Workshop on Bowhead Whale Stock Structure Studies in the Bering-Chukchi-Beaufort Seas: 2005-2006

23-24 February 2005
Traynor Room, Alaska Fisheries Science Center
National Marine Mammal Laboratory, Building 4
7600 Sand Point Way NE, Seattle, Washington

Conveners: Sue Moore and J. Craig George
Rapporteur: Marcia Muto

Purpose of workshop: Review/revision of 2005 and 2006 research plans for investigating stock structure of bowhead whales in the Bering, Chukchi and Beaufort Seas

Final Report: 11 April 2005

NOAA/AFSC/National Marine Mammal Laboratory
and
NSB/Department of Wildlife Management

EXECUTIVE SUMMARY

A five-part plan for studying stock structure of bowhead whales in the Bering, Chukchi and Beaufort Seas was developed by US researchers prior to and during the 2004 International Whaling Commission/Scientific Committee (IWC/SC) meeting. The study plan included techniques such as: increased tissue sampling during the harvests, biopsies, development of additional genetic markers, photo-identification, satellite tagging, isotopic analysis of baleen, acoustic detection and statistical modeling (Smith *et al*., 2004). These study methods were reviewed, refined and endorsed during the course of the workshop. The resultant list in the Projects and Priorities section is similar to that in the original plan. Short (2-5 page) project proposals have been requested for research endorsed for 2005 – proposals should be submitted to the North Slope Borough (NSB: George) or the National Marine Mammal Laboratory (NMML: Wade) by **29 April 2005**.

The 'Oslo bump,' a term used to describe a temporal pattern resulting from a statistical analysis of available genetic data, remains an enigma. The pattern is based on pair-wise microsatellite differences and is only evident in data from whales landed during the autumn migration at Barrow. Larger genetic differences occurred when paired samples were 5-11 days apart than when they were 0-5 or 12-25 days apart. If this or some other analysis (*e.g.* spatial segregation) indicates some type of stock structure in the Bering-Chukchi-Beaufort (BCB) bowhead population, then there are many data gaps to be filled. One of the most important gaps to fill will be an estimate of the size or relative size of the putative populations. If there is stock structure, population sizes of the putative stocks will be needed at least 6 months prior to the setting of the next bowhead quota at the in-depth assessment (IA) at the 2007 IWC meeting.

At the 2004 IWC/SC, modeling was proposed as a tool to investigate potential hypotheses; *e.g.* can the generational gene shift (GGS) hypothesis produce heterogeneity seen in extant data? The investigative modeling approach was endorsed at the workshop and an eight member **Steering Committee** was established consisting of: **George, Givens, Koski, Pastene, Punt (or Wade), Schweder, Taylor (Chair) and Zeh**. Initially, the group will investigate the feasibility of the GGS hypotheses using R-Metasim. In addition, proposals were tabled for the development of additional genetic markers and to analyze historical (archeological and museum) samples from the eastern Canadian Arctic to provide a context for stock structure investigations.

Biopsy samples from Chukotka and waters near St. Lawrence Island (SLI) are a very high priority. Permits must be acquired soon to allow the biopsy sampling offshore Chukotka during the summer of 2005. A biopsy project near SLI should be developed in co-operation with local whalers.

Photo-ID surveys are planned for waters adjacent to SLI in April 2005 to provide comparative data to photos taken during the 2-year mark-recapture study conducted near Barrow in 2003 and 2004 by the NSB and LGL Ltd. Photo-ID surveys offshore Chukotka are highly desirable but unlikely in the near term due to logistic constraints.

Acoustic surveys, using autonomous recorders, were completed northeast of Barrow in collaboration with the National Science Foundation (NSF) Shelf-Basin Interaction program during 2003-2004. Analyses of that data set are ongoing. Potential opportunities to deploy recorders during the 2005 NOAA Ocean Exploration cruise and in collaboration with the NSF/Study of the Northern Alaska Coastal System (SNACS) study were discussed and will be pursued to the limits of available funding.

The US Minerals Management Service (MMS) plans to fund the deployment of satellite tags on bowhead whales in co-operation with the Alaska Department of Fish and Game (ADF&G), the NSB and the Alaska Eskimo Whaling Commission (AEWC). The current plan calls for deployment of up to 25 tags per year for 5 years, beginning as soon as autumn 2005. Representatives from ADF&G, NSB and AEWC are working closely together to insure co-ordination between whalers (who will attach the tags) and researchers for optimal use of resultant data.

Traditional Ecological Knowledge (TEK) will be a very important part of the IA at the 2007 IWC meeting. A paper is needed from interviews with hunters at SLI including: observations of increases in whales at Gambell and Savoonga; changes in the size and age structure (*e.g.* observations of more sub-adults now); timing of migration; and behavior of migrating whales.

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WELCOME

Dr. DeMaster, Director of the Alaska Fisheries Science Center (AFSC) and the Chair of the International Whaling Commission (IWC)/Scientific Committee (SC), welcomed workshop participants to the AFSC and wished them well in their work.

INTRODUCTION AND BRIEF BACKGROUND

Moore—The workshop was convened to provide an opportunity for open discussion of approaches to investigate possible sub-stock structure in the Bering-Chukchi-Beaufort (BCB) bowhead population. Several papers on bowhead whale stock structure were presented at the 2004 IWC SC Meeting (see Appendix 1), from which a 5-point research plan was developed (Smith *et al.*, 2004). The focus of this workshop was to review and refine this study plan. A summary report describing this workshop will be prepared, circulated to participants and ultimately submitted as a 'For Information' document to the Bowhead-Right-Gray (BRG) Subcommittee at the 2005 IWC SC Meeting.

George—Welcomed all the participants (see Appendix 2) and thanked them for coming. The convening of the workshop was the culmination of work by many in the room and some not in the room. George thanked all for their contribution and help. He also noted the importance of stock-structure studies to the whale hunting communities in Alaska

REVIEW OF US FUNDING

Suydam—In June 2004 at the IWC meeting, stock structure was examined in depth, leading to hypotheses and discussion about how to answer the respective questions. The resulting research plan (Smith *et al.*, 2004) forms a framework for a stock structure research plan focused on the first 2 (*i.e.* 2005 and 2006) of 5 years. In 2005, the budget is $975K. The Alaska Eskimo Whaling Commission (AEWC) went to Senator Stevens to ask for funds because of the importance of these studies to the AEWC, the IWC and the North Slope Borough (NSB). The AEWC and NSB also asked the Bureau of Indian Affairs (BIA) for funds and received $200,000 more, which may help fill out study needs in 2005 or help jumpstart the 2006 and 2007 studies.

Wade—The $975K in 2005 will come from NOAA through NMFS; some will be administered through the National Marine Mammal Laboratory (NMML) and the rest will go through the NSB. In September 2004, there was a conference call to help formulate a draft spending plan. During the current workshop, the intent was to revise the research plan or propose new research priorities. After the workshop, the US Bowhead Research Group will take this revised research plan into account when planning spending (funds have already been committed for research at Saint Lawrence Island in April 2005).

