Fifty More Years Below Zero: 265-278
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The Influence of Harry Brower, Sr., an Iñupiaq Eskimo Hunter, on the Bowhead Whale Research Program Conducted at the UIC-NARL Facility by the North Slope Borough

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ABSTRACT: This account documents the influence of an Eskimo hunter, the late Harry Brower, Sr., on the long-term bowhead whale research program conducted by the North Slope Borough (NSB). Mr. Brower's influence upon this research program began over 20 years ago and continues. This paper consists of five parts: 1) background information regarding Harry Brower, Sr.; 2) the bowhead whale "problem" of the mid-late 1970s; 3) scientists seeking help in the early 1980s; 4) identifying aspects of Eskimo Traditional Knowledge relating to the behavior of spring-migrating bowhead whales; and 5) the continuing long-term bowhead whale research program based in large part upon relevant aspects of Eskimo Traditional Knowledge. Over 80 references are cited in this documentation of the evolution of bowhead whale research by the NSB.

Key Words: Acoustical survey methods, Alaska Eskimo Whaling Commission (AEWC), International Whaling Commission (IWC), North Slope Borough (NSB), NSB Science Advisory Committee, Traditional Knowledge

BACKGROUND: HARRY BROWER, SR.

Harry was born in Barrow on 18 October 1924. He was one of the nine children of the legendary Charles D. Brower and his Eskimo wife, Asianggataq. Some of Charles Brower's arctic experiences were set forth in his book "Fifty Years Below Zero" (Brower 1942). With help from his father and mother, Harry grew into a well-respected hunter and whaling captain. He married Annie Hopson and together they had ten children (one dying in infancy). While still a young man (in the early 1940s) Harry began providing assistance to scientists working on the North Slope. During a significant part of his adult life he worked for the Naval Arctic Research Laboratory (NARL) in Barrow. During his 27 years at NARL Harry distinguished himself as an excellent carpenter (becoming head of the NARL Carpentry Shop) and as a guide and general source of North Slope information for many NARL scientists.

I met Harry during my first visit to NARL in 1975. Even at our first meeting Harry impressed me with his quiet competence and his detailed knowledge of northern Alaska wildlife. It was during my time at NARL's Animal Research Facility (July 1977-June 1979), while on sabbatical leave from the University of Maryland's Department of Veterinary Science, that I began to develop a relationship with Harry. From our earliest conversations it was obvious that he was a great teacher, and throughout the 17 years of our friendship I always regarded myself as one of his students (Fig. 1). As recounted here, it was Harry's knowledge of the bowhead whale that came to our assistance time after time and even more importantly served as a guide for us over the years. The contributions of Harry Brower, Sr. to arctic science were recognized by the thanks he received from many scientists and by the award presented to him in 1988 by the Alaska Club of Sigma Xi. Sigma Xi is a scientific research society with membership of thousands of scientists in North America. Some aspects of Harry's life have already been documented (Brewster 1998; Hess 1988).

Fig. 1. Harry Brower, Sr., and the author during scientific consultations at Mr. Brower's house in the late 1970s. (Photo by Jerry Albert)

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Unfortunately, Harry Brower, Sr. died on 22 April 1992 having been predeceased by his wife Annie in 1984. They are survived by their nine children, eight of whom live in the dynamic community of Barrow (Fig. 2).

Fig. 2. Barrow, 10 August, 1989, with lagoon separating main portion of Barrow (foreground) from the Browerville portion. NARL and POW Main DEW site in distance toward Point Barrow. Chukchi Sea is on left, and the Beaufort Sea is barely visible beyond DEW site (note white "ball" of radome). (Photo by Tom Albert)

THE BOWHEAD WHALE "PROBLEM" OF THE MID-LATE 1970S

The bowhead whale is a large (to about 20m) ice-associated baleen whale that once existed in large numbers in northern circumpolar waters. Unrestricted commercial whaling, ending in about 1914, greatly reduced its numbers so that only five small populations are now recognized (Shelden and Rugh 1995). The largest, and best studied of these is referred to as the Bering-Chukchi-Beaufort Seas stock (BCB stock) or the Western Arctic stock or the Bering Sea stock. The BCB stock has long held cultural and nutritional significance for the coastal Native peoples of northern and northwestern Alaska, Chukotka (part of the Russian Far East), and northwestern Canada. Although commercial whaling on the BCB stock ended in 1914, coastal Native people in Alaska continued their centuries old subsistence harvest with its critical nutritional and cultural aspects. The subsistence harvest in Alaska is regulated by the U.S. National Marine Fisheries Service (NMFS) because that agency has regulatory control over whales in U.S. waters.

