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A Photographic Identification System for Bowhead Whales

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NOTICE

A PHOTOGRAPHIC IDENTIFICATION SYSTEM FOR BOWHEAD WHALES

by

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ABSTRACT

Representatives from the National Marine Mammal Laboratory (NMML), LGL Ltd., and the Naval Ocean Systems Center met 6-7 January and 21-23 March 1983 to discuss the mechanics and problems associated with developing a photoidentification system for bowhead whales. Recommendations were made for collecting photographs of bowheads, specifically, aerial-based vertical views using medium-format cameras with high speed black-and-white or color film, preferably on their summering ground. A variety of complications likely to occur in attempting matchings and the potential research gains from conclusive matchings were discussed. A photoidentification key was developed to help categorize characteristic natural markings. The key was evaluated at the January workshop using high quality photographs and found to be about 86% successful with experienced users and about 63% successful with first-time users. A lower success rate for experienced users resulted during the March workshop when photographs of lesser quality were categorized. Development of standardized approaches to data organization and computerization were considered, including the possible use of digitized scanning for recognizing whales. Other possible sources of bowhead photographs were identified and will be contacted to increase the data base. A glossary of terms specific to this effort was developed. A published catalog of identifiable whales was proposed for a future date.

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INTRODUCTION

A considerable amount of interest has been generated over the past several years concerning whether individual bowhead whales can be recognized using distinct white color patterns located on the lower jaws and caudal peduncles (e.g. Wursig et al. 1981). In addition to these natural markings, apparent scars often occur on the dorsal surface (Figure 1).

A workshop was convened to determine whether or not bowhead whales might be individually identified from visible marks (see Appendix I for a list of terms). This was, in part, a result of a discussion at the First Interorganization Bowhead Whale Research Planning and Technical Coordination Meeting (Braham 1982). Because most applicable photographs of bowheads are in the hands of only a few investigators, the number of participants was limited to principal scientists from three groups which had conducted recent aerial research on bowhead whales (Appendix II). This report is a summary of two workshops, held 6-7 January 1983, at the National Marine Mammal Laboratory, Seattle, Washington (agenda in Appendix III), and 21-23 March 1983 at the Southwest Fisheries Center, National Marine Fisheries Service (NMFS), La Jolla, California (agenda in Appendix IV).

Besides evaluating whether individual bowheads might be identified from visible marks, objectives of the workshops were to (1) discuss and identify methods of data collection and analysis, (2) list problems associated with recognizing individual whales, such as quality of photographs and physical characteristics of marks, (3) evaluate and

Figure 1.--(Next page) Photographs of bowhead whales used in identifying individuals: A - aerial view depicting characteristically marked lower jaw and unusually large caudal peduncle white marks (arrows at bottom) and irregular dorsal surface "scars" (arrows at top) (LGL number 82-11-02 by W. Koski on 16 August 1982, eastern Beaufort Sea, Canada); B - Oblique photo showing a lack of natural marks and depicting numerous irregular scars (arrows) (NMFS number 79-67-F14 by D. Rugh on 14 May 1979 near Point Barrow, Alaska).

