Sampling Strategy for Enumerating the Western Arctic Population of the Bowhead Whale

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Introduction

The National Marine Mammal Laboratory (NMML), National Marine Fisheries Service, NOAA, is conducting research on the population enumeration of the western Arctic stock of the bowhead whale, *Balaena mysticetus*. From a management viewpoint this research is critical for evaluating the status of this severely depleted stock. Because so little is known about the bowhead, inferences regarding the health of the population arise mostly from changes in total population size. The basis for this inference is the assumption that changes in population size reflect the summation of all life history processes of the bowhead. To state it rather coarsely, for this depleted stock a decline in total abundance may indicate a shift toward extinction; an increase, a shift toward survival.

At present our only scientific means of assessing the number of whales which can be safely removed from the bowhead stock is to estimate total abundance and then rely on theories of population growth to predict acceptable levels of removal. But estimating total abundance is a very costly endeavor for a wide ranging species like the bowhead and, furthermore, there is no guarantee that general theories of population growth will always apply. Regardless of the population level there is the possibility of decline induced, perhaps, from stress relating to activities of offshore oil development, subsistence harvest, or natural fluctuations of the ecosystem. It is with these problems in mind that this paper presents the NMML research strategy for estimating total abundance of the bowhead whale and discusses methods which eventually may be used to monitor relative abundance, i.e., annual changes in population size.

Study Area

The study area closely approximates the range of the western Arctic population of bowhead whales (Fig. 1). The range extends from the west-central Bering Sea north of approximately lat. 60°N, throughout the Chukchi and eastern East Siberian Seas, and eastward throughout the U.S. Beaufort Sea to Banks Island and Amundsen Gulf, Northwest Territories, Canada.