STOCK STRUCTURE HYPOTHESES

George—Following the approach of the IWC minke whale Revised Management Procedure (RMP) group, stock structure hypotheses, or archetypes, were created by about 12 people ('The Bowhead Group' = TBG) in an attempt to focus thinking about plausible bowhead stock structure hypotheses. Five stock structure archetypes were presented in a draft manuscript (TBG, 2005), complete with supporting arguments and maps depicting summer and winter distribution and migration paths for each of the five hypotheses.

Brief descriptions of the five hypotheses follow (from TBG, 2005):
1) Baseline Hypothesis (see Rugh *et al.*, 2003)—A single stock winters in the Bering Sea, migrates past Barrow to the Beaufort Sea in the summer to feed (whales are segregated by size and sex during the summer), migrates and feeds in fall along the coast of the North Slope of Alaska and the Chukotka (Russian) coast and then, with the advance of the seasonal ice, migrates back into the Bering Sea to winter. The distribution is highly labile, influenced by sea ice and prey densities.

2) Spatial Segregation Hypothesis—There are two stocks wintering in different areas in the Bering Sea (based on observations by the Russians, *e.g.* Melnikov *et al.*, 2004). One stock migrates in spring from St. Lawrence Island (SLI) past Barrow to the eastern Beaufort Sea where it summers. During the fall migration, this stock migrates past Barrow and then splits into two groups for the remainder of the migration to the Bering Sea: one group migrates south along the Alaska coast and the other migrates south along the Chukotka coast. The second stock winters in the Gulf of Anadyr and migrates to the north coast of Chukotka in summer.

3) Temporal Hypothesis—Two stocks sequentially migrate past Barrow in the spring in pulses segregated by size and sex, en route to the eastern Beaufort Sea. During the fall migration, both stocks migrate together past Barrow. A problem with this hypothesis is that the 'last pulse' during the spring migration at Barrow is composed mainly of reproductive females and calves and this is only one pulse, not two. The available evidence does not lend much support to this hypothesis (Rugh *et al*., 2004), although the pulse-like character of the migration at Barrow is well documented in the literature (George *et al*., 2004a, b).

4) Feeding Segregation Hypothesis—One stock mixes in the SLI and Gulf of Anadyr wintering areas in the Bering Sea; then most whales move to Barrow Canyon in early spring and on to the eastern Beaufort Sea, but some go northwest to the Chukchi Cap. In fall the whales move to the Chukchi Sea where the prey is aggregated. A third group of whales migrates from the Gulf of Anadyr later in the spring and summers along the Chukotka coast. Some whales are summering in the pack ice (*e.g.* see Moore, 2004). [This is similar to the 'Chukchi Circuit Hypothesis' discussed later in the meeting.]

5) Immigration Hypothesis—A few bowheads from Canadian stocks work their way into the Beaufort Sea. Supporting evidence for this hypothesis includes two whales harvested in the 1800s in waters west of Alaska that had harpoon tips from Davis Strait. With the current sea ice retreat, whales can travel through the Northwest Passage more easily now than in the past.

Burns (1993) states that the bowhead distribution is in flux. After all, whales could not migrate north of the Bering land bridge 21,000 years ago. Remains of bowheads have been found in the Canadian Arctic in an area that is now solid ice, and a bowhead stranded last year on the Alaska Peninsula. Bowhead distribution has expanded and contracted repeatedly over time.

UPDATE ON STOCK STRUCTURE RESULTS PRESENTED AT 2004 IWC SC MEETING

Schweder—There is interest in having access to all of the bowhead data. Research funds are available, and the search is underway for a statistician to fill a post-doctoral position to continue this study. Statistics show ($P = 0.005$) a temporal pattern in the autumn migration at Barrow based on pair-wise microsatellite differences, with larger differences occurring when pairs were 5-11 days apart than when they were 0-5 or 12-25 days apart (Jorde *et al.*, 2005). This was not affected by age or sex variables. The pattern is visible but not significant in the spring migration. We do not know why the fall pattern exists but suspect there may be genetically different components in the stock, possibly a 'majority' and 'minority' component. Only a few so-called 'minority' whales harvested at Barrow in autumn could produce these results. Weighted jackknifing determined which individuals contributed most (or more) to the pattern. Whales from two years (1996 and 2002) particularly contributed to the pattern (in those two years there were more whales caught 5-11 days apart).

Comment: According to IWC regulations, data were to be destroyed after being used in analyses and Schweder asked if this was absolutely necessary. DeMaster stated that it was his understanding that under the IWC/SC Data Availability Agreement, the decision to destroy data is made by the data contributor.

Bickham—See papers presented at the 2004 IWC SC Meeting (Appendix 1). Microsatellite data were analyzed at Texas A&M University (TAMU) and further reviewed at the meeting in Oslo (Jorde *et al.*, 2005). In 2004, there were an additional 45 samples collected from the hunt and 45 samples from SLI (skull scrapings and baleen). The TAMU lab will look at new loci; previously they relied on loci used by Rooney in other studies, but new microsatellite loci specific to bowheads and more loci are needed. The goal is to have a solid data set in the next 1-3 years with many good loci.

Pastene—Pastene *et al.* (2005) is an update of Pastene *et al.* (2004). This document describes a reanalysis of the data that was suggested at the 2004 IWC SC Meeting in Sorrento. If all the whales in the spring migration past Barrow were of the same stock, there should be homogeneity. Regarding Point 2 in the document (mitochondrial analysis) – a very small change in sample size equals a large change in the p-value. Regarding Point 3 in the document (microsatellite analysis) – there was still genetic heterogeneity with the exclusion of Tv18 from the analysis and both with and without the inclusion of Tv7 in the analysis.

Comment: For each analysis, there should be a log at the IWC noting which samples were used in which strata.

Melnikov (interpreted by Benson)—Surveys for bowheads in Chukotka started in 1990 with one observation post. Now there is a huge database of 50,000 records and observation posts at many sites along the coast of Chukotka (see Melnikov *et al.*, 1998; 2004). Maps were presented showing whale sightings, including data from Chukotka observation posts, from other Russian reports and from the literature. A seasonal summary of bowhead occurrence is as follows:
January-March—Bowheads are mainly in the western Bering Sea on the south coast of Chukotka and around SLI and St. Matthews Island (Brueggeman's vessel survey data).
April 1-20—Bowheads are north of SLI along the south end of Chukotka and in the Chukchi Sea (includes Ljungblad's aerial survey data).
April 20-30—Whales are seen in southern Chukotka, the Bering Strait and at Barrow.
May—Whales are seen around Chukotka, in the Bering Strait and at Barrow.
June—Whales are seen around Chukotka and in the Beaufort Sea.
July-August—Whales are observed in the central Chukchi Sea and also all along the Chukotka coast (Bering Sea to Chukchi Sea) (Melnikov *et al*., 1998; 2002; Smirnov, 2004).
September—Abundance is increasing along northern Chukotka and there are groups of whales at Barrow and in the Beaufort Sea (Doroshenko, 1982; US data = Moore *et al.*, 1995; 2000; Russia data = Melnikov *et al.*, 1997; 1998; 2002; 2004). Whales along Chukotka are coming from the north, probably from the Beaufort Sea past Barrow.
October—More whales are seen along the northern Chukotka coast.