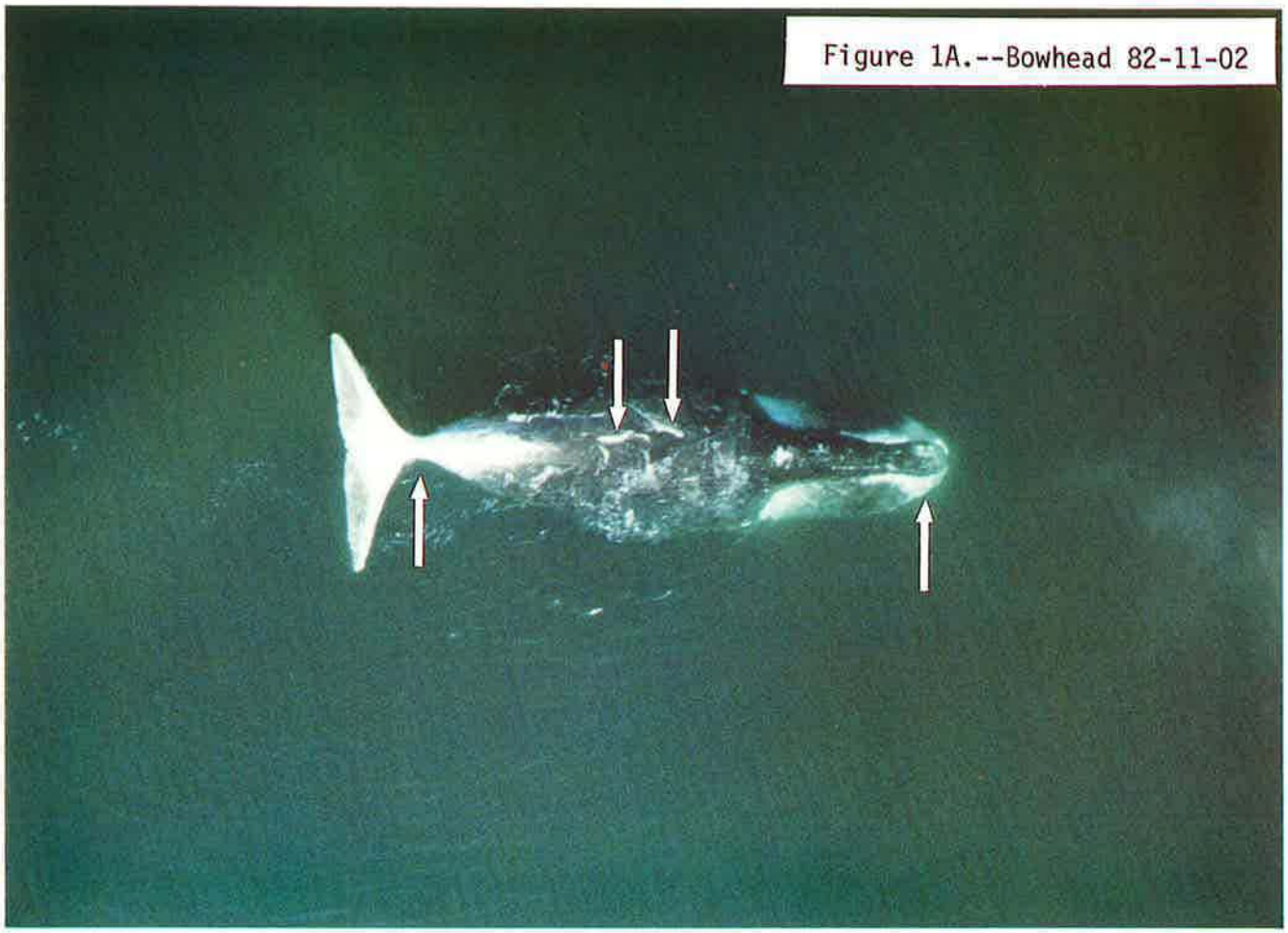

Figure 1A.--Bowhead 82-11-02

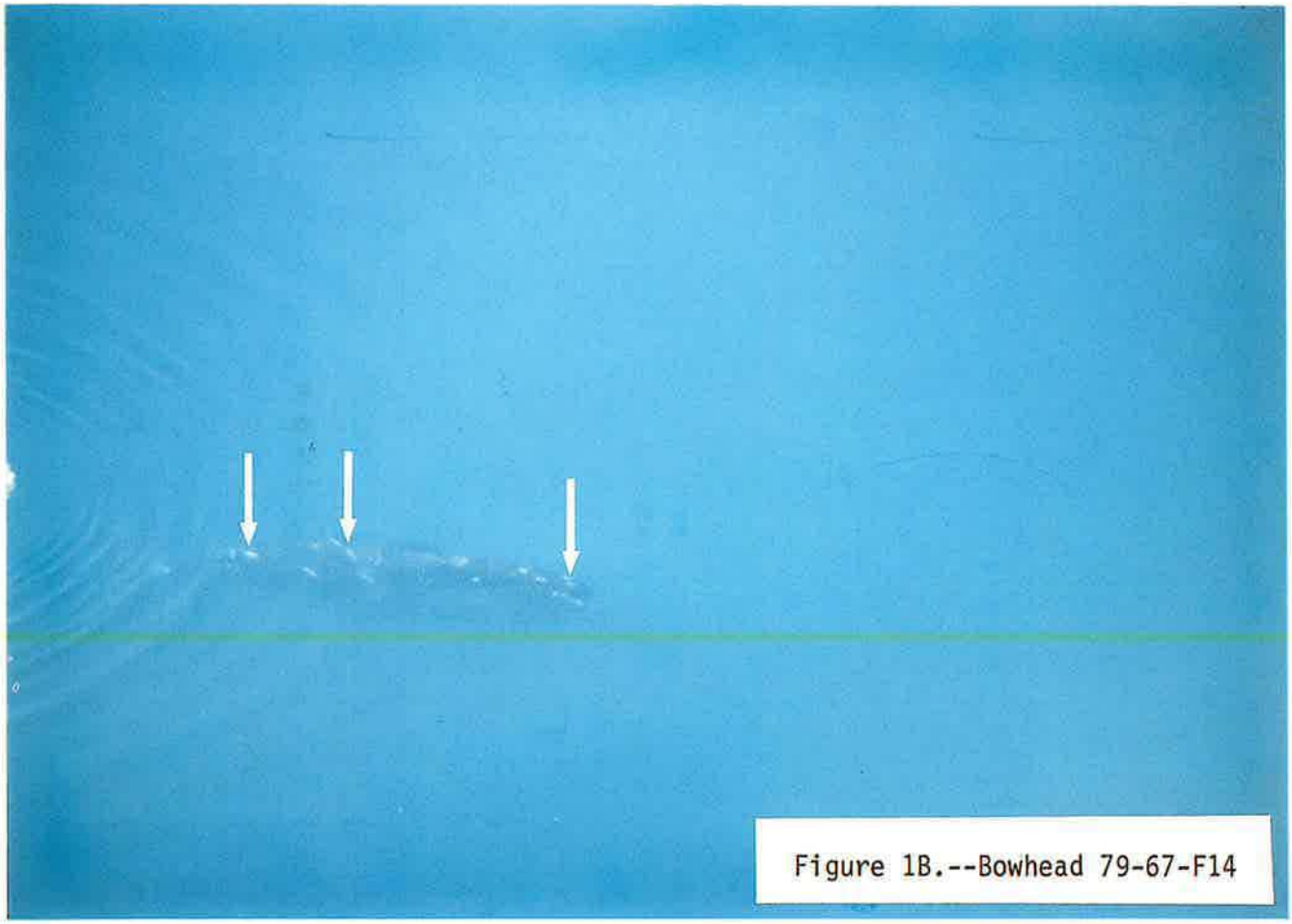

Figure 1B.--Bowhead 79-67-F14

further develop an identification key for classifying and thus cataloging whales, and (4) discuss the development and timeliness of publishing a catalog of identifiable bowheads, such as was done by Katona et al. (1980) for humpback whales. In addition, the participants were asked to (1) develop a list of reasons why continuation of photoidentification research is important, (2) review sample photographs, and try to successfully categorize whales into a set of files using the identification key (Appendix V), and (3) identify and contact other potential sources who have photographs of bowhead whales (Appendix VI).

Results of the aforementioned discussion constitute the basis of this report. Also, actions are recommended to address the short- and long-term needs for photoidentification research, including how this study can aid researchers and managers to solve certain problems associated with population enumeration and composition, life history (growth, recruitment, etc.), behavior, and effects of human intervention in relation to industrial development and whaling.

PHOTOIDENTIFICATION PROCEDURES

Research Activities

Three organizations have been involved in most of the bowhead research applicable to a photoidentification catalog: the National Marine Mammal Laboratory (NMML), LGL Limited, and the Naval Ocean Systems Center (NOSC). Other research endeavors, such as ice-based censuses now being conducted by the North Slope Borough, Barrow, Alaska, generally do not acquire photographs of a type that can be

used for identifying individual whales. Past studies using high altitude photography, such as that conducted by Dr. Carleton Ray of the University of Virginia (Ray and Wartzok 1980), may also prove useful. These and other investigators have been contacted in an effort to produce a more comprehensive catalog.

The National Marine Mammal Laboratory (NMML) has maintained an active study of bowheads from funds provided by the Bureau of Land Management and NOAA's Alaska Outer Continental Shelf Environmental Assessment Program (1976-77) and, beginning in 1978, from a five-year expanded research program funded by the NMFS. Each year, 1976-1981, aerial surveys were flown, primarily in the spring, and photographs were taken of migrating whales. Aircraft included a fixed-wing Neptune P2V, Grumman "Super" Goose (N780), and Aero Commander, plus UHIH, Sikorsky, and Bell 206 helicopters. Air speeds were generally 160-250 km/hr (90-140 kts) at 150-300+ m altitudes. Many shipboard and ice- or land-based observations were made as well during those years, but photographs of a quality sufficient for identification of individual whales come primarily from aircraft. Although a variety of aircraft and altitudes were used, photographs were consistently taken with 35 mm Nikon cameras using color film of ASA 200-400 and 105-210 mm lenses. The NMML has also collected photographs and records on many bowhead whales harvested since 1976 which have potential application to certain aspects of this study. To date 1,170 photographs of bowheads have been examined for identifying characteristics of which 135 (12%) showed distinctive markings. Only 5 to 28 of these prints were of catalog quality.