Seasonal movements of bowhead

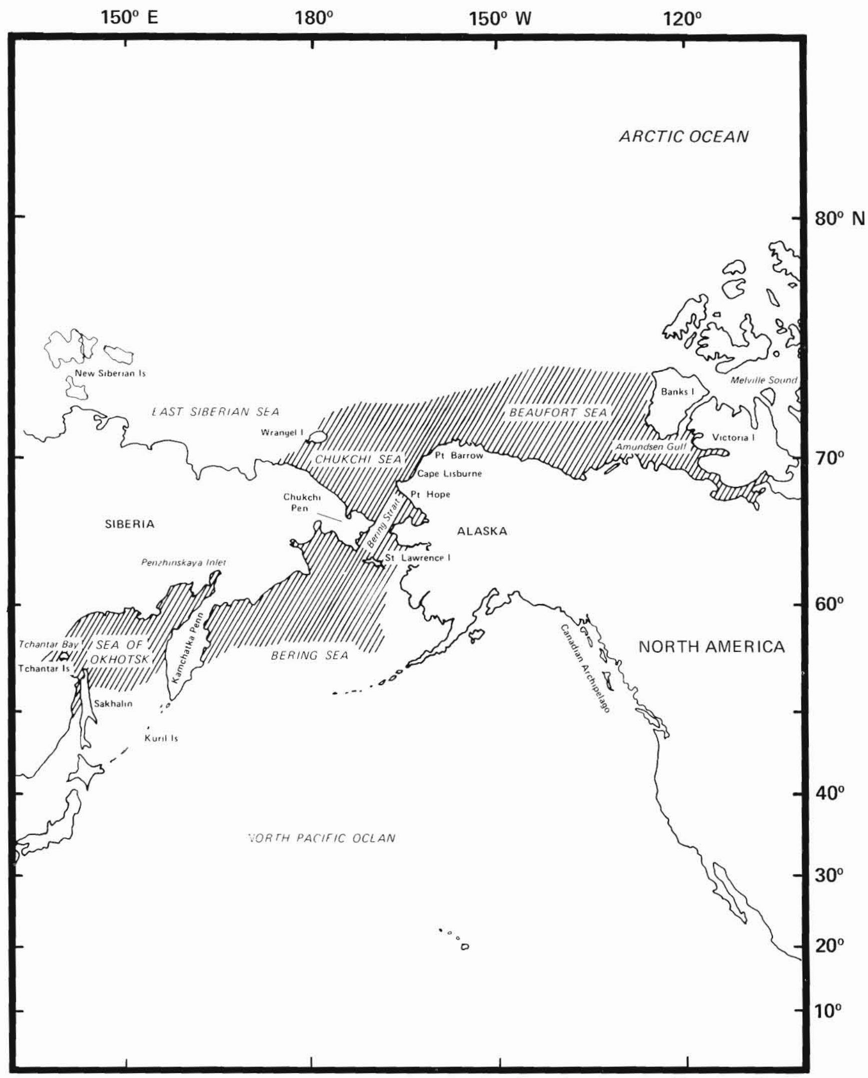

Figure 1.—Bowhead whale study area. Hatched lines indicate distribution of the western Arctic and Okhotsk populations of bowhead whales prior to commercial exploitation (Braham et al., footnote 4).

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whales closely parallel the seasonal distribution of ice. The northward spring migration from the Bering Sea is timed with the breakup of the pack ice (Bailey and Hendee, 1926) which occurs about April. Upon entering the Chukchi Sea the migration cuts northeastward toward Point Hope and along the northwest coast of Alaska, toward Point Barrow (Braham et al., 1980). The migration occurs closest to shore at Point Barrow, with most of the population passing from late April through May. Although the direction of migration toward Banks Island does not change, east of Point Barrow the coastline slants southeasterly toward Canada. Thus the spring migration route east of Point Barrow becomes progressively more offshore as the whales move easterly through the Beaufort Sea toward Banks Island.

During the spring migration bowheads confine themselves to open water areas in the pack ice. In their southern range the ice is thin and easily disturbed by winds and currents; open water areas are abundant. As bowheads penetrate further north, however, the ice becomes thicker and flaws in the ice commonly appear as long cracks, or leads. Along the northwest coast of Alaska these leads persist between the landfast ice and the pack ice forming a zone which may exceed 50 km in width towards the southern end near Cape Lisburne (Burns et al.[1]). This zone narrows dramatically to only a few kilometers at Point Barrow (Braham et al., 1979). East of Point Barrow the zone occurs further offshore (Marko, 1975).

From June to September bowheads frequent areas south and southwest of Banks Island; the autumn migration westward through the Beaufort Sea begins in August and September, with most sightings recorded in October near the 20 m depth contour line from Demarcation Bay to Point Barrow (Ljungblad et al.[2]). From Point Barrow the animals move westward toward Wrangel Island (Cook, 1926; Townsend, 1935) then south through the Chukchi Sea into their winter range, the Bering Sea.

Field Methodology

Ice and Land Camps

Each spring from 15 April through 30 May since 1976 we have counted bowhead whales as they migrated past Point Barrow in the nearshore lead. Because of constant daylight during late spring and summer in the Arctic, a 24-hour observation schedule was maintained. One camp was deployed in 1976 and 1977. In 1978 and 1979 two camps with seven persons each were deployed on the landfast ice next to the nearshore lead approximately 5 km north of Point Barrow.

The two camps, called South Camp and North Camp, were located 600-800 m apart depending on the availability of ice platforms or ridges of sufficient height to provide visual observation across the lead.

Bowheads moved northeastward in the nearshore lead from South Camp toward North Camp. South Camp observers maintained the primary count while North Camp observers estimated how many whales were missed at South Camp.

Documentation of the ice camp counting methodology is reported in Braham et al. (1979), Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage (1980), and Krogman et al.[3].

A land camp was located at Cape Lisburne in 1978 to study the onset and termination of spring migration along the northwestern coast of Alaska. Land camp methodology was similar to that used in the ice camps except that only one camp was used (Rugh and Cubbage, 1980).

Aerial Survey

Aerial survey procedures were designed to maximize our ability to delineate nearshore and offshore distribution of whales in seas covered with pack ice. The aircraft was flown over leads at elevations ranging from 70 to 300 m depending upon cloud cover. Documentation of aerial survey methodology used for this research is reported in Braham et al.[4] and Krogman et al.[5].