More whales were present feeding along the north Chukotka coast (where there are many lagoons) in 1994 (cold summer) than in 2002 (warm summer). In warm winters more whales are seen, but in all months there have been sightings of bowheads around Chukotka.

Comment: The US cannot fly surveys along the Russian coast; the Russian military would not permit it. They would have to be Russian surveys. There is a lab in the White Sea, but it would be very expensive. The White Sea lab has infrared and regular photography capabilities. Maybe bowhead surveys could be combined with walrus surveys, but the altitudes are different (300 m for walrus; 200 m for whales); the possibility of bowhead surveys *following* walrus infrared surveys is worth investigating with the US Fish and Wildlife Service (R. Meehan).

RESEARCH PLANS FOR 2005

Tissue sampling for genetic analysis

George—The North Slope Borough Department of Wildlife Management (NSB DWM) will attempt to sample every harvested whale from every whaling village in Alaska (NSB DWM, 2005). Possible numbers of whales to be landed in Alaska in 2005: approximately 4-5 SLI; 0 Kivalina; 6 Point Hope; 6 Wainright; 20 Barrow; 3 Nuiqsut; 3 Kaktovik. NSB is working with Russian scientists and hunters to obtain biopsies from bowheads this spring and autumn (*i.e.* 2005).

Melnikov (interpreted by Benson)—Hunters have been shown how to sample with crossbows. It should be easy to biopsy whales at every whaling village on the coast in the fall. There will be two biopsy teams in June. Although there is more interest in sampling in summer, there are not many whales in July and August. Most sampling will be on the north coast of Chukotka (in the Chukchi Sea) in summer and autumn. Sometimes there are opportunities in winter (January - March).

Comment: Biopsy samples are needed from the breeding stocks to be able to do assignment tests. March is the mating season; perhaps samples can come from SLI and the Gulf of Anadyr. But it would be easier to get aerial photographs than biopsies in winter.

Comment: It would be useful to review the stock structure hypotheses and put more thought into what type of samples are needed to discriminate between the different hypotheses presented (or others). That has been lacking so far.

Comment: Samples could be taken from different sides of SLI during different times. Alaskan hunters might collect biopsies in late February or early March, but sampling *during* the hunt is not a popular idea. At Barrow there might be an option to collect biopsies after the spring hunt, but the quota is rarely reached, so instead maybe biopsies can be taken during periods of 'cease fire' when hunting is stopped to process whales already taken or when sea ice prevents an effective take. Harvest samples have more information than biopsies.

Comment: More samples and not necessarily more loci are needed.

Comment: A strong suggestion was made to work with Canadian scientists to compare genetic data. The US and Canada need to use the same loci. Canadian representatives will be at the next IWC meeting. It is important early on (before new microsatellites are developed) to calibrate the US and Canada labs so the gels from one lab match the gels from another; we need their data to make assignment tests with Barrow and Canadian animals; and they can be helpful to us with advice on using kayaks to get biopsies.

Genetics - laboratory analyses

Bickham (TAMU)—Development of microsatellite loci is time consuming and expensive. NSB has provided the initial funding for this work. The aim is to find 20-25 loci that are consistent and easily scored. TAMU has developed 23 primer pairs and another 10 loci have been sequenced (no primer pairs yet). There are 300 samples to test (Bickham, 2005).

Comment: VNIRO has a center of molecular genetic identification. They are interested in specific recommendations for calibration and would like to get samples and results from US scientists. Synthetic DNA can be exchanged to standardize lab work.

Morin (Southwest Fisheries Science Center: SWFSC)—Currently there are 45 samples available from the SLI harvest and 45 samples from SLI baleen and skull scrapings yet to analyze (SWFSC, 2005). Special methods are needed to analyze the baleen and skull scrapings.

Genetics - statistical analyses

Givens—1) At the Oslo Meeting, significant progress was made on firming up statistical methods, but work is still needed on the interpretation, such as generational gene shift analysis; 2) Colorado State University (CSU) is conducting an interim update to the spatial analysis; data are needed on markers for old SLI and new Barrow samples; 3) An analysis is underway that asks the same questions in different ways than the Oslo paper (Jorde *et al.*, 2005).

Modeling

Taylor—At Sorrento, it was proposed that modeling should be used to investigate potential hypotheses; *e.g.* can the generational gene shift (GGS) hypothesis produce the heterogeneity seen in extant data (see Fig. 1)? If we are unable to reproduce the results that we actually see, then we can take the GGS model off the table. It is also important to look at the 'Oslo bump' hypothesis, *e.g.* how many whales would it take to produce the observed temporal pattern? It may be possible to present results at the 2006 IWC Meeting, but a collaborative modeling effort is needed first. SWFSC has a model to test spatial simulations using
R-Metasim. SWFSC also has a proposal (Morin *et al.*, 2005) to develop a new nuclear genetic marker (single nucleotide polymorphisms, SNPs) to consider data quality.