LGL Limited received funds from several sources to conduct bowhead research during the summers of 1980-82. In 1980 and 1981 funds were primarily from Dome Petroleum Limited, Canada, Sohio Alaska Petroleum Company, and numerous other oil companies, for studying the distribution, population size, and calf production of bowheads in the Beaufort Sea (Renaud and Davis 1981; Davis et al. 1982). In 1982 funds were provided by NMML to LGL for a length-frequency and photoidentification study of bowheads on the summer feeding ground in the Canadian Beaufort Sea, which included the first directed effort toward developing a photoidentification catalog (Davis et al. 1983). Systematic grid transects were flown in a Twin Otter aircraft at 200 km/hr and maintained at 152 or 305 m altitudes. Medium-format Pentax cameras (70 mm) with 105 mm lenses and highspeed Ektachrome film were used for technical photography. Photographs were taken vertically through a camera port in the floor of the aircraft.

Approximately 265 of 725 whale images recorded on film (37%) showed distinctive markings that (according to a subjective evaluation) would probably make the whale recognizable in a photograph of similar or better quality taken in another year. Photographs of a maximum of 221 individually identifiable bowhead whales are available. In addition, a collection of photographs of 58 different bowheads from a 1981 LGL study were available for consideration at the first workshop. Of these, 37 whales were considered sufficiently well marked to be recognizable in subsequent years for a two-year total of 258.

The Naval Ocean Systems Center (NOSC) in San Diego, California, has received funding from the Minerals Management Service each year 1979-83 in order to investigate the occurrence, population density, distribution, and behavior patterns of endangered whales in the Beaufort, Chukchi, and northern Bering Sea (Ljungblad et al. 1980; Ljungblad 1981). All surveys were conducted in the Grumman "Super" Goose (N780), flown at 180-200 km/hr (100-110 Kt) and at 80-300 m altitude (avg. 244 m). Photographs were taken opportunistically with 35 mm cameras. Both color slide and black-and-white negative film were used. There were 4,916 bowheads counted in 2,688 photographs of which 179 whales (3.6%) showed distinctive markings; 13 whale images were of catalog quality.

Recommended Field Techniques

The season which has produced the highest quality photographs is summer (usually August) because migrating whales in spring tend to be moving and diving (spending less time at the surface) more often than in summer when they are usually resting or feeding near the surface. In winter, weather causes frequent complications. Also, whales are often more difficult to locate and thus more elusive when associated with ice often occurring in winter and spring. In the summer, bowheads are found further from ice than at any other season. Spring research is important however, because most if not all of the population migrates past Point Barrow thus affording the researcher a unique opportunity to sample in a sytematic manner.

Medium-format cameras are preferred because of larger and higher resolution images, but 35 mm format is acceptable if conditions are very good. A 35 mm camera with a motor drive allows high shooting rates (i.e. several frames per pass over a whale), whereas medium formats generally do not. High resolution film, preferably black-and-white, is recommended, but high shutter speeds (>1/500) are necessary. Color assists with some shading discrimination and has received predominant use in the past; however, black-and-white film allows higher contrast and film speeds. The length of lens used depends on altitude and film size, but 105 or 135 mm lenses are recommended for use with a 70 mm camera at altitudes of approximately 150 m.

Vertical (82-90°) photographs taken at an altitude of 150 m or higher are recommended. Quality pictures are best obtained when whales lie still at the surface without complications arising from ice, splashing water (wakes), or reflections (glare). Multiple shots of each whale are recommended to catch marks that might not appear in a single frame due to lighting or a change in the whale's position.

Recommended procedures for field data collection are listed in Table 1.

Cataloging

The bowhead whale photoidentification system is based on 5"x7" photographic prints, either black-and-white or colored, depicting whale images enlarged to approximately 10 cm and set horizontally. Although aircraft altitudes and lens powers may vary, it is best to maintain a common image size in the final print. This allows for greater consistency

Table 1.--Methods recommended for acquiring high quality vertical photographs of bowhead whales for photoidentification.

Aircraft Type:	Low speed; forward-looking capability (co-pilot seat available to spotter); high wing aircraft are preferred.
Airspeed:	Generally less than 250 km/hr (135 kt); under 180 km/hr preferred.
Photo angles:	All photos should be taken vertically (82°-90° to water surface); a floor mounted fixed space is necessary.
Altitude:	150-300 m, but the lower altitudes are preferred.
Camera(s):	Medium-format (70 mm recommended), but 35 mm format may be acceptable under certain circumstances. Consider tradeoffs between a large spool of film versus a smaller spool to allow for more rapid photography with a motorized camera. Multiple cameras (at least two) are beneficial fired independently or simultaneously.
Lens:	105-135 mm.
Film:	High contrast black-and-white, but highspeed color is acceptable

between images in the collection and may improve chances of recognizing matches. Custom printing is used to provide high quality cropping and contrast.

Prints used for photoidentification will be retained at the National Marine Mammal Laboratory which will act as the center for reviewing identifiable bowhead photographs and will provide archival space for the collection. Each contributor will take the responsibility for making prints to fit the catalog standard and should key each whale into the appropriate file. At NMML, files will be reviewed for matches and compared for proper categorization. When two or more photographs of an identifiable whale are found, the photographers or organization sources will be contacted and will be provided with all available information pertaining to the respective photographs.

Eventually a printed catalog will be developed with selected photographs. Only high quality prints depicting whales with distinctive features will be included. The catalog should receive general circulation among all bowhead researchers to encourage further acquisition and exchange of worthy bowhead photographs.

Need for emphasis on increasing the photographic data base is apparent when considering the many potential complications in attempting matches as listed in Table 2. The more effort there is to photograph bowheads, the greater the chances of obtaining images of adequate quality, and the higher the likelihood a match will be found. Potential information to be gained from this type of research is listed in Table 3.

Table 2.--Complications that may arise when attempting matches between whale photographs.

1.	Poor photographic quality may prevent recognition of marks.
2.	Reflection of light may appear as marks or may disguise marks.
3.	Partially or completely submerged whales may cause a mark to be missed or distorted.
4.	Ice or splashing water (wakes) may distort or conceal identifying marks.
5.	Apparent size of markings may change or appear distorted as the angle of the photograph or whale changes.
6.	Oblique photographs are difficult to evaluate with an identification key based on vertical views.
7.	Evaluations by different individuals may differ concerning how characteristics of a whale in a photograph compare to standards in a key, thereby resulting in misfiling photographs.
8.	Differences in magnification may confuse matchings.
9.	Sloughing skin may be confused with or conceal natural white markings.
10.	The extent of markings may change through time.
11.	"Scars" are added through time.

TABLE 3.--Potential information to be gained from photographic matches.

