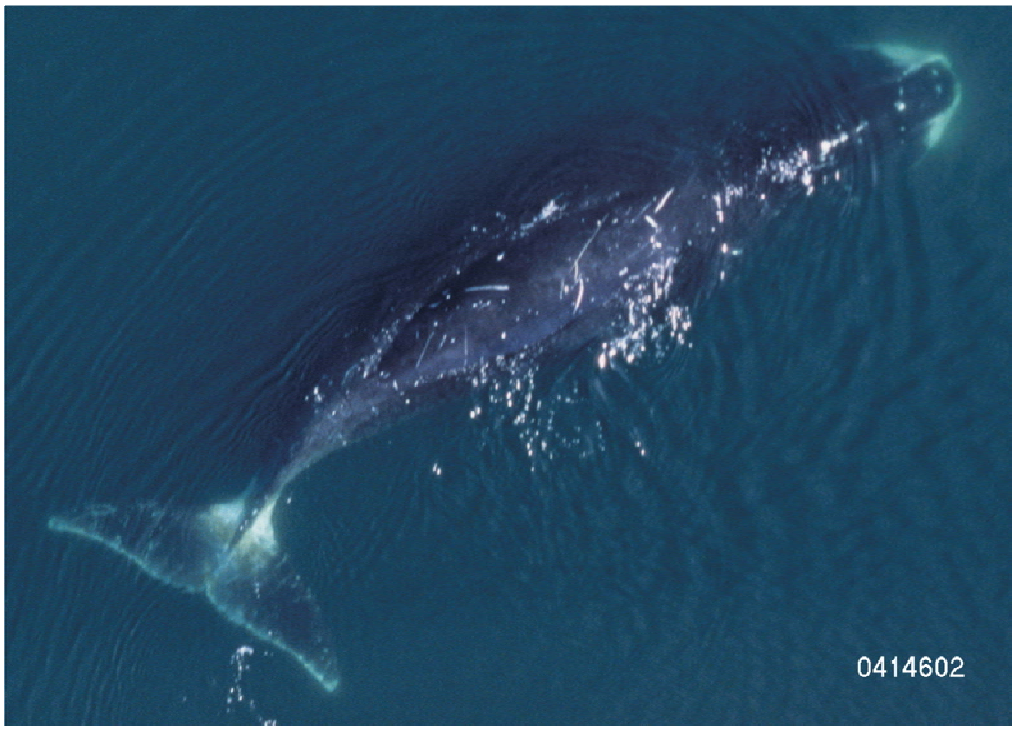

046902


047702


0411408


0413609


0414306



Test Results

Test 1 and Test 2 (50 images tested by NMML biologists)

Three people at NMML took the same test twice (with a simplified scoring system for Test 2). They were Christy Sims (CS), Katie Sweeney (KS), and Julie Mocklin (JM). Janice Waite (JW) took Test 2 only. I first created a series of pivot tables in Excel comparing myself to CS and KS on the original test. I then created a series of new pivot tables between me (JM) and CS, KS, and JW for Test 2. The percent agreements between JM × CS and JM × KS both improved from Test 1 to Test 2. This improvement is likely due to the learning process, because Test 2 was simplified, and/or because testers had benefited from more explicit training. Pivot tables were then created for JM × JM, CS × CS, and KS × KS to look at agreements among scorers compared to themselves for each category to see how consistent they were in their decisions. Comparing each scorer's results from Test 1 to Test 2 showed that the three scorers agreed with themselves 70% to79% on all categories combined. Agreement between JM × Others as well as Others × Themselves was always highest

when evaluating mud presence, amount, and confidence in any zone, and was lowest when scoring for mud descriptors (thick/thin, streaks/blotchy/covered).

In total, 70 different pivot tables were created to compare each permutation of scorers for each scoring category. Here, just the raw data are provided (therefore, no effort has been made to correct the data for missing or contradictory scores).

Table A5(a). -- JM's scores from Test 1 of the 50 image scoring test. This table has been split; A5(a) shows the general feeding column as well as all scores made on the head of the whale, A5(b) shows JM's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A5(a) and A5(b) to clarify which photo is being scored.

image number	feeding?	open mouth descriptor	confidence of open mouth	rostrum mud?	confidence of rostrum mud	rostrum mud amount	rostrum mud descriptor	rostrum mud coating	cheeks mud?	confidence of cheeks mud	cheeks mud amount	cheeks mud descriptor	cheeks mud coating
030107	no evidence of feeding			no mud	likely (>50%)				don't know				
030708.1	cant tell			don't know					yes mud	unsure (>10%)	<1/3	blotchy	thin
030803	yes: mud			yes mud	likely (>50%)	>2/3	covered	thin	yes mud	likely (>50%)	<2/3	blotchy	thin
030805	cant tell	slightly open	unsure (>10%)	don't know					no mud	unsure (>10%)			
031503	no evidence of feeding			no mud	probably (>70%)				don't know				
031510	no evidence of feeding			don't know					don't know				
031808	yes: mud			yes mud	unsure (>10%)	<1/3	blotchy	thin	don't know				
032104	no evidence of feeding			no mud	possible (>30%)				no mud	probably (>70%)			
032505	no evidence of feeding			no mud	likely (>50%)				no mud	likely (>50%)			
032808	no evidence of feeding			no mud	probably (>70%)				no mud	probably (>70%)			
032809	yes: mud			no mud	definitely (>90%)				yes mud	probably (>70%)	<2/3	blotchy	thin
037706	yes: mud			don't know					don't know				
038104	yes: mud			yes mud	unsure (>10%)	<1/3	blotchy	thin	no mud	likely (>50%)			
039706	no evidence of feeding			no mud	definitely (>90%)				no mud	probably (>70%)			
0311303	yes: mud			yes mud	definitely (>90%)	<2/3	blotchy	thick	yes mud	definitely (>90%)	<2/3	blotchy	thick
0311508	no evidence of feeding			no mud	possible (>30%)				no mud	possible (>30%)			

Table A5(a). --Continued.

0312310	no evidence of feeding			no mud	definitely (>90%)				no mud	probably (>70%)			
0312803	no evidence of feeding			no mud	definitely (>90%)				no mud	probably (>70%)			
0313007	no evidence of feeding			no mud	definitely (>90%)				no mud	probably (>70%)			
0313209	cant tell			don't know					don't know				
0313505	yes: mud			yes mud	possible (>30%)	<1/3	blotchy	thin	don't know				
0313506	no evidence of feeding			don't know					yes mud	possible (>30%)	<1/3	blotchy	thin
0401808	yes: mud			no mud	probably (>70%)				yes mud	likely (>50%)	<1/3	blotchy	thin
0402005	yes: mud			yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	possible (>30%)	<2/3	covered	thin
0402007	yes: mud			yes mud	unsure (>10%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin
0402407	no evidence of feeding			no mud	probably (>70%)				no mud	likely (>50%)			
0402409	yes: mud			don't know					yes mud	definitely (>90%)	<2/3	blotchy	thin
0402909	yes: open mouth	wide open	definitely (>90%)	no mud	probably (>70%)				don't know				
0403310	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0403907	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thin
0403908	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	<1/3	blotchy	thick
0403909	yes: mud			yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	blotchy	thick
0404404	yes: mud			yes mud	definitely (>90%)	<1/3	streaks	thick	yes mud	definitely (>90%)	<1/3	streaks	thick
0404405	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	blotchy	thick
0404610	yes: mud			yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	blotchy	thin
0406902	no evidence of feeding			no mud	probably (>70%)				no mud	probably (>70%)			

Table A5(a). --Continued.

0407702	yes: mud			yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	unsure (>10%)	<1/3	blotchy	thin
0409908	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thin	yes mud	definitely (>90%)	>2/3	covered	thin
0411408	yes: mud			yes mud	definitely (>90%)	<2/3	blotchy		yes mud	definitely (>90%)	<2/3	blotchy	thin
0413608	cant tell			don't know					don't know				
0413609	yes: mud			yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	>2/3	streaks	thick
0413810	no evidence of feeding			no mud	probably (>70%)				no mud	possible (>30%)			
0414306	yes: mud & open mouth	wide open	probably (>70%)	don't know					don't know				
0414307	yes: mud & open mouth	wide open	likely (>50%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0414510	yes: mud			yes mud	probably (>70%)	<1/3	blotchy	thick	yes mud	probably (>70%)	<1/3	blotchy	thin
0414602	no evidence of feeding			no mud	probably (>70%)				no mud	likely (>50%)			
0415707	cant tell			yes mud	possible (>30%)	<1/3	streaks	thin	yes mud	unsure (>10%)	<1/3	blotchy	thin
0415708	no evidence of feeding			no mud	probably (>70%)				no mud	possible (>30%)			
0416705	yes: mud & open mouth	wide open	definitely (>90%)	yes mud	possible (>30%)	<1/3	blotchy	thin	don't know				
0416706	yes: mud			yes mud	probably (>70%)	<2/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin

Table A5(b). -- JM's scores from Test 1 of the 50 image scoring test. This table has been split; A5(a) shows the general feeding column as well as all scores made on the head of the whale, A5(b) shows JM's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A5(a) and A5(b) to clarify which photo is being scored.

image number	back mud?	confidence of back mud	back mud amount	back mud descriptor	back mud coating	flukes mud?	confidence of flukes mud	flukes mud amount	flukes mud descriptor	flukes mud coating	plume present
030107	no mud	likely (>50%)				yes mud	possible (>30%)				No
030708.1	no mud	possible (>30%)				don't know					No
030803	yes mud	likely (>50%)	<2/3	streaks	thin	don't know					No
030805	no mud	unsure (>10%)				no mud	unsure (>10%)				No
031503	no mud	likely (>50%)				no mud	definitely (>90%)				No
031510	don't know					no mud	possible (>30%)				No
031808	yes mud	unsure (>10%)	<1/3	blotchy	thin	don't know					No
032104	no mud	probably (>70%)				don't know					No
032505	no mud	likely (>50%)				don't know					No
032808	no mud	possible (>30%)				no mud	definitely (>90%)				No
032809	yes mud	likely (>50%)	>2/3	covered	thin	no mud	likely (>50%)				No
037706	don't know					don't know					No
038104	don't know					don't know					No
039706	don't know					don't know					No
0311303	yes mud	definitely (>90%)	<1/3	blotchy	thick	no mud	probably (>70%)				No
0311508	no mud	definitely (>90%)				no mud	probably (>70%)				No
0312310	no mud	definitely (>90%)				no mud	probably (>70%)				No
0312803	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0313007	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0313209	no mud	likely (>50%)				no mud	probably (>70%)				No

Table A5(b). -- Continued.

