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Bowhead Whale (*Balaena mysticetus*) Length Estimations Based on Scapula Measurements

CRAIG GERLACH,[1] JOHN C. GEORGE[2] and ROBERT SUYDAM[2]

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ABSTRACT. This study presents data and a method for reliably predicting bowhead (*Balaena mysticetus*) length using one length and one width measurement of the scapula. The bowhead scapula preserves well and is common in coastal arctic archaeological sites. The length measurement is taken as the maximum straight-line measurement along the axis, excluding the scapular cartilage. The width measurement is recorded as a maximum transverse measurement of the ossified portion only. Using a least squares linear regression analysis to evaluate the scapula and whale length relationship, a strong correlation between the width and length measurement and whale length is demonstrated. This technique is useful because estimates of live whale length from complete or near complete scapula can be made to less than one metre.

Key words: bowhead whale, Thule, zooarchaeology, taphonomy, arctic archaeology, aboriginal whaling

RÉSUMÉ. Cette étude offre des données et présente une méthode de prédiction fiable de la taille de la baleine boréale (*Balaena mysticetus*), établie à l'aide d'une mesure de la longueur et de la largeur de l'omoplate. L'omoplate de la baleine boréale se conserve bien et on en trouve de nombreux exemplaires sur les sites archéologiques de la côte arctique. La mesure de la longueur correspond à la distance maximale en ligne droite le long de l'axe, sans tenir compte du cartilage scapulaire. La mesure de la largeur correspond à la distance transversale maximale de la partie ossifiée uniquement. L'utilisation d'une analyse de régression linéaire des moindres carrés pour évaluer le rapport entre la dimension de l'omoplate et celle de la baleine, révèle qu'il existe une forte corrélation entre les mesures de la largeur et de la longueur de l'omoplate et la longueur de la baleine. Cette technique s'avère utile vu qu'on peut déduire la longueur de l'animal vivant à partir d'une omoplate complète ou quasi complète, et ce, avec une marge d'erreur de moins d'un mètre.

Mots clés: baleine boréale, Thulé, zooarchéologie, taphonomie, archéologie arctique, pêche à la baleine par les aborigènes

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INTRODUCTION

The bowhead (*Balaena mysticetus*) and other baleen whales figured prominently in the history and development of maritime cultural adaptations in the North American and Siberian Arctic. Archaeologists working in the western Alaskan and the Canadian Arctic have shown that the bowhead whale played a pivotal role in the expansion and spread of Thule culture, although there are still lively discussions in the literature concerning the relative importance of bowhead hunting in the Thule subsistence pattern (McCartney and Savelle, 1985). There is no question, however, about the importance of the bowhead in the historic development of Inupiat, Yupik and Inuit subsistence strategies or about the cultural and economic significance of the bowhead to the north Alaskan Inupiat today (Mathiassen, 1927a:85, 1927b; Jenness, 1940; Larsen and Rainey, 1948; Collins, 1950, 1951, 1952, 1955; Giddings, 1961, 1967; Taylor, 1963, 1966; McGhee, 1969/70; Worl, 1980; Maxwell, 1985; Sheehan, 1985; Savelle and McCartney, 1990). Bogoslovskaya *et al.* (1982:391; see also Chlenov and Krupnik, 1984) have similarly argued that the intensification of bowhead whaling reflects a peak in the development of the maritime culture of the Asiatic Eskimo and the maritime Chukchi of Chukotka and the Siberian coast.

In spite of a long tradition of archaeological and historic research on bowhead whaling in the North American Arctic, there are still questions about 1) where and when Native American whaling first appears temporally and geographically in the archaeological record; 2) the timing and seasonal nature of whaling; 3) where and when whales were actively hunted rather than scavenged for meat, blubber and building material; 4) the extent to which historic and contemporary models of communal whaling may be used to study and interpret prehistoric whale hunting procurement techniques; 5) the limitations, if any, imposed by aboriginal hunting technologies on the size of bowheads taken through time (see Freeman, 1979; McCartney, 1980a, 1984; McCartney and Savelle, 1985:45; Savelle and McCartney, 1990); and 6) the relative importance of bowheads in Thule subsistence (see Rick, 1980; Morrison, 1983; Savelle and McCartney, 1990). These questions are important because their resolution will shed light on 1) the ecological conditions under which the coastal arctic regions were colonized (see Maxwell, 1985), 2) how the human use of these regions was sustained economically through whale hunting and use, 3) the role of intentional annual and seasonal whaling versus occasional whaling or scavenging in the spread of Thule, and 4) the importance of whale hunting relative to the hunting of other marine and land mammal species from Thule through the historic non-commercial whaling period.