1. Documentation of calving intervals can be made through inter-year sequential resightings of individual female whales.
2. Growth rate may be estimated through photographs with quality adequate for length calculations.
3. Long-term records may show at what size whales begin to calve.
4. The calving season may be estimated where length measurements of calves are made.
5. Better estimates of annual recruitment may be established through identifying individual cows and calves which would allow better recognition of the number of cow/calf pairs in groups.
6. Genetic consistency may be studied through comparing markings between cows and calves.
7. Groups may be compared for similarity in markings.
8. Group fidelity may be studied by reidentifying whales in association through time, providing clues to kin behavior.
9. Site fidelity for individuals may be identified.
10. Whale distribution may be better understood through tracing movements of individuals particularly in regard to nearshore and offshore migration routes.
11. Migration timing might be better assessed through following individuals.
12. Short-term and long-term responses to man-caused perturbations such as oil development may be approached through identifying individual whales.
13. Assistance could be provided to behavioral studies through recognition of individuals.
14. Recognizing individuals serves as a test for consistency in photogrammetric length studies.
15. Population size may be estimated through mark-recapture techniques by using photographs instead of direct contact marking.
16. Information from the Eskimo harvest may be made in assessing mark-recapture and population size.

TABLE 3.--Continued.

17.	Variance in characteristics and potential stock identification may be recognized through quantification of specific features observed in photographs.
18.	The nature of marks may be documented providing some indication of frequency of contact with ship propellors, killer whales, ice, or projectiles, especially as whales age.

A need for organization of data for the bowhead photoidentification collection is apparent. A system of entries, presented in Table 4, would allow a logical input and retrieval of commonly requested information. These entries may be computerized for rapid access and sorting. Each contributor of photographs should take the responsibility of filing in as many of these entries as possible (except the whale identification number and evaluation of photographic quality) in the order described. When the categorized photographs are received at NMML, they will then be given a number for each whale in the photograph and a common code for photographic quality. All of this information can then be computerized and made available, upon request. Whenever two images are found to be of the same whale, the whale identification numbers will be recorded in a separate listing as being equivalent.

A Photoidentification Key

A standardized system has been developed whereby photographed whales can be classified into 20 categories based on the extent of white pigmentation (or the lack of pigmentation) on the lower jaw and caudal peduncle (see Appendix III)

Identifying marks are considered primarily permanent, high contrast changes in skin coloration typically on either the lower jaw and caudal peduncle or in "scarring", perhaps a result of superficial and/or subepidermal trauma. In Figure 1, whale A demonstrates pronounced tail markings, while whale B has virtually no tail markings. Most adequately photographed whales can be classified as having more or

TABLE 4.--Recording scheme for identification of bowhead whales from photographs.

Column number	Heading	Comment
1	Blank	Kept open for filing logic.
2-6	Whale ID number	Sequential chronologically according to when photographs arrive in the collection. A separate listing will show which ID numbers refer to the same whale, that is, where links have been made.
7	Blank	
8-11	Photo source	Four letters identifying agency (e.g., NMML, NOSC, or LGL).
12-13	Photographer	Initials of photographer; full name should be available through above agency.
14-25	Time	Given as year, month, day, hour, minute, and second, each with two digits.
26-27	Roll	Original roll number or letter identification.
28-29	Frame	Original number.
30	Quality	Code established by primary reviewer of the photographic collection.
31	Blank	
32-37	Latitude	Degrees, minutes, seconds.
38	N	(= North)
39-45	Longitude	Degrees, minutes, seconds.
46	E or W	(= East or West)
47-49	Size	Estimated or calculated whale size in meters; column 49 to tenths of meters.

TABLE 4.--Continued.

Column number	Heading	Comment
50	Grade	Measurement quality.
51	Blank	
52-53	File	Location of stored photograph.
54 ff	Comments	

less white coverage than the standards, and thus they can be categorized into the file collection, reducing the effort in seeking a match. The more categories there are, the fewer photographs must be searched for possible matches within each file. However, increasing the number of files also increases the chances of discrepancies in choosing an appropriate file.

Final verification of matches will probably come with the aid of scars. Generally a match will not be conclusive unless there are several patterned marks that are convincingly similar between photographs, using qualitative and quantitative (measurement) evaluations. However, this will depend to some extent on the size and shape of the markings. Length measurements may also provide supporting identification clues. The identification key presented in Appendix V does not incorporate scars. It is used to facilitate the initial classification of whales into categories based on natural marks. Figure 2 provides a suggested breakdown of bowhead body parts to allow for a more elaborate key based on scarring. This will be further developed when the photographic collection is larger and an extensive sorting might significantly improve the efficiency of searching for matches where the need for scar data becomes acute. Until then, a separate, duplicate set of photographs of whales with particularly noticeable marks ("superscars") will be set aside for easier relocation.

Testing

Any new cataloging system must be tested to determine if the classification procedures are repeatable and without errors. Our strategy at the initial workshop was to review and evaluate the

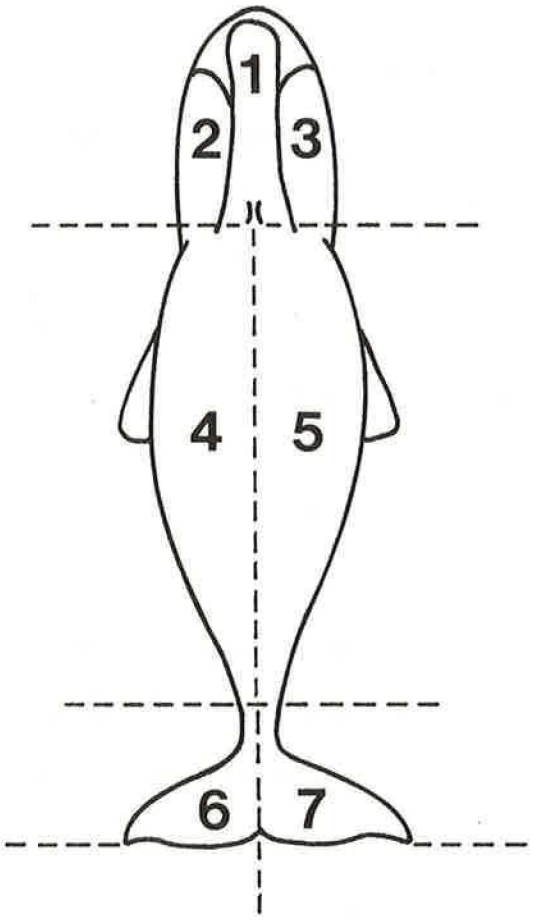

Figure 2.--Topographic depiction of the dorsal aspect of a bowhead whale divided into seven body regions where irregular marks (such as "scars") might be recorded in a standardized manner for the cataloging system.

identification key (Appendix V), not to fully test it. However, as part of the evaluation process, we decided to have all members test the key by trying to categorize each of several photographs supplied by LGL and NMML (Miller served as the control for the January test). The photo prints were not selected at random, but rather they were chosen because of their photographic clarity and thus catalog quality. The five participants scored each whale in each photo with a photo-id file number (from 16 files in the preliminary key used at the first workshop; the current key in Appendix V was used in the March test). A total of 18 photo prints were available for the test in January including 22 animals: 8 whales from LGL and 14 whales from NMML. A summary of the results is reported in Table 5. A total of 90 animals were available for the March test (of lesser quality than the January test): 56 whales from NMML and 34 from NOSC.