0313505	yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	possible (>30%)	<1/3	blotchy	thin	No
0313506	don't know					no mud	probably (>70%)				No
0401808	no mud	definitely (>90%)				no mud	possible (>30%)				No
0402005	no mud	probably (>70%)				yes mud	likely (>50%)	>2/3	covered	thin	No
0402007	don't know					yes mud	possible (>30%)	<1/3	blotchy	thin	No
0402407	no mud	definitely (>90%)				yes mud	possible (>30%)	<1/3	blotchy	thin	No
0402409	don't know					yes mud	unsure (>10%)	<1/3	blotchy	thin	No
0402909	don't know					don't know					No
0403310	yes mud	definitely (>90%)	<2/3	streaks	thin	yes mud	definitely (>90%)	>2/3	blotchy	thin	No
0403907	yes mud	unsure (>10%)	<1/3	blotchy	thin	no mud	possible (>30%)				No
0403908	yes mud	probably (>70%)	<1/3	streaks	thin	no mud	likely (>50%)				No
0403909	no mud	likely (>50%)				no mud	likely (>50%)				No
0404404	yes mud	possible (>30%)	<1/3	blotchy	thin	no mud	possible (>30%)				No
0404405	yes mud	definitely (>90%)	<2/3	blotchy	thin	don't know					No
0404610	yes mud	probably (>70%)	<2/3	covered	thin	don't know					No
0406902	no mud	probably (>70%)				don't know					No
0407702	yes mud	unsure (>10%)	<1/3	blotchy	thin	no mud	likely (>50%)				No
0409908	no mud	likely (>50%)				don't know					No
0411408	yes mud	possible (>30%)	<1/3	blotchy	thin	don't know					No
0413608	yes mud	unsure (>10%)	<2/3	blotchy	thin	no mud	probably (>70%)				No
0413609	yes mud	probably (>70%)	<1/3	streaks	thin	don't know					No
0413810	no mud	unsure (>10%)				no mud	unsure (>10%)				No
0414306	yes mud	likely (>50%)	<1/3	blotchy	thin	no mud	likely (>50%)				No
0414307	yes mud	likely (>50%)	<1/3	blotchy	thin	don't know					No

Table A5(b). -- Continued.

0414510	yes mud	possible (>30%)	<1/3	blotchy	thin	no mud	likely (>50%)				No
0414602	yes mud	unsure (>10%)	<1/3	covered	thin	no mud	likely (>50%)				No
0415707	yes mud	unsure (>10%)	<1/3	blotchy	thin	don't know					No
0415708	no mud	possible (>30%)				no mud	possible (>30%)				No
0416705	yes mud	unsure (>10%)	<2/3	covered	thin	no mud	probably (>70%)				No
0416706	no mud	possible (>30%)				don't know					No

Table A6(a). -- CS's scores from Test 1 of the 50 image scoring test. This table has been split; A6(a) shows the general feeding column as well as all scores made on the head of the whale, A6(b) shows CS's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A6(a) and A6(b) to clarify which photo is being scored.

image number	feeding?	open mouth descriptor	confidence of open mouth	rostrum mud?	confidence of rostrum mud	rostrum mud amount	rostrum mud descriptor	rostrum mud coating	cheeks mud?	confidence of cheeks mud	cheeks mud amount	cheeks mud descriptor	cheeks mud coating
030107	cant tell			don't know					no mud	unsure (>10%)			
030708.1	cant tell			yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	possible (>30%)		blotchy	thin
030803	cant tell			no mud	possible (>30%)				no mud	possible (>30%)			
030805	cant tell			yes mud	probably (>70%)	<2/3	blotchy	thin	yes mud	possible (>30%)	<1/3	blotchy	thin
031503	no evidence of feeding			no mud	definitely (>90%)				no mud	likely (>50%)			
031510	no evidence of feeding			no mud	likely (>50%)				no mud	likely (>50%)			
031808	cant tell			no mud	unsure (>10%)				no mud	unsure (>10%)			
032104	no evidence of feeding			no mud	definitely (>90%)				no mud	definitely (>90%)			
032505	cant tell			yes mud	possible (>30%)	<1/3	blotchy	thin	no mud	probably (>70%)			
032808	cant tell			no mud	probably (>70%)				no mud	probably (>70%)			
032809	yes: mud			no mud					yes mud	definitely (>90%)	<2/3	blotchy	thin
037706	cant tell			don't know	definitely (>90%)				don't know	definitely (>90%)			
038104	cant tell			yes mud	probably (>70%)	<1/3			no mud	probably (>70%)			
039706	cant tell	slightly open	probably (>70%)	no mud	definitely (>90%)				no mud	definitely (>90%)			
0311303	yes: mud			yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	blotchy	thick
0311508	yes: mud & open mouth	slightly open	definitely (>90%)	no mud	definitely (>90%)				yes mud	possible (>30%)	<1/3	blotchy	thin
0312310	no evidence of feeding			no mud	likely (>50%)				no mud	definitely (>90%)			
0312803	no evidence of feeding			no mud	definitely (>90%)				no mud	definitely (>90%)			
0313007	no evidence of feeding			no mud	definitely (>90%)				no mud	definitely (>90%)			

Table A6(a). -- Continued.

0313209	cant tell			don't know	definitely (>90%)				don't know	definitely (>90%)			
0313505	cant tell			yes mud	possible (>30%)				yes mud	likely (>50%)	<1/3	blotchy	thin
0313506	cant tell			don't know	probably (>70%)				no mud	likely (>50%)			
0401808	yes: mud & open mouth	slightly open	probably (>70%)	yes mud	likely (>50%)	<1/3	streaks	thin	yes mud	likely (>50%)	<2/3	streaks	thin
0402005	cant tell	slightly open	possible (>30%)	yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	unsure (>10%)	<1/3	blotchy	thin
0402007	cant tell			yes mud	likely (>50%)	<1/3	blotchy	thin	yes mud	definitely (>90%)	<1/3	blotchy	thin
0402407	yes: mud & open mouth	slightly open	probably (>70%)	yes mud	likely (>50%)	<2/3	streaks	thin	yes mud	probably (>70%)	<1/3	streaks	thin
0402409	cant tell			yes mud	unsure (>10%)	<1/3	blotchy	thin	yes mud	definitely (>90%)	<2/3	blotchy	thin
0402909	yes: open mouth	wide open	probably (>70%)	yes mud	unsure (>10%)	<1/3	blotchy	thin	yes mud	possible (>30%)	<1/3	streaks	thin
0403310	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0403907	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	<2/3	streaks	thick
0403908	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	probably (>70%)	<1/3	blotchy	thin
0403909	yes: mud			yes mud	definitely (>90%)	<2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	blotchy	thick
0404404	yes: mud			yes mud	definitely (>90%)	<1/3	streaks	thick	yes mud	definitely (>90%)	<1/3	streaks	thick
0404405	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	streaks	thick
0404610	yes: mud			yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	streaks	thick
0406902	no evidence of feeding			no mud	definitely (>90%)				no mud	definitely (>90%)			
0407702	cant tell			yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	unsure (>10%)	<1/3	blotchy	thin
0409908	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	<2/3	covered	thick
0411408	cant tell			yes mud	definitely (>90%)	<1/3	blotchy	thin	yes mud	definitely (>90%)	<1/3	blotchy	thin
0413608	cant tell			no mud	unsure (>10%)				yes mud	unsure (>10%)	<1/3	blotchy	thin
0413609	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	<2/3	covered	thick
0413810	yes: feces			no mud	probably (>70%)				no mud	probably (>70%)			
0414306	cant tell			yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	possible (>30%)	<1/3	blotchy	thin

Table A6(a). -- Continued.

0414307	yes: mud			yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	probably (>70%)	<2/3	blotchy	thin
0414510	yes: mud			yes mud	likely (>50%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin
0414602	no evidence of feeding			no mud	definitely (>90%)				no mud	definitely (>90%)			
0415707	cant tell			yes mud	likely (>50%)	<1/3	blotchy	thin	yes mud	likely (>50%)	<1/3	blotchy	thin
0415708	cant tell			no mud	probably (>70%)				yes mud	likely (>50%)	<1/3	streaks	thin
0416705	cant tell			yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	unsure (>10%)	<1/3	blotchy	thin
0416706	yes: mud			yes mud	definitely (>90%)	<2/3	blotchy	thin	yes mud	definitely (>90%)	<1/3	streaks	

Table A6(b). -- CS's scores from Test 1 of the 50 image scoring test. This table has been split; A6(a) shows the general feeding column as well as all scores made on the head of the whale, A6(b) shows CS's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A6(a) and A6(b) to clarify which photo is being scored.

image number	back mud?	confidence of back mud	back mud amount	back mud descriptor	back mud coating	flukes mud?	confidence of flukes mud	flukes mud amount	flukes mud descriptor	flukes mud coating	plume present
030107	no mud	probably (>70%)				no mud	probably (>70%)				No
030708.1	don't know					don't know					No
030803	yes mud	possible (>30%)	<1/3	blotchy	thin	don't know					No
030805	yes mud	possible (>30%)	<1/3	blotchy	thin	no mud	likely (>50%)				No
031503	no mud	probably (>70%)				no mud	definitely (>90%)				No
031510	yes mud	likely (>50%)				no mud	definitely (>90%)				No
031808	yes mud	possible (>30%)				no mud	likely (>50%)				No
032104	no mud	definitely (>90%)				no mud	definitely (>90%)				No
032505	no mud	probably (>70%)				don't know	definitely (>90%)				No
032808	don't know					no mud	probably (>70%)				No
032809	yes mud	likely (>50%)	<2/3	blotchy	thin	no mud	probably (>70%)				No
037706	don't know	probably (>70%)				yes mud	likely (>50%)	<1/3	blotchy	thin	No
038104	yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	possible (>30%)	<1/3	blotchy	thin	No
039706	yes mud	possible (>30%)	<1/3	blotchy	thin	don't know	definitely (>90%)				No
0311303	yes mud	definitely (>90%)	<2/3	streaks	thin	yes mud	likely (>50%)	<1/3	blotchy	thin	No
0311508	yes mud	possible (>30%)	<1/3	blotchy	thin	no mud	definitely (>90%)				No
0312310	no mud	likely (>50%)				no mud	definitely (>90%)				No
0312803	no mud	definitely (>90%)				no mud	probably (>70%)				No
0313007	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0313209	yes mud	possible (>30%)	<1/3	blotchy	thin	no mud	probably (>70%)	<2/3	blotchy	thin	No

Table A6(b). -- Continued.