By the mid 1970s information regarding an increasing impact of the subsistence harvest in Alaska reached the International Whaling Commission (IWC) with a subsequent call for more data and for greater regulation (Durham 1979; Marquette and Bockstoce 1980; Mitchell and Reeves 1980a, 1980b). In response, field activities were initiated by NMFS off Point Barrow, Alaska in an effort to count northward-moving spring migrants and thereby estimate the size of the BCB stock (Tillman 1980). NMFS also increased efforts to document the subsistence harvest (Marquette 1979; Tillman 1980). A large and very successful field effort was conducted by NMFS personnel during the spring 1978 bowhead migration (Braham, H., B. Krogman, S. Leatherwood, W. Marquette, D. Rugh, M. Tillman, J. Johnson and G. Carroll. 1979). Most of the NMFS work was centered at Point Barrow and included two camps of ice-based visual observers, some aerial survey in conjunction with the ice-based visual observers, and some recording of whale vocalizations.

From the initial census related fieldwork in 1976 and 1977 the IWC Scientific Committee believed that the data indicated a possible range of abundance of 600-2000 whales with a best estimate of 1300 (Tillman 1980). Data from the 1978 and 1979 NMFS field efforts resulted in a 1978 population size estimate of 1783-2865 (mean 2264) (Braham, Krogman, Johnson, Marquette, Rugh, Nerini, Sonntag, Bray, Brueggeman, Dahleim, Savage and Goebel 1980; IWC 1980b). The NMFS census effort depended primarily upon the visual sighting of passing whales by observers standing at the seaward edge of the shorefast ice (Krogman 1980). Some data were also supplied by a limited aerial survey that extended beyond the range of vision of the ice-based observers. The feeling that most spring-migrating bowhead whales passing Barrow were in the nearshore lead (Braham, Fraker and Krogman 1980) seemed reasonable to interested scientists in the late 1970s based upon the limited data available at the time. The "conventional scientific wisdom" among many at that time was that bowhead whales (like most people) were "afraid" of ice and therefore when migrating north in the spring tended to restrict themselves to the rather narrow open water channels (called "leads") in the ice and thereby avoid the "dangerous" ice. In view of increasing subsistence hunting impacts and such a low estimate of population size for the BCB stock, the IWC at its 1977 meeting set a subsistence harvest quota of zero for 1978 (IWC 1979a). Such precipitous action by the IWC caused great alarm among the bowhead whale-dependent Native people of the coastal areas of northern and northwestern Alaska (Adams 1979). Intense negotiations between the involved Native Alaskans and the U.S. government (NMFS) resulted in a U.S. request for a special IWC meeting latter in that same year (December 1977). At that special IWC meeting a revised harvest quota was set for 1978 consisting of 12 landed or 18 struck, whichever came first (Tillman 1980; IWC 1979b). The harvest quota for 1978 was revised upward at the 1978

meeting of the IWC so that hunting would cease "when either 20 have been struck or 14 landed" (IWC 1979c). Concern at the IWC was such that the Scientific Committee at its 1978 meeting reconfirmed its recommendation:

> "…that from a biological point of view the only safe course is to reduce the kill of bowhead whales from the Bering Sea stock to zero…" (IWC 1979d).

In response to this marked increase in outsiders' involvement with their bowhead subsistence harvest, the hunters formed the Alaska Eskimo Whaling Commission (AEWC). The AEWC was to represent the hunters in dealings with whale-related regulatory agencies at the U.S. federal level (NMFS and its parent agency the National Oceanic and Atmospheric Administration, NOAA), as well as at the international, or IWC, level (Freeman 1989). At the time of its founding (1977) the AEWC represented bowhead whale hunters in the villages of Gambell, Savoonga, Kivalina, Wales, Point Hope, Wainwright, Barrow, Nuiqsut, and Kaktovik. The AEWC comprised a single Commissioner from each village (therefore 9 Commissioners), one of whom was elected Chairman, and a small office, staffed by an Executive Director. The AEWC developed a management plan to formalize various procedures associated with the subsistence hunt. Over the years the AEWC has developed a cooperative agreement with NOAA, which, among other things, allows the AEWC to regulate the hunt at the local level. The AEWC has also become a strong advocate for minimizing industrial impacts to the whale's habitat (Ahmaogak 1989; Brower and Stotts 1984). More recently (1994) AEWC membership was expanded to include the hunters (and a Commissioner) from Alaska's Little Diomede Island.

One of the first actions of the AEWC following its founding was to point out what its members saw as inadequacies in the bowhead census effort conducted off Barrow by the U.S. government (Adams 1979). The AEWC and individual hunters believed that the census estimates of approximately 2000 bowheads were much too low based on their own experience as hunters, and on the general knowledge of the bowhead whale handed down from generation to generation ("Traditional Knowledge").

By the end of the 1970s it was clear that the bowhead whale "problem" was really two problems. Problem One was the lack of data regarding estimation of bowhead population size and its trend. Problem Two was the obvious difference in views separating the Eskimo hunters, who depend upon the bowhead whale, from the scientists drawn into the rapidly developing bowhead "issue" in U.S. northern waters.