Total Abundance

Results from aerial surveys flown to delineate the spring distribution of bowhead whales in the Bering, Chukchi, and Beaufort Seas, and results from feasibility studies conducted at St. Lawrence Island, Cape Prince of Wales, Point Hope, Cape Lisburne, and Point Barrow, indicate that the most reliable estimate of total abundance will result from counts made from the ice as migrating bowhead whales pass Point Barrow, Alaska, during their spring migration. Census methods which relied on aerial survey methodology were quickly disqualified because of the confounding effects of sea ice on sampling design. The other above-mentioned sites were considered for staging land/ice based counts, but each eventually proved inferior based on the criteria of proximity of location to migratory routes, ice, and prevailing weather conditions which influence visibility.

Counts made at Point Barrow do not constitute a complete census, however. In fact, before one can use the Barrow

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[1]Burns, J. J., L. H. Shapiro, and F. H. Fay. 1977. The relationships of marine mammal distributions, densities, and activities to sea ice conditions. *In* Environmental assessment of the Alaska continental shelf, annual reports of principal investigators for the year ending March 1977, Vol. 1, Receptors-mammals, p. 503-554. U.S. Dep. Commer., Natl. Oceanic Atmos. Admin., Environ. Res. Lab., Boulder, Colo.

[2]Ljungblad, D. K., M. F. Platter-Rieger, and F. S. Shipp, Jr. 1980. Aerial surveys of bowhead whales, North Slope, Alaska. Naval Ocean Systems Center Tech. Doc. 314, Final rep., Fall 1979, BLM Project No. 00L80AA851-1AO-1-ELEMENT OGB, 182 p. Bureau of Land Management, Code 733, 18 and C Streets N.W., Rm. 2657, Washington, DC 20240.

[3]B. D. Krogman, G. W. Priebe, and R. M. Sonntag. 1980. Arctic Whale Task ice camp survey data management format, document 1980 version. Unpubl. rep., 30 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

[4]Braham, H., B. Krogman, and G. Carroll. 1979. Population biology of the bowhead whale (*Balaena mysticetus*) II: Migration, distribution, and abundance in the Bering, Chukchi, and Beaufort Seas, with notes on the distribution of white whales (*Delphinapterus leucas*). Unpubl. final rep., OCSEAP contract R7120807, 118 p., Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

[5]Krogman, B. D., R. M. Sonntag, and H. W. Braham. 1979. Arctic Whale Task aerial survey format, 1979 version. Unpubl. rep., 28 p., Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

counts as the basis for estimating total abundance, it is necessary to consider all segments (components) of the bowhead population not accounted for by the Barrow counts.

To proceed along this line of reasoning, a total estimate (T) for the bowhead population can be expressed mathematically as:

$$T = \sum_{i=1}^{n} C_i \qquad (1)$$

where T = total population size,
C_i = ith component of the population, and
n = 5.

Letting C_1 = number of whales passing the ice camp during a specific sampling period in the spring (15 April-30 May),
then C_2 = number of whales passing by Barrow before the spring sampling period,
C_3 = number of whales passing by Barrow after the spring sampling period,
C_4 = number of whales which never pass the ice camp, perhaps remaining in the Chukchi and Bering Seas through summer, and
C_5 = number of whales passing by Barrow far offshore, beyond the range of sight of the observers at the ice camp.

The advantage of this technique is that each component can be studied separately and later combined to make a total abundance estimate. Research strategies for estimating each component will now be presented.

C_1 is typically greater than actual counts because there are intervals during the 15 April through 30 May period during which observers are unable to watch for whales. Unstable ice conditions and/or periods of poor visibility because of fog or ice-choked leads sometimes prevent observers from counting. It is thus necessary to interpolate for periods of missed watch so that C_1 will equal the total number of bowheads passing the counting stations during the field season.

To proceed, let C_1 be estimated by $\hat{C}_1$, defined as:

$$\hat{C}_1 = \sum_{i\ \mathrm{odd}}^{n} w_i + \sum_{i\ \mathrm{even}}^{n} w_i \qquad (2)$$

where $\sum_{i\ \mathrm{odd}}^{n} w_i$ = summation of the number of bowheads counted during each period of watch, and

$\sum_{i\ \mathrm{even}}^{n} w_i$ = summation of the number of bowheads estimated as moving by the camp during periods of no watch.

The length of each period w_i will vary with environmental conditions. The first watch period of the season w_1 lasts until observers must abandon watch. At the moment w_1 terminates, w_2 begins and continues until observers return to watch, demarcating the initiation of w_3, and so on.