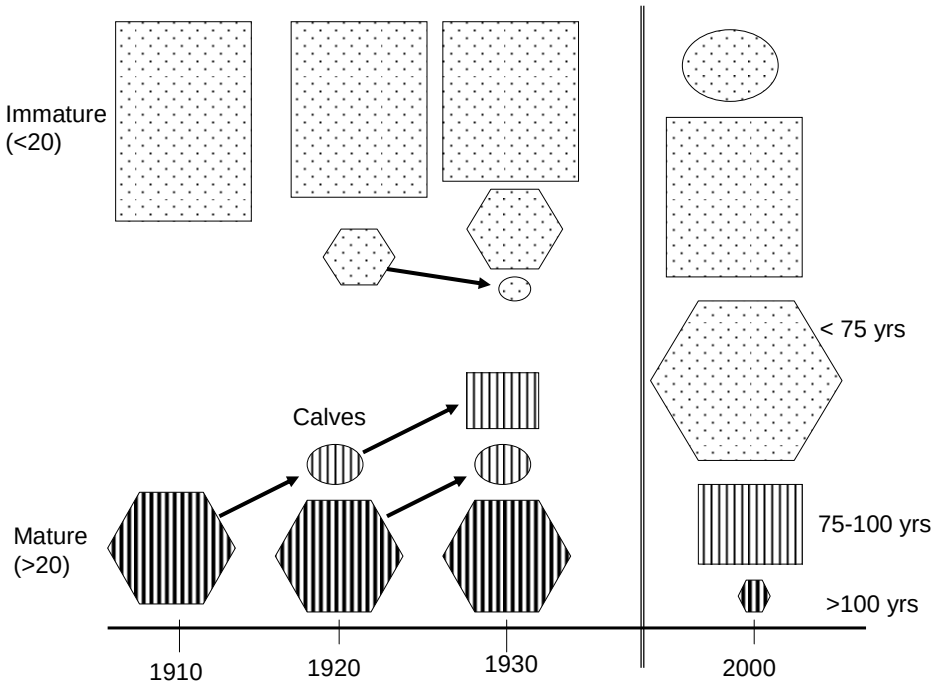

Figure 1. Schematic of generational gene shift hypothesis (from Taylor, 2005). Sizes very roughly represent abundance. Shapes represent mature (hexagon), immature (rectangle) and calves (ovals). In 1910 the population is depicted with two shades, although at that point they should be in genetic equilibrium. In 1920 the calves' gene frequencies could be expected to differ from the overall 1910 population with the degree of differentiation depending on differential reproduction of males and females. The light vertical line shading represents the age class expected to differ in gene frequencies. By 2000, the age of this age class should be between 75 and 100 years old. Very few of the holocaust survivors would remain. Most mature individuals would result from the whales that were immature in 1910 and their offspring (lightly dotted). Animals between 50 and 75 could well be a mix of gene frequency types if holocaust survivors continued to preferentially mate with each other even though other mates were available.

Comment: Models should tell us how accurate the age classes need to be. We may compare the very oldest age class to the very youngest; the middle years (60 years old) could be a mix of the two different groups.

Comment: Rooney found there has been no genetic bottleneck. Taylor's hypothesis is not that there is a bottleneck but that there is heterogeneity through reproductive heterogeneity. For example, in 1910 there was a handful of males that produced offspring (Fig. 1). Then, when individuals that were young in 1910 grew up and began reproducing, they would be contributing very different genes to their offspring. We need to compare these two groups of offspring. We must know about the biology and mating system of the animals.

Comment: Most whales have testes less than 20kg. A few have testes greater than 100kg. Is there sperm competition in this species? Are a few whales doing most of the breeding? At the end of commercial whaling, there were maybe 1,000-1,500 males left and perhaps a very few of these were large and mature and doing most of the reproduction.

Genetic diversity - Canada

Rosenbaum—A proposal has been prepared by Rosenbaum and Amato (2005) to analyze historical (archaeological and museum) samples of bowhead whales from the eastern Canadian Arctic to provide context for the current stocks. Bowheads will be sampled from several historical time periods to examine the effect of human (whaling) and climate induced changes in genetic variability and stock identity. There are samples in museums. The Los Angeles County Museum has a list of institutions that contain BCB material and there is a lot of material that has been collected within the last 200 years.

Spatial distribution and abundance

Photo ID analysis from 2003 and 2004

Rugh—Currently, there are 12,100 available bowhead images in the collections at NMML and LGL of which 10,366 have been categorized. During photographic (aerial) surveys of the spring migration in Barrow, LGL took 1,150 photos in 2003 and 1,443 photos in 2004. Proposed research of animal mixing and abundance in 2005-2008 includes photographic surveys of SLI in 2005, Chukotka in 2006 and the Alaskan coast in 2007. The intent is to have a mark-recapture analysis, using the two best categories of photos (in terms of quality) in which the whale must be marked (*i.e.* have identifiable marks on its back). LGL will take the photos and scan them; then both LGL and NMML will categorize the photos and make the comparisons. Previous abundance estimates from mark-recapture in aerial photographs compared very favorably with abundance estimates from the ice-based survey.

Photo ID from Saint Lawrence Island

Koski—An aerial photographic survey will be based out of Nome and/or SLI in April 2005. The survey area will be northwest of the island but will also include other adjacent areas. They will be careful not to impact the hunt. By conducting the survey out of SLI, local hunters can be included, and they can show where they have hunted in the past. At SLI, the migration routes vary offshore, but hunters are restricted to a few areas. We should be able to take photos without bothering the hunters.

Previous aerial photography has focused on Barrow in the spring and the Beaufort in the summer. Surveys at SLI will provide a comparison of recapture rates. Currently there is a 27-28% recapture rate of well-marked whales in Barrow.

Comment: A tiny stock that co-mingles off SLI and Barrow could not be distinguished. Instead look at whales photographed at SLI that are migrating past Barrow at different times.

Comment: It will be interesting when all the data (photo ID, satellite tagging, biopsy sampling) are integrated. We need modeling to determine how to do this.

Comment: What if two stocks overlap but do not interbreed (*e.g.* are acoustically different)? The current technology cannot segregate bowhead stocks based on their calls. Bowheads produce a wide variety of calls (second only to humpbacks) but, at this point, acoustics will not give us that behavioral information.

Traditional knowledge
George—The intent of this project is to contract a resident of Savoonga (George Noongwook) to document traditional knowledge specifically regarding bowhead whales at SLI. People in both SLI villages will be interviewed by Noongwook.

Brower—At Barrow, hunters make trails and get out to leads in April and May. In early April, they see whales in small numbers, as they migrate east. The hunt starts in April. Seal hunters have seen a few whales in March. In 1993, the first pulse of large whales (45-50ft) and many small whales began about 15 April. The second part of the migration (in late April - mid-May) was a mixed group of small and large whales. We take the smaller whales that the community prefers at this time, into May or even June. Now the whales are arriving earlier. We are seeing whales around 9-10 April and harvest them beginning around 15-16 April. In later May (15 May-June), we see large whales and cow/calf pairs. We see the same pattern each year. In the fall migration, the same groups pass by Barrow in the opposite order. Although the migration has been starting earlier in recent years, the cow/calf pairs continue to show up at about the same time. The natives believe that there is one stock. They are all the same color but different sizes and shapes. Researchers are the ones concerned about stocks. Whale size can be estimated by the size of the blowhole (1.5ft blowhole = over 40ft whale; 1ft blowhole = ~40ft whale; <1ft blowhole = less than 40ft whale) and the girth of the whale (*i.e.* is it larger than the boat?). We can also see white flukes (older whales have more white on the flukes) from the ice and from the boats. We do not like to harvest large whales because they are tougher. Hunters have decided to hunt later in the fall to avoid large whales, such as the end of September or early October.

Comment: Census observations make it look like there are two pulses of large whales and two pulses of cows/calves. Are two stocks migrating sequentially? No: most calves are in the third group, so there would be only one stock with calves, if you are arguing for two stocks. Also, weather and ice conditions can have a big influence on apparent temporal patterns.