Faunal remains provide clues to subsistence and economics that are missing from isolated studies of material culture and artifacts. Zooarchaeological analysis is most valuable when accurate techniques of identification and measurement of skeletal elements are available. Although considerable biological data are available for bowhead whales, relatively little attention has been paid to the use of skeletal elements from archaeological sites for reconstructing human subsistence practices or whale hunting techniques. The most notable exception to this is the long-term research on prehistoric and historic bowhead whaling by Allen P. McCartney in collaboration with E.D. Mitchell (McCartney, 1979, 1980a,b, 1984) and James Savelle (McCartney and Savelle, 1985; Savelle and McCartney, 1988, 1990, 1991). Through the pioneering efforts of McCartney and colleagues, the first morphometric measurements on bowhead whales were systematically applied to skeletal elements recovered from archaeological sites. Further, McCartney and associates (McCartney, 1978, 1979, 1980a,b) were the first to

[1]Department of Anthropology, University of Alaska Fairbanks, 310 Eielson Building, Fairbanks, Alaska 99775-0160, U.S.A.
[2]North Slope Borough, Department of Wildlife Management, Box 69, Barrow, Alaska 99723, U.S.A.

design a morphometric study that provided both the baseline bowhead data using modern specimens of known live length and the necessary multiple regression equations needed to predict whale length using various combinations of skeletal element measurements. This research is ongoing and was stimulated in part by the need to recognize differential size and age selection through selective culling strategies by prehistoric bowhead whale hunting groups in the Canadian Arctic.

In this paper we build on McCartney's research through presentation of data and a method that will help archaeologists and paleontologists determine the length of bowhead whales using only two measurements of the scapula (for additional data see Withrow and Angliss, 1993; Koski et al., in press; Nerini et al., 1988). In comparison to McCartney's bowhead length calculation, which requires five measurements, the scapula length and width measurements used here are less complicated but equally accurate (see McCartney, 1978; McCartney and Savelle, 1985). We initially chose the scapula for measurement since it preserves well in archaeological sites and because it is frequently recovered in a complete or near complete condition. Recently, we also began recording mandible lengths because this is another element that preserves well and was often used in prehistoric and historic house construction. The consistent use of an accurate method for demonstrating preferential size and age selection is useful, as it will contribute to a better understanding of when bowheads were intentionally hunted, when an occasional kill was made and if naturally stranded whale carcasses were scavenged rather than hunted (see McCartney and Savelle, 1985).

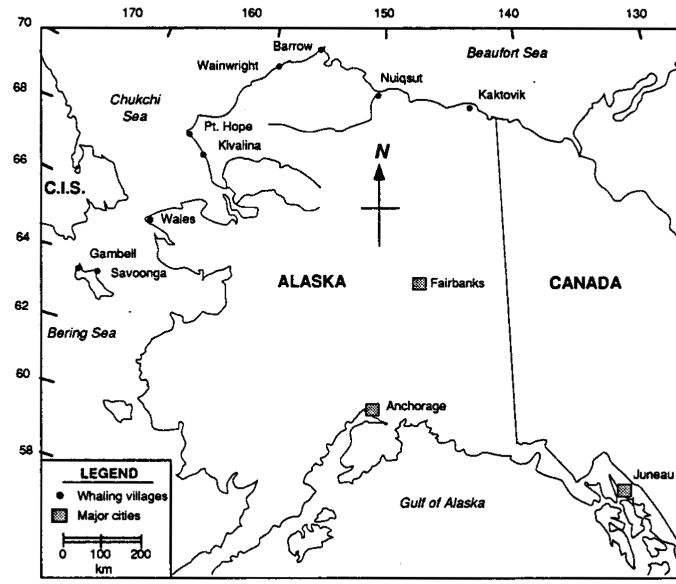

FIG. 1. Locations of the nine Alaskan bowhead whaling villages.