Obviously the value of each $w_{i\ \mathrm{odd}}$ equals the number of whales counted during each period of watch. It is now left to estimate $w_{i\ \mathrm{even}}$. After considerable investigation of alternative methods, such as polynomial curve fitting, it was concluded that for any missed period x, $w_{i\ \mathrm{even}}$ can best be approximated by interpolation using the average rate(s) of whale movement based on counts made during the two adjacent periods, each also equal in length to period x. Thus, if 2 hours are missed, an estimate of that missed period is calculated based upon the preceding 2 hours and following 2 hours of data. If 3 days are missed, then 3 days preceding and 3 days following are used. Also, as is likely to occur in the latter example, if some portion of an adjacent period is also missed, the rate is computed on whatever data are available in that adjacent period.

The computation of $\hat{C}_1$ yields a value similar to that reported as the "ice camp index" in Braham and Krogman[6] and Braham et al. (1979), particularly when only a small percentage of the total watch period is missed. The ice camp index was computed as the summation of the products of the average rate of whales per hour of watch during each day multiplied by 24 hours. In 1978, it was computed as 2,264 with a total range of uncertainty equal to 1,082 (Braham et al., 1979). Regretfully, the term "index" has been a source of confusion for some, and thus the term C_1 is introduced here as the "Barrow estimate."

C_2 and C_3 were evaluated by a field study conducted at Cape Lisburne in the early spring of 1978 (Rugh and Cubbage, 1980). The main objective of that study was to determine the onset and termination of the spring migration along the northwestern coast of Alaska. Results were combined with aerial survey results and ice camp counts to estimate the magnitude of C_2 and C_3.

The value of C_2 was negligible according to results from Cape Lisburne. Bowheads were seen migrating past Cape Lisburne before Point Barrow. In 1978, regular watches at Cape Lisburne commenced 10 April and the first confirmed sighting of bowheads occurred 8 days later; bowheads were seen daily thereafter. At Point Barrow, regular watches commenced 15 April, and the first bowhead was observed 5 days later. Again, they were seen daily thereafter. These similarities in temporal distribution indicate that few, if any, bowheads migrated past Point Barrow prior to the commencement of the Point Barrow ice camp census.

C_3 is estimated to be less than 4 percent of C_1. This estimate for the number of bowheads moving by Point Barrow after the spring sampling period was derived from ice camp data and was verified by results from aerial surveys, as explained below.

A comparison of trends in daily movements of bowhead whales migrating by Point Barrow for the years 1976-78 (Fig. 2) showed a decline in movement during the last third of the 15 April through 30 May period. An average rate per day beyond 30 May was computed as 3.08 (0.94 SD). The ending dates of our observations for each year were: 2 June 1976, 3 June 1977, 5 June 1978, and 30 May 1979. Using

[6]Braham, H. W., and B. D. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whale in the Bering, Chukchi and Beaufort Seas. Processed rep., 29 p. Natl. Mar. Mammal Lab., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

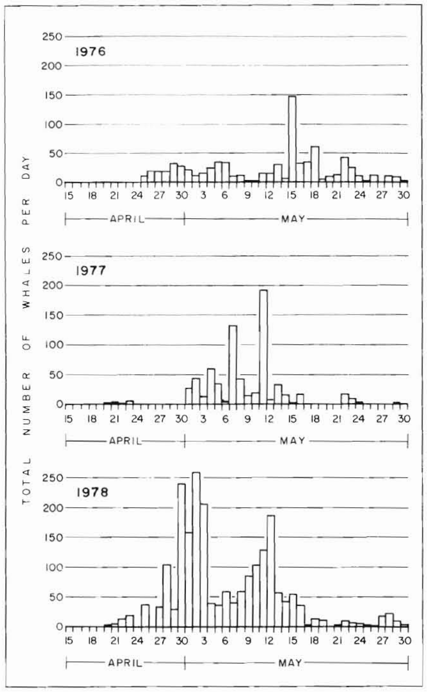

Figure 2.—Comparison among years (1976-78) of estimated total number of bowhead whales migrating northward past Point Barrow, Alaska, 15 April-30 May. For purposes of comparison, totals are based on hourly rates per day times 24 hours. Estimated yearly totals are 796, 715, and 2,264 for 1976, 1977, and 1978, respectively. Differences in total estimates are ascribable to observer effort and weather. The 1978 estimate is considered the best available to date (Braham et al., 1979).