SEEKING HELP IN THE EARLY 1980S

Although the NMFS had begun efforts in 1976 to count spring-migrating bowhead whales off Point Barrow (under the direction of Dr. Howard Braham), by the early 1980s the responsibility for this census work had been transferred to the people of northern Alaska. By the spring of 1982, the bowhead census effort and examination of harvested whales had become the responsibility of the North Slope Borough (Dronenburg, Carroll, Rugh and Marquette 1983). This placed a heavy burden upon NSB personnel who had to struggle with the design and conduct of field efforts, while balancing the value of the "conventional scientific wisdom" against the numerous forceful comments of Eskimo hunters regarding spring-migrating bowhead whales. The transfer of the census program to the North Slope Borough was in large part due to the efforts of Ray Dronenburg, who was also critical in organizing the Borough's early field efforts.

Following the IWC's imposition of harvest quotas, many Eskimo hunters during the late 1970s and early 1980s became suspicious of all scientists including those of us working for the North Slope Borough. Although the Eskimo hunters had developed many insights into the behavior of spring migrating bowhead whales, some were reluctant to share their knowledge with scientists for fear that their bowhead information would be used against them by the federal government, the IWC, or both. Partially offsetting this problem were positive personal relationships established during the late 1970s between a few scientists at the Naval Arctic Research Laboratory (NARL) and several key hunters in Barrow. In the 2-3 years before the Navy's departure, NARL had become involved in a major bowhead research effort which was not, however directed at censusing (Kelley 1978; Kelley and Laursen 1980). NARL-based bowhead studies included examination of harvested whales at Barrow (Fig. 3). These scientists made the first systematic collection of a wide range of tissue specimens that were provided to several cooperating scientists for laboratory-based morphological, dietary, microbiological, serological, toxicological and genetic studies (Albert 1981a). These studies over three years (1978-1980) involved the detailed examination and sampling of spring and fall harvested whales, which required participating NARL scientific personnel to gain the support of the AEWC, the Barrow Whaling Captains Association (BWCA),

Fig. 3: Harry Brower, Sr. (facing camera) with his whale (80B8, male, 8.7 m) on the ice off Barrow 27th May 1980. We collected 156 specimens (for light and electron microscopy, serological, microbiological and toxicological evaluation, etc.) from this animal, making it the most extensively sampled bowhead whale (see specimen listing in Albert 1981a). Mr. Brower made a point of allowing us to sample his whale fully. Thanks to receiving his "blessing," our subsequent access to whales taken by other hunters was excellent. (Photo by Tom Albert)

and key individual hunters in Barrow. Critical to gaining such approval of the study and the cooperation of successful hunters at the harvest site were personal relationships established between scientists and two highly regarded hunters (Harry Brower, Sr. and William Kaleak), the then Chairman of the AEWC (Jacob Adams), and the then President of the BWCA (Eugene Brower). These personal relationships formed a nucleus of trust that facilitated later discussions (1981 and onward) regarding whale migratory behaviors that are relevant to the censusing of whales off Barrow.

When taking responsibility for the census effort, it was recognized that; a) we would have to conduct a very high quality research program since many would scrutinize our work (some critics might feel that counts would be inflated to justify a higher harvest quota), and b) we must give careful consideration to the many comments regarding whale behavior received from Eskimo hunters.

TRADITIONAL KNOWLEDGE OF THE BEHAVIOR OF SPRING MIGRATING BOWHEAD WHALES

Eskimo hunters believed that the IWC estimate of about 2200 bowhead whales passing Barrow in spring 1978 was far below the real number of whales. The hunters based their criticism on their knowledge that many whales were passing unobserved under the ice, and others were unseen because they swam far offshore, beyond the range of vision of the ice-based observers (Adams 1979).

Well-respected hunters (Harry Brower, Sr., Arnold Brower, Sr., Jacob Adams, Eugene Brower, William Kaleak, and others) all seemed to agree:

> "There are a lot of bowheads out there that the scientists aren't counting. Many are out in the ice and therefore are not seen when they pass by Barrow. As a result of poor counting the scientific community helps put these unfair quotas upon us."

After listening to many hunters it became obvious to us that there was a major difference between the conventional scientific wisdom at the time, and Eskimo traditional knowledge regarding bowhead whale migration. Through discussions with senior hunters in Barrow, particularly Harry Brower, Sr., it became clear that traditional knowledge regarding the bowhead whale spring migration off Point Barrow could be restated as four testable concepts.

1. A bowhead whale population size estimate of about 2000 whales is a significant underestimate.
2. Bowheads pass Point Barrow on a broad front (up to 20 km wide) and are not restricted to the open water of the nearshore lead or any other lead.
3. Bowheads are not "afraid" of ice. They move through areas of broken ice and heavy ice, not just through areas of open water.
4. Bowheads can break ice to breathe. They use their blowhole area (Fig. 4) to fracture suitable ice from below to produce very small breathing holes that are easily missed by observers.

The North Slope Borough research program was designed to assess the validity of these concepts.