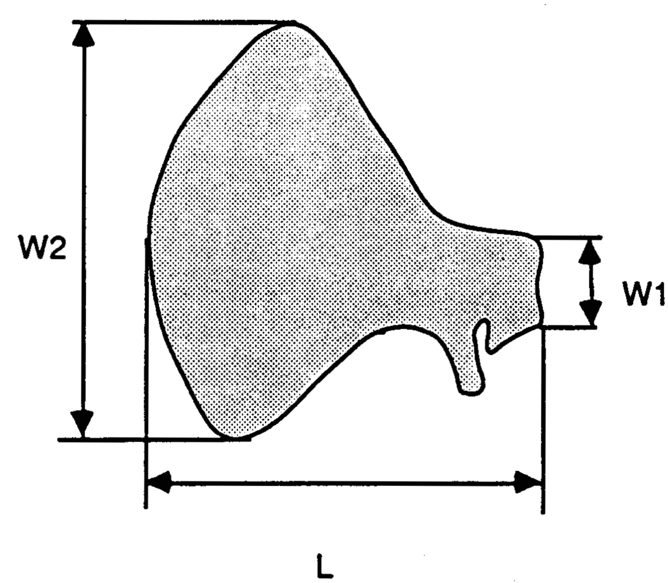

FIG. 2. Schematic of a bowhead whale (*Balaena mysticetus*) scapula adapted from Eschricht and Reinhardt (1866). L = maximum length of ossified portion; W2 = maximum width of ossified portion; W1 = width of glenoid cavity.

METHODS

Biologists from the Department of Wildlife Management, North Slope Borough (NSB), have collected morphometric data from landed bowhead whales since 1982, after this responsibility was taken over from the National Marine Mammal Laboratory (NMML) under the National Oceanic-Atmospheric Administration (NOAA). The measurements used by George et al. (1990) were developed initially by scientists from the National Marine Mammal Laboratory who collected morphometric data on landed bowhead whales from 1975 to 1981. In combination the NMML and NSB data bases provide an excellent sample of modern whales of both sexes and of different age groups and lengths from virtually all of the Alaskan whaling villages.

During the annual spring and fall bowhead hunts, North Slope Borough biologists and field technicians systematically record up to 40 measurements for every bowhead landed and butchered at sites located primarily in Barrow and Kaktovik, Alaska (Fig. 1). Standard measurements for each whale include total length, snout-to-blowhole, and fluke width (George et al., 1990). Prior to our present study, however, few standardized and routine measurements were made on bowhead skeletal elements left at the butchering sites by contemporary Inupiat whale hunters. In the fall of 1990, we began measuring scapulae from previous kill and butchering episodes, and the scapula measurement is now included in the routine collection of biological data for bowhead whales from modern kills in the north Alaskan whaling villages.

Our analysis includes straight-line measurements of the length and width of the scapula and the width of the glenoid cavity of scapulae from harvested bowhead whales (Fig. 2). The length measurement is taken as the maximum straight-line measurement along the axis, excluding the scapular cartilage. Width measurements are recorded as a maximum transverse measurement only on the ossified portion. Measurements were made on landed bowheads at the butchering site(s) and on scapulae from previously harvested specimens of known length that are now stored at the UIC-NARL in Barrow, Alaska. Total whale length measurements were made by placing a tape measure on the ground and recording the straight-line measurements from the tip of the rostrum to the notch in the fluke. Orientation (right or left) was not noted in all cases and therefore is not considered in this analysis. We use linear regression analysis to evaluate the scapula and whale length relationship. Mandible lengths were taken as a straight-line measurement from the proximal to distal end of the ossified portion of the bone.

RESULTS

The scapula measurements for 15 bowhead whales ranging in length from 8.8 to 16.8 m are presented in Table 1. Such body lengths are representative of the length range of whales typically landed by Inupiat hunters on the north Alaskan coast today. Tomilin (1957) reports the maximum scapula length for bowheads at 118.6 cm, a finding nearly identical to that of whale 87B4, suggesting that the animal was very near physical maturity (see Table 1). Because the 87B4 whale is considerably larger than other whales in the sample and may have biased the results, regression equations were calculated with and without this measurement. However, as shown in Figure 3, the results are roughly similar.

Least squares regression analysis indicates a high correlation between whale length and scapula length (r = 0.985) and whale length and scapula width (r = 0.986; Table 1; Fig. 3). Mandible length relative to whale length is also strongly correlated, as shown in Figure 4 (see also Table 2.) The equations describing the regression lines are: 1) WL = 11.943*SL + 212.586, where WL = whale length (m) and SL = scapula length (cm) (the mean whale length to scapula length ratio is 0.067 [s = 0.004; n = 14]); 2) WL = 12.021*SW + 183.173, where WL = whale length (m) and SW = scapula width (cm); and 3) WL = 2.657*ML + 122.631, where ML = mandible length.

Measurements of the glenoid cavity width were obtained for only three whales (Table 2). Although this is a relatively small sample, this measurement does not appear to correlate well with body length. Fossa widths for the 11 and 16 m whales are essentially equal and are, therefore, not useful measurements for the determination of whale length from complete, near complete or fragmentary scapulae. In any event, the fossa or cavity "width" is a very difficult measurement to work with, because the margins of the cavity are almost impossible to locate and define so that they may be measured consistently by different investigators.