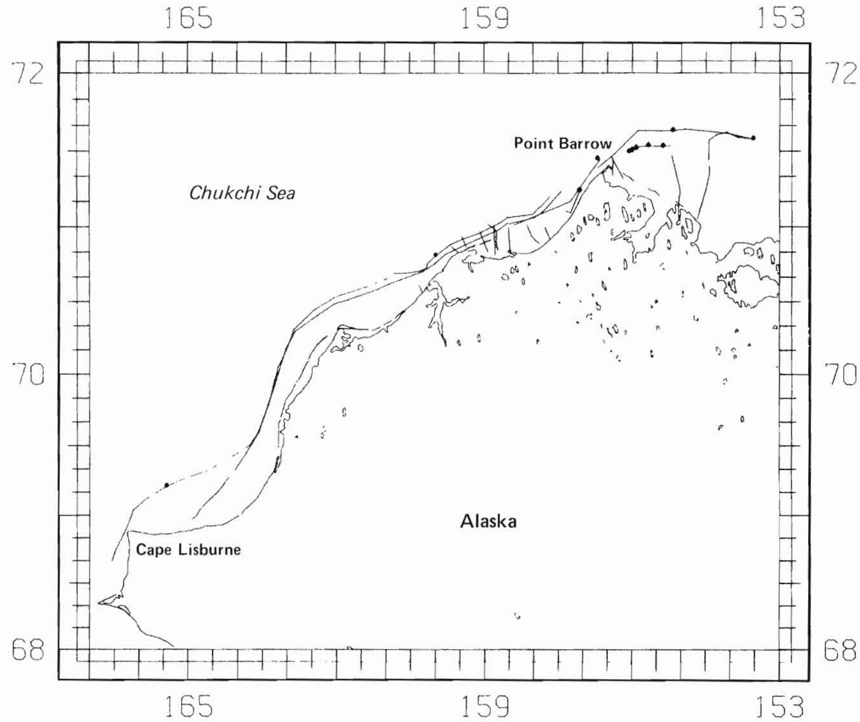

Figure 3.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas on 1, 4, and 5 June 1976. Dots represent presence of bowhead whales: 20 whales were counted with a mean group size of 1.8 (SD=1.1).

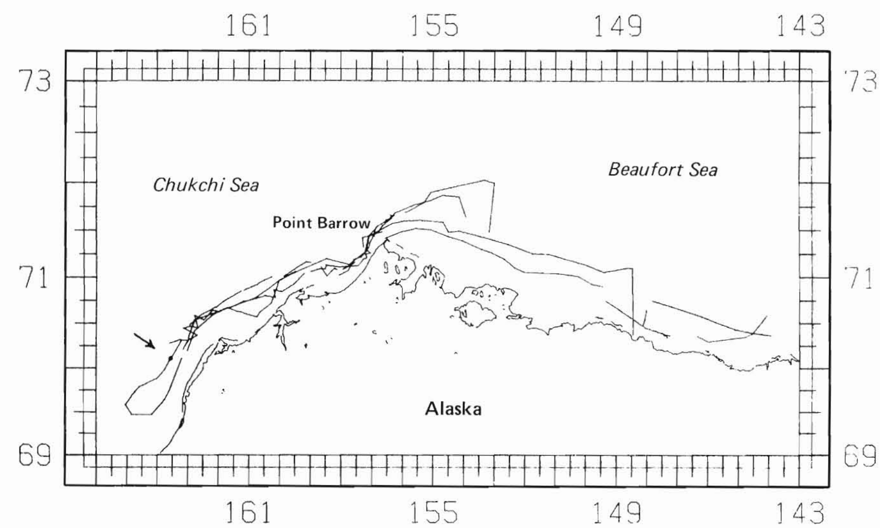

Figure 4.—Aerial survey tracklines flown in the eastern Chukchi and western Beaufort Seas 18-20 June 1976. The dot (indicated by an arrow) represents one bowhead whale.

only this average as a basis for extrapolating through the month of June, it can be estimated that approximately 92 whales pass Point Barrow after the ice camp counting station closes.