In most cases hunters also had direct personal experience concerning one or more of the above points. While many hunters provided information over a period of about five years, Harry Brower, Sr. was clearly the most critical in helping identify the four points noted above. Not only was Mr. Brower very patient in telling and retelling personal experiences but he kindly persuaded other senior hunters to share personal hunting experiences and to discuss information handed down through the generations. From having spoken to many hunters and from extended conversa-

Fig. 4. Partial view of bowhead whale (facing to the left) near visual census station at ice edge during "open lead" conditions. Note the prominent "peak" on the dorsal midline of the whale's "bowed" head. The nostrils are located here. As Harry Brower, Sr., and other whalers showed scientists, whales use this peaked area, to apply pressure to the under-surface of the ice and thereby create cracks large enough to allow breathing. (Photo by John "Craig" George)

tions with Harry Brower, Sr. it became clear that there was a very specific body of knowledge regarding the bowhead whale that was held by these people. This knowledge had been handed down from fathers to sons for generations, it was tested over many years, it definitely had survival value, and in view of this the designation "Traditional Knowledge" seemed appropriate.

LONG-TERM BOWHEAD WHALE CENSUS EFFORT, SHAPED BY ESKIMO TRADITIONAL KNOWLEDGE

The AEWC and its hunters perceived that bowhead population estimates based only upon visual sightings made from the edge of the shorefast ice would be under-estimates of whale numbers because the many whales passing in the broken ice remained unseen and therefore underrepresented. If the bowhead population size remained consistently underestimated, the hunters knew that harvest quotas set by the IWC would be small and not sufficient to meet the cultural and nutritional needs of the people dependent upon the whale. Recognizing that the views of the AEWC and its hunters were largely ignored (as was the hunters' traditional knowledge specifically related to bowheads) and recognizing that harvest quotas set by the IWC would be largely based upon available scientific evidence, the AEWC successfully negotiated with NMFS to take over the task of censusing spring migrating bowheads off Barrow. The AEWC oversaw a census effort in 1981 but then turned over responsibility for subsequent census efforts to the North Slope Borough (NSB) under a cooperative agreement. This assignment of responsibility was reasonable since the NSB (approximately 88 000 square miles or 228 000 square kilometers area) is the regional government for northern Alaska and among its administrative units was a division (now known as the Department of Wildlife Management) whose staff had the technical expertise to conduct a scientifically sound bowhead census effort (Albert 1988).

In 1982 when the NSB took responsibility for censusing spring-migrating bowhead whales and for examining harvested whales, there was no shortage of advice provided (from other scientists and from Eskimo hunters) as to how best to conduct the fieldwork. In those days, the term "Traditional Knowledge" was new, and one could justifiably wonder how much "weight" should be given to it in the design of what was sure to be a long-term (many years) and very expensive (millions of dollars) research program.

When considering the design of the bowhead census studies, NSB personnel recognized that: 1) scientific data regarding the bowhead were very sparse; 2) the Eskimo people of AEWC affiliated villages have an ancient cultural and nutritional relationship with the bowhead; 3) the AEWC and its individual hunters have strong views (based upon traditional knowledge and personal experience) regarding the behavior of spring migrating bowheads; 4) the AEWC felt that bowhead population size estimates based primarily upon visual sightings by observers at the seaward edge of the shorefast ice off Barrow were unreliable, and were strongly biased downward; and 5) future census efforts to obtain estimates of population size and trend must withstand rigorous peer review and provide clear and convincing data to a wide audience (scientists, Eskimo hunters, conservation groups, industry personnel, etc.).

One of the earliest topics of discussion pertained to identifying the best site at which to conduct the bowhead census. After due consideration it seemed clear that the Barrow area was probably the best place to census the spring migrants because: 1) reports from all sources indicated that the whales consistently came close to shore (Figs. 5, 6) at Barrow; 2) available data indicated that soon after passing the Barrow area the whales "turned to the right" (moving in an easterly direction when entering the Beaufort Sea); and 3) the existing NMFS database was focused in the Barrow area.

Recognizing that bowhead data relating to estimation of population size and estimation of oil spill

Fig. 5. Aerial view of a well-defined open nearshore lead off NARL, May 1978. Visual census stations (informally called "perches) have been located on suitably elevated piles of landfast ice in foreground, at water's edge since the late 1970s. In later years 3-4 hydrophones have been hung over the ice edge, at about 200-m intervals. Drifting ice is visible at the far side of lead. (Photo by Tom Albert)

Fig. 6. Whaling Captain George Ahmaogak (at rear of boat) and fellow hunters in umiaq *(wooden frame covered by skin from bearded seals) enter the well-defined open lead to pursue a passing bowhead whale in May 1980. Typical of whalers' choice sites, the tent of this hunting camp is located at the edge of low, flat ice at right. (Photo by Tom Albert)*

impacts are of great interest to a very wide audience, the NSB has sought review by: 1) the Scientific Committee of the IWC at its annual meetings; 2) the Science Advisory Committee of the NSB; and 3) sponsorship of five major conferences devoted to bowhead whale biology (Albert 1990; Albert, Kelley and Dronenburg 1982).