TABLE 2. Results of regression analysis (all slopes are significantly different from 0 [P ≥ 0.05])

	WL × SL	w/o 87B4	WL ×SW	w/o 87B4	WL × ML
Constant	212.586	246.789	183.173	167.163	122.631
Std. error of Y estimate	46.481	44.870	45.856	47.505	52.547
R squared	0.971	0.96	0.972	0.952	0.973
No. of observations	15	14	14	13	14
Degrees of freedom	13	12	12	11	12
R value	0.985	0.980	0.988	0.975	0.987
X coefficient	11.943	11.409	12.021	12.246	2.657
Std. error of coefficient	0.572	0.671	0.589	0.084	0.127

WL = whale length; SL = scapula length; SW = scapula width; ML = mandible length.

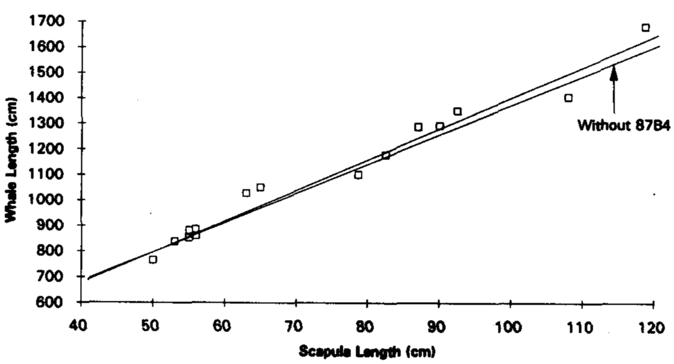

FIG. 3. Scatter plot of bowhead body length and scapula length.

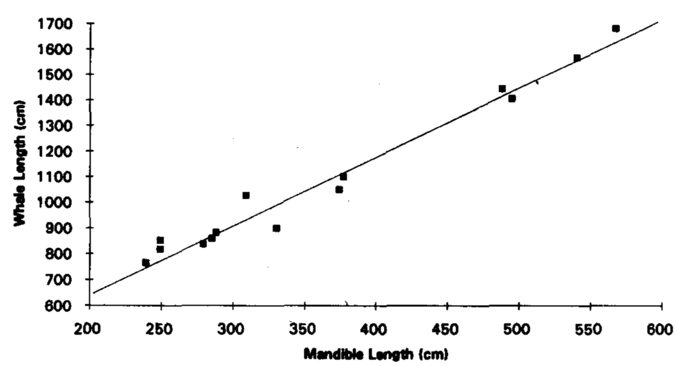

FIG. 4. Scatter plot of bowhead body length and mandible length.

TABLE 1. Scapula measurements taken from whales landed by Alaskan Inupiat in Barrow and Kaktovik, Alaska

Whale ID number	Whale length (cm)	Scapula length (cm)	Scapula width (cm)	SL/WL ratio	SW/WL ratio	Glenoid fossa width (cm)
87B4	1680	118.7	125.7	0.071	0.075	26.7
88B1	885	55.9	59.7	0.063	0.067	15.2
90B3	1177	82.5	87.6	0.070	0.074	26.7
90B7	838	53.0	54.0	0.063	0.064	—
90B8	1287	87.0	87.0	0.068	0.068	—
90B9	1291	90.0	88.0	0.070	0.068	—
90B10	1350	92.5	—	—	0.069	—
90B11	1405	108.0	103.0	0.077	0.073	—
90KK1	1050	65.0	67.0	0.062	0.064	—
91B1	765	50.0	54.0	0.065	0.071	—
91B2	859	56.0	58.0	0.065	0.068	—
91B3	882	55.0	54.0	0.062	0.061	—
91B6	1100	78.7	78.7	0.072	0.072	—
91B8	1027	63.0	67.0	0.061	0.065	—
92B1	853	55.0	59.0	0.064	0.069	—

DISCUSSION

This method for measuring bowhead scapulae supports McCartney (1978, 1980a,b) and McCartney and Savelle (1985:45-46) on the importance of uniformly applied measurements of selected skeletal elements for the reconstruction of bowhead whale length. The advantage of the method proposed here is that whale length may be predicted using only two measurements on a single bone — the scapula. The scapula is useful because it preserves well and commonly occurs as a skeletal element in arctic coastal archaeological sites dating from the late prehistoric through the historic non-commercial whaling period in northern Alaska and Canada. The disadvantage of a length/width measurement like this one is that it works only on complete or near complete elements. This basic whole element measurement will obviously not be applicable in all cases, since the scapula is sometimes split longitudinally through the glenoid fossa and back to the dorsal border.