January Test

Although this test was not without some bias, the intent was realized, that is, to determine the clarity and effectiveness of the key as it was presented. Even though three of the five participants had previous experience at using the key, no one was able to correctly categorize all the whales. Among the three, only six misclassifications were made from 44 attempts (an 86.4% success rate). There was a statistically significant difference between the experienced and inexperienced groups, the inexperienced group performing at a 63.5% success rate (Table 5). The misclassifications were not consistent among participants (only 5 of 44, or 11%, were the same photo).

TABLE 5.--Results of a test conducted January 7, 1983, to classify LGL bowhead whale photographs into one of 16 files. (The key in Appendix III, with 20 files, is a revision of that used for this test, with 16 files.) Participants 1-3 had previous experience using the key in Appendix V whereas participants 4 and 5 did not.

	Participant's Scores[a]				
	1	2	3	4	5
Number missed	1	3	2	8	7
Number reviewed	8	22	14	21	19
Proportion correct	.875	.864	.857	.619	.632
Pooled number missed		6		15	
Pooled number correct		38		25	
Pooled number reviewed		44		40	

[a] Pooled data, comparing experieced (1-3) versus inexperienced (4-5) participants: $\chi^2 = 6.36$ (d.f.=1), $P<0.02$ (Chi-square contingency test)

These results suggest the key required greater clarity to ensure that questionable decisions concerning some identification characters in the photographs are eliminated (or at least reduced). The group went over each classification procedure in the key and recommended changes. Some of the recommendations have been incorporated into the revised key presented in Appendix V. It was also clear that completely inexperienced users are likely to make more errors than experienced ones, thus ultimate users of the key should practice with previously cataloged whales before using the key on a new, unidentified whale.

Discrepancies between people keying photographs were reviewed. Most of the problems centered around subjectivity in judging a mark as larger or smaller than the standard. In some cases people were willing to change their judgments when presented with other choices, but often the discrepancy was simply a difference in opinion. Where there was asymmetry in the marks on a standard whale, that is, the mark appeared slightly larger on one side than the other, there was increased confusion. It is apparent that photographic standards are easier to use than schematic drawings, but there remains the problem of subjectivity. The basis of keying whale photographs into categories is to reduce the search effort when trying to make a match. A conservative approach would be to match each photo against all others in the collection, or, more reasonably, to file photos with a liberal allowance for ambivalence, thus keeping more files open for cross-checking.

March Test

The photographs available for review at the March meeting were the "remaining" photos which might provide some information for cataloging but were clearly of inferior quality to those tested in January. The results reflected this problem (Table 6). As an illustration, of the 90 whales categorized, all five members chose different files for 8 whales (about 9%). In other words, there were 8 photographs in which each whale was categorized into 5 different files. And, to illusrate the poor performance of the group reviewing low quality photographs, in only 11 instances (about 12%) did all members independently agree on files (of these, 3 were misfiled after a reevaluation by the group!).

The conclusion from this test was that for filing photographs, and especially for future catalog documentation, the clarity and resolution of the photographs plus the position and amount of whale visible are critical elements for reliable categorization.

Digitized Scanning

The possibility of using digitized scanning techniques for identifying whales was discussed. Rick Van Schoik and John Bennett of NOSC will experiment with several good quality prints to test the computer's ability to detect marks. If this technique proves viable, photographs could be scanned automatically, and identifying marks could be entered into a computerized retrieval system. Another possibility considered was manually marking a whale's scars on a model and using computers to sort these inscribed marks.

TABLE 6.--Results of a test conducted March 21, 1983 to classify NMML and NOSC bowhead whale photographs into one of 20 files as listed in Appendix V. All participants had some experience at categorizing photos.

	Participants score				
	1	2	3	4	5
Number missed	49	44	44	39	33
Number reviewed	89	88	90	82	86
Proportion correct	0.449	0.500	0.511	0.524	0.630
Pooled missed ($\bar{x}$)	41.8 (SD, 6.06)				
Proportion correct ($\bar{x}$)	0.523 (SD, 0.066)				

Larry Hansen, of the Southwest Fisheries Center, described his work in digitizing dolphin fin marks. He showed how an increase in rate of resightings of identifiable dolphins can be used as a barometer of population size; however, this assumes any potential matches are recognized if they are in the file. This is generally an unsafe assumption considering the range in quality of photographs of bowheads. The probability of making population estimates based on rates of resightings, if likely, probably will come only from high quality photographs. There is the added complication of marks that might change through time, some being added, others enlarging or perhaps shrinking. These reduce the likelihood of recognizing a match even though it is present.

Theoretical Considerations

An important use of photoidentification may be for "mark-recapture" analysis in support of estimating population abundance. The following formula was used in order to determine how many whales we might expect to reidentify in subsequent years given the current number of identified whales:

$$R = \frac{C\,M}{N}$$

where, R = the expected number of reidentified animals

C = the number of photos (samples) needed to achieve R

M = the number of previously identified individuals

N = the estimated population size

There are currently 258 individually identifiable bowheads in the LGL photographic files. Using just these photographs for comparison, 13 resightings of bowheads would be expected assuming (1) 200 new photos are taken of the same population in 1983, and (2) that the current population is about 4,000 (Table 7). Using a smaller population size estimate would increase the number of expected resightings, and increasing the number of photographs taken would have the same effect. This calculation shows four resightings should have occurred using the 1982 data and the 37 photos from 1981. So far, no confirmed resightings have resulted. All photographs are, however, being evaluated in greater detail.

These preliminary results suggest that (1) there may have been segregation in the population, especially between 1981 and 1982, (2) the population could be larger than currently estimated, (3) the current sample size is still too small and the variance too large to exclude zero (no resightings) as part of the mathematical calculations, (4) whales with marks are not as readily reidentified as expected, and/or (5) age classes may be differentially marked.

The most likely reason that all animals in the population have not had a chance to be sampled is that they may be spatially segregated (e.g. Davis et al. 1982, 1983). If this pattern is related to individual (or group) preference, or to sex and/or age-class, then we may be resighting the same groups year after year if the sample is restricted to one area of the feeding grounds. Greater temporal and spatial

TABLE 7.--Theoretical estimate of the number of reidentified bowhead whales expected at various population sizes (N) and number of individual photographs taken (C), assuming a previously marked sample size of M = 258 (the current number of identified animals).

Number of identified bowheads	Population Estimates		
	3,000	4,000	5,000
100	9	6	5
200	17	13	10
300	26	19	15
400	34	26	21

coverage in future years is essential. This recommendation should be especially followed in 1984 if results of studies in 1983 provide no matches, or far more than expected. Similarly studies conducted in spring might eliminate this bias as essentially the entire population would be available to sample.

CONCLUSIONS AND RECOMMENDATIONS

The objectives of the two workshops were to design and evaluate a photoidentification system for bowhead whales. Specifically, we developed and assessed (1) methods of data collection and analysis, (2) problems expected in recognizing matches, (3) an identification key, (4) potential gains from this kind of research, (5) a test of the key in light of photograph quality, and (6) potential sources of bowhead photographs to add to the data base.