The NSB bowhead research effort and related activities that began in 1982 (Dronenburg, *et al*. 1983), continues to this day, and over the 18-year period has cost at least 10 million dollars. Most of the NSB bowhead research program has been devoted to estimating population size and trend (for example, Murphy and Jarrell 1983; Raftery and Zeh 1998; Zeh, George and Suydam 1995) with additional basic biological studies regarding food habits, reproduction and estimating likely impacts (to eye, skin, respiration, etc.) should a whale contact spilled oil (Albert 1981b).

Initial bowhead census efforts conducted off Barrow by the NSB (Dronenburg, Carroll, Rugh and Marquette 1983; Dronenburg, George, Krogman, Sonntag and Zeh 1986) were similar to those conducted earlier by NMFS personnel (Braham, Fraker and Krogman 1980; Braham, Krogman, Johnson, Marquette, Rugh, Nerini, Sonntag, Bray, Brueggeman, Dahleim, Savage and Goebel 1980). Nevertheless, NSB biologists promptly began searching for ways to address criticisms raised by the AEWC and its hunters. As the research program was designed and then implemented during the early to mid-1980s we relied very heavily upon the advice of Harry Brower, Sr. As noted earlier, these discussions identified the four basic aspects of bowhead behavior that guided the census effort from that point forward.

Mr. Brower was always willing to assist us and to spend many hours carefully explaining how he and the other hunters knew that the above points were correct. His own personal observations were especially helpful. He described how hunters with boats had seen and heard bowheads breathing in the broken ice on the far side of the lead. By contrast these whales could not be seen by ice-based census observers and are seldom seen by aerial observers. He also showed us how to find proof of their ice breaking behavior by looking for the small (~10-cm) holes in the ice where the whale came up from below and cracked the ice by exerting upward force with the blowhole area (Fig. 4). These small breathing holes, when seen by a person standing on the ice, appear similar to a glass window, with cracks radiating from a central point, after having been struck by a small stone or a "B-B" pellet (George, Clark, Carroll and Ellison 1989).

Mr. Brower and other hunters urged us to modify the census field program so that the unseen passing whales could be properly included in the count. He patiently and repeatedly explained that the unseen passing whales included: 1) unseen whales in the open water of a lead that were within the range of visual detection of ice-based observers; 2) whales in the open water of a lead that were beyond the range of visual detection; and 3) whales that were under the ice whether near to or distant from the observers. The hunters knew that whales passed Point Barrow on a wide front (sometimes 15 km or more wide) and that many were

traveling under the broken and drifting ice. The lead off Point Barrow can range from "wide open" (open water to the horizon) to "closed" when there is no open water, only shifting floating ice as seen from the visual counting station. Observers at the seaward edge of the shorefast ice will have a limited ability to see whales passing at a distance, and even during good viewing conditions the ice-based visual census cannot supply reliable data concerning whales passing more than 3 km (about 2 miles) offshore from the observers (Zeh, Raftery and Styer 1988).

It seemed initially that whales passing on a broad front should be detectable by aerial survey (Fig. 7), acoustic, or both methods. The use of limited aerial survey in support of the ice- based visual observers had been conducted by NMFS in the late 1970s and mid 1980s but few whales were usually seen beyond the nearshore lead (Braham, Krogman, Leatherwood, Marquette, Rugh, Tillman, Johnson and Carroll 1979; Krogman 1980; Nerini and Rugh 1986). Aerial survey results thus initially supported the view of many scientists that most bowheads use the nearshore lead when passing Point Barrow. Aerial surveys in 1985 and 1986, however, did show that a significant percentage of passing whales (61% and 84% respectively) could have passed beyond the effective visual range of the ice-based observers (Withrow and Goebel-Diaz 1989). Census-related aerial survey efforts at Point Barrow have two major drawbacks: 1) seeing whales in the broken ice is difficult as few were seen in early studies even though we now know that many were passing; and 2) the hunters object to aircraft flying overhead while they are trying to conduct a subsistence hunt. Although the use of aerial survey in support of censusing off Point Barrow has not proved of great significance, spring aerial photogrammetric surveys have been very successful in helping determine length frequency of bowhead whales (Withrow and Angliss 1992). The use of "active sonar," projecting a pulse under the water to detect whales (such as in detecting a submarine), would similarly be rejected by hunters as interference. During the spring of 1978 NMFS personnel had limited success in a small test of the usefulness of active sonar in detecting passing whales (Braham, Krogman, Leatherwood, Marquette, Rugh, Tillman, Johnson and Carroll 1979). The use of passive acoustics seemed the logical way to proceed when trying to locate passing whales that are not detected by visual observers. The passive acoustic technique involves use of underwater microphones (hydrophones) to document vocalizations, which can then be used to locate the vocalizing whales. Initial but limited use (primarily by NMFS personnel) of the passive acoustic technique during the 1979 and 1980 field seasons (Braham, Krogman, Johnson, Marquette, Rugh, Nerini, Sonntag, Bray, Brueggeman, Dahlheim, Savage and Goebel 1979; Clark 1983; Clark and Johnson 1984; Johnson, Braham, Krogman, Marquette, Sonntag and Rugh 1981) showed definite promise that the method could help detect unseen passing whales. After consulting with several acousticians it seemed that passive acoustics could be used to detect and then locate whales that vocalize. It also seemed that the use of passive acoustics, to supplement the visual census, would not interfere with the hunt. Mr. Brower's observations regarding the passage of many unseen whales encouraged us to proceed with a feasibility study using passive acoustics. Dronenburg (this volume) describes the earliest phases of this feasibility study.