Aerial survey results suggest, however, that daily rates decline through the month of June. Figures 3 and 4 illustrate the difference in the number of bowhead whales observed during the first week versus the third week of June 1976. Thus, the estimated 92 whales can be considered a maximum value. The value 92 is 4 percent of 2,264, which is the current estimate of the number of bowheads which pass Point Barrow during the 15 April through 30 May period (Braham et al., 1979).

C_4 is apparently insignificant. Results from vessel and aerial survey research conducted since 1976 indicate that few if any bowhead whales remain in the Bering and Chukchi Seas south of the pack ice after the closure of the ice camps (Braham et al., footnote 4; Dahlheim et al., 1980).

C_5 is difficult to measure because the perimeter of the sample space, i.e., the farthest distance that observers can reliably count whales, is not discrete. Measurement of C_5 has been attempted primarily through aerial survey, but results have been slow in coming because the number of bowheads is small, and technological limitations have prevented an accurate determination of the position of whales relative to the ice camps.

Based on results from aerial survey, few, if any, bowheads migrate more than 8 km seaward of the ice camp; most are within 3 km (Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage, 1980). On the other hand, results from the ice camps indicate that almost all bowheads migrate within 5 km—most within 1 km—of the landfast ice edge. This discrepancy is ascribable to differences in methodology that have yet to be resolved.

Further complicating the determination of the magnitude of C_5 is the probability that the number of whales passing beyond the range of sight of observers is not constant. Yearly fluctuations in ice configurations may contribute to shifts in whale distribution relative to the ice camps. And, certainly, location and condition of ice at the camps affect the observer's ability to count whales. Changes in distributional patterns of whales relative to the ice camps therefore prevent a reliable determination of C_5 at this time. A subjective estimate based on field experience is that the upper bound of C_5 does not exceed 30 percent of the Barrow estimate and in some years, such as 1978, it is much lower.

In summary, the above analyses suggest that components C_2, C_3, and C_4 will probably account for only a small number of whales in the total estimate of abundance. Too little is known regarding the magnitude of C_5 to predict its effect on future estimates. Furthermore, this analysis supports the conclusions made by Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage (1980) that the "ice camp index" or "Barrow estimate" under certain conditions can serve as an approximation of total abundance.

Relative Abundance

Until now, out of interest in presenting an overview, I have postponed any discussion of accuracy or precision. In all likelihood, if the estimate of total abundance is accurate, it will also be precise, but not vice versa. A statement of accuracy describes how close to the true value a particular estimate falls, whereas precision refers to the closeness of each repeated measurement of the same quantity. In this section, the research strategy for determining accuracy and precision will be presented. Note that the following discussion deals almost exclusively with the evaluation of C_1, as its magnitude so overshadows the other components.

A typical approach to studying accuracy is to uncover sources of error or bias. The sources of error associated with estimating C_1 are closely associated with how well observers are able to count whales. An obvious error would be for an observer to miss seeing a whale altogether (e_1). This error was studied in 1978 and 1979 using two ice camps (see Field Methodology section) and is estimated at approximately 20 percent, i.e., 20 percent of all whales which swim by one camp are never seen (Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage, 1980). Other errors occur, but these must be defined as they relate to the way observers score whales.

Observers are asked to score all sightings made during a period $w_{i\ \mathrm{odd}}$ as: New sightings, duplicate or repetitive sightings, or conditional sightings, which occur when observers are unsure as to which of the previous two categories in which a whale sighting belongs. Here, error terms can be defined as: e_2, when an observer incorrectly scores a whale as new after the whale has already been counted; or e_3, when an observer incorrectly scores a whale as a duplicate before it has been counted as a new whale. No error per se can be made regarding conditional whales.

To determine the accuracy of the estimate of C_1 it is necessary to determine the magnitude of e_2 and e_3 and to determine, if possible, the proportion of conditional whales which were new rather than duplicates. To determine the precision of the estimate of C_1, it is necessary to determine the variation in magnitude of these sources of error—observer variability.