0313505	yes mud	likely (>50%)	<1/3	blotchy	thin	no mud	definitely (>90%)				No
0313506	yes mud	possible (>30%)	<1/3	blotchy	thin	no mud	definitely (>90%)				No
0401808	no mud	probably (>70%)				don't know	definitely (>90%)				No
0402005	don't know	probably (>70%)				yes mud	likely (>50%)	<1/3	streaks	thin	No
0402007	don't know					yes mud	likely (>50%)	<1/3	blotchy	thin	No
0402407	yes mud	likely (>50%)	<1/3	blotchy	thin	yes mud	likely (>50%)	<1/3	blotchy	thin	No
0402409	don't know					no mud	probably (>70%)				No
0402909	don't know					don't know					No
0403310	yes mud	definitely (>90%)	<2/3	streaks	thin	yes mud	definitely (>90%)	<2/3	blotchy	thin	No
0403907	yes mud	definitely (>90%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<2/3	blotchy	thin	No
0403908	yes mud	definitely (>90%)	<1/3	blotchy	thin	don't know					No
0403909	no mud	probably (>70%)				yes mud	likely (>50%)	<1/3	blotchy	thin	No
0404404	yes mud	likely (>50%)	<1/3	blotchy	thin	don't know	definitely (>90%)				No
0404405	yes mud	definitely (>90%)	<2/3	streaks	thin	yes mud	probably (>70%)	<1/3	blotchy	thin	No
0404610	yes mud	definitely (>90%)	<1/3	blotchy	thin	don't know					No
0406902	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0407702	no mud	probably (>70%)				yes mud	possible (>30%)	<1/3	blotchy	thin	No
0409908	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin	No
0411408	don't know					don't know					No
0413608	yes mud	possible (>30%)	<1/3	blotchy	thin	no mud	unsure (>10%)				No
0413609	yes mud	definitely (>90%)	<1/3	streaks	thin	don't know					No
0413810	no mud	probably (>70%)				no mud	probably (>70%)				No
0414306	yes mud	probably (>70%)	<1/3	blotchy	thin	don't know					No
0414307	don't know					don't know					No

Table A6(b). -- Continued.

0414510	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	likely (>50%)	<1/3	blotchy	thin	No
0414602	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0415707	yes mud	likely (>50%)	<1/3	blotchy	thin	don't know					No
0415708	yes mud	possible (>30%)		blotchy	thin	no mud	probably (>70%)				No
0416705	yes mud	possible (>30%)	<1/3	blotchy	thin	no mud	definitely (>90%)				No
0416706	don't know					yes mud	likely (>50%)	<1/3	blotchy		No

Table A7(a). -- KS's scores from Test 1 of the 50 image scoring test. This table has been split; A7(a) shows the general feeding column as well as all scores made on the head of the whale, A7(b) shows KS's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A7(a) and A7(b) to clarify which photo is being scored.

image number	feeding?	open mouth descriptor	confidence of open mouth	rostrum mud?	confidence of rostrum mud	rostrum mud amount	rostrum mud descriptor	rostrum mud coating	cheeks mud?	confidence of cheeks mud	cheeks mud amount	cheeks mud descriptor	cheeks mud coating
030107	no evidence of feeding			no mud	likely (>50%)				no mud	unsure (>10%)			
030708.1	no evidence of feeding			no mud	likely (>50%)				no mud	definitely (>90%)			
030803	cant tell			yes mud	unsure (>10%)	<1/3	blotchy	thin	yes mud	unsure (>10%)	>2/3	covered	thin
030805	cant tell			yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	unsure (>10%)	<2/3	blotchy	thin
031503	no evidence of feeding			no mud	definitely (>90%)				no mud	probably (>70%)			
031510	no evidence of feeding			don't know					don't know				
031808	cant tell			don't know					don't know				
032104	no evidence of feeding			no mud	definitely (>90%)				no mud	probably (>70%)			
032505	cant tell			no mud	likely (>50%)				no mud	likely (>50%)			
032808	no evidence of feeding			no mud	probably (>70%)				no mud	probably (>70%)			
032809	cant tell			yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin
037706	no evidence of feeding			don't know					don't know				
038104	no evidence of feeding			no mud	probably (>70%)				no mud	definitely (>90%)			
039706	no evidence of feeding			no mud	definitely (>90%)				no mud	definitely (>90%)			
0311303	yes: mud			yes mud	definitely (>90%)	>2/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin
0311508	no evidence of feeding			no mud	definitely (>90%)				no mud	definitely (>90%)			

Table A7(a). -- Continued.

0312310	no evidence of feeding			no mud	probably (>70%)				no mud	probably (>70%)			
0312803	no evidence of feeding			no mud	definitely (>90%)				no mud	definitely (>90%)			
0313007	no evidence of feeding			no mud	probably (>70%)				no mud	probably (>70%)			
0313209	cant tell			don't know					don't know				
0313505	no evidence of feeding			don't know					no mud	likely (>50%)			
0313506	no evidence of feeding			no mud	likely (>50%)				no mud	probably (>70%)			
0401808	yes: mud			no mud	probably (>70%)				yes mud	probably (>70%)	<1/3	blotchy	thin
0402005	yes: mud			yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	possible (>30%)	<2/3	blotchy	thin
0402007	cant tell			yes mud	unsure (>10%)	<1/3	blotchy	thin	yes mud	likely (>50%)	<1/3	blotchy	thin
0402407	no evidence of feeding			yes mud	likely (>50%)	<1/3	blotchy	thin	don't know				
0402409	cant tell			yes mud	likely (>50%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<2/3	blotchy	thin
0402909	yes: open mouth	wide open	definitely (>90%)	no mud	probably (>70%)				don't know				
0403310	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0403907	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0403908	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	<1/3	streaks	thick
0403909	yes: mud			yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	blotchy	thick
0404404	yes: mud			yes mud	probably (>70%)	<2/3	streaks	thin	yes mud	definitely (>90%)	<1/3	streaks	thick
0404405	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thin	yes mud	definitely (>90%)	>2/3	covered	thin
0404610	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thin	yes mud	definitely (>90%)	<1/3	blotchy	thin
0406902	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	<2/3	blotchy	thick

Table A7(a). -- Continued.

0407702	yes: mud			yes mud	likely (>50%)	<1/3	blotchy	thin	yes mud	likely (>50%)	<1/3	blotchy	thin
0409908	yes: mud			yes mud	probably (>70%)	<2/3	blotchy	thick	yes mud	probably (>70%)	>2/3	blotchy	thin
0411408	yes: mud			yes mud	probably (>70%)	<2/3	blotchy	thin	yes mud	probably (>70%)	<2/3	blotchy	thin
0413608	cant tell			don't know					don't know				
0413609	yes: mud			yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0413810	yes: feces			no mud					no mud				
0414306	yes: mud			don't know					yes mud	unsure (>10%)	<1/3	blotchy	thin
0414307	yes: mud & open mouth	wide open	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0414510	yes: mud			yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin
0414602	no evidence of feeding			no mud	definitely (>90%)				no mud	probably (>70%)			
0415707	no evidence of feeding			no mud	probably (>70%)				no mud	probably (>70%)			
0415708	no evidence of feeding			no mud	definitely (>90%)				no mud	probably (>70%)			
0416705	yes: open mouth	wide open	definitely (>90%)	no mud	probably (>70%)				no mud	probably (>70%)			
0416706	yes: mud			yes mud	probably (>70%)	<2/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin

Table A7(b). -- KS's scores from Test 1 of the 50 image scoring test. This table has been split; A7(a) shows the general feeding column as well as all scores made on the head of the whale, A7(b) shows KS's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A7(a) and A7(b) to clarify which photo is being scored.

image number	back mud?	confidence of back mud	back mud amount	back mud descriptor	back mud coating	flukes mud?	confidence of flukes mud	flukes mud amount	flukes mud descriptor	flukes mud coating	plume present
030107	no mud	definitely (>90%)				no mud	probably (>70%)				No
030708.1	no mud	probably (>70%)				no mud	possible (>30%)				No
030803	yes mud	unsure (>10%)	<2/3	streaks	thin	don't know					No
030805	yes mud	possible (>30%)	<1/3	streaks	thin	yes mud	possible (>30%)	>2/3	covered	thin	No
031503	no mud	definitely (>90%)				no mud	definitely (>90%)				No
031510	no mud	possible (>30%)				no mud	probably (>70%)				No
031808	don't know					don't know					No
032104	no mud	probably (>70%)				no mud	probably (>70%)				No
032505	no mud	possible (>30%)				don't know	unsure (>10%)				No
032808	don't know	possible (>30%)				no mud	probably (>70%)				No
032809	yes mud	likely (>50%)	<1/3	blotchy	thin	don't know					No
037706	no mud	probably (>70%)				no mud	probably (>70%)				No
038104	no mud	probably (>70%)				no mud	probably (>70%)				No
039706	no mud	probably (>70%)				don't know					No
0311303	yes mud	definitely (>90%)	<2/3	streaks	thin	no mud	probably (>70%)				No
0311508	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0312310	no mud	probably (>70%)				no mud	probably (>70%)				No
0312803	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0313007	no mud	probably (>70%)				no mud	probably (>70%)				No

Table A7(b). -- Continued.