Migration patterns
Acoustic recorders
Moore—In 2003, as part of the Western Arctic Shelf-Basin Interaction (SBI) program funded by the National Science Foundation (NSF), three acoustic recording packages (ARPs) were deployed northeast of Barrow to listen for bowheads (Moore, 2004). The ARPs were deployed for a full year, and two of the three were recovered in October 2004. NSF is funding a fine-scale hydrographic survey in August 2005 (Moore, 2004). We would like to add acoustics to this program, but we will be operating from a small boat. Acoustics can detect bowheads, and variation in call-types has been described for migrating and socializing whales (Clark and Würsig, 1993), but we can not yet interpret what the various calls mean.

Comment: Chris Clark's acoustic data were collected along with visual observations during the spring migration past Barrow. These data could be used to categorize some calls (*e.g.* up-down calls while moving; see Clark and Würsig, 1993).

Comment: Perhaps ARPs can be put where bowheads are mating. However, the US cannot deploy acoustic recorders in Russian waters, and the northern Bering Sea is shallow, which can be a problem for these instruments. Pop-ups could be deployed for a few months from small boats around SLI. In collaboration with Phyllis Stabeno (Pacific Marine Environmental Laboratory, OAR, NOAA), NMML has some ARPs on moorings near St. Matthew Island, along the 70-m bathymetry contour in the southeast Bering Sea and in slope basin water west of Bristol Bay. Although these recorders have been deployed to detect North Pacific right whale calls, they sample continuously and seasonal records for all baleen whale species are anticipated.

Satellite telemetry
Quakenbush—The Alaska Department of Fish and Game (ADF&G) will use satellite tags to study bowhead movements and behavioral ecology; biopsies will be collected in tandem with tagging efforts whenever possible (Quakenbush, 2005). Tagging options were discussed with the NSB and the AEWC and they want to be involved at all stages of the research. It is likely that the hunters will deploy the tags and will decide when to tag and when to hunt. There may be funding to attempt to tag 25 whales per year for 5 years at places and times depending on the

objectives selected. Tagging may start in fall 2005. Some whalers want more information, but others are afraid the information will be used against them. Stock studies are not the initial goal of this tagging program but will be included where practical. The US Minerals Management Service (MMS) is funding this research. Although satellite tracking was a part of the original stock structure study plan (Smith *et al.*, 2004), it was anticipated that tagging could not begin until 2007 (largely due to funding constraints).

Comment: The current NMML permit is limited to 10 tags per year. The NSB already has 3 tags. That limits ADF&G to 7, except that we may be able to 'borrow' against next year's allowance; a modification to the permit has been requested allowing 25 tags per year (maybe by 2006). The SWFSC permit will also be investigated for use.

Comment: MMS should be concerned about stock structure, especially if there is a second, small stock. If tag life is 3 months to 1 year, the data that are gathered will apply to many objectives.

Comment: There is tentative support for the project by AEWC, but not if it harms animals; *e.g.* if they harvest an animal with a tag that caused an abscess, can the whale still be eaten? For instance, some whales harvested at SLI were tagged in the Canadian Beaufort; one looked thin, and the whalers were not sure about eating it.

Comment: MMS is interested in feeding aggregations northeast of Barrow. Tagging options will depend on the whaling community. The community would have a large role in deciding when and how to tag, and ADF&G would compensate them for doing tagging. They would likely use harpoons (so they would not need projectiles) and use the hunters' knowledge of animals and conditions in order to deploy the tags.

Baleen analysis

George—Eleven baleen plates (probably from different animals) were collected at Gambell in fall 2004. The plates are from whales harvested from the mid 1980s until recently. They will be examined (using the methods of D. M. Schell and S. C. Lubetkin) to look at carbon isotopes for Bering and Beaufort signals. We are looking for evidence of a non-migratory signal in the baleen-carbon of these animals. The carbon analysis will be done at the University of Alaska, Fairbanks. However, we have sent baleen samples to the SWFSC for genetic analysis as well.

Comment: These baleen plates are probably the largest pieces from the respective whales. A 3m plate can cost >$1,000 to analyze.

Comment: There are obvious cycles in isotopic signature along the length of the baleen, but a 'Bering' isotopic signal can be obtained anywhere west of Barrow in the Chukchi Sea from prey transported there by the major inflow currents.

24 February 2005

FRAMEWORK PLAN FROM PREVIOUS DAY'S DISCUSSION

Moore—At the end of day one, George, Suydam and Moore tried to identify 'key' hypotheses for the group to discuss on day two, to focus discussion on sampling requirements. First we present a re-cap, or outline of the conceptual hypotheses to test, bearing in mind *how* to test these hypotheses and determine the priorities for data collection.

Outline hypotheses

Temporal Migration

George—In the Temporal Hypothesis (TBG, 2005), there are two stocks and two putative wintering areas. The two groups migrate separately past Barrow in spring and migrate together past Barrow to the Bering Sea in the fall.

Immigration from Canada

George—In the Immigration Hypothesis (TBG, 2005), bowheads move through the Canadian Archipelago. Evidence for this hypothesis is the recovery of two harpoon tips from whales harvested in Alaskan waters during the 1800s commercial hunt.

Chukchi Circuit

Moore—This is a new hypothesis, based on Russian observations and oceanographic data. This hypothesis takes Melnikov's observations at Chukotka into account and results of zooplankton studies conducted during the NSF/Sheba project, whereby bowhead prey (copepods) were reported to vertically migrate towards the surface at the Chukchi Borderland as early as March. Melnikov *et al.* (2004) and Bogoslovskaya (2003) describe a delay in spring migration of bowheads out of the Gulf of Anadyr and north through Bering Strait as well as sightings on the Chukotka coast in summer and early autumn. A 'second population' of bowheads leaves the Bering Sea in late May and June and heads northwest on the Chukotka coast, then heads towards the Barrow Canyon (but not all the way to the eastern Beaufort), and then moves back down to the Bering Sea. The second population is coming down from the north (ice edge, or Chukchi Borderland) in the fall and past Barrow, and a few may be harvested during autumn whaling at Barrow. The 'first, or main population' migrates normally from the Bering Sea to the Beaufort Sea and back again in fall past Barrow.

Comment: This hypothesis coincides with MMS's observations regarding many whales feeding close to Barrow in September and October in some years and not in others. For instance, Moore saw many bowheads feeding near Barrow in 1984 and 1989 in mid to late September through early October but not in all years (1981-1991). Now it is more common to see them at that time (see MMS BWASP reports for the 1990s). George and Brower also report bowheads at Barrow in early September through October. They are all large whales at this time followed later by small whales mixed in with large ones.

Comment: Data on fetus size by date from all villages show that conception is fairly tightly controlled, which is suggestive of one stock.

Comment: NSB will examine the baleen carbon composition in collaboration with Zeh to age the baleen and look for Bering and Beaufort signals. Whales do not have to be feeding in the Bering Sea to have a Bering signal in the baleen because ocean currents can move the prey into the Chukchi Sea.