The workshops were the first step in developing and employing a photoidentification system, which will be a long-range project probably not achieving great immediate success but should provide invaluable information over the ensuing years. The identification system to be established at NMML is a low-cost study assuming photographs can be collected under other projects. Basic to the study is the need for a large sample size; accordingly, an effort should be made to collect more quality photographs each season as well as through contacting other bowhead researchers for previously taken photographs. Appropriate prints will be archived at the National Marine Mammal Laboratory upon agreement with the collaborator and the files will be examined for matches as photographs arrive.

A catalog will be developed later with photographs of the most identifiable whales published in an easily circulated form. The earliest target date for the bowhead catalog is late 1984 or early 1985. As the collection enlarges, the identification key may become more refined and the results computerized for higher efficiency in searching data.

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LJUNGBLAD, D. K., M. F. PLATTER-RIEGER, and F. S. SHIPP, Jr.

1980. Aerial surveys of bowhead whales, North Slope, Alaska. NOSC TD 314. 181 p.

RAY, G. C. and D. WARTZOK.

1980. Remote sensing of marine mammals of Beringea. Results of BESMEX: The Bering Sea Marine Mammal Experiment. Final Report of Contract No. NAS2-9300 prepared for the National Aeronautics and Space Administration. 77 p.

RENAUD, W. E., and R. A. DAVIS.

1981. Aerial surveys of bowhead whales and other marine mammals off the Tuktoyaktuk Peninsula, N.W.T., August-September 1980. Rep. by LGL Limited, Toronto, Ontario, to Dome Petroleum Limited, Calgary, Alberta. 55 p.

WURSIG, B., C. W. CLARK, E. M. DORSEY, M. A. FRAKER and R. S. PAYNE.

1981. Normal behavior of bowheads, p. 21-90. In: W. J. Richardson (ed.), Behavior, disturbance responses and feeding of bowhead whales in the Beaufort Sea, 1980. Chapter by New York Zool. Soc. in Unpubl. Rep. from LGL Ecol. Res. Assoc., Inc., Bryan, TX, for U.S. Bureau of Land Management, Washington. 273 p.

APPENDIX I

Bowhead whale identification glossary.

Catalog: A published volume of bowhead whale photographs containing all available prints of a quality suitable to allow reidentification if another photograph of similar quality is taken of the same whale.

Caudal peduncle: A whale's tail stock, that is, the lowermost portion of the body forward of the flukes and including a central portion of the flukes; an area frequently seen as gray or white in large bowhead whales.

Ephemeral marks: Visible irregularities of short term nature, generally lasting only several days or weeks but certainly not between years.

File: A collection of photographs of bowhead whales having common characteristics, as determined by the photoidentification key, such that all whale images with relatively similar amounts of white on the lower jaw and on the caudal peduncle are located together.

Leading edge of fluke: The forward perimeter of the fluke. Leading refers to the travel direction.

Lower jaw: The forward extension of the mandibular region, especially that area which is often characteristically white in bowheads.

Mottling: Stippled marks, blotches, or irregular small colorations usually caused by sloughing skin but may also be minor pigmentation marks.

Natural marks: White areas (those with an absence of pigmentation), particularly on the lower jaw and caudal peduncle, generally symmetrical, and apparently of genetic origin.

Photoidentification: Recognition of an individual bowhead whale in photographic images. Preferably the identification should be such that the whale can be reidentified in other, high quality photographs.

Scars: Acquired marks, generally white, irregular, and peculiar to each individual.

Sloughing: Apparent epidermal ecdysis or shedding of skin which gives whales splotchy, irregular, gray markings, assumedly temporary in nature.

Trailing edge of fluke: The perimeter along the rearmost portion of the fluke, sometimes appearing white. Trailing refers to the travel direction.

APPENDIX II

List of workshop participants.

Name	Organization
Howard W. Braham, PhD (convenor)	National Marine Mammal Laboratory, NMFS Seattle, Washington
Janet Clarke[1]	Naval Ocean Systems Center, San Diego, California
Rolph A. Davis, PhD	LGL Ltd., Toronto, Ontario, Canada
William R. Koski[2]	LGL Ltd., Edmonton, Alberta, Canada
Donald K. Ljungblad	Naval Ocean Systems Center San Diego, California
Gary W. Miller	LGL Ltd., Toronto, Ontario, Canada
David J. Rugh	National Marine Mammal Laboratory, NMFS Seattle, Washington

1 At the March workshop only.

2 At the January workshop only.

APPENDIX III

Agenda for the first workshop on bowhead whale photoidentification.

Dates: 6-7 January 1983

Location: National Marine Mammal Laboratory, NMFS
Seattle, Washington

Objectives:

1. Review existing photographs of bowhead whales and methods of photoidentication.
2. Develop a list of information needs that can be addressed by photographic identification research.
3. Agree on a preliminary photoidentification cataloging system, and discuss reporting and publication.

Thursday 6 January:

9:45 AM	Presentations and display of photoidentification developments to date, and informal discussions of objectives and information needs.
1:45 PM	Lunch
2:30 PM	Further discuss objectives and begin outlining problems, and methods of cataloging.
7:00 PM	Dinner and informal discussion of photoidentification problems.

Friday 7 January:

9:00 AM	Sample test and discuss standardizing the photo-identification catalog key.
11:00 AM	Complete discussion on objectives.
12:45 PM	Lunch
2:00 PM	Discuss and summarize problems and methods.
4:00 PM	Discuss future research needs, procedures for cataloging and computerization, workshop reporting and publication.

APPENDIX IV

Agenda for the second workshop on bowhead whale photoidentification.

Dates: 21-23 March 1983

Location: Southwest Fisheries Center
National Marine Fisheries Service
La Jolla, California

Objectives:

1. Review results from the first workshop, and update each other on developments.

2. Establish a format for standardizing data input including discussion on potential computerization.

3. Critically review the filing system with discussion on the implementation of a published catalog.

4. Examine all available identifiable bowhead photographs for potential matches.

5. List other potential sources of bowhead photographs and divide the responsibility for contacting these sources among the workshop participants.

6. Develop a glossary of terms particular to bowhead photoidentification work.

Monday 21 March

10:00 AM	Discussion of results from the first workshop with a decision to include results from the second workshop in a common report. Decide on a standardized format for reporting data pertinent to each photograph. Practice using and testing the identification key.
12:50 PM	Lunch
1:40 PM	Continue keying photographs. Then evaluate results and discrepancies.
4:00 PM	Judge photographs worthy of cataloging
6:00 PM	Dinner and informal discussions.

Tuesday 22 March

9:30 AM	Continue evaluating the key and discussing problems.
11:30 AM	Presentation of a modified key. Rekey 18 of NMML and NOSC photographs, filing by consensus.
12:40 PM	Lunch
2:00 PM	Continue examination of second key. Discuss a potential key based on scars. Start a glossary of terms peculiar to this effort.
5:40 PM	Dinner and informal discussions.