0313209	yes mud	possible (>30%)	<1/3	blotchy	thin	no mud	likely (>50%)				No
0313505	no mud	likely (>50%)				no mud	definitely (>90%)				No
0313506	no mud	probably (>70%)				no mud	definitely (>90%)				No
0401808	yes mud	likely (>50%)	<1/3	blotchy	thin	yes mud	unsure (>10%)	>2/3	blotchy	thin	No
0402005	no mud	probably (>70%)				yes mud	likely (>50%)	>2/3	blotchy	thin	No
0402007	yes mud	unsure (>10%)	<1/3	blotchy	thin	yes mud	likely (>50%)	<2/3	blotchy	thin	No
0402407	yes mud	probably (>70%)	<1/3			yes mud	likely (>50%)	<1/3	streaks	thin	No
0402409	no mud	unsure (>10%)				yes mud	likely (>50%)	<2/3	blotchy	thin	No
0402909	don't know					don't know					No
0403310	yes mud	definitely (>90%)	>2/3	streaks	thin	yes mud	definitely (>90%)	<2/3	blotchy	thin	No
0403907	yes mud	likely (>50%)	<1/3	blotchy	thin	no mud	likely (>50%)				No
0403908	yes mud	likely (>50%)	<1/3	blotchy	thin	don't know					No
0403909	yes mud	unsure (>10%)	<1/3	blotchy	thin	yes mud	possible (>30%)	>2/3	blotchy	thin	No
0404404	no mud	likely (>50%)				don't know					No
0404405	yes mud	definitely (>90%)	<2/3	streaks	thin	yes mud	possible (>30%)	<1/3	blotchy	thin	No
0404610	yes mud	definitely (>90%)	<2/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin	No
0406902	yes mud	definitely (>90%)	<2/3	blotchy	thin	yes mud	possible (>30%)	<2/3	blotchy	thin	No
0407702	yes mud	possible (>30%)	<1/3	blotchy	thin	yes mud	unsure (>10%)	<1/3	blotchy	thin	No
0409908	no mud	possible (>30%)				no mud	possible (>30%)				No
0411408	don't know					don't know					No
0413608	don't know					don't know					No
0413609	yes mud	probably (>70%)	<1/3	streaks	thin	don't know					No
0413810	no mud					no mud					Yes
0414306	yes mud	possible (>30%)	<2/3	blotchy	thin	no mud	probably (>70%)				No

Table A7(b). -- Continued.

0414307	no mud	likely (>50%)				don't know					No
0414510	yes mud	probably (>70%)	<1/3	streaks	thin	don't know					No
0414602	no mud	definitely (>90%)				no mud	probably (>70%)				No
0415707	no mud	probably (>70%)				don't know					No
0415708	no mud	probably (>70%)				no mud	probably (>70%)				No
0416705	no mud	probably (>70%)				no mud	probably (>70%)				No
0416706	yes mud	possible (>30%)	<1/3	blotchy	thin	no mud					No

Table A8(a). -- JM's scores from Test 2 of the 50 image scoring test. This table has been split; A8(a) shows the general feeding column as well as all scores made on the head of the whale, A8(b) shows JM's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A8(a) and A8(b) to clarify which photo is being scored.

image number	feeding?	jm open mouth descriptor	confidence of open mouth	rostrum mud?	confidence of rostrum mud	rostrum mud amount	rostrum mud descriptor	rostrum mud coating	cheeks mud?	confidence of cheeks mud	cheeks mud amount	cheeks mud descriptor	cheeks mud coating
030107	cant tell	no	likely (<70%)	no mud	likely (<70%)				can't tell				
030708.1	yes: mud	no	definitely (>90%)	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<2/3	covered	thin
030803	cant tell	can't tell		yes mud	likely (<70%)	<2/3	blotchy	thick	yes mud	likely (<70%)	<1/3	blotchy	thin
030805	cant tell	slightly open	likely (<70%)	yes mud	likely (<70%)	>2/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
031503	no evidence of feeding	no	likely (<70%)	no mud	likely (<70%)				yes mud	likely (<70%)	<1/3	blotchy	thin
031510	cant tell	no	likely (<70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell				
031808	cant tell	no	likely (<70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)			
032104	no evidence of feeding	no	likely (<70%)	no mud	likely (<70%)				no mud	probably (>70%)			
032505	cant tell	no	likely (<70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
032808	no evidence of feeding	no	likely (<70%)	no mud	likely (<70%)				no mud	likely (<70%)			
032809	yes: mud	no	probably (>70%)	no mud	probably (>70%)				yes mud	probably (>70%)	<2/3	blotchy	thin
037706	cant tell	can't tell		yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
038104	cant tell	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)			
039706	no evidence of feeding	no	likely (<70%)	no mud	definitely (>90%)				no mud	probably (>70%)			
0311303	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	<2/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin
0311508	no evidence of feeding	no	likely (<70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)			

Table A8(a). -- Continued.

0312310	no evidence of feeding	no	probably (>70%)	no mud	likely (<70%)				no mud	likely (<70%)			
0312803	no evidence of feeding	no	definitely (>90%)	no mud	probably (>70%)				no mud	likely (<70%)			
0313007	no evidence of feeding	no	probably (>70%)	no mud	probably (>70%)				no mud	probably (>70%)			
0313209	cant tell	can't tell		no mud	likely (<70%)				can't tell				
0313505	cant tell	wide open	likely (<70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell				
0313506	cant tell	no	probably (>70%)	no mud	likely (<70%)				yes mud	likely (<70%)	<1/3	blotchy	thin
0401808	cant tell	no	likely (<70%)	no mud	likely (<70%)				yes mud	likely (<70%)	<2/3	blotchy	thin
0402005	cant tell	no	likely (<70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<2/3	blotchy	thin
0402007	yes: mud	no	probably (>70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin
0402407	cant tell	no	likely (<70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0402409	yes: mud	no	probably (>70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	definitely (>90%)	<2/3	blotchy	thin
0402909	yes: open mouth	wide open	definitely (>90%)	no mud	probably (>70%)				can't tell				
0403310	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0403907	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	blotchy	thin
0403908	yes: mud	no	likely (<70%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	<1/3	blotchy	thin
0403909	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	<2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	blotchy	thick
0404404	yes: mud	no	probably (>70%)	yes mud	definitely (>90%)	<1/3	streaks	thin	yes mud	definitely (>90%)	<1/3	streaks	thick
0404405	yes: mud	no	probably (>70%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	blotchy	thick
0404610	yes: mud	no	probably (>70%)	yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	blotchy	thin
0406902	no evidence of feeding	no	probably (>70%)	no mud	likely (<70%)				no mud	likely (<70%)			

Table A8(a). -- Continued.

0407702	cant tell	no	probably (>70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0409908	yes: mud	no	probably (>70%)	yes mud	definitely (>90%)	>2/3	covered	thin	yes mud	definitely (>90%)	>2/3	covered	thin
0411408	yes: mud	no	probably (>70%)	yes mud	definitely (>90%)	<2/3	blotchy	thin	yes mud	definitely (>90%)	<2/3	blotchy	thin
0413608	cant tell	no	likely (<70%)	can't tell					can't tell				
0413609	yes: mud	no	probably (>70%)	yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	>2/3	streaks	thick
0413810	yes: feces	no	probably (>70%)	no mud	likely (<70%)				can't tell				
0414306	yes: open mouth	wide open	probably (>70%)	can't tell					can't tell				
0414307	yes: mud & open mouth	wide open	probably (>70%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0414510	cant tell	no	probably (>70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0414602	no evidence of feeding	no	probably (>70%)	no mud	probably (>70%)				no mud	likely (<70%)			
0415707	cant tell	no	probably (>70%)	yes mud	likely (<70%)	<1/3	streaks	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0415708	no evidence of feeding	no	probably (>70%)	no mud	likely (<70%)				yes mud	likely (<70%)	<1/3	blotchy	thin
0416705	yes: open mouth	wide open	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell				
0416706	yes: mud	no	probably (>70%)	yes mud	probably (>70%)	<2/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin

Table A8(b). -- JM's scores from Test 2 of the 50 image scoring test. This table has been split; A8(a) shows the general feeding column as well as all scores made on the head of the whale, A8(b) shows JM's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A8(a) and A8(b) to clarify which photo is being scored.

image number	back mud?	confidence of back mud	back mud amount	back mud descriptor	back mud coating	flukes mud?	confidence of flukes mud	flukes mud amount	flukes mud descriptor	flukes mud coating	plume present
030107	no mud	likely (<70%)				no mud	likely (<70%)				No
030708.1	can't tell					can't tell					No
030803	yes mud	likely (<70%)	<2/3	streaks	thick	can't tell					No
030805	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
031503	no mud	likely (<70%)				no mud	likely (<70%)				No
031510	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
031808	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
032104	no mud	probably (>70%)				no mud	likely (<70%)				No
032505	yes mud	likely (<70%)	<2/3	blotchy	thin	can't tell					No
032808	can't tell					no mud	probably (>70%)				No
032809	yes mud	probably (>70%)	>2/3	covered	thin	can't tell					No
037706	can't tell					can't tell					No
038104	can't tell					can't tell					No
039706	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
0311303	yes mud	definitely (>90%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
0311508	no mud	probably (>70%)				no mud	likely (<70%)				No
0312310	no mud	likely (<70%)				no mud	likely (<70%)				No
0312803	no mud	probably (>70%)				no mud	probably (>70%)				No
0313007	no mud	probably (>70%)				no mud	probably (>70%)				No
0313209	no mud	likely (<70%)				no mud	probably (>70%)				No

Table A8(b). -- Continued.

0313505	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
0313506	can't tell					no mud	probably (>70%)				No
0401808	no mud	probably (>70%)				can't tell					No
0402005	no mud	probably (>70%)				yes mud	likely (<70%)	<2/3	blotchy	thin	No
0402007	can't tell					yes mud	likely (<70%)	<1/3	blotchy	thin	No
0402407	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
0402409	can't tell					yes mud	likely (<70%)	<1/3	blotchy	thin	No
0402909	can't tell					can't tell					No
0403310	yes mud	definitely (>90%)	<1/3	streaks	thin	yes mud	definitely (>90%)	<2/3	blotchy	thin	No
0403907	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
0403908	yes mud	probably (>70%)	<1/3	streaks	thin	no mud	likely (<70%)				No
0403909	no mud	likely (<70%)				no mud	likely (<70%)				No
0404404	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
0404405	yes mud	definitely (>90%)	<2/3	blotchy	thin	can't tell					No
0404610	yes mud	probably (>70%)	<2/3	blotchy	thin	can't tell					No
0406902	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
0407702	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
0409908	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
0411408	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
0413608	can't tell					no mud	likely (<70%)				No
0413609	yes mud	likely (<70%)	<1/3	streaks	thin	can't tell					No
0413810	no mud	likely (<70%)				no mud	likely (<70%)				No
0414306	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
0414307	can't tell					can't tell					No

Table A8(b). -- Continued.