Fig. 7. Bowhead whale off Point Barrow as seen from an aircraft. Note the massive head (about 1/3 of body length) with its narrow rostrum and very large lower lips. The numerous white "spots" are areas of unpigmented epidermis representing small healed wounds probably due to ice contact. Images like this initially raised optimism for aerial survey census techniques. (Photo by personnel from National Marine Mammal Laboratory)

As part of the first conference on the biology of the bowhead whale (held early in 1982), the AEWC Science Advisory Committee (later renamed the NSB Science Advisory Committee) recommended that the passive acoustic technique (including the localization of calling whales) become part of the spring 1982 field effort (Albert, Kelley and Dronenburg 1982). This marked an important point in the evolution of the census study design. Passive acoustical location of passing whales would become a major part of the field effort because: 1) limited acoustic efforts in 1979 and 1980 by NMFS were encouraging; 2) most Eskimo hunters had no objection to use of the technique while they were hunting; and 3) the AEWC Science Advisory Committee recommended the technique. Consensus among several viewpoints was thus being achieved early in the NSB census program.

During the spring 1982 field season a significant and successful effort was made to determine the feasibility of actually locating vocalizing whales with an array of three hydrophones deployed at the edge of the shorefast ice. It was shown in 1982 that vocalizing whales could be located to distances of up to 10 km (6 miles) (Cummings and Holliday 1985; Cummings, Holliday, Ellison and Graham 1983). The actual locating of vocalizing whales in 1982 was a major step forward as compared to the earlier field studies in 1979 and 1980 when whales were detected acoustically but their position (location) could not be determined. Localizing calling whales at significant distances seaward from the visual observation site, enabled us to use acoustic data to develop correction factors for: a) whales too distant to be seen by the ice-based observers; and b) whales that pass when the visual census is adversely impacted due to unacceptable visibility (Figs. 8, 9) or dangerous ice (Krogman, Ko, Zeh, Grotefendt and Sonntag 1984).

Fig. 8. Scattered open areas in drifting ice off NARL, May 1978. Under such conditions, visual observers at edge of shorefast ice would likely see few passing whales. Aerial census techniques also proved to be unreliable under these conditions. Use of a hydrophone array at the ice edge allows passive acoustic location of vocalizing whales out to distances of 15-20 km (10-12 miles). (Photo by Tom Albert)

Another major advance occurred during the spring of 1984, when bowhead whales were acoustically tracked moving past Point Barrow (Clark, Ellison and Beeman 1985; Ellison, Clark and Beeman 1985). Therefore, it was during the spring of 1984 that the passive acoustic technique of locating whales was fully integrated into the census related fieldwork (Clark, Ellison and Beeman 1985; Dronenburg, George, Krogman, Sonntag and Zeh 1986). In order to utilize the acoustic data more fully a tracking algorithm was developed (Ellison, Sonntag and Clark 1987; Ko and Zeh 1988; Sonntag, Ellison, Clark, Corbit and Krogman 1986). That tracking algorithm was a computer program that could link together a sequence of acoustic locations, visual sightings, or both, from the 1984 and 1985 field seasons, to form a whale track. Each track represented one whale that was detected more than once. This was an important event because the computer-assisted process of preparing "whale tracks" provided a high degree of assurance that the numerous whale call locations during a given time period could be "reduced" to a minimum or conservative estimate of the number of whales moving through the area. The tracking algorithm has become a major component in the evaluation of the combined visual and acoustic data, and has been further refined over the years (Clark 1989; Clark, Charif, Mitchell and Colby 1996; Clark and Ellison 1989; Sonntag, Ellison and Corbit 1988; Zeh, Raftery and Yang 1990). The importance of the acoustic technique was clearly shown during a four day period (3-7 May) in 1984 when the lead was "closed" by ice most of the time and only three whales were seen by the ice-based observers but yet the acoustic system showed that at least 130 whales passed by (Ko, Zeh, Clark, Ellison, Krogman, and Sonntag 1986). During this period most of the passing whales were beneath the ice of the closed lead and most were also well beyond the visual detection range of 3 km. A similar situation was noted in 1986 (Fig. 10) during a period when the lead was consistently narrow (usually 3 km wide or less) and sometimes clogged with ice (Zeh, Raftery and Styer 1988). During 574 hours of acoustic monitoring (with functional array) in 1986 a total of 50,552 bowhead calls were detected (Clark and Ellison 1989). In support of numerous comments by hunters regarding bowhead movement beneath the ice, there is some evidence that such whales may use the "reflection" of