Wednesday 23 March

9:30 AM	Discuss digitizing experiments to recognize individuals through computer scanning. Larry Hansen describes digitizing dolphin fin marks.
12:00 PM	Lunch
1:00 PM	Finish keying out photographs using the revised key. Search the files for potential matches.
4:30 PM	End workshop.

APPENDIX V

Bowhead Whale Photoidentification Key

by Gary W. Miller

(revised by David J. Rugh, May 1983)

The following key is intended as an aid to the recognition of individual bowhead whales. In order to avoid the onerous task of matching each photograph against all others in the collection, this key provides a system whereby the relative extent of markings on the lower jaw and caudal peduncle can be used to sort photographs into files with bowheads having similar markings. Therefore matches need to be sought only with other photographs in the appropriate file or files. Compare your photograph to each of the four standard photographs as indicated in this key in steps A through E. For each step a decision must be made as to whether the whale in question has more (1), less (2), or an undeterminable (0) amount of white compared to that apparent in the standard photographs. After recording these decisions for A through E, go to Appendix Table 1. Starting with 1A in the "Key Directives," follow through the key based on the above decisions until you arrive at a file number. Where there is a number and letter under the key choices (1, 2, or 0), look for that number/letter further down the leftmost column and continue keying. Where there is a number only, you have reached a file identification. For example, if A is 1 (more white on the lower jaw than on #82-01-09), B is 2 (less white on the lower jaw than on #82-03-08), C is 0 (white is not

obvious enough to compare to #82-05-04), D is 1 (there are white marks on the caudal peduncle), and E is 2 (the caudal marks are less than #82-04-06), then the progression in the "Key Directives" would be: step 1A to 1B; step 1B to 1C; step 1C to 7D; step 7D to 7E; and step 7E to file 18.

"Key Steps" in the table may be used as a check of the file choice against the numeric decisions made in steps A-E. "Alternate files" are also shown; that is, where features have not been distinctive enough to categorize, a photo may have been filed under somewhat more ambivalent status. A photograph in File 20 would have indistinctive or invisible markings on the lower jaw and caudal peduncle but may still have highly recognizable markings elsewhere and should be checked against every other file. The more discrete the markings and the better the photographic quality, the more likely a whale will be properly categorized. With increased ambivalence, the search becomes less efficient and more files must be reviewed. When submergence, glare, blurring, wash, or mottling confuse a characteristic, it is preferable to classify it as undeterminable (0), thereby making a conservative approach and reducing the likelihood of an erroneously filed photograph.

Key Steps

A. Compare the white on the lower jaw to that on #82-01-09.

If greater than or approximately equal, class the whale 1.

If obviously less than, class the whale 2.

If undeterminable, class the whale 0.

B. Compare the white of the lower jaw to that on #82-03-08.

If greater than or approximately equal, class the whale 1.

If obviously less than, class the whale 2.

If undeterminable, class the whale 0.

C. Compare the white on the lower jaw to that on #82-05-04.

If greater than or approximately equal, class the whale 1.

If obviously less than, class the whale 2.

If undeterminable, class the whale 0.

D. Are there obvious bilaterally symmetrical white markings on the caudal peduncle?

If there are, class the whale 1.

If there are not, class the whale 2.

If undeterminable, class the whale 0.

E. Compare white caudal peduncle markings with those on #82-04-06.

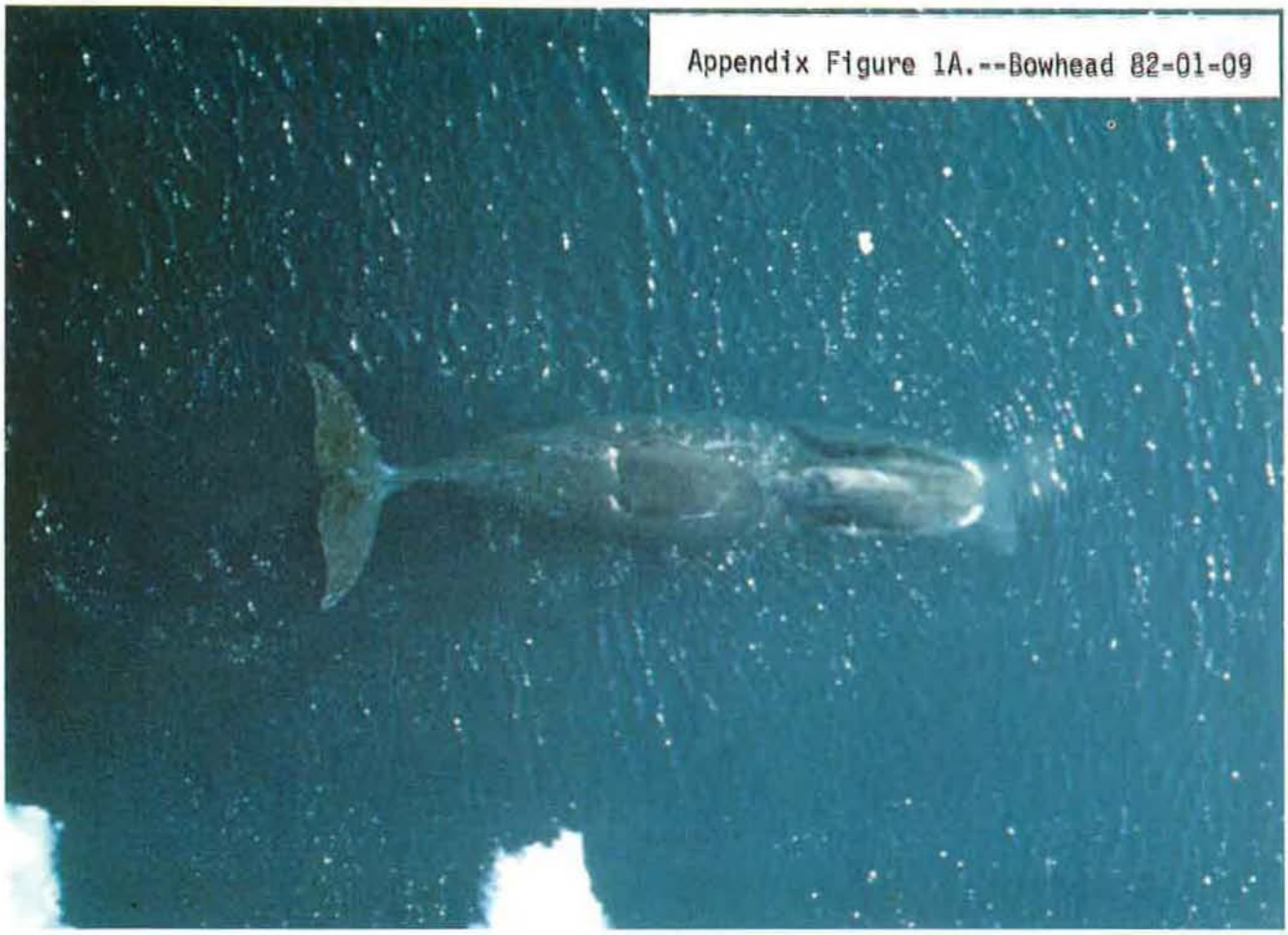
If greater than, class the whale 1.