Comment: If sperm competition is in effect what does it mean? Males stop growing around age 50. There is also sperm competition in right whales. There could be a few males doing all the breeding. Sperm volume (*i.e.* large testes) is the key. What if we examine the small group of whales in the Sea of Okhotsk and determine paternity to see if a few males are fathering all the calves?

Comment: How can two stocks going by Barrow maintain a ~7-day separation with two sequential migrations by two stocks (*i.e.* the Oslo bump)? When the first stock went by, animals 7 days apart would be in the first stock; then

there could be animals within each stock separated by 7 days in mid-migration; but then animals in the second stock would be the pair separated by 7 days.

Comment: In the Chukchi Circuit Hypothesis, the genetic signal may be explained by the leading edge of the second stock going by Barrow 7 days before or after the eastern Beaufort stock passed by. However, the Oslo-bump signal makes more sense when two stocks overlap. A plausible archetype has two stocks passing by with a phase shift of 7 days (a small shift is enough to get a signal).

Comment: We need to re-visit the paired-sample data that results in the Oslo bump. Are there two subadult-pairs that are from the two separate genetic groups? The fall migration is segregated by size. The first animals may be coming from the marginal ice zone in the central Beaufort Sea—traveling south to the Alaskan coast. They may be a separate (sub) stock, or this may be simply an issue of size segregation, as seen along the Yukon coast (juveniles) in late summer and early autumn.

Comment: We need to test the single stock hypothesis. The mtDNA findings from autumn to spring were almost significant. Even the early spring to late spring differences are almost significant. Overall, we need a broad hypothesis to be able to fit incoming data from mitochondrial DNA samples to come.

Comment: If there are two stocks, the more distinct they are genetically, the more they can overlap and still be detected.

Comment: We need to model the Chukchi Circuit Hypothesis to see if it can produce the signal. We need to do this to determine what sampling is necessary. We need simulations to see if any model matches the data. Taylor has not seen anything like the temporal structure in the Jorde paper (Jorde *et al.*, 2005).

Comment: Eastern Canadian immigration is in a totally different category. It does not fit our data. It could be investigated by putting together the US and Canadian genetic datasets and examining them.

Comment: There are also other possibilities, such as spatial segregation.

Comment: Ice may drive the whole show. In some years, some whales may not migrate past Barrow. According to Burns (1993), the stock is labile; constantly in flux, reacting to environmental changes.

Comment: The discussion has brought us back to the Stock Archetype paper (TBG, 2005) but leaving out the Immigration Hypothesis and now adding the Chukchi Circuit Hypothesis. So, there are five hypothetical situations to test:

1) One stock – baseline hypothesis accepted by the IWC SC = the null hypothesis
2) One stock with generational gene shift (GGS)
3) Temporal Segregation
4) Spatial Segregation
5) Chukchi Circuit

Collaboration/coordination with other bowhead projects

MMS BWASP and aerial photography analysis

Monnett—The BWASP (Bowhead Whale Aerial Survey Project) has been a long-term study since 1979. Initially the surveys were conducted by personnel from the Navy Marine Mammal Program through a US Department of Commerce-Department of Defense inter-agency agreement (Leatherwood/Ljungblad: 1979-1987). MMS took over the Beaufort surveys in 1988, although SAIC (Moore and Clarke) continued surveys near Barrow and in the Chukchi Sea from 1989-1991. The MMS has continued BWASP surveys in the Beaufort Sea to investigate whether or not bowheads remain in the same migratory corridor, *i.e.* are not displaced to the north by oil and gas extraction activities. There are differences in whale distribution and numbers from year to year. We need to analyze all these data taking survey effort into account. The number of whales sighted in beginning September - late October has varied from 25-1,600 whales. In the early 1980s, most feeding was near Kaktovik. In the last 10 years, feeding is common near Barrow, but not Kaktovik. We are looking at the data; we don't know why this change has

occurred—maybe from changes in the sea ice? BWASP also records sea ice conditions and can provide visual data on ice back to the 1980s. The NODC (National Ocean Data Center) has a database (including metadata) through 2004, which is available to all. MMS has provided modest support for photo data analysis (see Photo ID section).

The tagging study (see Satellite Tagging section) is one piece of a larger study planned for 5-10 years, including: tagging (5 years); feeding (behavior work, including prey biology and oceanography); and physical oceanography from Cape Halkett to Barrow. It is funded to begin in 2005. The tagging study is on a fast track. Other parts may start in 2006 or 2007 (depends on politics). The study is well funded.

Comment: Currently, the MMS dataset cannot be integrated with the physical oceanography data from the NSF/SBI project.

NSF/SBE and ICARPII

Moore—SBI is just wrapping up Phase 2 (fieldwork) and will enter SBI Phase 3 (synthesis) with an announcement of opportunity scheduled for August 2004 (NSF web site). Three international programs will focus on Arctic ecosystems: 1) Shelf-Basin Exchange (SBE); 2) the International CircumArctic Research Program (ICARP); and 3) the International Polar Year (IPY= 2007), with opportunities for research that may be relevant to this group. We are looking at ways to look at especially long datasets for ice and hydrography and integrate them in such a way as to make them relevant for bowhead habitat investigation. These are large research programs that should add biological components, including top predators, to their studies.

George—The Berengia Group is doing biopsy work on bowheads in Bering Strait—funded by the National Park Service. At Barrow and Kaktovik, NSB is sampling bowhead reproductive organs and stomach contents (there are 25 years of data). Scientists come to Barrow to do tissue studies, anatomy and contaminant work. Studies in both spring and fall animals include a long-term health assessment study of bowheads, including percent lipids in blubber, contaminant levels and blood serology (diseases). We should expect a change in the health of bowheads if they are reaching carrying capacity. There is some money from Teri Rowles (NMFS Marine Mammal Health and Stranding Response Program) and some money from EPA for a hydrocarbons study by John Reynolds (Mote Marine Laboratory, Sarasota, FL).

Comment: Perhaps contaminants can be used to look at stock separation.

Comment: ADF&G has funds to sample SLI animals in spring 2005; they will examine the same suite of characteristics that are examined at Barrow and Kaktovik.

Working group reports

Spatial working group summary

Moore—The standing recommendation will be to always biopsy any whale that is satellite tagged; biopsy additional whales during tagging efforts, if possible.

Hypothesis Framework (generational gene shift can be considered as part of any of these hypotheses)

- Null Ho = Single stock (Archetype #1)
- Ho #1 = Spatial Segregation
- Ho #2 = Temporal Segregation
- Ho #3 = Chukchi Circuit

Sampling Tools

A) Satellite tagging and biopsies (collect metadata: location; date-time; approximate size of whale; photographs)
   1) SLI (Gambell and Savoonga): early spring and late fall.
   2) Chukotka: southern coast (near Sireniki) in spring; northern coast (Uelen) in June to early September (AVOID mid-September through October).
   3) Barrow in mid-June when whales are lingering post migration.