Morphometric measurements are important because they are required for a variety of zooarchaeological studies. Depending upon the species under consideration, varying combinations of length, size and age estimations are needed for determining mortality profiles and for reconstructing the age and sex composition of archaeological faunal samples (see Klein and Cruz-Uribe, 1984; see Schell *et al.*, 1989, for a discussion of age estimations in bowhead whales). As shown by Savelle and McCartney (1991), such information is extremely useful for analyzing the extent to which hunting rather than scavenging characterized Thule subsistence and for demonstrating whether or not Eskimo hunters focused their hunting efforts on younger or smaller whales prior to the introduction of modern whaling technology. Although our sample size is still relatively small (n = 15), enough data are available now to indicate that these scapula measurements will allow archaeologists to predict whale length to within less than one metre — and in most cases to 0.5 m. The mandible measurement (see Fig. 4) maybe equally useful, as it appears to demonstrate a size-length correlation that is similarly robust.

Because bowhead whale age and length relationships are not fully understood, it is still not possible to determine the "precise" chronological age for whales represented in faunal remains (see, however, Schell *et al.*, 1989). The biggest difficulty is in correlating length with age for mature whales, although it is well established that bowheads mature at lengths of about 12-14 m (Nerini *et al.*, 1988). As McCartney (pers. comm. 1992) points out, "there is indeed a size-age relationship up to the point of maturity (full-sized animals) . . . and the size of whale bones from calves (less than a year) through yearlings and up through 4-6 year animals can be shown to correspond with age." This relationship results from the fact that bowheads in northern Alaska are available only during a restricted period each year because of their seasonal migration patterns. The implication is that "gaps" in the reconstructed age profile will occur among calves, yearlings and older animals. Once maturity has been achieved at 12-14 m, growth slows and size alone is not related to age.

Based on our knowledge of the size of whale bones recovered from many north Alaskan archaeological sites, the selection of the young or small whales shown in the Canadian Arctic may have been part of a patterned preference for smaller bowhead whales throughout the prehistoric and early historic periods in the North American Arctic and Chukotka (McCartney and Savelle, 1985:45-46; Savelle and McCartney, 1990:716, 209-215). While Krupnik (1987, 1988) argues for a preferential selection of gray whales and gray whale calves at Whale Bone Alley and other sites in Chukotka, McCartney and colleagues (see references) have demonstrated a clear tendency for the selective introduction of small bowhead whales into Thule sites in the Canadian Arctic. We suspect that the modern emphasis on large bowhead whales in northern Alaska, the females generally being the largest, may be the legacy of the 19th-century whaling industry and the use of such modern technology as block and tackle for hauling whales onto the ice and bomb guns for more efficient killing.

Obviously there are many variables that will determine the size and condition of bowhead whales taken at any point in time. Today large whales are not always taken — even when they are available. For example, many contemporary whalers prefer the smaller whales because they taste better. Some whaling captains avoid the larger whales for safety reasons, and sometimes larger whales are not taken because of logistical considerations and the distance required to travel from the kill site to the village or butchering site before the whale spoils. The latter occurs more frequently during fall whaling, because whales are usually transported to the village for butchering and processing. During the spring hunt, whales are generally butchered on the ice, in relatively close proximity to the kill, so transport and spoilage are typically not a problem. Generally whales must be butchered within a 12-24 h period for optimal utilization of the carcass, although the actual time will vary, depending on the size of the whale. Since the early 1980s the International Whaling Commission and the Scientific Committee on Protected Species have recommended that Inupiat whalers avoid the larger and reproductively active whales to help the stock recover.

All of the above have to do with choice rather than with technological limitations in determining the size of bowhead whales taken by modern hunters. Although we understand something about conditions of choice in the present, it is important to study how differential selection and culling strategies were practiced in the past. Ultimately this will require a large grid of archaeological sites from different time periods, analysis of a large sample of bowhead skeletal elements and accurate techniques for reconstructing bowhead length. In general, Alaskan archaeology lags behind Canadian archaeology in the way that marine mammal remains from archaeological sites are used to confront problems of anthropological and biological significance (for an important exception see Stanford, 1976). We therefore encourage archaeologists working west of the Canadian border to begin studying bowhead and other marine mammal remains in ways that will provide for meaningful comparisons to the Canadian cases. The technique for determining whale length described in this study will contribute to this effort, since it provides a simple, quick and reliable way to determine length of bowhead whales using scapulae from archaeological sites.

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