0414510	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
0414602	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	probably (>70%)				No
0415707	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
0415708	no mud	likely (<70%)				no mud	likely (<70%)				No
0416705	yes mud	likely (<70%)	<1/3	covered	thin	no mud	probably (>70%)				No
0416706	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No

Table A9(a). -- CS's scores from Test 2 of the 50 image scoring test. This table has been split; A9(a) shows the general feeding column as well as all scores made on the head of the whale, A9(b) shows CS's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A9(a) and A9(b) to clarify which photo is being scored.

image number	feeding?	open mouth descriptor	confidence of open mouth	rostrum mud?	confidence of rostrum mud	rostrum mud amount	rostrum mud descriptor	rostrum mud coating	cheeks mud?	confidence of cheeks mud	cheeks mud amount	cheeks mud descriptor	cheeks mud coating
030107	no evidence of feeding	no	probably (>70%)	can't tell					can't tell				
030708.1	yes: mud	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<2/3	blotchy	thin
030803	yes: mud	can't tell		yes mud	probably (>70%)	<2/3	blotchy	thin	can't tell				
030805	yes: mud	no	likely (<70%)	yes mud	definitely (>90%)	<2/3	covered	thick	yes mud	definitely (>90%)	<2/3	blotchy	thin
031503	no evidence of feeding	no	definitely (>90%)	no mud	probably (>70%)				no mud	probably (>70%)			
031510	cant tell	can't tell		can't tell					can't tell				
031808	cant tell	can't tell		yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell				
032104	no evidence of feeding	no	probably (>70%)	no mud	probably (>70%)				no mud	probably (>70%)			
032505	cant tell	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
032808	no evidence of feeding	no	definitely (>90%)	no mud	likely (<70%)				no mud	probably (>70%)			
032809	cant tell	no	definitely (>90%)	no mud	definitely (>90%)				yes mud	definitely (>90%)	<1/3	blotchy	thin
037706	cant tell	can't tell		can't tell					can't tell				
038104	cant tell	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	definitely (>90%)			
039706	no evidence of feeding	no	probably (>70%)	no mud	definitely (>90%)				no mud	definitely (>90%)			
0311303	yes: mud	no	probably (>70%)	yes mud	likely (<70%)	<2/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin
0311508	yes: open mouth	slightly open	probably (>70%)	no mud	definitely (>90%)				no mud	definitely (>90%)			
0312310	no evidence of feeding	no	probably (>70%)	no mud	probably (>70%)				can't tell				

Table A9(a). -- Continued.

0312803	no evidence of feeding	no	definitely (>90%)	no mud	definitely (>90%)				no mud	definitely (>90%)			
0313007	no evidence of feeding	no	definitely (>90%)	no mud	definitely (>90%)				no mud	definitely (>90%)			
0313209	no evidence of feeding	can't tell		can't tell					can't tell				
0313505	no evidence of feeding	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	definitely (>90%)			
0313506	cant tell	no	definitely (>90%)	can't tell					yes mud	likely (<70%)	<1/3	blotchy	thin
0401808	cant tell	no	probably (>70%)	no mud	likely (<70%)				yes mud	likely (<70%)	<1/3	blotchy	thin
0402005	no evidence of feeding	no	probably (>70%)	can't tell					no mud	probably (>70%)			
0402007	cant tell	no	probably (>70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0402407	yes: mud	no	probably (>70%)	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<1/3	streaks	thin
0402409	yes: mud	no	definitely (>90%)	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	definitely (>90%)	<1/3	blotchy	thin
0402909	yes: mud & open mouth	wide open	definitely (>90%)	yes mud	probably (>70%)	<1/3	blotchy	thin	can't tell				
0403310	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0403907	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	probably (>70%)	<2/3	blotchy	thin
0403908	yes: mud	no	probably (>70%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	probably (>70%)	<1/3	blotchy	thin
0403909	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	<2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	blotchy	thick
0404404	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	<1/3	streaks	thick	yes mud	definitely (>90%)	<1/3	streaks	thick
0404405	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0404610	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	blotchy	thin
0406902	no evidence of feeding	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)			
0407702	cant tell	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin

Table A9(a). -- Continued.

0409908	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	<2/3	covered	thick	yes mud	definitely (>90%)	<2/3	covered	thick
0411408	yes: mud & open mouth	wide open	probably (>70%)	yes mud	definitely (>90%)	<2/3	blotchy	thick	can't tell				
0413608	cant tell	no	probably (>70%)	can't tell					can't tell				
0413609	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0413810	no evidence of feeding	no	definitely (>90%)	no mud	definitely (>90%)				no mud	probably (>70%)			
0414306	yes: mud & open mouth	wide open	probably (>70%)	can't tell					can't tell				
0414307	yes: mud & open mouth	slightly open	probably (>70%)	yes mud	definitely (>90%)	>2/3	covered	thin	yes mud	probably (>70%)	<2/3	blotchy	thin
0414510	cant tell	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	definitely (>90%)	<1/3	blotchy	thin
0414602	no evidence of feeding	no	definitely (>90%)	no mud	definitely (>90%)				no mud	probably (>70%)			
0415707	no evidence of feeding	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0415708	cant tell	no	definitely (>90%)	no mud	probably (>70%)				no mud	likely (<70%)			
0416705	yes: mud & open mouth	wide open	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell				
0416706	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	<2/3	blotchy	thin	yes mud	definitely (>90%)	<2/3	blotchy	thin

Table A9(b). -- CS's scores from Test 2 of the 50 image scoring test. This table has been split; A9(a) shows the general feeding column as well as all scores made on the head of the whale, A9(b) shows CS's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A9(a) and A9(b) to clarify which photo is being scored.

image number	back mud?	confidence of back mud	back mud amount	back mud descriptor	back mud coating	flukes mud?	confidence of flukes mud	flukes mud amount	flukes mud descriptor	flukes mud coating	plume present
030107	no mud	definitely (>90%)				can't tell					No
030708.1	can't tell					can't tell					No
030803	yes mud	definitely (>90%)	>2/3	covered	thick	can't tell					No
030805	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
031503	no mud	probably (>70%)				no mud	definitely (>90%)				No
031510	can't tell					yes mud	likely (<70%)	<1/3	blotchy	thin	No
031808	yes mud	probably (>70%)	<2/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
032104	no mud	probably (>70%)				can't tell					No
032505	no mud	likely (<70%)				can't tell					No
032808	can't tell					no mud	definitely (>90%)				No
032809	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
037706	no mud	likely (<70%)				can't tell					No
038104	no mud	definitely (>90%)				yes mud	likely (<70%)	<1/3	blotchy	thin	No
039706	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
0311303	yes mud	probably (>70%)	<2/3	streaks	thin	no mud	probably (>70%)				No
0311508	no mud	probably (>70%)				no mud	definitely (>90%)				No
0312310	no mud	probably (>70%)				no mud	probably (>70%)				No
0312803	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0313007	no mud	probably (>70%)				no mud	probably (>70%)				No
0313209	no mud	probably (>70%)				no mud	probably (>70%)				No

Table A9(b). -- Continued.

0313505	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	probably (>70%)				No
0313506	no mud	probably (>70%)				no mud	probably (>70%)				No
0401808	no mud	probably (>70%)				no mud	likely (<70%)				No
0402005	no mud	likely (<70%)				no mud	probably (>70%)				No
0402007	can't tell					yes mud	likely (<70%)	<1/3	blotchy	thin	No
0402407	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
0402409	can't tell					yes mud	likely (<70%)	<1/3	blotchy	thin	No
0402909	can't tell					can't tell					No
0403310	yes mud	definitely (>90%)	<2/3	streaks	thick	yes mud	probably (>70%)	<2/3	blotchy	thin	No
0403907	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
0403908	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
0403909	no mud	probably (>70%)				can't tell					No
0404404	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
0404405	yes mud	definitely (>90%)	<2/3	blotchy	thick	yes mud	probably (>70%)	<2/3	blotchy	thin	No
0404610	yes mud	probably (>70%)	<2/3	blotchy	thin	can't tell					No
0406902	no mud	probably (>70%)				can't tell					No
0407702	can't tell					yes mud	likely (<70%)	<1/3	blotchy	thin	No
0409908	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
0411408	can't tell					can't tell					No
0413608	can't tell					can't tell					No
0413609	yes mud	definitely (>90%)	<1/3	blotchy	thin	can't tell					No
0413810	no mud	likely (<70%)				no mud	probably (>70%)				No
0414306	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	probably (>70%)				No
0414307	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
0414510	yes mud	probably (>70%)	<1/3	blotchy	thin	no mud	probably (>70%)				No
0414602	no mud	probably (>70%)				no mud	probably (>70%)				No

Table A9(b). -- Continued.

0415707	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	probably (>70%)				No
0415708	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	probably (>70%)				No
0416705	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	probably (>70%)				No
0416706	yes mud	definitely (>90%)	<1/3	blotchy	thin	can't tell					No

Table A10(a). -- KS's scores from Test 2 of the 50 image scoring test. This table has been split; A10(a) shows the general feeding column as well as all scores made on the head of the whale, A10(b) shows KS's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A10(a) and A10(b) to clarify which photo is being scored.

image number	feeding?	open mouth descriptor	confidence of open mouth	rostrum mud?	confidence of rostrum mud	rostrum mud amount	rostrum mud descriptor	rostrum mud coating	cheeks mud?	confidence of cheeks mud	cheeks mud amount	cheeks mud descriptor	cheeks mud coating
030107	no evidence of feeding	no	probably (>70%)	no mud	probably (>70%)				no mud	definitely (>90%)			
030708.1	no evidence of feeding	no	probably (>70%)	no mud	definitely (>90%)				no mud	probably (>70%)			
030803	yes: mud & open mouth	slightly open	likely (<70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
030805	cant tell	no	probably (>70%)	yes mud	likely (<70%)	>2/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
031503	no evidence of feeding	no	definitely (>90%)	no mud	probably (>70%)				no mud	likely (<70%)			
031510	cant tell	can't tell		can't tell					can't tell				
031808	cant tell	can't tell		can't tell					can't tell				
032104	no evidence of feeding	no	definitely (>90%)	no mud	definitely (>90%)				no mud	definitely (>90%)			
032505	cant tell	no	probably (>70%)	can't tell					can't tell				
032808	no evidence of feeding	no	likely (<70%)	no mud	likely (<70%)				no mud	likely (<70%)			
032809	cant tell	no	likely (<70%)	no mud	probably (>70%)				yes mud	probably (>70%)	<1/3	blotchy	thin
037706	cant tell	can't tell		can't tell					can't tell				
038104	no evidence of feeding	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	probably (>70%)			
039706	no evidence of feeding	no	definitely (>90%)	no mud	definitely (>90%)				no mud	probably (>70%)			
0311303	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	<2/3	blotchy	thin	yes mud	definitely (>90%)	<1/3	blotchy	thin
0311508	no evidence of feeding	no	probably (>70%)	no mud	definitely (>90%)				no mud	definitely (>90%)			

Table A10(a). -- Continued.