If less than or approximately equal, class the whale 2.

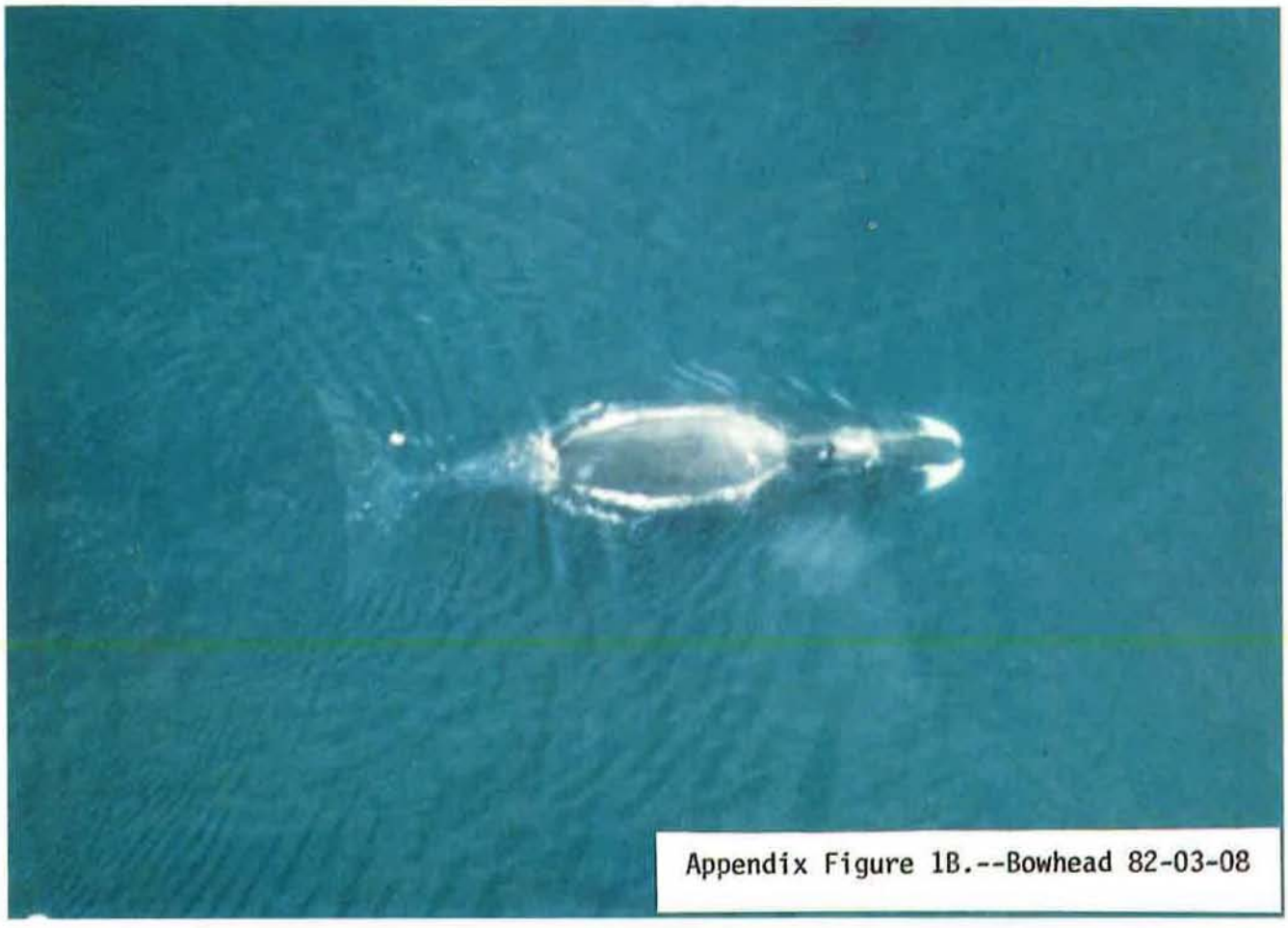
If undeterminable, class the whale 0.

APPENDIX TABLE 1.--Bowhead whale photoidentification key. Use "Key Directives" to find the appropriate file number. Use "Key Steps" to check your file choice against decisions made in statements A through E.

Key Directives				Key Steps						Alternate Files
	Decision									
Step	1	2	0	File	A	B	C	D	E	
1A	1B	1D	2B	1	1	1	-	1	1	13,17,20
1B	2D	1C	3C	2	1	1	-	1	2	13,18,20
1C	3D	4D	7D	3	1	1	-	2	-	13,19,20
1D	1E	12	16	4	1	2	1	1	1	14,17,20
1E	10	11	16	5	1	2	1	1	2	14,18,20
2B	2D	2C	4C	6	1	2	1	2	-	14,19,20
2C	3D	5D	8D	7	1	2	2	1	1	15,17,20
2D	2E	3	13	8	1	2	2	1	2	15,18,20
2E	1	2	13	9	1	2	2	2	-	15,19,20
3C	6D	4D	9D	10	2	-	-	1	1	16,17,20
3D	3E	6	14	11	2	-	-	1	2	16,18,20
3E	4	5	14	12	2	-	-	2	-	16,19,20
4C	6D	5D	10D	13	1	1	-	0	-	1-3,17-20
4D	4E	9	15	14	1	2	1	0	-	4-6,17-20
4E	7	8	15	15	1	2	2	0	-	7-9,17-20
5D	5E	19	20	16	2	-	-	0	-	10-12,17-20
5E	17	18	20	17	0	-	-	1	1	1,4.7,10,13-16,20
6D	6E	19	20	18	0	-	-	1	2	2,5,8,11,13-16,20
6E	17	18	20	19	0	-	-	2	-	3,6,9,12,13-16,20
7D	7E	19	20	20	0	-	-	0	-	1-19
7E	17	18	20							
8D	8E	19	20							
8E	17	18	20							
9D	9E	19	20							
9E	17	18	20							
10D	10E	19	20							
10E	17	18	20							



Appendix Figure 1A.--Bowhead 82-01-09



Appendix Figure 1B.--Bowhead 82-03-08

Appendix Figure 2A.--Bowhead 82-05-04

Appendix Figure 2B.--Bowhead 82-04-06

APPENDIX VI

Organizations and people to be contacted regarding photographs of identifiable bowhead whales.

Marie Adams, Alaska Eskimo Whaling Commission
P.O. Box 69, Barrow, Alaska 99723

Dr. Thomas Albert, North Slope Borough
P.O. Box 69, Barrow, Alaska 99723

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Cascadia Research Collective
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U.S. Dept. of the Interior
P.O. Box 1159
Anchorage, Alaska 99510

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