Fig. 9: Continuous ice off NARL May 1978 (compare with Figs. 5 and 8). During "closed lead conditions" passing whales cannot be seen by ice-based or airborne visual observers. Whales nevertheless continue to pass, as documented with the aid of hydrophones that locate vocalizing whales. (Photo by Tom Albert)

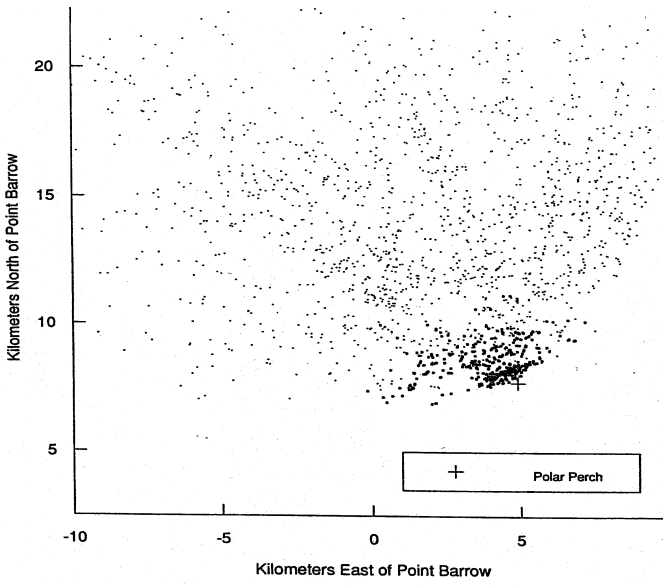

Fig. 10: Locations of bowhead whales seen by ice-based observers (large dots) and vocalizing whales detected through hydrophone array at ice edge (small dots) from 5 AM May 17 to 11 AM May 26, 1986 off Point Barrow. During that period there were 430 visual locations recorded during 218 hours of monitoring and 1534 acoustic locations during 45 hours of acoustic monitoring (107 acoustic locations were outside the plot boundaries). At this time the lead was consistently narrow (usually 3 km or less) and sometimes clogged with ice. As can be seen, the range at which passing whales can be detected acoustically is far beyond that of the ice-based visual observers. (Data from Zeh, Raftery and Styer 1988).

their own vocalizations to aid in navigation beneath the ice (Ellison, Clark and Bishop 1987; George, Clark, Carroll and Ellison 1989; George, Rugh and Zeh 1995).

The research program quickly evolved so that the census effort consisted of four basic components:

1. The visual detection, by ice-based observers, of passing whales in a lead out to distances of 3-5 km;
2. The recording of calls of passing whales (out to 15-20 km) by an array of hydrophones (3-4) deployed off the edge of the ice near the visual observers;
3. The passive acoustic location data are evaluated by cooperating acousticians;
4. The visual sightings data and the acoustic location data are combined by cooperating statisticians, and a population size estimate is prepared.

At the 1985 meeting of the IWC Scientific Committee, for the first time, acoustic location data were used to determine the minimum number of whales passing the census site that were unaccounted for by the ice-based visual census (Clark and Ellison 1985; Clark, Ellison and Beeman 1986; Ko, Zeh, Clark, Ellison, Krogman and Sonntag 1986).

The idea of acoustically locating distant (up to 15-20 km) vocalizing whales, then using these locations to help estimate the number of passing whales, was only slowly accepted by the Scientific Committee of the IWC. It took about three years for the technique to be accepted. By 1985, after initial incorporation of at least some acoustics data, the IWC estimate of bowhead population size had risen to 4417 (95% confidence interval of 2613-6221) (IWC 1986). The first estimate of population size based upon combining visual and acoustic data took place at the 1987 meeting of the IWC Scientific Committee when they agreed the best estimate to be 7200 (2400 standard error) based upon data from the 1985 field effort (Gentleman and Zeh 1987; IWC 1988; Zeh, Turet, Gentleman and Raftery 1988). With the acoustic data more fully incorporated the IWC estimate rose to 7800 (95% confidence interval 5,700-10,600) in 1988 (IWC 1989). By 1996, with an improved statistical evaluation of the visual and acoustic data, the IWC accepted estimate of population size was 8200 with a 95% estimation interval from 7200 to 9400 (IWC 1997; Raftery and Zeh 1998). The estimated annual rate of increase (after hunting removals) from 1978 to 1993 was 3.2% with a 95% confidence interval 1.4% to 5.1% (Raftery and Zeh 1998). With increased precision of the estimates of population size and rate of increase, the size of the harvest quota has risen to more reasonable levels. The most recent harvest quota, set in 1997, allows a maximum of 280 bowhead whales to be taken during the five-year period of 1998 through 2002 (IWC 1998). The greater precision of the most recent estimates is largely due to: a) the highly successful field effort in 1993 when 3383 whales were actually detected visually (George, Suydam, Philo, Albert, Zeh and Carroll 1995); b) the full incorporation of acoustic location data; and c) application of a powerful statistical methods (such as Bayes empirical Bayes) to the evaluation of census-related data (Givens, Raftery and Zeh 1993; Raftery, Turet and Zeh 1988; Raftery and Zeh 1998; Raftery, Zeh, Yang and Styer 1990). The 1993 census field effort was the most successful yet, thanks to reasonable weather, a dedicated field crew, and the fine leadership of the effort by John "Craig" George.