0312310	no evidence of feeding	no	probably (>70%)	no mud	definitely (>90%)				no mud	probably (>70%)			
0312803	no evidence of feeding	no	definitely (>90%)	no mud	definitely (>90%)				no mud	definitely (>90%)			
0313007	no evidence of feeding	no	definitely (>90%)	no mud	definitely (>90%)				no mud	definitely (>90%)			
0313209	cant tell	can't tell		can't tell					can't tell				
0313505	no evidence of feeding	no	likely (<70%)	no mud	probably (>70%)				no mud	probably (>70%)			
0313506	no evidence of feeding	no	probably (>70%)	no mud	probably (>70%)				no mud	probably (>70%)			
0401808	no evidence of feeding	no	definitely (>90%)	no mud	definitely (>90%)				no mud	probably (>70%)			
0402005	no evidence of feeding	no	likely (<70%)	no mud	probably (>70%)				no mud	probably (>70%)			
0402007	no evidence of feeding	no	probably (>70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0402407	no evidence of feeding	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0402409	cant tell	slightly open	likely (<70%)	no mud	probably (>70%)				yes mud	likely (<70%)	<2/3	blotchy	thin
0402909	yes: open mouth	wide open	definitely (>90%)	no mud	definitely (>90%)				no mud	probably (>70%)			
0403310	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0403907	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	blotchy	thin
0403908	yes: mud	no	probably (>70%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	<1/3	blotchy	thin
0403909	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	<2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	blotchy	thick
0404404	no evidence of feeding	no	definitely (>90%)	yes mud	definitely (>90%)	<1/3	streaks	thin	yes mud	definitely (>90%)	<1/3	streaks	thin
0404405	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thin	yes mud	definitely (>90%)	<2/3	streaks	thin
0404610	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	<1/3	streaks	thin
0406902	cant tell	no	likely (<70%)	no mud	likely (<70%)				no mud	likely (<70%)			

Table A10(a). -- Continued.

0407702	no evidence of feeding	no	definitely (>90%)	no mud	probably (>70%)				no mud	probably (>70%)			
0409908	yes: mud	can't tell		yes mud	probably (>70%)	<2/3	covered	thin	yes mud	probably (>70%)	<2/3	covered	thin
0411408	no evidence of feeding	no	definitely (>90%)	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin
0413608	no evidence of feeding	no	likely (<70%)	no mud	probably (>70%)				no mud	probably (>70%)			
0413609	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	blotchy	thin	yes mud	definitely (>90%)	>2/3	covered	thin
0413810	yes: feces	no	definitely (>90%)	no mud	definitely (>90%)				no mud	definitely (>90%)			
0414306	cant tell	no	probably (>70%)	no mud	likely (<70%)				no mud	likely (<70%)			
0414307	yes: mud & open mouth	wide open	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thin	yes mud	probably (>70%)	>2/3	covered	thin
0414510	cant tell	no	probably (>70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0414602	no evidence of feeding	no	definitely (>90%)	no mud	definitely (>90%)				no mud	definitely (>90%)			
0415707	no evidence of feeding	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)			
0415708	no evidence of feeding	no	definitely (>90%)	no mud	definitely (>90%)				no mud	definitely (>90%)			
0416705	yes: open mouth	wide open	definitely (>90%)	no mud	probably (>70%)				no mud	likely (<70%)			
0416706	no evidence of feeding	no	definitely (>90%)	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin

Table A10(b). -- KS's scores from Test 2 of the 50 image scoring test. This table has been split; A10(a) shows the general feeding column as well as all scores made on the head of the whale, A10(b) shows KS's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A10(a) and A10(b) to clarify which photo is being scored.

image number	back mud?	confidence of back mud	back mud amount	back mud descriptor	back mud coating	flukes mud?	confidence of flukes mud	flukes mud amount	flukes mud descriptor	flukes mud coating	plume present
030107	no mud	probably (>70%)				no mud	likely (<70%)				No
030708.1	no mud	probably (>70%)				no mud	likely (<70%)				No
030803	yes mud	likely (<70%)	<2/3	blotchy	thick	can't tell					No
030805	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	>2/3	covered	thin	No
031503	no mud	probably (>70%)				no mud	definitely (>90%)				No
031510	no mud	likely (<70%)				no mud	likely (<70%)				No
031808	can't tell					can't tell					No
032104	no mud	definitely (>90%)				no mud	probably (>70%)				No
032505	can't tell					can't tell					No
032808	no mud	likely (<70%)				no mud	probably (>70%)				No
032809	yes mud	likely (<70%)	<1/3	streaks	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
037706	no mud	probably (>70%)				no mud	likely (<70%)				No
038104	no mud	likely (<70%)				yes mud	likely (<70%)	<1/3	blotchy	thin	No
039706	no mud	probably (>70%)				can't tell					No
0311303	yes mud	definitely (>90%)	<1/3	streaks	thin	no mud	likely (<70%)				No
0311508	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0312310	no mud	probably (>70%)				no mud	likely (<70%)				No
0312803	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0313007	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0313209	can't tell					no mud	probably (>70%)				No
0313505	no mud	probably (>70%)				no mud	definitely (>90%)				No

Table A10(b). -- Continued.

0313506	no mud	probably (>70%)				no mud	definitely (>90%)				No
0401808	no mud	definitely (>90%)				no mud	likely (<70%)				No
0402005	no mud	definitely (>90%)				no mud	probably (>70%)				No
0402007	yes mud	likely (<70%)	<2/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
0402407	no mud	probably (>70%)				no mud	probably (>70%)				No
0402409	no mud	likely (<70%)				yes mud	likely (<70%)	<2/3	blotchy	thin	No
0402909	can't tell					can't tell					No
0403310	yes mud	definitely (>90%)	<2/3	streaks	thin	yes mud	definitely (>90%)	<1/3	blotchy	thin	No
0403907	no mud	probably (>70%)				no mud	probably (>70%)				No
0403908	no mud	probably (>70%)				no mud	definitely (>90%)				No
0403909	no mud	probably (>70%)				no mud	probably (>70%)				No
0404404	yes mud	probably (>70%)	<1/3	streaks	thin	can't tell					No
0404405	yes mud	definitely (>90%)	<2/3	streaks	thick	yes mud	likely (<70%)	<1/3	blotchy	thin	No
0404610	yes mud	definitely (>90%)	<2/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thin	No
0406902	no mud	likely (<70%)				no mud	likely (<70%)				No
0407702	no mud	probably (>70%)				no mud	probably (>70%)				No
0409908	no mud	probably (>70%)				no mud	probably (>70%)				No
0411408	can't tell					can't tell					No
0413608	no mud	probably (>70%)				no mud	probably (>70%)				No
0413609	yes mud	probably (>70%)	<1/3	streaks	thin	can't tell					No
0413810	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0414306	yes mud	likely (<70%)	<2/3	blotchy	thin	no mud	likely (<70%)				No
0414307	yes mud	probably (>70%)	<1/3	blotchy	thin	can't tell					No
0414510	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
0414602	no mud	definitely (>90%)				no mud	definitely (>90%)				No

Table A10(b). -- Continued.

0415707	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
0415708	no mud	definitely (>90%)				no mud	definitely (>90%)				No
0416705	no mud	probably (>70%)				no mud	probably (>70%)				No
0416706	no mud	probably (>70%)				yes mud	likely (<70%)	<1/3	blotchy	thin	No

Table A11(a). -- JW's scores from Test 2 of the 50 image scoring test. This table has been split; A11(a) shows the general feeding column as well as all scores made on the head of the whale, A11(b) shows JW's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A11(a) and A11(b) to clarify which photo is being scored.

image number	feeding?	open mouth descriptor	confidence of open mouth	rostrum mud?	confidence of rostrum mud	rostrum mud amount	rostrum mud descriptor	rostrum mud coating	cheeks mud?	confidence of cheeks mud	cheeks mud amount	cheeks mud descriptor	cheeks mud coating
030107	cant tell	no	likely (<70%)	can't tell					can't tell				
030708.1	yes: mud	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<2/3	streaks	thin
030803	cant tell	can't tell		can't tell					can't tell				
030805	cant tell	no	likely (<70%)	yes mud	likely (<70%)	>2/3	blotchy	thick	yes mud	likely (<70%)	<2/3	covered	thin
031503	cant tell	can't tell		no mud	likely (<70%)				can't tell				
031510	cant tell	can't tell		can't tell					can't tell				
031808	cant tell	can't tell		can't tell					can't tell				
032104	no evidence of feeding	no	definitely (>90%)	no mud	probably (>70%)				no mud	probably (>70%)			
032505	cant tell	can't tell		can't tell					can't tell				
032808	cant tell	can't tell		can't tell					can't tell				
032809	yes: mud	no	definitely (>90%)	no mud	probably (>70%)				yes mud	definitely (>90%)	<1/3	blotchy	thick
037706	cant tell	can't tell		yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell				
038104	yes: mud	no	probably (>70%)	yes mud	probably (>70%)	<1/3	blotchy	thin	no mud	probably (>70%)			
039706	cant tell	no	probably (>70%)	no mud	probably (>70%)				no mud	probably (>70%)			
0311303	yes: mud	no	likely (<70%)	yes mud	likely (<70%)	>2/3	blotchy	thick	yes mud	likely (<70%)	<1/3	blotchy	thick
0311508	cant tell	slightly open	probably (>70%)	no mud	definitely (>90%)				no mud	probably (>70%)			

Table A11(a). -- Continued.

0312310	cant tell	no	definitely (>90%)	yes mud	likely (<70%)	>2/3	streaks	thin	can't tell				
0312803	no evidence of feeding	no	definitely (>90%)	no mud	probably (>70%)				no mud	probably (>70%)			
0313007	cant tell	no	probably (>70%)	no mud	probably (>70%)				no mud	probably (>70%)			
0313209	cant tell	can't tell		can't tell					can't tell				
0313505	cant tell	can't tell		yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell				
0313506	cant tell	can't tell		can't tell					can't tell				
0401808	cant tell	no	probably (>70%)	yes mud	likely (<70%)	<2/3	streaks	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0402005	cant tell	can't tell		can't tell					can't tell				
0402007	yes: mud	no	likely (<70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0402407	cant tell	no	probably (>70%)	yes mud	likely (<70%)	>2/3	streaks	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0402409	yes: mud	slightly open	probably (>70%)	can't tell					yes mud	probably (>70%)	<2/3	blotchy	thin
0402909	yes: mud	no	likely (<70%)	no mud	probably (>70%)				yes mud	definitely (>90%)	<2/3	streaks	thick
0403310	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0403907	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	streaks	thick	yes mud	definitely (>90%)	<2/3	blotchy	thin
0403908	yes: mud	no	probably (>70%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	probably (>70%)	<1/3	blotchy	thin
0403909	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	<2/3	blotchy	thick
0404404	yes: mud	no	definitely (>90%)	yes mud	probably (>70%)	<2/3	blotchy	thin	yes mud	probably (>70%)	<1/3	streaks	thin
0404405	yes: mud	no	probably (>70%)	yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	streaks	thick
0404610	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	<2/3	blotchy	thin
0406902	cant tell	can't tell		no mud	likely (<70%)				can't tell				

Table A11(a). -- Continued.