Computer Modeling to Improve Accuracy and Precision

Counting errors e_2 and e_3 are being evaluated using computer modeling. Field data collected on the diving profiles of bowhead whales were used as the basis for developing a model which generates the surfacing pattern of a population of bowhead whales during migration. The model creates a data base similar to the one based upon raw field data, except that for the modeled population, it is known exactly which whales that "swim by the camp" are new and which are duplicates. The next step in the modeling procedure involves the development of a counting program to independently evaluate the model population for new and duplicate whales. As the counting program processes each "sighting" it evaluates it against all previous sightings and, based upon probabilities, the program decides whether or not the sighting is new or duplicate.

On the average, the counting program overestimates the number of new whales by 8 percent, and underestimates the number of duplicate whales by 2 percent. But these results must be further verified through field experiments. The counting program will be implemented in the field through use of a microcomputer. As observers at the ice camps record observations, they will also relay their data by radio to a nearby laboratory for evaluation by the counting program. Feedback based upon computer evaluation will then be provided to the observer. Through this two-way communication much can be learned about the nature of errors made by observers and by the counting program.

The results of this study will be applicable to evaluation of accuracy and precision of the estimate of C_1. Assuming that the counting program is verified, it will be applied to previous years' field data for evaluation of counting errors. Upward or downward adjustments can be made, resulting in a more accurate estimate of C_1. Since adjustments in counts will also have the effect of negating much of the observer variability apparent from year to year (see Table 1, Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage, 1980), the precision of the estimate of C_1 will also be improved.

Measurement of Accuracy and Precision for Missed Data

Unfortunately, there are more factors than just observer variability which influence the accuracy and precision of the estimate of C_1 by Equation (2). As environmental conditions worsen, and observational effort becomes more discontinuous, the accuracy and precision of the estimate of C_1 become a concern. Simply stated, an estimate of C_1 based upon 95 percent watch effort would be considered more reliable than an estimate based upon only 35 percent. For the 95 percent case, interpolation to determine the number of whales which passed the ice camp during periods of missed watch would be required 5 percent of the time; for the latter case, 65 percent of the time. Thus, as percent watch effort decreases, the estimate of C_1 becomes less a measurement and more an inference.

The accuracy of Equation (2) and the rate at which its precision decreases are being studied with the aid of a computer model. The basis of this model is a data base which contains whale counts made during a continuous period of watch which lasted 18 days from 2 to 20 May 1978. The total number of whales counted during this period equaled 1,133 and, for the purposes of this experiment, is considered equal to C_1, the true number of bowheads which passed the counting station.

The model simulates the effects of reduced watch effort by introducing periods of missed watch which vary in length and frequency. Theoretically, watch effort can be varied from 0 to 100 percent, but for practical reasons, experiments have been run from 6 to 98 percent by increments of 2 percent. A determination of accuracy and precision is made for each increment.

As an example of how accuracy and precision are determined for a given percentage of watch effort, consider a season where 80 percent of the time was spent watching. The model would initially remove 20 percent of the data, and calculate an estimate of C_1. The difference between the estimate and the true C_1 is called a residual. Following this, the model would reselect 20 percent of the data for removal, and recompute C_1, again computing a residual. After performing this test many times, an average and standard deviation are computed for the residuals.

It is the average of the residuals which is used to evaluate accuracy. Theoretically, if the experiment is repeated often enough and if Equation (2), which is used to estimate C_1, is unbiased, then the average residual should equal zero; that is, there should be no difference between estimated and true values of C_1. A significant upward departure from zero indicates that Equation (2) is upward biased, i.e., tends to overestimate the number of whales which swim by during periods of missed watch. A significant downward departure similarly indicates that Equation (2) is downward biased. Preliminary results suggest that Equation (2) is unbiased, or accurate.

The standard deviation of the residuals forms the basis for determining precision. When Equation (2) repeatedly estimates C_1 very closely, the standard deviation of the residuals will be small, indicating good precision. When repeated estimates of C_1 vary widely, the standard deviation of the residuals will be large, indicating a lack of precision. Through the use of the computer model, the rate of growth of the standard deviation is being traced as a function of watch effort.

In summary, this research should eventually provide the criteria which will allow annual changes in estimates of C_1 to be evaluated statistically, thus improving the chances of detecting significant changes in population size if and when they occur. Furthermore, the evaluation will take into account variations in percent total watch effort, thereby increasing the usefulness of marginal counting years for monitoring population stability.