B) Aerial Survey/Photo ID
   1) Chukotka: northern coast in late June and July; southern coast in May and June 2006 (Russian aircraft); talk with USFWS (Meehan) about aircraft availability post-walrus surveys. Conduct photogrammetry, if possible.
   2) Reiterated support for planned surveys from SLI in 2005 (would like 10 great looking, easily identified 'new' whales).

C) Passive Acoustics
   1) Investigate possibility for long-term recorders for deployment in the Chukchi Borderland during 2005 NOAA/OE cruise; to be recovered in 2006.
   2) Exploration of existing data from spring census at Barrow: a) temporal analysis of spring data (7-10 day bins?; see also Clark *et al.*, 2004), and b) variability of song - including data from the Alaska Beaufort (Greene) and Davis Strait, etc.
   3) Short-term recorders for deployment during NSF/SNACs work near Barrow; recover at the end of autumn migration (August – November).

D) Tissue Studies
   1) From landed whales: longest baleen plate, eye globe (age), muscle (stable carbon nitrogen analysis).
   2) From biopsies: reproductive status of females and maturity of males.
   3) Feces (anak) studies: collect when possible.

Comment: Use a simple data form (*e.g.* size of whale) for biopsy work and use the same form at all places.

Comment: Use a Russian plane for Chukotka surveys.

Comment: Natives could go on a SWFSC blue whale biopsy cruise to learn techniques.

Comment: Russians will collect samples with crossbows from small boats. They will use paper forms (not tape recorders) to collect date, coordinates, approximate size of the whale, position of the biopsy on the body, and maybe photos of the left and right sides.

Comment: Look at hormonal levels in biopsy blubber samples to see if animals are mature or immature or pregnant. With dolphins, pregnancy is very clear. In bowheads, it is more difficult to detect because it takes longer for hormones to permeate the blubber (this is in the research and development phase).

Comment: When possible, feces samples should be collected when tagging animals.

Genetics working group summary

Temporal Phase Hypothesis

- Sample in February-April in Gulf of Anadyr and south of Saint Lawrence Island.
- Biopsy in Barrow throughout the autumn. Fill in data cells in Oslo paper of whales caught specific days apart (*e.g.* before and after the hunt).
- Biopsy in extremes of summer distribution—eastern Beaufort Sea and western Chukchi Sea (Chukotka).

Chukchi Circuit

- Biopsy on north side of Chukotka Peninsula as soon as possible in spring/summer.
- Biopsy at Saint Lawrence Island in spring and summer, as possible.
- Biopsy north of Barrow during late June, July and early August.

Generational Gene Shift

- Collect historical samples from bones but need to know whales' biological age, time period it lived (want samples from whales alive in ~1910) and when it was harvested.
- Biopsy large, old whales near Saint Lawrence Island and Barrow in the late spring or <u>early</u> autumn.

Other Comments

- Collection of samples near SLI and Chukotka is a high priority.
- Determine whether there is Traditional Knowledge about bowheads around St. Matthew Island.
- Collect data that could be used for assignment tests. Data for assignment tests do not need to be 100% accurate but should provide information on probability of being assigned correctly.

Choice of Genetic Markers

- In choosing a marker, allelic diversity should be an important consideration. Markers should be of 'intermediate diversity.'

Historical Data

- Selectivity in the hunt through time.
- Distribution of calves.

Comment: The value of collecting historical samples from bones is to increase the sample size of animals alive in 1910 (if alive today, they would be 80-100 years old). Big whales harvested in the 1980s at SLI would be the same age as old whales today.

Comment: Biopsy samples wanted by the group:

1) SLI
2) Chukotka
3) Barrow

Comment: Recommendations are to get old whales and look at stock structure at Barrow. Biopsies in early autumn will get old whales, fill in the missing data cells for the Oslo paper and look at whether there are differences in early versus late autumn.

Comment: The NMML permit allows 5 biopsies this year and 10 tags. An amendment to the permit will allow 100 biopsies and 25 tags. The Russians can biopsy in Chukotka (not on the US permit).

Comment: Bockstoce and Botkin have ice data from historical whaling data logbooks. They will reexamine latitudinal extirpation of bowheads from their summer range by ~3°N/year and compare current distribution to historical distribution. Any ideas on how these data might be analyzed to examine substock structure are welcome. Taylor did some modeling but needs to bracket uncertainty about selectivity in the hunt through time.

Comment: Look at evidence of cow/calf pairs in the data. A problem of the Chukchi Circuit is that few (if any) calves are seen along the Chukotka coast in summer.

Research priorities from working groups

Suggested steering committee for modeling: Taylor, Givens, Schweder, Zeh, Koski, Pastene, George and Punt or Wade. The purpose of the model would be checking the feasibility of generational gene shift (use R-Metasim), but it would be structured in a way that the two stock hypothesis can be examined.

Comment: Do not do further sampling of historical material unless the size of the whale and the date harvested can be determined accurately, as they are in samples from current harvests. If there is not enough money for everything, spend it on analyzing samples from recently harvested SLI whales and analyze only those historical samples that have the best chance of shedding light on GGS, Chukchi Circuit and other such key hypotheses.

Comment: Allocation of 2005 funds needs to be documented in a more transparent way. It would also be a good record of research that is occurring. Short proposals (2-5 pages) and budgets should be prepared for each project.

ACTION ITEMS

1. Aerial surveys to get underway in early April: contracting and logistics required.
2. Taylor to convene bowhead modeling group (BMG) to arrive at agreement on approach and to conduct modeling runs. BMG = 8 members: Taylor (Chair), George, Givens, Koski, Pastene, Punt (or Wade), Schweder and Zeh.
3. Preparation of 2005 project proposals and budgets.

Projects and priorities for 2005 and 2006
Overall research plans were not dramatically altered from the base plan reviewed at the outset of the workshop. Funds listed are approximate. Each project should be summarized in a 1-2 page proposal, complete with a rough budget itemizing costs.