0407702	cant tell	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0409908	yes: mud	can't tell		yes mud	definitely (>90%)	>2/3	covered	thick	yes mud	definitely (>90%)	>2/3	covered	thick
0411408	yes: mud	no	likely (<70%)	yes mud	probably (>70%)	>2/3	blotchy	thin	yes mud	probably (>70%)	<2/3	blotchy	thin
0413608	cant tell	can't tell		can't tell					can't tell				
0413609	yes: mud	no	definitely (>90%)	yes mud	definitely (>90%)	>2/3	blotchy	thick	yes mud	definitely (>90%)	>2/3	blotchy	thick
0413810	yes: feces	no	probably (>70%)	no mud	likely (<70%)				can't tell				
0414306	cant tell	can't tell		can't tell					can't tell				
0414307	yes: mud	no	likely (<70%)	yes mud	definitely (>90%)	>2/3	streaks	thick	yes mud	probably (>70%)	<2/3	streaks	thick
0414510	yes: mud	no	probably (>70%)	yes mud	probably (>70%)	<1/3	blotchy	thick	yes mud	likely (<70%)	<1/3	blotchy	thin
0414602	cant tell	no	probably (>70%)	no mud	probably (>70%)				no mud	probably (>70%)			
0415707	cant tell	no	probably (>70%)	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin
0415708	cant tell	no	definitely (>90%)	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	probably (>70%)			
0416705	yes: open mouth	wide open	probably (>70%)	no mud	likely (<70%)				can't tell				
0416706	yes: mud	no	definitely (>90%)	yes mud	probably (>70%)	>2/3	blotchy	thin	yes mud	probably (>70%)	<2/3	blotchy	thin

Table A11(b). -- JW's scores from Test 2 of the 50 image scoring test. This table has been split; A11(a) shows the general feeding column as well as all scores made on the head of the whale, A11(b) shows JW's scores for the back and flukes, and whether a mud plume was present. The image numbers have been repeated for A11(a) and A11(b) to clarify which photo is being scored.

image number	back mud?	confidence of back mud	back mud amount	back mud descriptor	back mud coating	flukes mud?	confidence of flukes mud	flukes mud amount	flukes mud descriptor	flukes mud coating	plume present
030107	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
030708.1	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
030803	can't tell					can't tell					No
030805	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	>2/3	covered	thick	No
031503	no mud	likely (<70%)				no mud	probably (>70%)				No
031510	can't tell					yes mud	likely (<70%)	<1/3	blotchy	thin	No
031808	yes mud	likely (<70%)	<2/3	blotchy	thick	yes mud	likely (<70%)	<1/3	blotchy	thin	No
032104	no mud	probably (>70%)				can't tell					No
032505	can't tell					can't tell					No
032808	can't tell					yes mud	likely (<70%)	<1/3	blotchy	thin	No
032809	yes mud	probably (>70%)	>2/3	covered	thin	can't tell					No
037706	no mud	likely (<70%)				can't tell					No
038104	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
039706	yes mud	likely (<70%)	<2/3	blotchy	thin	can't tell					No
0311303	yes mud	probably (>70%)	<2/3	streaks	thick	no mud	likely (<70%)				No
0311508	no mud	likely (<70%)				no mud	likely (<70%)				No
0312310	yes mud	likely (<70%)	<2/3	streaks	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
0312803	no mud	definitely (>90%)				no mud	probably (>70%)				No
0313007	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	probably (>70%)				No
0313209	can't tell					no mud	likely (<70%)				No

Table A11(b). -- Continued.

0313505	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
0313506	no mud	likely (<70%)				can't tell					No
0401808	no mud	probably (>70%)				can't tell					No
0402005	no mud	probably (>70%)				yes mud	likely (<70%)	>2/3	blotchy	thin	No
0402007	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<1/3	blotchy	thick	No
0402407	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
0402409	can't tell					yes mud	likely (<70%)	>2/3	blotchy	thin	No
0402909	can't tell					can't tell					No
0403310	yes mud	definitely (>90%)	>2/3	streaks	thin	yes mud	definitely (>90%)	>2/3	blotchy	thick	No
0403907	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	>2/3	blotchy	thin	No
0403908	yes mud	probably (>70%)	<1/3	streaks	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
0403909	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
0404404	yes mud	likely (<70%)	<1/3	blotchy	thin	can't tell					No
0404405	yes mud	definitely (>90%)	<2/3	streaks	thick	yes mud	likely (<70%)	<2/3	blotchy	thick	No
0404610	yes mud	probably (>70%)	>2/3	blotchy	thick	yes mud	likely (<70%)	>2/3	blotchy	thick	No
0406902	yes mud	likely (<70%)	>2/3	blotchy	thin	can't tell					No
0407702	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<2/3	blotchy	thin	No
0409908	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<2/3	blotchy	thin	No
0411408	can't tell					can't tell					No
0413608	can't tell					can't tell					No
0413609	no mud	likely (<70%)				can't tell					No
0413810	can't tell					can't tell					No
0414306	yes mud	likely (<70%)	<1/3	blotchy	thin	no mud	likely (<70%)				No
0414307	can't tell					can't tell					No
0414510	yes mud	probably (>70%)	<2/3	blotchy	thin	yes mud	likely (<70%)	<2/3	blotchy	thin	No

Table A11(b). -- Continued.

0414602	no mud	likely (<70%)				no mud	probably (>70%)				No
0415707	yes mud	likely (<70%)	<2/3	blotchy	thin	can't tell					No
0415708	yes mud	likely (<70%)	<1/3	blotchy	thin	yes mud	likely (<70%)	<1/3	blotchy	thin	No
0416705	no mud	likely (<70%)				no mud	probably (>70%)				No
0416706	yes mud	probably (>70%)	<1/3	blotchy	thin	yes mud	probably (>70%)	<2/3	blotchy	thin	No

Mud Test Training Protocol
(given to NMML biologists before they took Test 2)

1. "Feeding?": This is your overall assessment, and it's ok to contradict (over-ride) a mud score below. It's sometimes helpful to answer this last. Whenever open mouth or feces are visible you should indicate that the whale is feeding in this column. However, mud on the whale is more a judgment call—if you say there is definitely a tiny amount of mud on the whale, you can still decide that it would not be fair to conclude that the whale is feeding. This is up to your discretion. You are free to put "can't tell" here when you have low confidence of what is going on (unlike "can't tell" in #6 below).

2. Open mouth: See example in the reference set (image #033706). If the mouth is open more than this, I consider it wide open. If it is open this much or less, it's slightly open. My reasoning is that if I'm seeing a gap any bigger than this from 1,000 ft up in a plane, then I think the mouth must actually be pretty wide open to be so detectable.

3. Confidence (provide a confidence score for every "yes" or "no" answer):
Definitely = you are sure about your answer (> 90% sure).
Probably = you feel strongly in support of your answer but can't say with total confidence, (you are > 70% sure but < 90% sure).
Likely = you think your answer is true but you can't say so with a lot of confidence. The range here is big; you are anywhere from 1 to 69% sure. Therefore, I don't expect you to have a lot of confidence for your answer here, but you should be giving your answer based on *something* that leads you to say likely.

4. Be wary of sloughing. This is the biggest caution against giving too high a confidence score. It is very difficult to tell faint mud versus sloughing skin. Therefore, if you think something is mud but can imagine that somebody could easily argue that it is sloughing skin, you should probably just call it mud "likely". If you feel like you could make a good argument for the presence of mud, then you might score it as "probably". If you think it's practically inarguable since it's so obviously mud, then score it as "definitely".

5. If you answer no, then all you have to do provide a confidence score and move on since there is nothing to describe.

6. The "can't tell" option: This is reserved for when you feel no reasonable assessment of a region could be made; that is, too much splash, glare, blurry, not visible. Scoring the region is not possible in your estimation. When you assign a "can't tell" score, there is no need to give a corresponding confidence code.

7. Mud descriptor:
Streaks = clear linear pattern of mud down the body part.
Blotchy = amorphous mud patterns on body part, not fitting a good description.
Covered = the region is covered in mud and therefore, there is no way to describe the pattern.

8. Mud coating: This is an evaluation of thin versus thick mud. Basically, I try to imagine that there is a scar below the mud, if I think a scar would show through, I call it a thin coat of mud, if not, I say it's thick. In other words, if the mud is thick enough to cover marks below it, then I consider it to be a thick coat of mud.

9. Plume present: This is to describe the situation when mud may be visible in plumes around or behind the whale.

10. Feces tend to be red and trail behind the whale. See example of feces in the reference set (image # 033705). This is rarely captured photographically, so I did not provide a space for you to score confidence. If you think you might see feces but aren't sure, please make a note of it on this paper. If you are sure you see feces, just fill out the appropriate answer under "Feeding".

11. Bowheads have varying degrees of white pigment on their heads and tails (and tail stocks). For the head, the white pigmentation (when present) should be on the cheeks and chin but not on the rostrum. For the tail, the white is on the dorsal surface and typically emanates from the center of the tail stalk outwards and on the trailing edge occasionally. Pigment ranging from all black to a lot of white is normal and should not be confused for mud.

12. Note that diatoms are possibly present but tend to look yellowish/gold and could be potentially confusing. If you think you see diatoms, please write down the image number so that I can keep track of them. See example in reference set (image # 0415906.1).

13. Please give useful feedback. I want to know what you thought was difficult, what didn't make sense, what was a stupid thing to be scoring….etc. Suggestions are welcome.

Provide feedback here:

Mini-Test Set of Photographs
(given to bowhead experts before they took Test 3)

(15 images from the original test set)

Muddy:

- Definitely- you are sure there is mud on the whale.
- Probably- you are pretty confident that there is mud on the whale.
- Unsure- you see some evidence on the whale that may be mud but you couldn't be sure, it could be sloughing skin or diatoms.