There now seems to be no doubt that the bowhead whale population that passes Point Barrow is much larger than scientists had estimated a few years ago. There is also no doubt that the herd is increasing, that

the whales pass on a wide front (up to 15-20 km), are not "afraid" of ice, are not confined to the "open lead," and can break ice to breathe.

Since 1985 when the Borough's Department of Wildlife Management moved to the UIC-NARL Facility, our research effort has been conducted out of the UIC-NARL Facility. The Borough's bowhead whale research effort has continued to the present and each year is the largest, or one of the largest, research projects staged from the "old NARL." Approximately 75% of this research effort is concerned with estimating population size and trend while about 25% of the effort pertains to the study of specimens from harvested whales (morphology, microbiology, etc.) that help in estimating likely impacts should the whales encounter oil-fouled waters. The population related studies have been very fruitful over the years producing numerous publications, only a few of which are mentioned in this paper. Studies involving specimen materials have also been very productive, only a few mentioned here, resulting in a basic understanding of critical tissues and systems (Duffield, Haldiman and Henk 1992; Haldiman, Henk, Henry, Albert, Abdelbaki and Duffield 1984; Henk, Abdelbaki, Haldiman and Albert 1986; Henk and Mullan 1996; Henry, Haldiman, Albert, Henk, Abdelbaki and Duffield 1983; Philo, Hanns and George 1990; Smith, Skilling, Benirschke, Albert and Barlough 1987; Tarpley, Hillmann, Henk and George 1997; Tarpley, Sis, Albert, Dalton and George 1987; Zhu 1998).

In acknowledging tissue-based studies, it is important again to refer to the critical role of Harry Brower, Sr. During the "early days" (late 1970s and early 1980s) of our efforts to examine and sample harvested whales, Mr. Brower's assistance was critical, such as during the spring hunt of 1980 at Barrow, in gaining hunter acceptance of our efforts (Fig. 3). Once we had the "blessing" of Harry Brower, Sr., hunter resistance to our efforts at the harvest site virtually disappeared.

Over the years since 1981, the Borough (with help primarily from the State of Alaska and the Federal Government) has spent millions of dollars in gaining a better understanding of the spring migration of bowhead whales passing Point Barrow. Although many people have contributed to this successful research effort the single most important person, in my opinion, is Harry Brower, Sr. He "pointed the way" when the path for scientists was not clear. It is a pleasure to report that his basic observations (and those of his fellow hunters) have been fully validated through many years of scientific effort. The success of this program is strong evidence that scientists and other technical people should carefully consider the traditional knowledge held by local people.

In a field and analytic effort as large as described above and extending over so many years there have obviously been many contributors. It is a pleasure to acknowledge the critical help provided, especially in the early years, by members of the Barrow Whaling Captains Association (in particular long-time President Eugene Brower, William Kaleak, Arnold Brower, Sr.) and by the Alaska Eskimo Whaling Commission (in particular Burton Rexford, Maggie Ahmaogak, Marie Adams Carroll, Jessica Lefevre, Lynn Sutcliffe). Early help was also provided in Kaktovik by Herman Aishanna, Joe Kaleak and Nolan Solomon, and in Point Hope by John Oktollik, Sr.

Administrative help was provided over the years by the Mayors of the North Slope Borough (Jacob Adams, Eugene Brower, George Ahmaogak, Jeslie Kaleak, Ben Nageak) and the Directors of the Borough's Department of Wildlife Management (Lester Suvlu, Ron Nalikak, Ben Nageak, Charles Brower).

Support in data analysis was provided by several cooperating scientists, in particular Judy Zeh, Chris Clark, Adrian Raftery, Geof Givens, Bruce Krogman and Ron Sonntag.

Numerous people were involved in fieldwork (censusing whales and examination of harvested whales) with great thanks due to John Craighead ("Craig") George, Ray Dronenburg, Mike Philo, Geoff Carroll, Dave Ramey and Gordon Jarrell.

Encouragement was provided to me in the early years, especially by John Kelley (NARL), Art Callahan (Office of Naval Research), Rev. J.A. Panuska (Georgetown University) and Marnie Albert.

Financial support was provided primarily by the North Slope Borough, with important supplemental funding from the National Oceanic and Atmospheric Administration (NOAA), the State of Alaska and the oil industry.

As mentioned in this chapter, Harry Brower, Sr. was the "guiding light" in the early days as the study design was structured and modified. By helping with this study Harry has influenced the bowhead-dependant people from Saint Lawrence Island to Barter Island. As is true for most great people, the good done by Harry Brower, Sr. extends far beyond his home, and far beyond his lifetime.

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