No.	Project	2005	2006
1	**Research Planning and Hypothesis Testing**	**$K**	**$K**
1a	Planning and coordination	25	10
1b	Modeling and hypothesis testing	35	30
2	**Genetics Sampling and Analysis**		
2a	Tissue collection: US harvest sampling	135	95
2b	Tissue sampling: Russian & US biopsy	100	100
2c	Genetics analysis methods & application	200	200
3	**Animal Mixing and Abundance**		
3a	Photographic survey: St. Lawrence Is.	200[2]	50[2]
3b	Photographic analysis: AK Coast	200[1]	100[2]
3c	If possible, photographic survey: Chukotka		100
4	**Spatial Distribution and Abundance**		
4a	Traditional knowledge	25	45
4b	Historical catch data reanalysis		20
4c	Collaboration with Russian Scientists		100
5	**Migration patterns**		
5a	Analysis/acquisition of LT acoustic data	30[2]	
5b	Satellite tracking		95
5c	Isotopic analysis of baleen	25	25
	Total	**$975**	**$970**

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APPENDIX 1. 2004 IWC SC MEETING SELECTED DOCUMENTS (SC/56/BRG)

1. ZEH, J.E. and PUNT, A.E. Updated 1978-2001 abundance estimates and their correlations for the Bering Chukchi-Beaufort Seas stock of bowhead whales.
2. KOSKI, W.R., RUGH, D.J., PUNT, A.E. and ZEH, J. A new approach to estimating the length-frequency distribution of the Bering-Chukchi-Beaufort bowhead whale population using aerial photogrammetry and a summary of other life-history parameters estimated from photoidentification/photogrammetry data.
3.LUBETKIN, S.C., ZEH, J.E., ROSA, C. and GEORGE, J.C. Deriving von Bertalanffy age-length relationships for bowhead whales (*Balaena mysticetus*) using a synthesis of age estimation techniques.
4. PUNT, A.E. Updated assessments of the Bering-Chukchi-Beaufort Seas stock of bowhead whales using length, age and abundance data.
5. HEIDE-JORGENSEN, M.P., LAIDRE, K.L., JENSEN, M.V., DUECK, L. and POSTMA, L.D. Dissolving stock discreteness with satellite tracking: Bowhead whales in Baffin Bay.
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9. GEORGE, J.C., KOSKI, W.R., SUYDAM, R. and RUGH, D. Body stretching of bowhead whales during hauling and butchering during the subsistence hunt.
10. GEORGE, J.C., SUYDAM, R., ZEH, J. and KOSKI, W.R. Estimated pregnancy rates of bowhead whales from examinations of landed whales.
11. SUYDAM, R.S., GEORGE, J.C., O'HARA, T.M., HANNS, C. and SHEFFIELD, G. Subsistence harvest of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos during 2003.
12. SUYDAM, R.S. and GEORGE, J.C. Subsistence harvest of bowhead whales (*Balaena mysticetus*) by Alaskan Eskimos, 1974 to 2003.
13. LEDUC, R. and TAYLOR, B. A spatial analysis of bowheads in the North Pacific using mtDNA.
14. LEDUC, R. and TAYLOR, B. A comparison of age/length classes of bowheads in the North Pacific using mtDNA.
15. LEDUC, R. and TAYLOR, B. A temporal analysis of migrating bowheads in the North Pacific using mtDNA.
16. MARTIEN, K.K., TAYLOR, B.L. and LEDUC, R. A temporal analysis of migrating BCBS bowhead whales using Boundary Rank.
17. GIVENS, G.H., BICKHAM, J.W., MATSON, C.W. and OZAKSOY, I. Examination of Bering-Chukchi-Beaufort Seas bowhead whale stock structure hypotheses using microsatellite data.
18. BICKHAM, J.W., HUNTER, D.D., MATSON, C.W., HUEBINGER, R.M., PATTON, J.C., GEORGE, J.C. and SUYDAM, R. Genetic variability of nuclear microsatellite loci in Bering-Chukchi-Beaufort Seas bowhead whales (*Balaena mysticetus*): A test of the genetic bottleneck hypothesis.
20. BRANDON, J. and WADE, P.R. Assessment of the Bering-Chukchi-Beaufort Seas stock of bowhead whales.
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26. KOSKI, W.R., GEORGE, J.C., SUYDAM, R., RUGH, D.J. and BRANDON, J. Aerial photography of bowhead whales at Barrow, Alaska, during the 2003 and 2004 spring migrations.
27. KOSKI, W.R., MILLER, G.W., RICHARDSON, W.J. and WURSIG, B. Bowhead whale (*Balaena mysticetus*) mothers and calves during spring migration in the Alaskan Beaufort Sea: movements, behavior and life history data.
28. KOSKI, W.R. and MILLER, G.W. Habitat use by different size classes of bowhead whales in the central Beaufort Sea during late summer and autumn.
29. GIVENS, G.H., GEORGE, J.C. SMITH, T.D., BICKHAM, J.W. and TAYLOR, B.L. Evaluation of the sequentially alternating stock hypothesis for Bering-Chukchi-Beaufort Seas bowhead whales based on microsatellite DNA evidence.

31. LEDUC, R. and TAYLOR, B. Using 'structure' to assess microsatellite loci quality and to address the implications of the suggested populations.
32. PASTENE, L.A., GOTO, M. and KANDA, N. Genetic heterogeneity in the B-C-B stock of bowhead whale as revealed by mitochondrial DNA and microsatellite analyses.
33. BANDO, T., ZENITANI, R. and OHSUMI, S. Preliminary investigation of stock structure of B-C-B bowhead whales based on analyses of biological parameters.
34. MORIN, P.A. and LE DUC, R.G. Analysis of bowhead DNA quantity and microsatellite characteristics: implications for potential biases in population structure analysis.
35. COSENS, S.E. Baffin Bay-Davis Strait and Hudson Bay-Foxe Basin bowheads: update on research 2003/04.
36. JORDE, P.E., SCHWEDER, T. and STENSETH, N.C. The Bering-Chukchi-Beaufort stock of bowhead whales: one homogeneous population? Annex C.doc 2 09/08/04
37. TAYLOR, B.L. Comparing assessment of stocks for bowhead and minke whales in the North Pacific.
44. TAYLOR, B.L, LEDUC, R. and GEORGE, J. Interpreting genetic heterogeneity in the B-C-B stock of bowhead whales: a response to SC/56/BRG32.
45. GIVENS, G.H., SMITH, T.D. and BICKHAM, J.W. Comment on how Jorde *et al*. (2004) attribute tablewide bowhead whale heterozygote deficiency equally to all microsatellite loci.

APPENDIX 2. WORKSHOP ATTENDEES

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AEWC = Alaska Eskimo Whaling Commission, St. Lawrence Island, Alaska
AFSC = Alaska Fisheries Science Center, NMFS, Seattle, Washington
CSU = Colorado State University, Fort Collins, Colorado
ICR = The Institute of Cetacean Research, Tokyo, Japan
IWC = International Whaling Commission, Cambridge, UK
LGL = LGL, Ltd., Environmental Research Associates, King City, Ontario, Canada
MMS = Minerals Management Service, Anchorage, Alaska
NEFSC = Northeast Fisheries Science Center, NMFS, Woods Hole, Massachusetts
NMML = National Marine Mammal Lab, AFSC, NMFS, Seattle, Washington
NSB = North Slope Borough, Barrow, Alaska
POI = Pacific Oceanological Institute, Far East Branch of Russian Academy of Sciences, Vladivostok, Russia
RAS = Institute of Ecology Problems and Evolution, Moscow, Russia
SWFSC = Southwest Fisheries Science Center, NMFS, La Jolla, California
TAMU = Texas A&M University, College Station, Texas
UO = University of Oslo, Oslo, Norway
UW = University of Washington, Seattle, Washington
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WCS = Wildlife Conservation Society, Bronx, New York