Discussion and Conclusion

This paper was written primarily to explain the National Marine Mammal Laboratory's research strategy for population enumeration of bowhead whales. Other avenues of research that have been seriously investigated have not been addressed in this report. For example, censusing techniques using active and passive acoustic devices have received considerable attention (Braham, Krogman, Johnson, Marquette, Rugh, Sonntag, Bray, Brueggeman, Dahlheim, Nerini, and Savage, 1980; Braham, Krogman, Nerini, Rugh, Marquette, and Johnson, 1980). Aircraft have been used as platforms for validating ice camp counts (Braham et al., 1979). Even remote sensing methods which utilize satellites have been explored. These alternative censusing methods are being investigated because it is through independent verification of research results that meaningful statements regarding population abundance can be made.

It should be remembered, too, that no matter how difficult it may be to estimate total population size, it is entirely feasible that we can monitor the status of this population by detecting changes in its size through time. One simple approach might be to eliminate the problem of observer judgments and whale counting by having observers record only the number of sightings they make without attempting to translate the number of sightings into number of whales. For example, assuming environmental factors are standardized, if the number of sightings increases 5-fold over a period of years, an inference could be made that the total population size is also increasing. It would be premature to adopt this methodology, however, since it has not been shown that observers do not count accurately. It may be that inquiries will show not only that observers are highly reliable, but that both total abundance and relative abundance can be reliably estimated.

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Spring Migration of the Western Arctic Population of Bowhead Whales

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Introduction

Each spring the western Arctic population of bowhead whales, *Balaena mysticetus*, migrates from the Bering Sea, through the Chukchi Sea, and into the Beaufort Sea. For centuries, coastal Eskimos of western Alaska and eastern Siberia have taken bowheads during spring as the whales moved past their villages soon after openings formed in the pack ice. Traditionally, Eskimos sailed or paddled their boats out into cracks and open water areas in the ice, called leads and polynyas, respectively, from April to June to hunt the whales. The breakup of the pack ice and migration pattern of the whales are so regular that the whales are reliably accessible to whalers each spring, but only for a few weeks. At St. Lawrence Island, Alaska, for example, present-day whaling occurs from approximately the first week in April to about the first week in May; at Barrow, Alaska, the peak of both migration and whaling activity occurs from the last week in April to the last week in May (Braham and Krogman[1]; Marquette[2], 1979; Braham et al., 1979; Braham et al.[3]).

Townsend (1935) plotted the locations of bowheads killed by Yankee whalers operating in the Bering Sea and Arctic Ocean from 1848 to 1919. His map suggests that bowheads may have formerly occurred in the Bering and Chukchi Seas, as well as in the Beaufort Sea, during the summer months, well beyond the present-day whaling season. Data collected since 1974, however, indicate that bowheads do occur in the eastern Beaufort Sea during the summer (Fraker and Bockstoce, 1980), but that probably only a few occur in the Bering and southern Chukchi Seas during summer (Braham et al., footnote 3; Braham, Krogman, Nerini, Rugh, Marquette, and Johnson, 1980; Dahlheim et al., 1980).

Although the general timing and pattern of movements of bowheads during the spring migration are known (Bailey and Hendee, 1926; Tomilin, 1957; Foote[4]; Durham[5]; McVay, 1973; Braham and Krogman; footnote 1), the precise pathway that they take has not been fully described—especially in the largely frozen Beaufort Sea. In this paper we discuss the spring migration route, March through June, and describe ice conditions encountered by the whales. In addition to gaining an understanding of an important part of

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[1]Braham, H., and B. Krogman. 1977. Population biology of the bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whale in the Bering, Chukchi and Beaufort Seas. Processed rep., 29 p. Natl. Mar. Mammal Lab., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

[2]Marquette, W. M 1977 The 1976 catch of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, with a review of the fishery, 1973-1976, and a biological summary of the species. Processed rep., 80 p. Natl. Mar. Mammal Lab., NOAA, 7600 Sand Point Way N.E., Bldg. 32, Seattle, WA 98115.

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[5]Durham, F. E. 1972. Biology of the bowhead whale (*Balaena mysticetus*) in the western arctic. Unpubl. manuscr., 93 p. Dep. Biol., Univ. South. Calif., Los Angeles, CA 90007.