Clean:

- Definitely- you are sure there is NO mud on the whale, at least for the visible parts of the whale.
- Probably- you are pretty confident that there is NO mud on the whale
- Unsure- you see NO evidence of mud on the whale but you couldn't be sure that it's clean

Mini-Muddy-Test (15 images)

Circle the answer! Comments Welcome!

Name_____ Date:_____

1.	Muddy:	definitely	probably	unsure
	Clean:	definitely	probably	unsure
2.	Muddy:	definitely	probably	unsure
	Clean:	definitely	probably	unsure
3.	Muddy:	definitely	probably	unsure
	Clean:	definitely	probably	unsure
4.	Muddy:	definitely	probably	unsure
	Clean:	definitely	probably	unsure
5.	Muddy:	definitely	probably	unsure
	Clean:	definitely	probably	unsure
6.	Muddy:	definitely	probably	unsure
	Clean:	definitely	probably	unsure
7.	Muddy:	definitely	probably	unsure
	Clean:	definitely	probably	unsure
8.	Muddy:	definitely	probably	unsure
	Clean:	definitely	probably	unsure
9.	Muddy:	definitely	probably	unsure
	Clean:	definitely	probably	unsure
10.	Muddy:	definitely	probably	unsure
	Clean:	definitely	probably	unsure
.				
.				
.				
15.	Muddy:	definitely	probably	unsure
	Clean:	definitely	probably	unsure

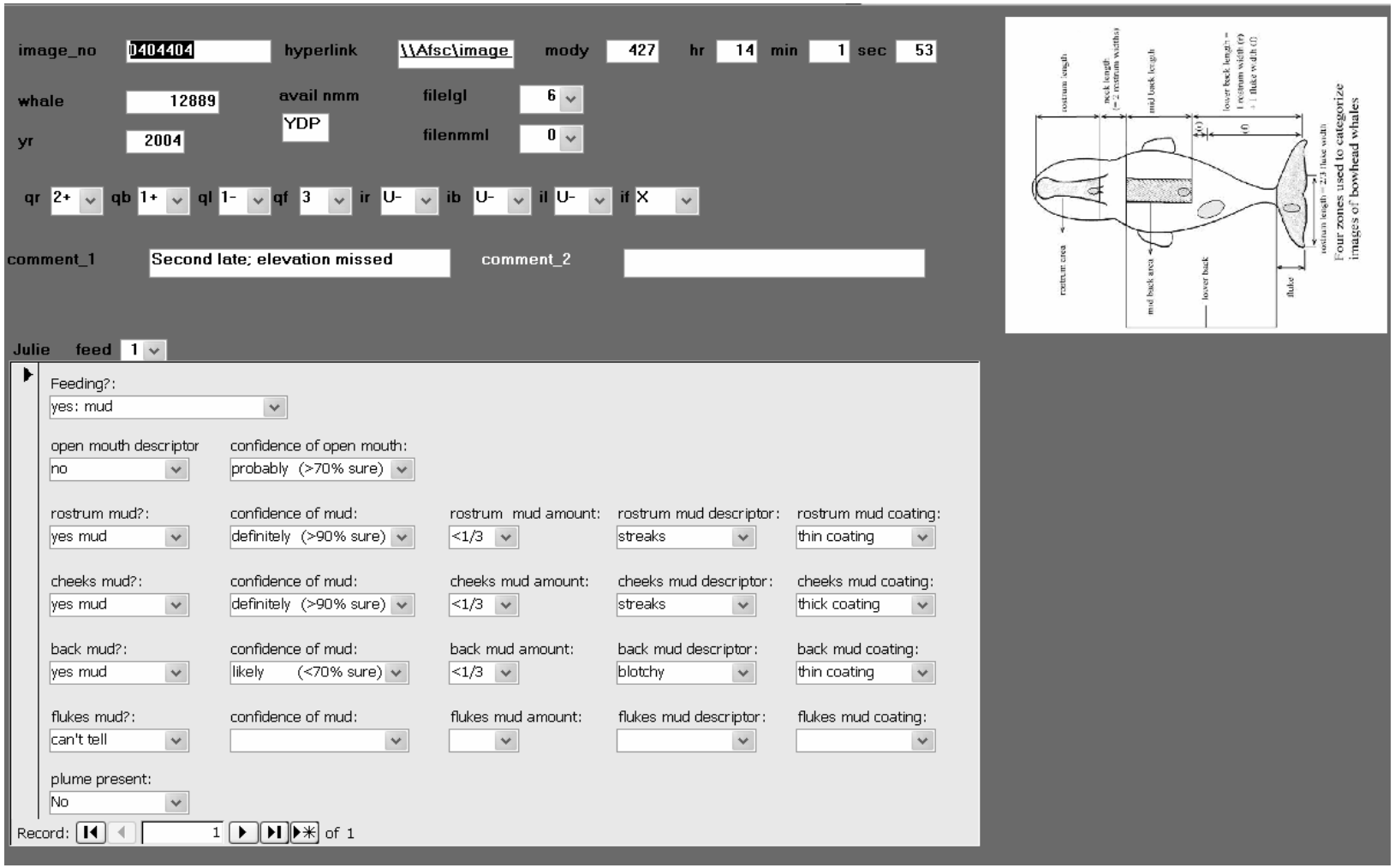


Figure A1. -- Screen capture of the Access form that was used for scoring. Only the light grey box contains information relevant to this study.

Appendix B: Statistics

Example of empirical logistic transform for binary data:

Comparison between the proportion of muddy juveniles to the proportion of muddy adults in the sample, using 1985 as example.

from Cox and Snell (1989)

m = individuals in the sample

R = number of successes

$Z = \ln((R1 + 0.5)/(m1-R1 + 0.5)$

$V = \frac{(m1+1)(m1+2)}{m1(R1+1)(m1-R1+1)}$

1985 juv *vs.* adult

H_o= 49/76 = 68/109

(comparing 0.64 = 0.62)

R1 =	49	R2 =	68
m1 =	76	m2 =	109

Z1 =	ln((R1+.5)/(m1-R1 + 0.5)	Z2 =	ln((R1+ 0.5)/(m1-R1 + 0.5)
	ln((49+.5)/(76-49 + 0.5)		ln((68+ 0.5)/(109-68 + 0.5)
	ln(49.5/27.5)		ln((68.5)/(41.5)
	ln(1.8)		ln(1.65060)
Z1 =	0.58779	Z2 =	0.50114

$V1 = \frac{(77)(78)}{76(50)(28)}$ $V2 = \frac{(110)(111)}{109(69)(42)}$

V1 = 0.05645 V2 = 0.03865

From Zar (1999)

$\sigma V1\text{-}V2 = SQRT(V1+V2)$

$\sigma V1\text{-}V2 = 0.30838$

$t = \frac{Z1-Z2}{\sigma V1\text{-}V2}$

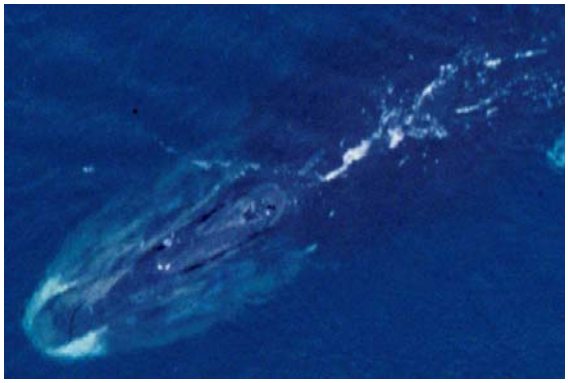
$t = 0.28097$

$P = 0.78$

Appendix C: Mud Persistence

12:33:03 71.57397/154.89552

16:09:34 71.59592/154.94807



16:44:33 71.60868/154.95677

Total Time Difference: 4:11:30

Figure C1. --Example of photographic proof of mud persisting on an individual whale for over 4 hours (images # 0413410, 0413603, 0413605).

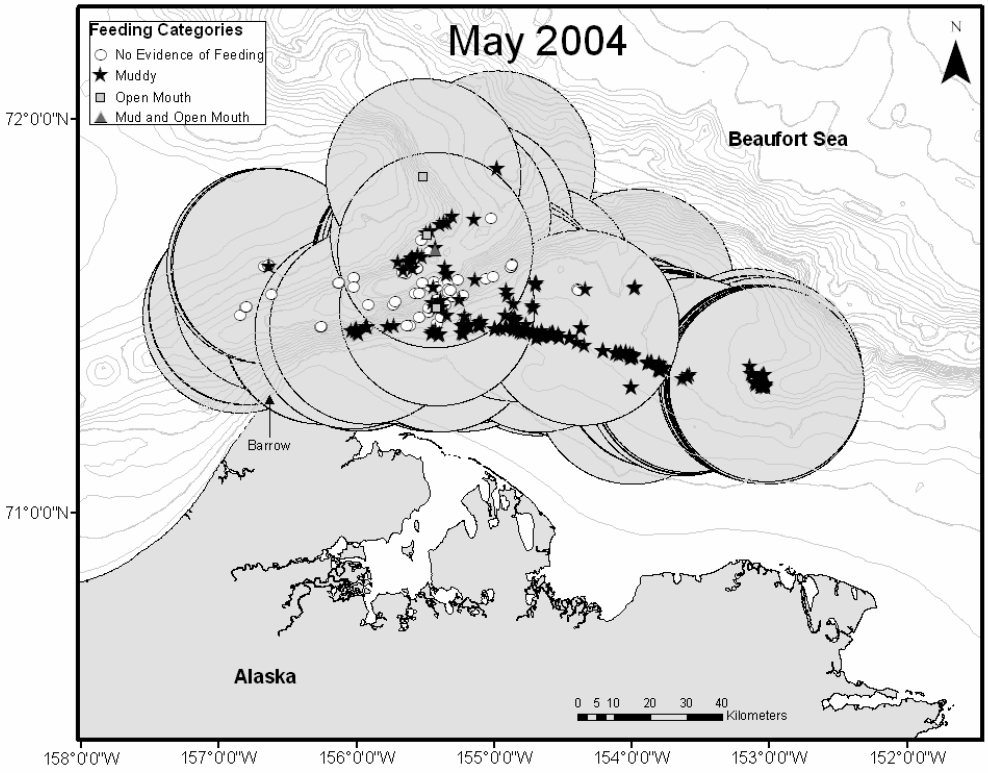


Figure C2. --Example showing 27 km buffers around each photograph to illustrate the uncertainty around each point regarding where a whale was feeding. This is based on the flow tank test that ran for 9 hours at 3 km/hour.